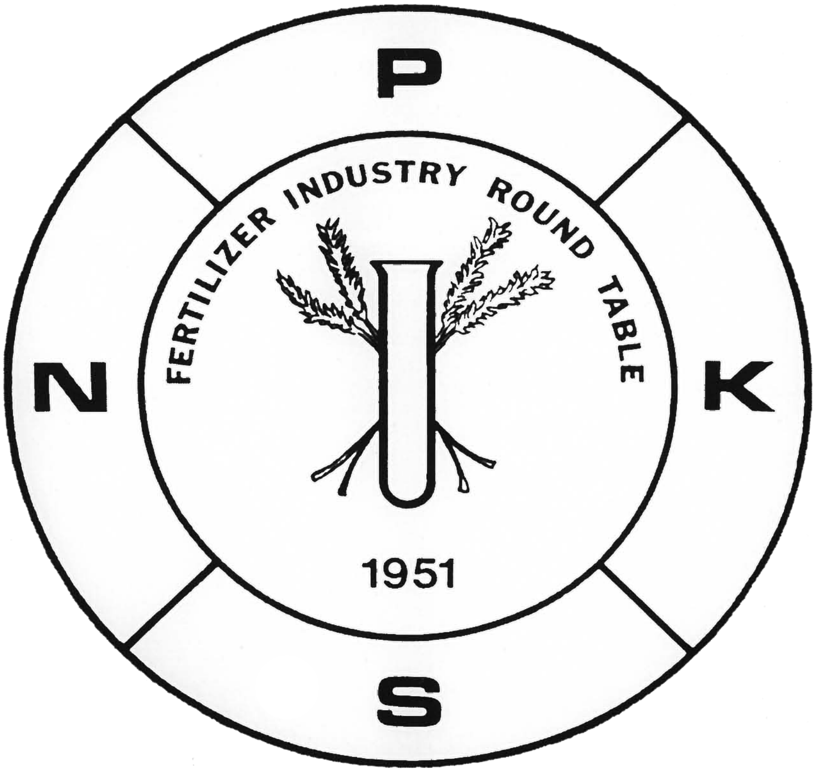
PROCEEDINGS
OF THE 46th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1996



October 28, 29, and 30, 1996
Hyatt Regency Savannah
Savannah, Georgia

Copies of Proceedings:
(Subject to availability)

Current Year	$35.00
Previous Year(s)	$25.00

Plus postage where applicable

Please make checks payable to
The Fertilizer Industry Round Table
Paul J. Prosser, Jr., Secretary/Treasurer
5234 Glen Arm Road
Glen Arm, Maryland 21057

PROCEEDINGS
OF THE 46th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1996

October 28, 29, and 30, 1996
Hyatt Regency Savannah
Savannah, Georgia

Table of Contents

Monday, October 28, 1996
Morning Session I
Moderator:
Luc M. Maene

Monday, October 28, 1996
Afternoon Session II
Moderator:
Ed Huber, Jr.

Tuesday, October 29, 1996
Morning Session III
Moderator:
Frank P. Achorn

Tuesday, October 29, 1996
Afternoon Session IV
River Boat Tour of Savanna
Chemical Industry Area
(no papers presented)

Wednesday, October 30, 1996
Morning Session V
Moderator:
Michael Hancock

INDEX OF PARTICIPANTS

Frank P. Achorn
SE-ME
P.O. Box 493
Florence, AL 35631

David Asbidge
CF INDUSTRIES, INC.
Salem Lake Drive
Long Grove, IL 60047

Darlene Blair
GOVN'T. OF CANADA
59 Camelot Drive, East
Nepean, Ontario, Canada
K1A0Y9

Greg N. Brown
GENERAL ELECTRIC
ENVIRONMENTAL SERV.
200 N. 7th Street
Lebanon, PA 17042

J. Douglas Campbell
ARCADIAN CORPORATION
6750 Poplar Ave, Suite 600
Memphis, TN 38138

Randy Charlot
CF INDUSTRIES
P.O. Drawer L
Plant City, FL 33564

C.E. "Chuck" Childers
PCS INC.
PCS Tower, Suite 500
122 1st Ave. S.
Sasakatoon, Saskatchewan
S7K 7G3 Canada

Leigh English
ECOGEN, INC.
2005 Cabot Blvd. West
Langhorne, PA 19047

William L. Hall, Jr.
IMC AgriBusiness
P.O. Box 1272
Winter Haven, FL 33882

Michael Hancock
OISC, PURDUE UNIV.
1154 Biochemistry Bldg.
W. Lafayette, IN 47907

Lance Hester
(President, AAPCO)
AL DEPT. OF AGR. & INDS.
Beard Bldg.,1445 Federal Dr
Montgomery, AL 36109

Ed Huber, Jr.
6615 Pheasant Drive
Elkridge, MD 21227

Gunnar Kongshaug
HYDRO AGRI EUROPE
Postboks No. 110
Porsgrunn 3901, Norway

Mr. Rene' L. Latiolais
FREEPORT-MCMORAN
1615 Poydras Street
New Orleans, LA 70121

J.R. LeBlanc
The M.W. Kellogg Technology
Company
601 Jefferson Avenue
Houston, TX 77210-4557

Luc M. Maene
INTERNATIONAL FERTILIZER
INDUS. ASSOC
28 Rue Marbeuf
75008 Paris, France

Vernon Meacham
HARMONY PRODUCTS
2121 Old Greenbrier Road
Chesapeake, VA 23320

Robert M. Millaway
HYDRO AGRI, N.A.
100 N. Tampa St, Ste.3200
Tampa, FL 33602

Ed Norris
THE ANDERSONS INC
P. O. Box 119
Maumee, OH 43537

Robert E. Robinson
ROBERT E. ROBINSON &
ASSOC.
111 Maplewood Drive
Beaver, PA 15009-1337

J. Larry Sanders
AMILAR INTERNATIONAL
6502 South Archer Road
Bedford Park, IL 60501

Lance Smith
SGL TECHNIC, INC.
21945 Drake Road
Strongsville, OH 44136

Roy M. Stephen
ARISE REASEARCH &
DISCOVERY
Rt. 3, Box 34
Martinsville, IL 62442

Steve Sutter
THE ANDERSONS INC
P.O. Box 119
Maumee, OH 43537

David Terry
UNIVERSITY OF KENTUCKY
103 Regr. Service Bldg.
Lexington, KY 40546

Thomas Torretti
PEAVEY BARGE LINES
100 N. Broadway
St. Louis, MO 63102

Whit Yelverton
THE FERTILIZER INSTITUTE
501 Second Street
Washington, DC 20002

1996 BOARD OF DIRECTORS

FRANK P. ACHORN
SE-ME
P.O. BOX 493
FLORENCE, AL

B.E. ADAMS
CONSULTANT
3509 WOODLAWN STREET
HOPEWELL, VA 23860

THOMAS B. ATHEY
219 HERON POINT
CHESTERTOWN, MD 21620

BOBBY S. AVANT
IMC AGRI-BUSINESS
1611 OAK AVENUE
AMERICUS, GA 31707

LEO BEWER
PCS SALES
122 1 ST AVE. S.
SASAKATOON,
SASKATCHEWAN
S7K 7G3 CANADA

HAROLD D. BLENKHORN
525 BEACONSFIELD
BEACONSFIELD, QUEBEC
CANADA H9W 4C8

PATRICIA BOSTICK
AGRIUM U.S., INC.
2405 W. VASSAR ROAD
REESE, MI 48757

G. CAMERON BOWEN
CAMERON CHEMICALS, INC.
1316 SMITH DOUGLAS
CHESAPEAKE, VA 23320

JAMES C. BROWN
SYLVITE SALES (USA),INC
P.O. BOX 929
LEBANON, PA 17042

DOUGLAS CAINE
CONSULTANT
P.O. BOX 491
WHITING, IN 46394

VERNON C. CARLTON
WINSTON-WEAVER FERT.
CO. P.O. BOX 7366
WINSTON-SALEM, NC 27109

KURT CONSTANT
THE WORLD BANK
1818 H STREET
WASHINGTON, DC 20433

DAVID CRERAR
6, WESTMORLAND ROAD
FELIXSTOWE, SUFFOLK
I P119TB U. K.

MR. DONALD P. DAY
PCS PHOSPHATE CO., INC.
P.O. BOX 30321
RALEIGH, NC 27622

DALE DUBBERLY
FL DEPT OF AGRICULTURE
3125 CONNER BLVD
TALLAHASSA, FL 32399-1650

ROBERT FELGENHAUER
ARCADIAN CORPORATION
6750 POPLAR AVE., STE 600
MEMPHIS, TN 38138

JOHN M. FRENCH
BRITISH SULPHUR CORP.
LTD.
31 MOUNT PLEASANT
LONDON WCIX OAD
ENGLAND

JAMES GREENE
SOUTHERN STATES COOP
2582 SALISBURY HWY.
STATESVILLE, NC 28677

WILLIAM L. HALL, JR.
IMC AGRI-BUSINESS
2121 3RD STREET, SW
WINTER HAVEN, FL 33882

MICHAEL HANCOCK
OISC, PURDUE UNIVERSITY
1154 BIOCHEMISTRY BLDG.
W LAFAYETTE, IN 47907

G. CONRAD HARDIE, JR.
LYKES AGRI SALES
P.O. BOX 13989
FT. PIERCE, FL 34979

ED HUBER, JR.
6615 PHEASANT DRIVE
ELKRIDGE, MD 21227

K.C. KNUDSEN
TOFTEVEJ 9
DK-2840 HOLTE
DENMARK

JAMES J. KUHLE
LEBANON CHEMICAL CORP.
P.O. BOX 180
LEBANON, PA 17042

DAVID W. LEYSHON
JACOBS/DORRCO DIV
P.O. BOX 2008
LAKELAND, FL 33803

OLE H. LIE
NORSK HYDRO A.S.
P.O. BOX 2594 SOLLI
N-OSLO 2 NORWAY

LUC M. MAENE
INTERNATIONAL FERTILIZER
28 RUE MARBEUF
75008 PARIS, FRANCE

DONALD L. MESSICK
THE SULPHUR INSTITUTE
1140 CONNECTICUT AVE.,NW
WASHINGTON, DC 20036

ED NORRIS
THE ANDERSONS, INC.
P.O. BOX 119
MAUMEE, OH 43537

JAMES G. PERKINS
MS CHEMICAL CORP.
P.O. BOX 388
YAZOO CITY, MS 39194

PATRICK E. PETERSON
CF INDUSTRIES, INC.
SALEM LAKE DRIVE
LONG GROVE, IL 60047

GARRY PIGG
FREEPORT-MCMORAN, INC
1615 POYDRAS STREET
NEW ORLEANS, LA 70112

PAUL J. PROSSER, JR
THE PROSSER COMPANY
P.O. BOX 5036
GLEN ARM, MD 21057

JOHN RENNEBURG
CONSULTANT
515 BIGHTWOOD CLUB DR
LUTHERVILLE, MD 21093

JOSEPH E. REYNOLDS, JR.
CONSULTANT
5518 SOUTHWOOD DR.
MEMPHIS, TN 38119

ROBERT E. ROBINSON
ROBERT E. ROBINSON &
ASSOC
111 MAPLEWOOD DRIVE
BEAVER, PA 15009

WALTER J. SACKETT, JR.
THE A.J. SACKETT & SONS
CO M PANY
1701 SOUTH HIGHLAND
BALTIMORE, MD 21224

JAMES J. SCHULTZ
INTERNATIONAL FERTILZER
DEV.CTR
P.O. BOX 2040
MUSCLE SHOALS, AL 35662

WILLIAM F. SHELDRICK
38 RAVINE ROAD
CANFORD CLIFFS
POOLE, BH13 7HY DORSET
UNITED KINGDOM

SR. ADOLFO SISTO
MESETA 200, DEL A.
OBREGON
01900 MEXICO, D.F.

MICHAEL D. STEGMANN
LANG E-STEG MANN
ONE ANGELICA STREET
ST. LOUIS, MO 63147

DAVID J. VETERE
HEYL & PATTERSON, INC.
P.O. BOX 36
PITTSBURGH, PA 15230

GLEN H. WESENBERG, P.E.
FEECO INTERNATIONAL,
INC.
3913 ALGOMA ROAD
GREEN BAY, WI 54311

PHILLIP W. (WHIT)
YELVERTON
THE FERTILIZER INSTITUTE
501 SECOND STREET
WASHINGTON, DC 20002

OFFICERS

WALTER J. SACKETT, JR.	CHAIRMAN
OLE H. LIE	VICE CHAIRMAN
PAUL J. PROSSER, JR.	SECRETARY/TREASURER

ACTIVE PAST CHAIRMEN

Joseph E. Reynolds, Jr.	Past Chairman
Rodger C. Smith	Past Chairman
Frank P. Achorn	Past Chairman
Harold D. Blenkhorn	Past Chairman
John L. Medbery	Past Chairman
William F. Sheldrick	Past Chairman
Paul J. Prosser, Jr.	Past Chairman
David W. Leyshon	Past Chairman

COMMITTEE CHAIRMEN

Entertainment	Thomas B. Athey
Meeting Dates & Places	Thomas B. Athey
Finances	Paul J. Prosser, Jr.
Program-Annual Meeting	Harold D. Blenkhorn
Nominating	Joseph E. Reynolds, Jr.
Public Relations	Walter J. Sackett, Jr.
International Relations	William F. Sheldrick

Opening Remarks

Walter J. Sackett, Jr., Chairman

Good morning ladies and gentlemen and welcome to the 46th annual meeting of The Fertilizer Industry Round Table.

Our organization was founded by a small group of men headed by the late Dr. Vince Sauchelli and has met every year since 1951. The Round Table is dedicated to the development and improvement of all aspects of the fertilizer industry. The organization receives no financial support from companies, governments or any other vested interests and is run entirely on a voluntary basis by its members. The Board of Directors of The Round Table are a dedicated group of individuals who receive no compensation and bear all of their own expenses.

Having stated this, which is well known to the majority here, but bears repeating, I would like to say that the Board has again put together an outstanding agenda. As you can see from your copy of the program, we have an "All Star" cast of speakers this morning, being headed by another all star, Mr. Luc Maene, who will introduce our Keynote Speaker. Ladies and Gentlemen, I give you my friend, Mr. Luc Maene.

Monday, October 28, 1996

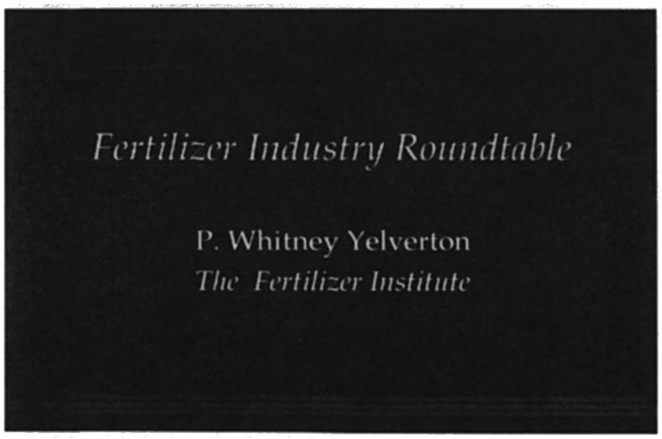
Session I
Moderator:

Luc M. Maene

Keynote Address
Phillip "Whit" Yelverton
The Fertilizer Institute

Thank you for inviting me to be here today. It's an honor to be a keynote on such a distinguished panel.

I know you'll get the best supply and demand perspectives around later this morning as Doug, Rene and Chuck take the podium so my job this morning is to give you a big picture view of developments in Washington and in agriculture and perhaps look into the crystal ball and make a few predictions about where the fertilizer industry is going in the legislative and regulatory arenas as well as in the farmer's field.



Fertilizer Industry Roundtable

P. Whitney Yelverton
The Fertilizer Institute

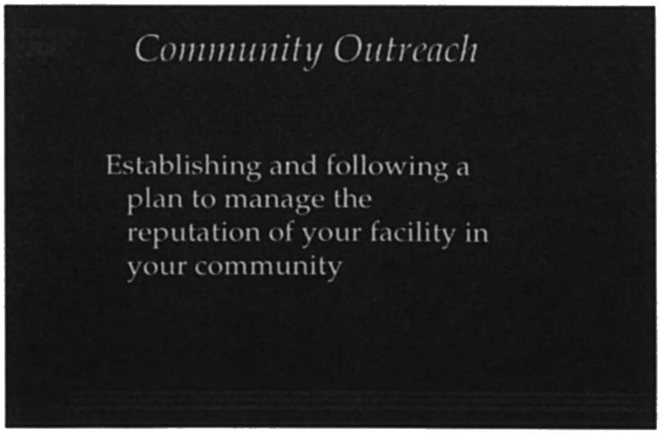
For today, I will cover three developments which have the ability to make a major impact on the way fertilizer companies do business in the future:
- EPA's Risk Management Program Rule
- New environmental standards coming from the latest farm bill
- New "precision" technologies from the field

Fertilizer Industry Challenges:

Risk Management Program Rule
Farm Bill: Environmental Standards
New Technologies

Community Outreach:

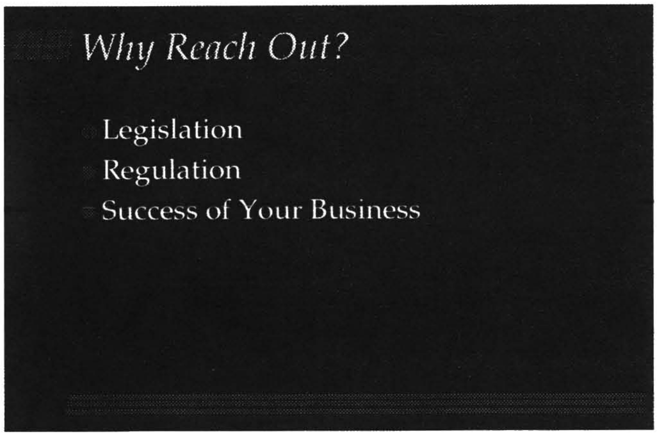
- Part of EPA's Risk Management Program Rule
- Necessary to start planning for making community outreach a greater part of your company's activities.



Community Outreach

Establishing and following a plan to manage the reputation of your facility in your community

- Companies' future financial success tomorrow may well depend upon how well they interact with communities today.

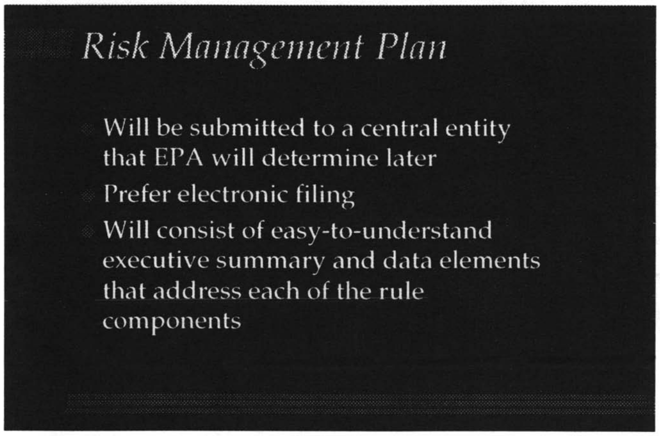


Why Reach Out?

- Legislation
- Regulation
- Success of Your Business

How EPA envisions risk management plans:

- submitted to a central entity
- electronic filing preferred
- will be made up of easy-to-understand executive summary and data that addresses each of the rule components

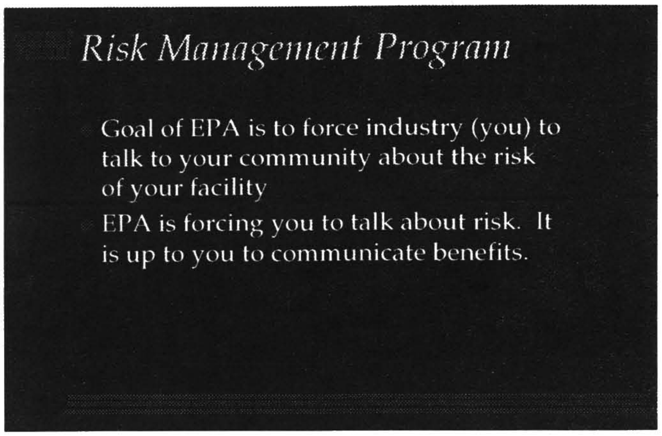


Risk Management Plan

- Will be submitted to a central entity that EPA will determine later
- Prefer electronic filing
- Will consist of easy-to-understand executive summary and data elements that address each of the rule components

Risk Management Program:

- Union Carbide's Bophal, India accident in the 1980's spurred this program's inception in Congress.
- EPA's goal is to force the industry to talk to communities about risks of your facility.
- It's imperative that companies use the *requirement* to talk about risk as an *opportunity to talk about benefits.*

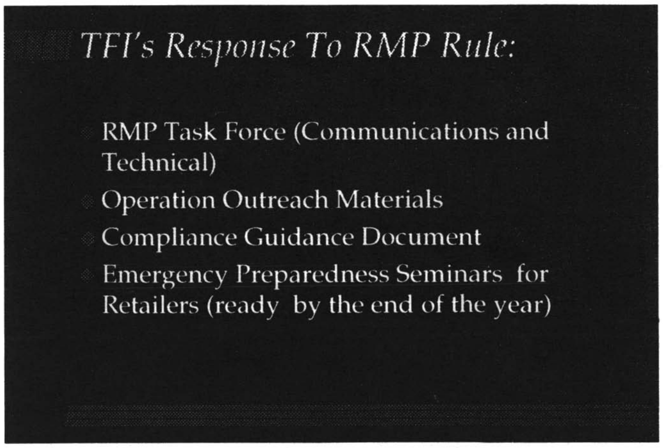


Risk Management Program

- Goal of EPA is to force industry (you) to talk to your community about the risk of your facility
- EPA is forcing you to talk about risk. It is up to you to communicate benefits.

TFI's Response to the RMP Rule:

- RMP Task Force (industry communications and technical experts).
- "Operation Outreach" Materials
- Compliance guidance document
- Emergency preparedness seminars for retailers (ready by the end of the year).



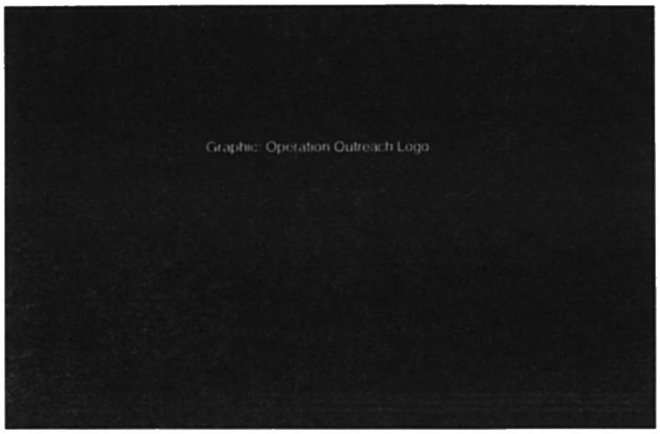
TFI's Response To RMP Rule:

- RMP Task Force (Communications and Technical)
- Operation Outreach Materials
- Compliance Guidance Document
- Emergency Preparedness Seminars for Retailers (ready by the end of the year)

A tool we at TFI have developed to help the industry understand and deal with RMP and these issues is Operation Outreach. It consists of:

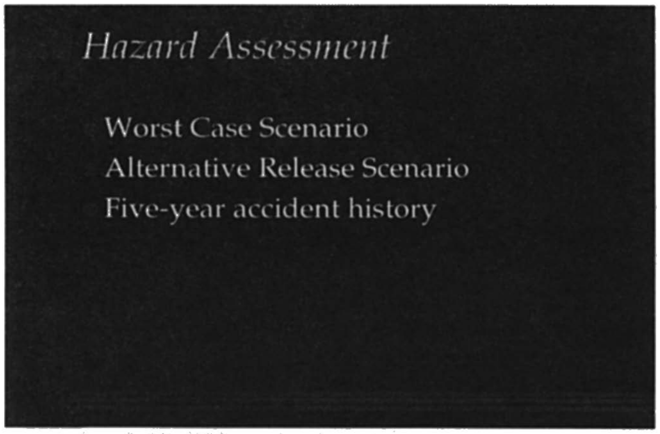
- A workbook
- An instructional videotape

It's available for free, from TFI and we hope that companies can take a couple of these, duplicate them on their own and distribute them to outlets and facilities.



Graphic: Operation Outreach Logo

- Your hazard assessment must include the following
  - Worst case scenario.
  - Alternative release scenario.
  - Five year accident history.



Hazard Assessment

Worst Case Scenario
Alternative Release Scenario
Five-year accident history

Switching Gears, I'd like to take a few minutes to look at the final farm bill and how a few of its provisions could affect the industry and agriculture.

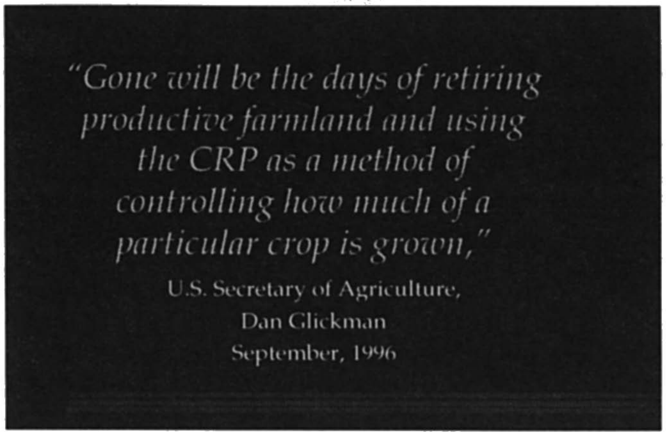
First off, the new, revamped Conservation Reserve Program as proposed by USDA will switch the focus from "highly erodible" "environmentally sensitive" lands.

Additionally:

- Maximum 36 million acres
- 10 percent limit on the acres a state may designate as conservation priority areas.

Even USDA admitted its mistakes of the past and vowed to stop using the CRP as a grain supply control mechanism.

Anyone who has followed TFI's dialogue with USDA throughout the past 15 years, can recognize what a great shift this statement presents.

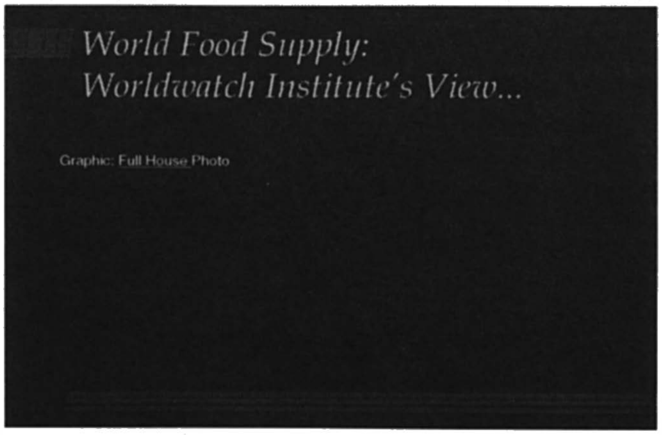


"Gone will be the days of retiring productive farmland and using the CRP as a method of controlling how much of a particular crop is grown,"

U.S. Secretary of Agriculture,
Dan Glickman
September, 1996

DOOM and GLOOM:

Yet, we are still forced — in many cases — to share the stage with doomsayers like Lester Brown of WorldWatch Institute.

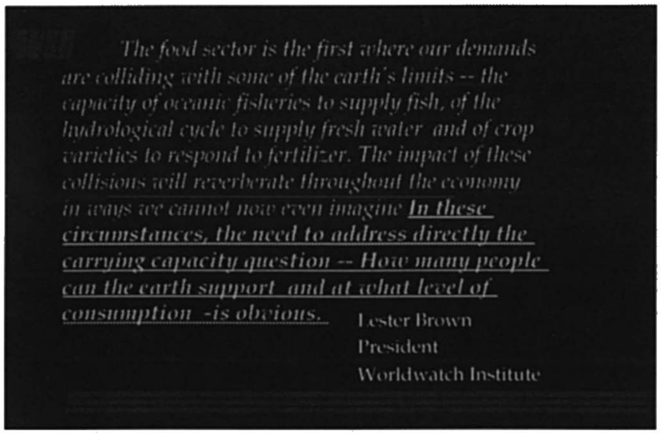


World Food Supply:
Worldwatch Institute's View...

Graphic: Full House Photo

Here is yet another example of Brown's inaccurate predictions about limits of the earth's "carrying capacity".

His assumption that we are somehow at the end of the agronomic spectrum ignores the great developments now occurring in our industry and in agriculture.



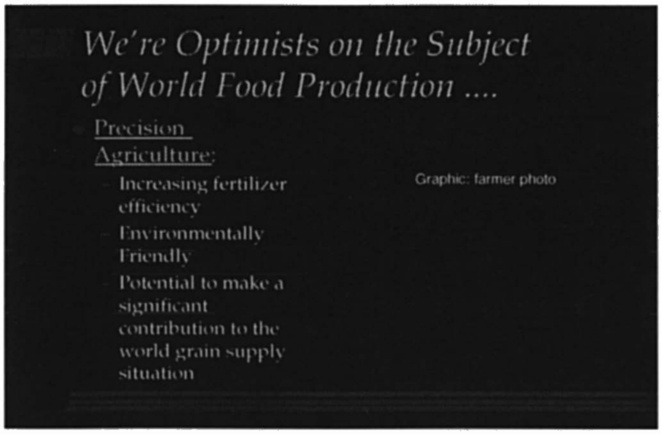
The food sector is the first where our demands are colliding with some of the earth's limits -- the capacity of oceanic fisheries to supply fish, of the hydrological cycle to supply fresh water and of crop varieties to respond to fertilizer. The impact of these collisions will reverberate throughout the economy in ways we cannot now even imagine ***In these circumstances, the need to address directly the carrying capacity question -- How many people can the earth support and at what level of consumption -is obvious.***

Lester Brown
President
Worldwatch Institute

We, on the other hand, are optimists on the subject of the world's carrying capacity.

Precision Agriculture:

- Is increasing fertilizer efficiency.
- Is environmentally friendly.
- Has the potential to make a significant contribution to the world's grain supply.



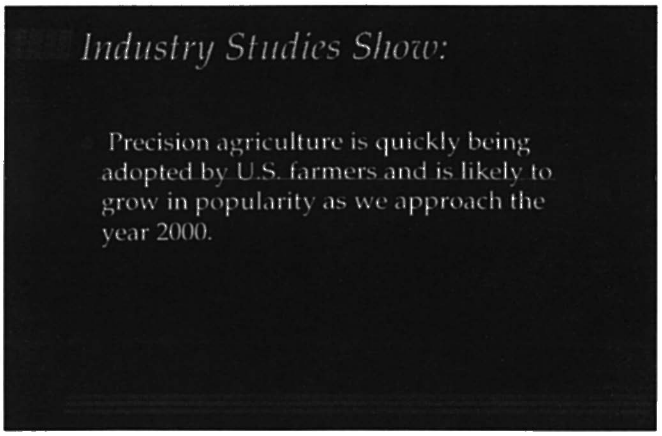
We're Optimists on the Subject of World Food Production ....

- Precision Agriculture:
  - Increasing fertilizer efficiency
  - Environmentally Friendly
  - Potential to make a significant contribution to the world grain supply situation

Graphic: farmer photo

Within the past few years, I have seen precision take off — from farm shows to the field, farmers are quickly recognizing this technology has the power to give them far greater control over the end result of their work in the field. . .

The precision revolution is a dynamic one — even some of our most progressive farmers are wondering how to separate the *tools* from the *toys*.

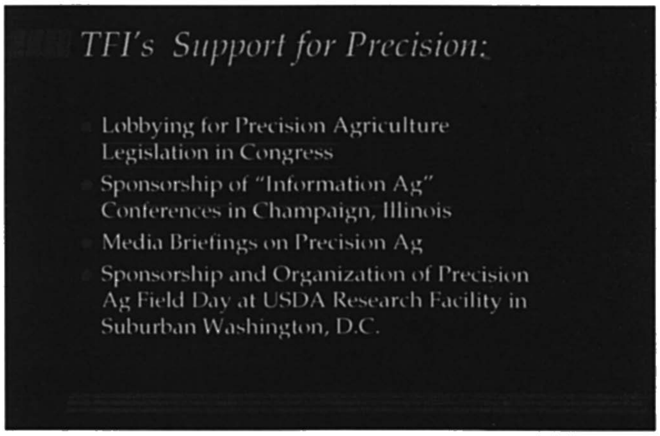


Industry Studies Show:

Precision agriculture is quickly being adopted by U.S. farmers and is likely to grow in popularity as we approach the year 2000.

Our support for precision is well documented:

- We've lobbied Congress for a research bill supporting precision agriculture.
- We've co-sponsored the Illinois-based "Information Ag" precision conference for the past two years.
- We've held media briefings on precision.
- We spearheaded and sponsored a precision ag field day for Congress.

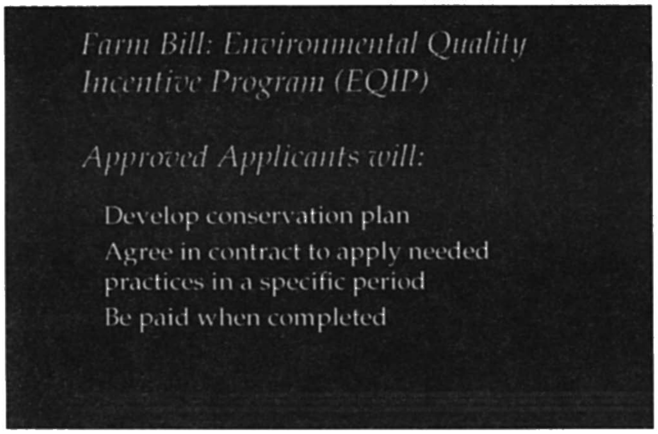


TFI's Support for Precision:

- Lobbying for Precision Agriculture Legislation in Congress
- Sponsorship of "Information Ag" Conferences in Champaign, Illinois
- Media Briefings on Precision Ag
- Sponsorship and Organization of Precision Ag Field Day at USDA Research Facility in Suburban Washington, D.C.

During its first full year, this program has been allotted $200 million.

- Final implementation will occur after proposed rule and a 30 day comment period.
- Will be administered by the Commodity Credit Corporation.



Farm Bill: Environmental Quality Incentive Program (EQIP)

Approved Applicants will:

- Develop conservation plan
- Agree in contract to apply needed practices in a specific period
- Be paid when completed

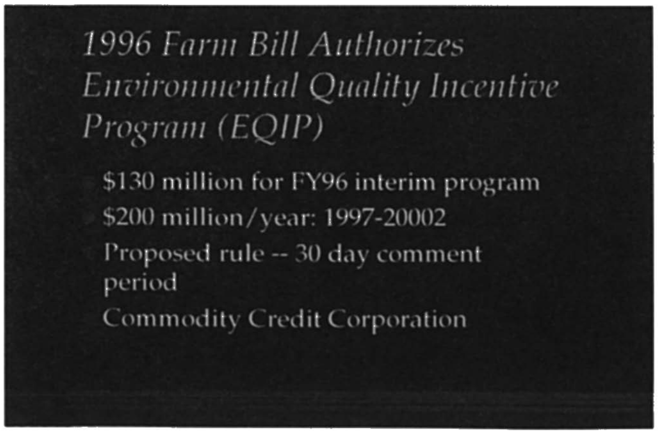
Moving to another key provision of the new farm bill, I'd like to say a few words about the Environmental Quality Incentive program — known as EQIP.

Key components:

- Development of a conservation plan.
- Agreement to apply needed conservation practices.
- Payment upon completion.

Guidance for the program will come from USDA national headquarters.

- State technical committees will make recommendations to state conservationists.
- States will submit final plans to USDA in Washington for approval.

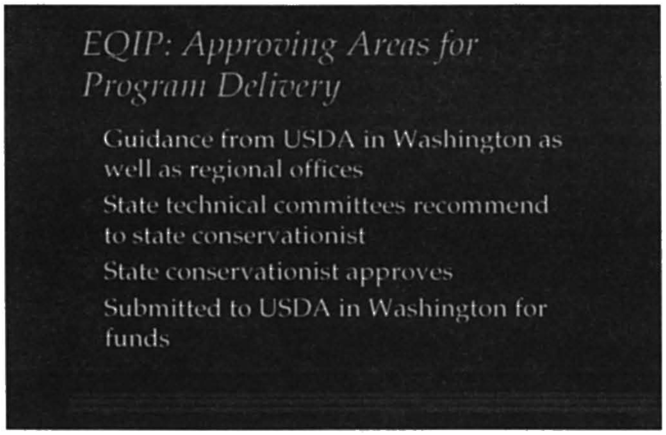


1996 Farm Bill Authorizes Environmental Quality Incentive Program (EQIP)

- $130 million for FY96 interim program
- $200 million/year: 1997-20002
- Proposed rule -- 30 day comment period
- Commodity Credit Corporation

Environmental Quality Incentive Program Final Rule

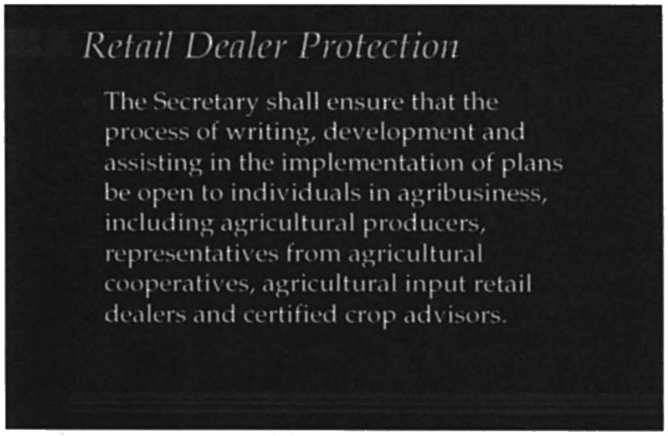
- Includes TFI language.
- Many $ decisions at local and state level.
- Industry involvement is key to assuring dealer role is not ignored as rule is implemented.



EQIP: Approving Areas for Program Delivery

- Guidance from USDA in Washington as well as regional offices
- State technical committees recommend to state conservationist
- State conservationist approves
- Submitted to USDA in Washington for funds

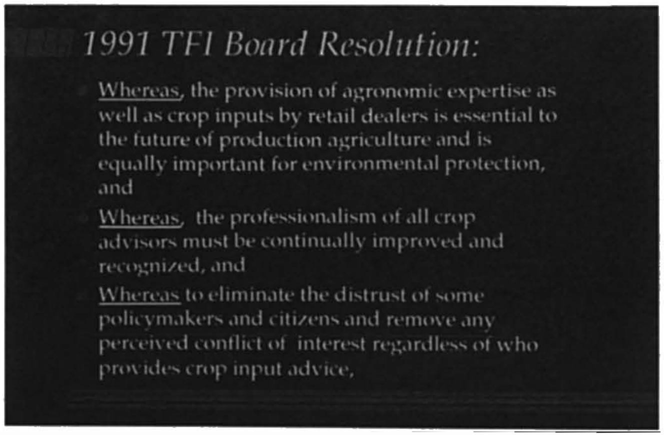
Initially, TFI lobbied to ensure retail dealers were included in the process of writing these EQUIP plans.



Retail Dealer Protection

The Secretary shall ensure that the process of writing, development and assisting in the implementation of plans be open to individuals in agribusiness, including agricultural producers, representatives from agricultural cooperatives, agricultural input retail dealers and certified crop advisors.

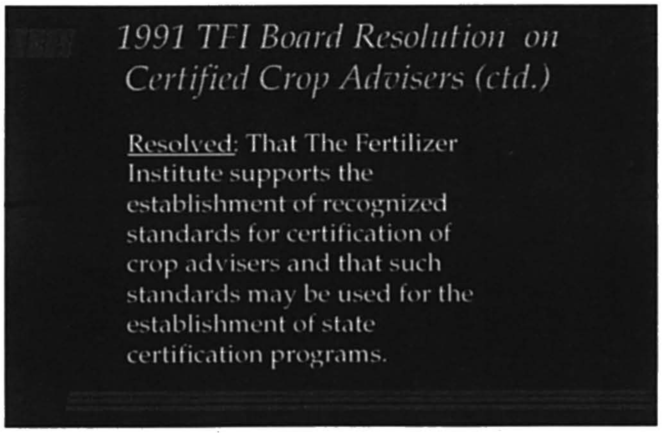
Back in 1991, believing this was a long-term issue that required TFI's attention, our board passed a resolution encouraging a certification program for crop advisers.



1991 TFI Board Resolution:

- Whereas, the provision of agronomic expertise as well as crop inputs by retail dealers is essential to the future of production agriculture and is equally important for environmental protection, and
- Whereas, the professionalism of all crop advisors must be continually improved and recognized, and
- Whereas to eliminate the distrust of some policymakers and citizens and remove any perceived conflict of interest regardless of who provides crop input advice,

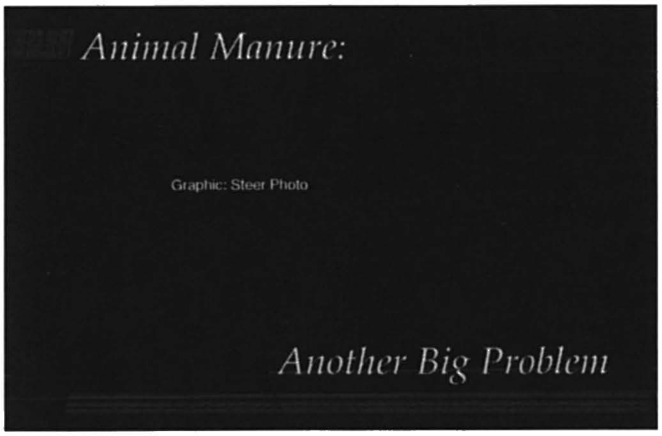
This resolution has acted as our guide as we have supported this program and its growth within the states.



1991 TFI Board Resolution on Certified Crop Advisers (ctd.)

Resolved: That The Fertilizer Institute supports the establishment of recognized standards for certification of crop advisers and that such standards may be used for the establishment of state certification programs.

Research being done within the fertilizer industry shows how fast precision is taking off, many believe that some form of precision — likely a yield monitor — will be a part of harvesting all major crops soon after the year 2000.

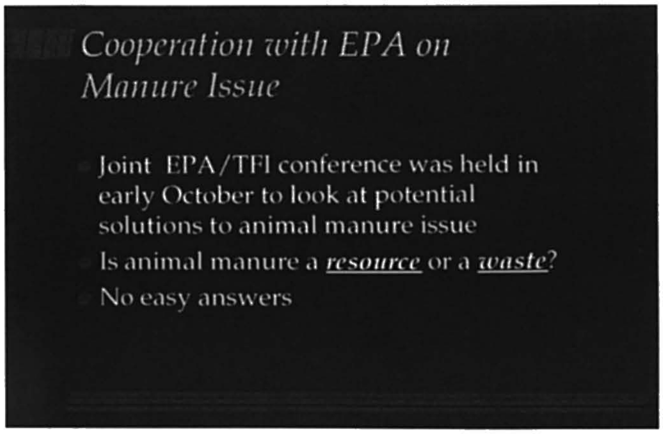


Animal Manure:

Graphic: Steer Photo

Another Big Problem

A final issue I'd like to address here is that of Animal manure. Laugh if you want to, but this is a dead serious issue within EPA, where many seem to think animal waste is a great nutrient resource.



Cooperation with EPA on Manure Issue

- Joint EPA/TFI conference was held in early October to look at potential solutions to animal manure issue
- Is animal manure a *resource* or a *waste*?
- No easy answers

We have cooperated with the Agency on a two day symposium, held early this month in Washington. Is animal manure a waste or a resource? Differing opinions on this prevail within the bureaucracy and so this is one that is not likely to go away soon.

We believe the industry needs to weigh in on this issue and will continue to work with EPA to investigate options and opportunities.

In concluding this presentation, I would like to point out that while this is a very exciting time for the fertilizer industry, there are many thorny issues afloat that have the potential to change the way you do business. Whether it is risk management for a fertilizer plant or farm bill regulations for the grower in the field, we plan to be there every step of the way, seeing to the best of our ability that the commercial fertilizer industry gets a level playing field and a fair shake in the legislative and regulatory process.

Outlook For Nitrogen

J. Douglas Campbell

Arcadian Corporation

Mr. Chairman, Ladies and Gentlemen of the Fertilizer Round Table, thank you for inviting me to discuss the Outlook for the U.S. Nitrogen Industry for 1997. It is especially good to be with you this year following what perhaps was the most profitable season in the nitrogen business and at a time when prospects for the coming year seem equally positive.

Today we'll review some of the successes and some of the shortcomings of the Nitrogen Industry over the past year. We'll look at the operational status of the several segments of our industry, and compare current prices and costs to those of last year and the recent past.

Lastly we will review where we stand on some of the driving forces which affect our industry. We will review current changes in our governmental Ag Programs and their probable effect on acreage planted. We will look at crop prices and their relationship to fertilizer prices and resulting rates of fertilizer applied per acre. We will set the basis for an estimated 5-8% increase in nitrogen use in crop year 1996/97 — *if* the weather cooperates *and* there are no other major surprises.

Let me take this opportunity to thank Dr. John Douglas of Douglas Associates for doing the work behind this presentation.

U.S. Farm Season 1996

(Slide 3 – 1995/96 Nitrogen Fertilizer Season)

The 1996 farm season has truly been different - different from past seasons and certainly different from what we expected. We all expected major increased acreage of all grains and oilseeds. We expected increased fertilizer application rates per acre to result from the high crop prices and the profitability of fertilizing.

In the fall of 1995 as crops were harvested and land was plowed for the 1996 spring season, it appeared that our expectations were being met - with the largest fall fertilizer application in many years. We entered spring 1996 in excellent condition:

- good sales under our belts for the 1st 6 months of the crop year,
- inventories slightly up to take care of expected spring rush,
- good grain and fertilizer prices.

We were ready for a banner year.

Then came the rains across the Midwest and drought across the Southwest. The rains kept coming, delaying fertilization and in some cases causing corn land to be planted in beans or not at all, and cotton land in the Southwest to be planted to sorghum. At least 10% of our corn was planted after June 1, and 5% after June 15. The entire season was very late in the Midwestern cornbelt.

Sales of nitrogen slowed to almost a halt. As a result, inventories increased and prices of some nitrogen products dropped.

In spite of this, 1995/96 crop year may well have been the best year in all history for the Nitrogen Industry based upon inferences from the *Quarterly Financial Summary* of TFI.

(Slide 4 – U.S. Fertilizer Season 1996)

The late season in Spring 1996 also brought about many changes in nitrogen fertilizer demand. We didn't get the banner year we expected - although we did get a good one! In fall 1995 our domestic disappearance of anhydrous ammonia was up by 6% or more, but by the end of the crop year (June 30) this had been reduced to only about a 4% increase over the 1995 crop year. In December 1995, UAN disappearance was up by 20% - by June this had been reduced to only a 7% increase. The solid urea pattern was different with a 2% decrease at the end of December and a 1% increase at the end of June. Domestic shipments of all nitrogen products (excluding ammonia) indicated a 6% increase in Fall shipments ending in December 1995 vs. the first six months of 1994/95 crop year; but only a 3% increase on June 30 vs. the prior year end. We had an excellent fall which made up for much, but certainly not all, of a slow and sharply reduced spring season of 1996.

U.S. Fertilizers, Crop Year 1996

(Slide 5 – U.S. Nitrogen Industry Operating Rates)

In many ways the U.S. nitrogen industry in crop year 1996 continued operating much like it has in the past, and will for the foreseeable future . Results, however, were far different. The nitrogen industry continued operating its plants at as near 100% operational rate as possible and making sufficient net imports to maintain a working supply/demand balance. Ammonia plants have operated at 100% level throughout the 1990's and based upon current announcements will continue to do so at least through the rest of the century. Solid urea plants for the past two years or more have been at the 100% level. This, too, should continue through the rest of this century. UAN solutions and ammonium nitrate plants have varied their operating rates based upon the relative profitability of the two products and the availability of nitric acid to produce the two.

In short, the nitrogen industry in the U.S. is operating at capacity and should continue to do.

Supply-Demand Balances

(Slide 6 – Net Imports Balance Supply/Demand Situation of Nitrogen)

It is estimated by the *Fertilizer Record* that total U.S. ammonia *production* was up by only one (1) percent in spite of essentially full time operation by three new plants (Port Neal, IA, Kennewick, WA and Gordon, GA). We produced more nitrogen solutions (+4%) and less ammonium nitrate (-8%) and about the same solid urea as in 1995. In total, we produced only 1% more anhydrous ammonia than in 1994/95 crop year and almost the same amount of N in other products such as urea, UAN, AN, ammonium sulfate and ammonium phosphates.

(Slide 7 – U.S.A. Imports)

Meanwhile, to balance nitrogen supply/demand, we imported over 5.8 million tons N, including about 4.6 million tons of ammonia and almost 3.0 million tons of urea. Our imports of ammonia from the F.S.U. decreased by over 25% and those from the Arabian Gulf also decreased as imports from the Western Hemisphere increased. Our imports of urea held constant for the year, but as a result of the late spring with less than expected demand, some of our importers were forced to re export large quantities at year-end—often at prices below its original cost. We ended the crop year with net imports of urea 18% below those in 1995. Net imports of all N fertilizer were almost 0.5 million tons N less than that of 1995.

Fertilizer Year-End Inventories

(Slide 8 – Nitrogen Fertilizer Inventories)

In crop year 1995 the U.S. fertilizer industry ended the year at June 30 with inventories of most products at near record highs. In 1996, inventories of most products were much lower than in 1995 and in some cases were below normal in spite of the long drawn out wet spring.

In 1996 based upon data from *The Fertilizer Record* of TFI, U.S. producers had in inventory only the equivalent of 25 days production of ammonia vs. 33 days in 1995 — a 24% reduction. By the end of August it stood at 34% below the prior August. Urea and Ammonium Nitrate were down by 26% and 42% respectively at June year-end. By the end of August 1996 these were down 27% and 58% respectively from August 1995. Inventory of UAN solution was up by 15% over 1995 but by August this was pulled down to 4% below August 1995.

In 1996 the U.S. has made significant reductions in inventories of all major nitrogen fertilizers and as we enter the 1997 crop year our major problem may be that of finding enough nitrogen to supply increasing demand.

1996 Production Costs

(Slide 9 – Changes in U.S. Nitrogen Production Costs)

The production cost of anhydrous ammonia during much of 1996 was higher than the cost in 1995 as natural gas prices escalated over short periods of time to over $3.00/MMBtu and averaged over $2.10/MMBtu vs. an average cost in 1995 of $1.62/MMBtu. Many producers have, however, ameliorated these cost increases by judicious hedging of their future supplies. Average cost increase is estimated at not more than $20/ton of ammonia in calendar year 1996 vs. 1995.

The cost of other nitrogen fertilizers also increased significantly reflecting the added cost of ammonia used in production of other nitrogen products—perhaps as much as $12 per ton of solid urea or $8 per ton of 32% UAN solution.

1996 Average Fertilizer Pricing, USA

(Slide 10 – Ammonia Price - Del Midwest)

In the U.S., fertilizer pricing in 1996 has seen its ups and downs as the long drawn out wet spring changed the timing, and in some cases reduced the total quantity of sales. Ammonia pricing fell sharply from April onward but by late September had recovered all its losses and was once again headed above year ago levels.

(Slide 11– Urea Price - Midwest)

Urea prices also took a severe hit in mid spring as it became evident that too much had been imported and prices on the Gulf Coast were reduced in order to re export large quantities. This has been done and now U.S. urea prices in the major using areas are back to their levels of last year.

(Slide 12 – Ammonium Nitrate Price – Del South Central)

On the other hand, prices of ammonium nitrate in the major using areas have been up throughout 1996 — an average of 8% over last year and 41% over the five year average for 1989-1993.

(Slide 13 – 30% UAN Solution Price – FOB Midwest)

Prices of UAN solution this year have been about equal to those of last year and 37% above the 1989-1993 average.

All in all the nitrogen industry can not help being pleased with fertilizer prices as compared to the past.

The Farmer Situation

(Slide 14 – Net Cash Farm Income)

Now I'd like to take a quick look at some of the factors which are basic driving forces for the nitrogen fertilizer business as well as other fertilizers.

Net Cash Farm Income for U.S. farmers for the past 10 years has averaged over $50 billion annually—and 1996 is expected to top them all at up to $59 billion or more.

(Slide 15 – Cash Receipts From Crops)

Cash receipts from crops in 1996 for the first time ever are expected to exceed $100 billion as it hits as high as perhaps $110 billion. We all recognize that most of our fertilizer is sold to crop farmers and this year they will have more cash flow than ever before. They will have money to pay for fertilizer.

(Slide 16 – Farm Debt)

What did the farmer do with all this net cash income of the past decade? First he reduced his debt. He reduced his total debt from $194 billion in 1984 to $137 billion in 1990 - and it's only climbed back to $155 billion in 1996, even with his many purchases of high priced land and new farm machinery.

(Slide 17 – Total Farm Equity)

Meanwhile, total farm equity which in 1986 had been reduced to only $567 billion, has now in 1996 grown to an all time record $832 billion, and is growing more rapidly each year as farm prices escalate.

(Slide 18 – Debt-To-Equity Ratio)

As a result, the U.S. farmer's debt-to-equity ratio has decreased from 30% in 1985 and 20% in 1989 to its current 18.6%.

Success In Overcoming World Food Problems

(Slide 19 – World Total Grain Situation)

In 1996 concerted World efforts to rebuild drastically reduced inventories of grain and other Ag commodities were only partially successful.

(Slide 20 – World Total Grain Stocks-To-Use Ratio)

World total grain supplies which had been pulled down to a 14% supply-to-use (S/U) ratio prior to this years crop, now appear to have stopped their decline of the past decade. In the 1996/97 market year they may actually increase — but only by 1% to 1.5%. Even this small improvement could change as a result of continuing inclement weather during harvest, a sudden increase in demand or numerous other possibilities.

(Slide 21 – U.S. Total Grain Situation)

In the U.S. the story is much the same. In spite of a new Governmental Ag Program with relaxed acreage restrictions leading to increased acreage of many crops—especially corn, wheat and other grains—total production for 1996 is not now expected to be sufficiently high to bring inventories of grains back to an acceptable level.

(Slide 22 – U.S. Total Grain Stocks-To-Use Ratio)

The S/U ratio of 8% at the end of crop year 1995 is expected to increase only to 12% with the 1996 crop. Even this may be high since it can be accomplished only with a 13% reduction in exports of total grain. Prior to the 1995 crop we've never since WWII seen such low inventories. The pressure is still on for more production. We may have stopped the long decline in inventories, but we've made very little progress in rebuilding stocks.

New U.S. Agricultural Programs

(Slide 23 – New U.S. Agricultural Programs)

In 1996 the U.S. Congress passed into law a new Ag Program which changes the basic programs of the past half century. Since mid century our Ag Program has been founded upon some form of *Supply Control* mechanism. Our new program, put into law for the next seven years, does away with the supply control provisions recently incorporated under the Acreage Reserve Program (ARP) and allows farmers to decide how much of individual crops they will plant. Thus, our farmers will be able to plant more total acres and to pick their crops based upon profit expected.

The Conservation Reserve Program (CRP), which was in reality also a form of a supply control clothed in political respectability as a "Conservation" program, has been radically changed. Many acres now in this program will no longer be eligible and will go back into production. Other acres may be drawn out by the lure of higher crop prices, and perhaps lower government payments for land in the CRP. New regulations on the CRP were only announced in mid-September, so it is difficult to predict the final outcome, other than to say that some added acres will become available for corn, wheat, other grains and oilseed crops.

Crop Prices

(Slide 24 – Average Prices Received By U.S. Farmers)

Crop prices in 1996 have been indeed spectacular. Almost all grains and cotton hit all time highs for extended periods during 1996. Although, as harvest approaches, we see some weakness, the price levels still are far higher than in many years. As October approaches we see corn selling at $3/bu or more, wheat at $4/bu or more, soybeans at $7.50/bu, rice at $10/cwt and cotton at over 75 cents/lb. These prices will certainly encourage *more acres - and higher fertilizer application rates/acre.*

(Slide 25 – Nitrogen/Corn Price Ratios)

Fertilizer prices today in the U.S., as in the rest of the world, are high. However, the farmer knows his profit is determined by the bushels of corn grown vs. the cost of fertilizer and other inputs. In this respect the prices of fertilizers today are low!

For example, a typical application rate for corn in the Midwest would be: 150 lbs. of nitrogen, 60 lbs. of phosphate and 90 lbs. of potassium. This fertilizer application should yield 150 bushels per acre of corn under normal conditions. Without any fertilizer you should expect only 75 bushels per acre of corn, a net gain attributable to fertilizer of 75 bushels per acre. Based on a price for corn of $3.25 per bushel, the farmer gains $244 per acre for a fertilizer cost of $57 per acre. The net gain is $187 per acre, a 300% return on the fertilizer cost.

Although corn and other crop prices are probably not going to stay at these levels forever, we see no reason for a major decline in crop or fertilizer prices as long as grain inventories stay as low as they are and should be for the next year.

Without question, the value the farmer is receiving from fertilizer is great ,and is a bargain! If the weather cooperates, the farmer will certainly use more fertilizer per acre on more acres in 1997!

Acreages Expected For 1997 Crops

(Slide 26 – Summary of Planted Acreage of the Major U.S. Crops)

Now for a summary of what we expect for 1997 planted acreage of the eight major U.S. crops. In total we expect the acreage of the eight primary crops to increase by about over 3% from 1996 acreage of 262 million to about 270 million in 1997. The acreage of the crops which are major users of nitrogen (corn, wheat and cotton) will increase over 4%. This of course assumes normal weather—and no other major changes.

We should see up to 83 million acres of corn vs. the 79.5 million in 1996—again more than a 4% increase.

Wheat acreage too is expected to increase by 4-6% as the lure of higher wheat prices pulls land from the CRP back into cultivation.

Cotton acreage, much of which did not get planted in 1996, can be expected to increase to 15 million vs. the 14.2 million in 1996 - a 5-6% increase. It could go even higher if cotton prices continue recent increases.

All in all we should see a 4-5% increase in nitrogen use to result from increased acres, and a 1–3% increase to result from increased rates per acre —a total increase of 5-8% from crop year 1996.

Summary, 1996

(Slide 27 – Summary 1996)

- The year 1996 for the U.S. fertilizer industry was not the true banner year most had expected. It was, however, a good year in spite of the long drawn out wet spring.

- We sold slightly more fertilizer than we did in 1995 crop year in spite of the bad weather.

- Prices in some cases were not as high as they had been in 1995 but were 40-75% higher than their 1989-93 average. Prices of some nitrogen products were the highest in this decade.

- Production costs of ammonia generally were up as the cost of natural gas escalated in some cases for short periods of time to above $3.00/ MMBtu with an average price above $2.00/ MMBtu. Average costs of other nitrogen materials were increased by the increased cost of the ammonia used and by increased capital costs of new plant units to debottleneck total N production.

- Year end inventories were very low — critically low for anhydrous ammonia.

Now for the Coming Year 1996/97

(Slide 28 – Outlook for 1997 and Beyond)

- The decade long drop in carryover inventories of ag commodities in the World and U.S. has been halted — but we've seen precious little success in rebuilding these depleted stocks.

- New U.S. Ag Program deletes the ARP "supply control" program and restricts the CRP programs — thus more grain acres.

- Crop prices remain high — to encourage higher fertilizer rates/acre.
- All of this indicates a 5-8% increase in nitrogen fertilizers in 1996/97.

U.S. Nitrogen Outlook Slide Presentation

1995/96 NITROGEN FERTILIZER SEASON, USA

I. **Great Expectations!!**
   + 8-12% Grain Acres
   + 7-10% Fertilizer

II. **Fall 1995**
   Good Weather
   Outstanding Sales
   Good Prices

III. **Spring 1996**
   Corn Belt Rains!
   Southwest Drought!
   Corn and Cotton Planted Late!
   Some Changed to Beans or Sorghum
   Nitrogen Sales Dropped!
   So Did Prices!
   But may have been Best Year in History!

Prepared by: Douglas Associates for Arcadian Corporation

Slide 3

U.S. FERTILIZER SEASON 1996

	DOMESTIC SHIPMENTS vs 1994/95 CROP YEAR	
PRODUCT	JULY-DEC 1995	FERT. YEAR 1995/96
NH_3	+6%*	+4%
UAN SOLUTION	+20%	+7%
UREA	-2%	+1%
TOTAL N PRODUCTS EXCEPT NH_3	+6%	+3%

* October 1995
Source: Computed from USDC Cendata, The Fertilizer Record and TFI Export/Import Statistics

Prepared by: Douglas Associates for Arcadian Corporation

Slide 4

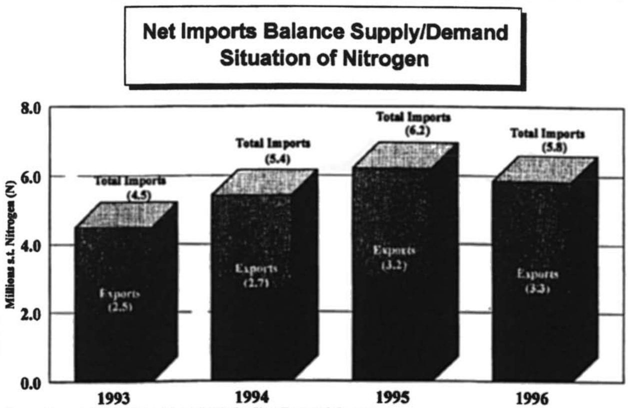
U.S. NITROGEN INDUSTRY OPERATING RATES (%)

	1993	1994	1995	1996
ANHYDROUS AMMONIA - USA	101	102	102	100
SOLID UREA - USA	96	87	103	99
UAN SOLUTION	97	94	87	87
SOLID AMMOMIUM NITRATE	85	90	86	75
AMMOMIUM SULFATE	93	99	104	100

Percent computed from TFI Semiannual Production Surveys, February and September 1996

Prepared by: Douglas Associates for Arcadian Corporation

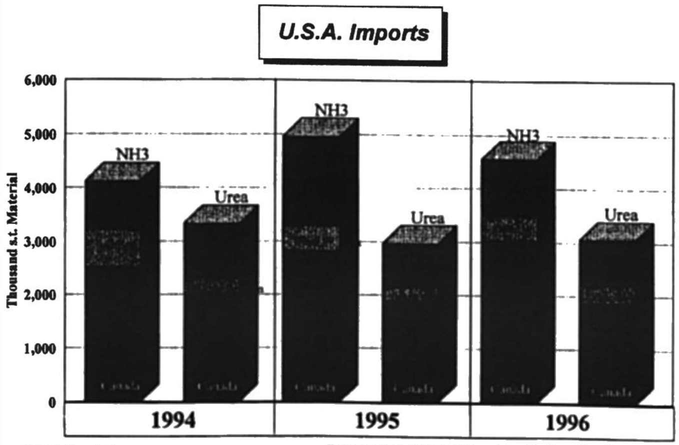
Slide 5


Net Imports Balance Supply/Demand Situation of Nitrogen

Source: Computed from TFI printouts of U.S. Fertilizer Exports & Imports

Prepared by: Douglas Associates for Arcadian Corporation

Slide 6


U.S.A. Imports

Prepared by: Douglas Associates for Arcadian Corporation

Slide 7

NITROGEN FERTILIZER INVENTORIES

	June 30		%
Fertilizer Material	1995	1996	Change
	(Days Production)		
ANHYDROUS AMMONIA	33	25	-24%
UREA	43	32	-26%
AMMONIUM NITRATE	19	11	-42%
UAN SOLUTION	48	55	15%
ESTIMATED TOTAL N, ALL N PRODUCTS EXCEPT NH_3	36	32.5	-10%

Source: Computed from *The Fertilizer Record*, TFI

Prepared by: Douglas Associates for Arcadian Corporation

Slide 8

CHANGES IN U.S. PRODUCTION COSTS, 1996

I. Anhydrous Ammonia

1. Higher Natural Gas Costs

   Over $2.10/MM btu in 1996 Vs. $1.62 Average in 1995

2. Higher Maintenance Cost With Aging Plants

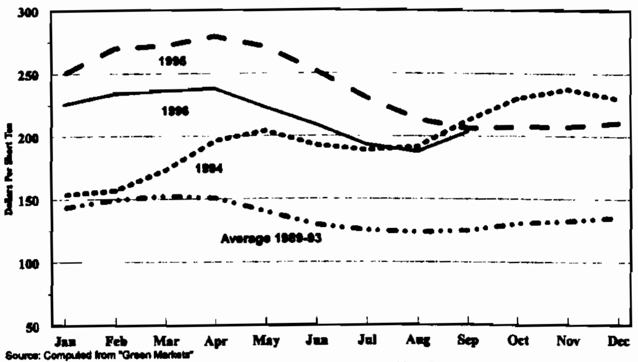
II. Other Nitrogen Products

1. Higher Cost of Ammonia
2. High Costs of Building New Nitric Acid Capacity to Eliminate Bottlenecks

Prepared by: Douglas Associates for Arcadian Corporation

Slide 9

Ammonia Price (Del Midwest)

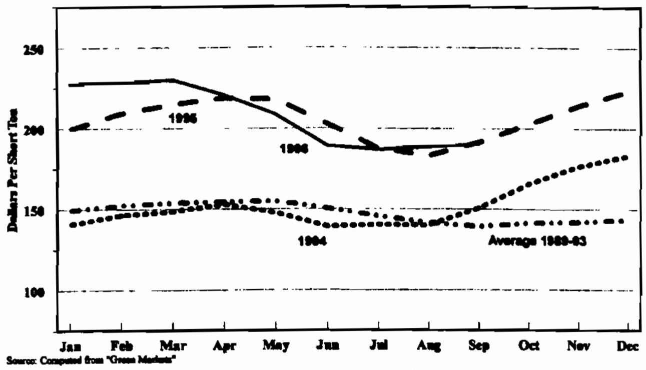


Source: Computed from "Green Markets"

Prepared by: Douglas Associates for Arcadian Corporation

Slide 10

Urea Price (Midwest)

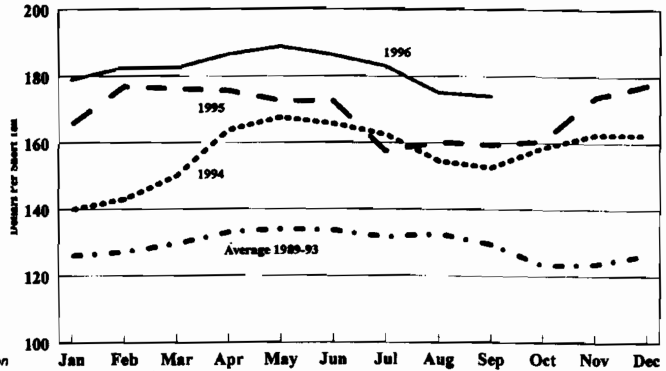


Source: Computed from "Green Markets"

Prepared by: Douglas Associates for Arcadian Corporation

Slide 11

Ammonium Nitrate Price (Del South Central)

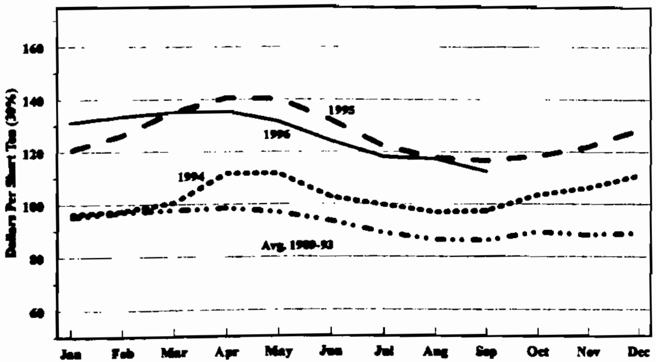


Computed from "Green Markets"

Prepared by: Douglas Associates for Arcadian Corporation

Slide 12

30% UAN Solution Price (f.o.b. Midwest)

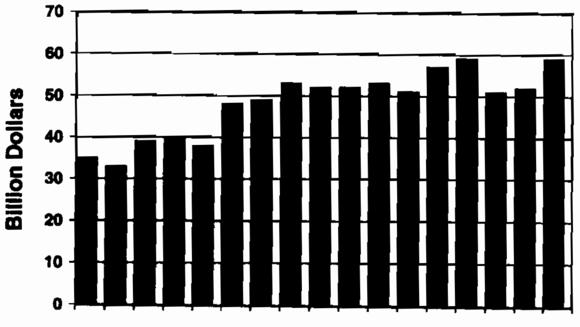


Source: Computed from "Green Markets"

Prepared by: Douglas Associates for Arcadian Corporation

Slide 13

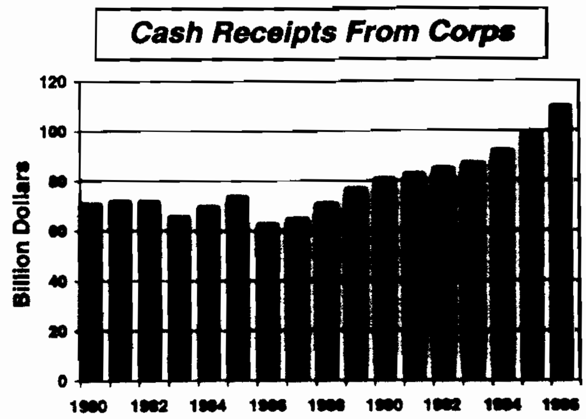
Net Cash Farm Income



Source: USDA, ERS

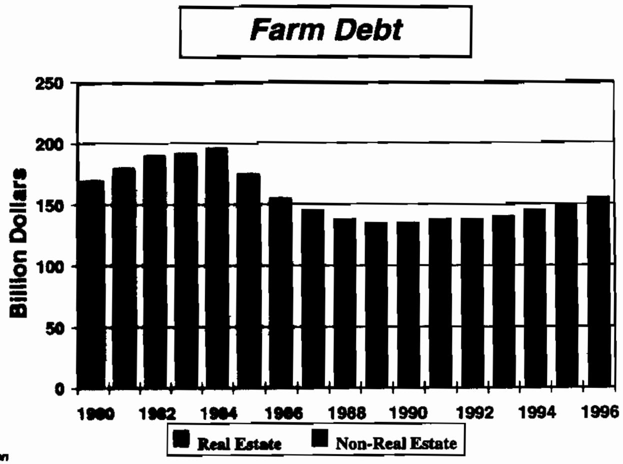
Prepared by: Douglas Associates for Arcadian Corporation

Slide 14



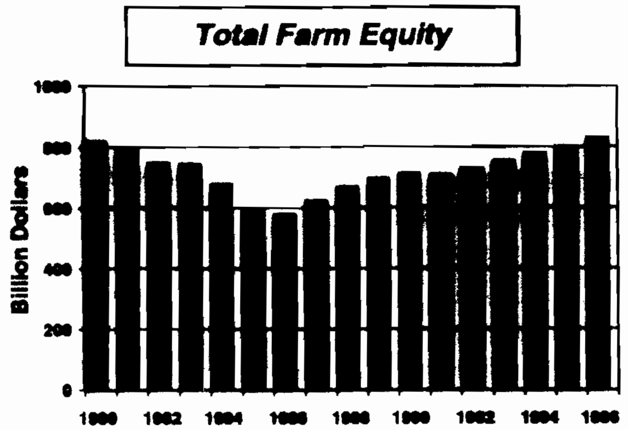
Source: USDA, ERS *Prepared by: Douglas Associates for Arcadian Corporation*

Slide 15



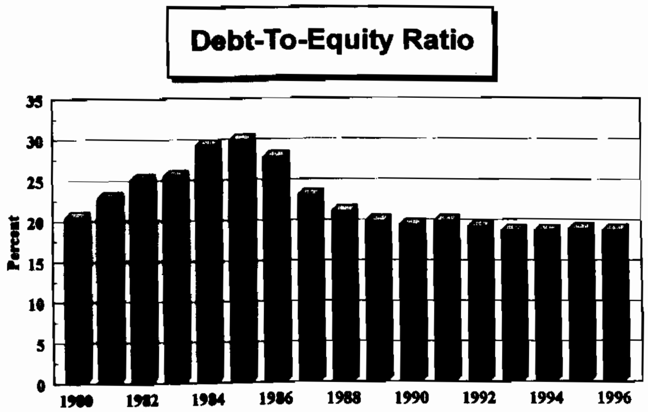
Source: USDA, ERS *Prepared by: Douglas Associates for Arcadian Corporation*

Slide 16



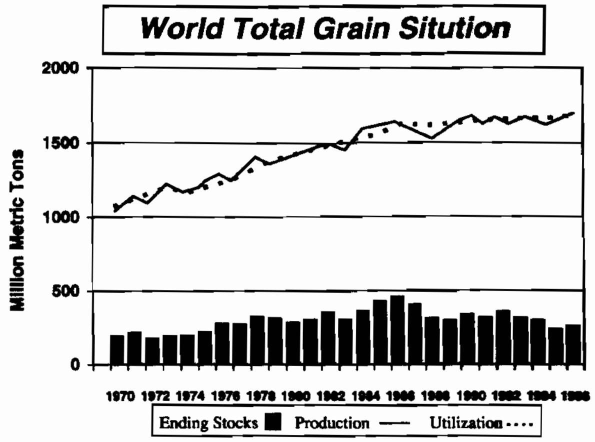
Source: USDA, ERS *Prepared by: Douglas Associates for Arcadian Corporation*

Slide 17



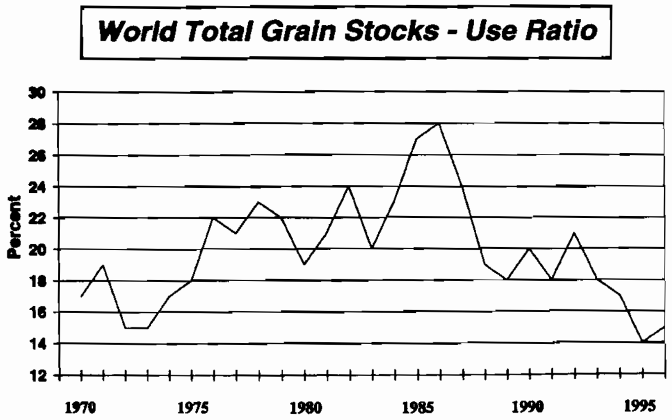
Source: USDA, ERS *Prepared by: Douglas Associates for Arcadian Corporation*

Slide 18



Source: USDA, WAOB *Prepared by: Douglas Associates for Arcadian Corporation*

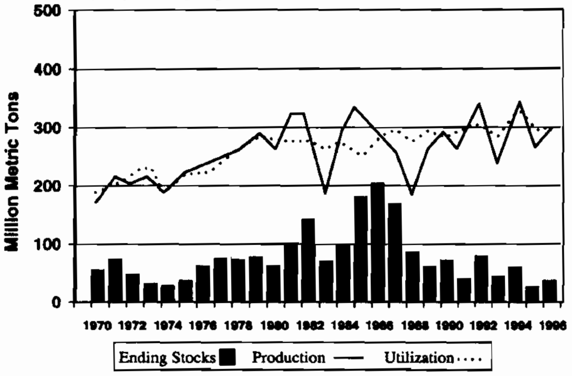
Slide 19



Source: USDA, WAOB *Prepared by: Douglas Associates for Arcadian Corporation*

Slide 20

U.S. Total Grain Sitution

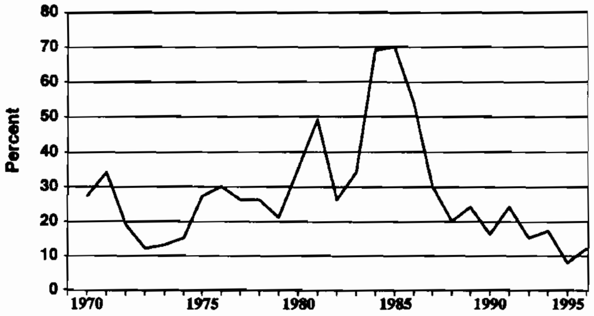


Source: USDA, WAOB

Prepared by: Douglas Associates for Arcadian Corporation

Slide 21

U.S. Total Grain Stocks-Use Ratio



Source: USDA, WAOB

Prepared by: Douglas Associates for Arcadian Corporation

Slide 22

NEW U.S. AGRICULTURAL PROGRAM

I. Acreage Reduction Program (ARP) Cut

Farmer Freedom to Choose Crops and Acreage
Means More Acreage of Grains

II. Radically Changed Conservation Reserve Program (CRP)

Now More Tuned To Conservation

Will Also Mean More Acres To Farm

Prepared by: Douglas Associates for Arcadian Corporatior

Slide 23

AVERAGE PRICES RECEIVED BY U.S. FARMERS

	10-Year Average <u>(1986-1995)</u>	<u>1995</u>	9-Months 1996 <u>(Jan-Sept)</u>	USDA Projection <u>1997</u>
		(Dollars Per Bushel)		
CORN	**2.24**	**2.56**	**3.83**	**3.00-3.40**
WHEAT	**3.24**	**4.09**	**4.97**	**4.10-4.70**
SOYBEANS	**5.89**	**5.87**	**7.40**	**7.00-8.00**
		(Dollars Per Cwt)		
RICE	**7.01**	**7.55**	**9.56**	**8.76-9.75**
COTTON	**61.48**	**81.27**	**76.20**	**N.A.**

Source: Ag Prices and Ag Crop Situation, September 1996, USDA, NASS

Prepared by: Douglas Associates for Arcadian Corporation

Slide 24

FERTILIZER - A VALUE AND A BARGAIN

Corn Yield Benefits

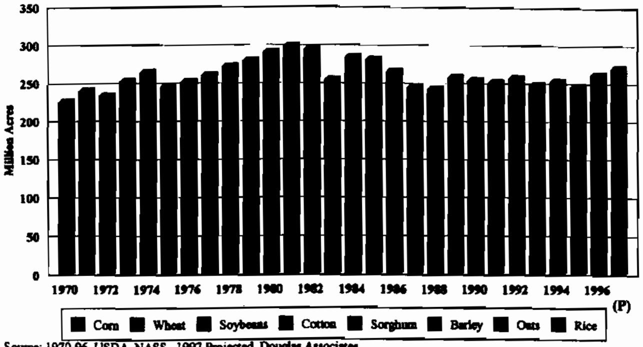
<u>Fetilizer Applications</u>:	**<u>Anticipated Yield Per Acre</u>**
(150N-60P-90K) lbs. Per Acre	**150 bushels**
No Fertilizer	**<u>75</u> bushels**
Yield Improvement	**75 bushels**
<u>$ Return Per Acre</u>	
Yield Improvement Value @ $3.00/bu x 75bu	**$225**
Fertilizer Costs	**$<u>57</u>**
Margin Improvement	**$168**
Return on Fertilizer Investment	**<u>294</u>%**

Corn Price Estimate - $3.00/bu

Prepared by: Douglas Associates for Arcadian Corporation

Slide 25

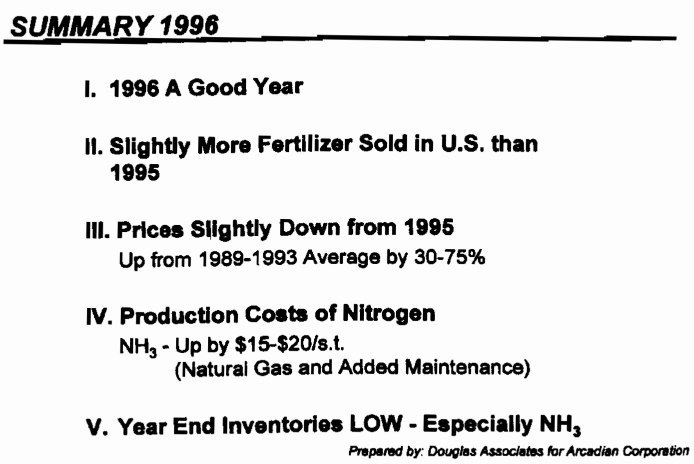
Planted Acreage Of The Major U.S. Crops



Source: 1970-96, USDA, NASS. 1997 Projected, Douglas Associates

Prepared by: Douglas Associates for Arcadian Corporation

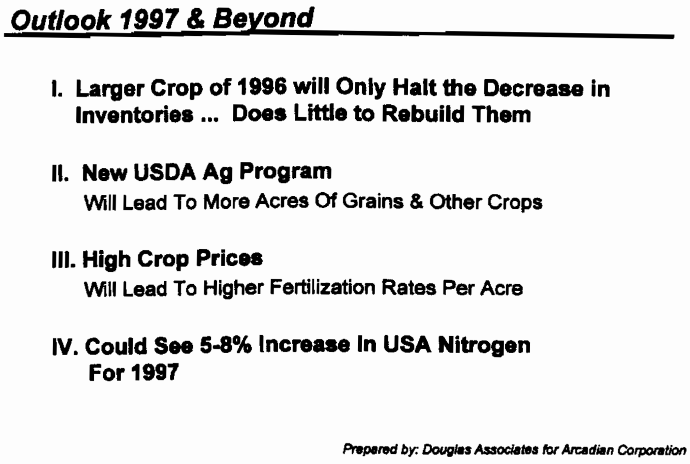
Slide 26


SUMMARY 1996

- **I. 1996 A Good Year**
- **II. Slightly More Fertilizer Sold in U.S. than 1995**
- **III. Prices Slightly Down from 1995**
  - Up from 1989-1993 Average by 30-75%
- **IV. Production Costs of Nitrogen**
  - NH_3 - Up by $15-$20/s.t. (Natural Gas and Added Maintenance)
- **V. Year End Inventories LOW - Especially NH_3**

Prepared by: Douglas Associates for Arcadian Corporation

Slide 27


Outlook 1997 & Beyond

- **I. Larger Crop of 1996 will Only Halt the Decrease in Inventories ... Does Little to Rebuild Them**
- **II. New USDA Ag Program**
  - Will Lead To More Acres Of Grains & Other Crops
- **III. High Crop Prices**
  - Will Lead To Higher Fertilization Rates Per Acre
- **IV. Could See 5-8% Increase In USA Nitrogen For 1997**

Prepared by: Douglas Associates for Arcadian Corporation

Slide 28

Outlook for Phosphates and Sulphur

René L. Latiolais
Freeport McMoRan, Inc.

The business of feeding people today is much larger than selling fertilizers to farmers or selling fertilizers to dealers. It is a very large business, the largest business in the world. In many countries of the world, particularly those in Asia, agriculture represents the single largest component of what you might consider to be their gross domestic product. It is an extremely large and very complex business.

As you can see in the first chart, it is a business where the raw materials on the left side of this chart have a great deal to do with profitability. We believe vertical integration in this business is critical. In the case of our company and our joint venture with IMC, we produce phosphate rock in Florida. We also produce sulphur at Main Pass 299, offshore in the Gulf of Mexico and at our Culberson mine in West Texas. The IMC-Agrico joint venture has phosphoric acid facilities and facilities to produce granular phosphate products. Much of this material is applied on corn fields in the United States and over half of our fertilizer products are exported, primarily to China, India and Pakistan. (Fig. 1).

As we examine the key factors driving our business today, we see a situation where growing world populations and improved dietary standards are creating increased requirements for fertilizer products. While the same demand side forces are at work for nitrogen and potash products, we believe the phosphate market situation is more positive given the uncertainty of the supply side of the phosphate equation. (Fig. 2).

If you look at the demand side of the agricultural picture, on the left axis, we see the metric tons of grain that are produced and consumed around the world. On the right side of the chart, using the bar graphs, we have tried to show you this usage in terms of inventory levels and what percentage of inventory is available to satisfy this growing demand situation. You can see that the chart continues to suggest that looking forward, there is a production shortfall. If you really look at a macro view of the chart, it is pretty clear that for some time, world production has not been sufficient to feed the people of the world. We have relied on inventories. And for the first time since 1992, this year's grain harvest is expected to outpace global consumption. This is expected to rebuild stocks to 271 million metric tons or approximately 15% of use, a modest increase from last year's record low level of about 13-14%, but still significantly below the 20% level averaged over the past 10 years. (Fig. 3).

It is important to understand why the agricultural situation has changed. Production in the Former Soviet Union hit a 40 year low last year while global demand for grain, particularly in Asia, is increasing. Farmers in the US, Latin America, Australia and Europe are being challenged to increase yields to meet these demands — and it appears it is going to get a lot tougher. As we have seen over the past year, this situation will result in higher grain prices and increased global demand for fertilizer products.

Consider the factors driving grain demand globally. Clearly the population growth is no surprise to any of us. But the dietary standard improvement around the world is quite striking. This graph illustrates the shift in the Chinese dietary standards from 1960 to 1990 and would look very similar in many parts of the developing world. And as the middle class of Asia emerges, the importance of food and the quality of food is going up. (Fig. 4). But even with the significant improvement in Asian diets over the 30 year period, the standard is still well below the U S average as you can see from the chart. Consider that it takes over a pound of grain to raise a pound of chicken, closer to four and a half pounds for a pound of pork and somewhere around seven pounds for beef. As the Asians begin to eat more beef rather than pork, or more pork rather than chicken, and more chicken rather than grain, this has a compounding and leveraging effect on the population growth phenomenon adding up to a tremendous amount of grain demand. (Fig. 5 & 6).

The next chart illustrates the World Bank's projected per capita grain demand by country which we should look at in conjunction with the population dilemma. We have somewhere in the neighborhood of 5.8 billion people on the planet today and this is growing by nearly three people every second. This equates to 10,000 new mouths to feed every hour and about 240,000 every day. China and India are critical to this equation. A 2% increase in per capita grain demand in India and a projected 24% gain in per capita increase in China, coupled with a 600 million person population increase in these two countries equates to a staggering increase in grain demand.

Let's look at the demand picture another way. If you look at base demand for grain over the past 25 years, you will see the upward trend in world grain consumption. If we apply a linear trend, what is interesting is that to satisfy that trend line between now and the year 2010, the new demand triangle is what has to be added to the system — over 400 million tons of grain to feed a population of roughly 7 billion. What is additionally interesting is that if you look at the application of fertilizer today at about 82 pounds per acre and consider the demand driven increases in required yields, we would expect N-P-K application rates to increase by 50% to the year 2010 to grow this additional grain on the arable land available in the world today. (Fig. 7).

Let's look at that gap slightly differently. Just how big is the gap? If you take the grain growing capacity of the greatest grain growing regions in the world: Canada, the United States, Brazil, Argentina, Australia; these countries make up nearly two-thirds of the world trade in 1995 for wheat, coarse grains and rice. If you add up the annual production from these major growing regions, you come up with a number of just over 400 million tons — the number we need to fill the gap we discussed in the previous chart. A very dramatic story. (Fig. 8).

The next chart examines the fertilizer demand situation and clearly reminds us of the market disruption that took place in the early 90's with the demise of the FSU and the fallout of Eastern Europe. After reaching a high of eight and a half million tons of fertilizer demand in 1988, second only to Asia, demand within the Former Soviet Union plummeted to under a million tons by 1994. Working estimates show that phosphate use in the FSU rose slightly last year and is showing signs of further strengthening this year. Going forward, Fertecon expects demand to rise at an annual rate of 2.3% over the next decade. At this rate, it will take approximately seven years just to get back to the level of demand recorded in 1988. (Fig. 9).

If we look at projected demand growth on a regional basis, growth in Asia represents approximately 40% of the projected increase over the next decade. This increase equates to 3.5 million tons, conservative in comparison to the 7.6 million ton level over the past ten years. We can debate whether the recent growth of phosphate use in the FSU will be sustained, but we believe the state governments in the CIS will find the fiscal recipe to increase food production. Of the 2.5 million tons P_2O_5 produced in the Former Soviet Union in 1995, 1.7 million tons were exported to markets outside the region Increases in transportation costs out of the region will continue to channel more product into the local markets. (Fig. 10).

In the next chart, we illustrate the major purchasers of DAP/MAP. It is important to note the influence China has in our markets. They are clearly a very important consumer of our products. The industrial changes in China have come at the expense of the agricultural economy and as a result, the development of agriculture and food supply is a primary goal in the policy of the Chinese government. China is no longer an exporter of grain. (Fig. 11).

We are very bullish on the long-term outlook for phosphate trade in general, especially for DAP. We believe this year's imports of DAP/MAP will show a slight decline from the 1995 levels due in large part to a reduction in China where trade was disrupted because of a jurisdictional dispute between Sinochem and provincial buyers and a reduction in India where regressive subsidies are worked in favor of internally produced DAP.

Moving to the supply side, let's first review the structural changes that have taken place in the phosphate industry. In the US, the dominant country in the world of phosphates for many years, the changes in the industry are dramatic. Fewer plants run by fewer players has changed the dynamics of the industry. The IMC-Agrico joint venture has emerged as a strong market leader. Its discipline to match production rates with market demands has been extremely successful in eliminating costly inventory builds for the industry. (Fig. 12).

The next chart shows P_2O_5 capacity utilization rates in the US. Even with the rate curtailment actions taken by IMC-Agrico, industry operating rates have exceeded capacity since 1994. In the quarter ended September 1996, the number was 108% of capacity. As you will see in the next chart, we will need more phosphate capacity to satisfy the increases in demand we discussed earlier. (Fig. 13).

We think this illustration of the world P_20_5 supply/demand outlook is one of the main reasons why Wall Street has become enamored with the phosphate industry. The fact is that the phosphate industry has experienced a prolonged period where prices have not justified the addition of new capacity. As a result, the projections of growth will outstrip global capacity within the next 2-3 years, creating what we have referred to as the supply gap. (Fig. 14).

Filling the gap will require an additional eight million tons of P_20_5 capacity with a price tag amounting to roughly $10 billion to build the necessary rock mines and upgrading capacity and maintain our existing facilities. Who are the players who can make such investments and where will these investments be made? We, along with others in the business, continually receive offers to participate in phosphate-based projects across the globe. (Fig. 15). This chart identifies areas where phosphate projects may be feasible. Just last month, IMC-Agrico entered into a letter of intent with the Chinese to jointly evaluate a potential phosphate rock and upgrading project in China's Yunnan province. Freeport also continues to progress a phosphate project in Sri Lanka and is involved in discussions with the government of Saudi Arabia on the development of a phosphate rock deposit in that country. (Fig. 16).

The next chart identifies the list of potential new production sources. Outside of the relatively small projects in Israel and Jordan which are expected to add a total of roughly 525 metric tons of capacity in the next two years, there are significant hurdles to cross for these projects to progress to the completion stage before the year 2000. (Fig. 17). As many of you know, the development of new grassroots capacity requires long lead times. With regard to the project in Saudi Arabia, although the access to competitive sources of sulphur and ammonia make this project attractive from a cash cost perspective, the $2 billion capital requirement currently limits the economic attraction of this opportunity. We have recently received governmental approval to develop the Eppawala phosphate deposit in Sri Lanka and are currently finalizing the necessary agreements with the government. We believe this is an attractive opportunity but will need to complete a feasibility study before moving ahead on the development of this resource. (Fig. 18).

As we review the list of potential projects, we see that the limitations on capacity additions are not due to a lack of technology or available quality resources. The limitations lie in the location of these resources and the prices and margins required to attract major western investors to invest large sums of capital in generally high risk areas of the world.

We have tried to show in the next chart the list of what we think the capacity additions will be before the turn of the century. We do not expect very much new capacity and after considering the plants that will potentially close for environmental reasons, we see only 12-15% of the supply gap being filled through new capacity before the year 2000. (Fig. 19).

We believe attracting the new capacity is a matter of price. Here's a snapshot of a typical Florida-based DAP plant, illustrating the cost components and margin for a low cost producer since 1990. You will notice that margins have generally improved over the past few years and reached the $70 per ton level during the first quarter of 1996 when domestic prices in central Florida reached $210 per ton. (Fig. 20).

Based on the project economics presented in this chart, a sustainable price of $210 per short ton FOB Central Florida is required to justify a typical grassroots DAP facility. And $210 per ton assumes a low hurdle rate of 15%. We believe the required rate of return would actually need to be higher to attract investors to the opportunities that exist today. Nonetheless, current prices and margins are still well below required reinvestment levels. (Fig. 21).

It is no surprise that we have not seen any real changes in world P_20_5 capacity since 1985. Prices over the past 10 – 15 years have not justified reinvestment levels. Over this period what we have seen is debottlenecking of plants within the US where the economics made sense. But on a global basis, capacity additions have not been justifiable and marginal operations have been closed. In contrast, prices in the late 70's did attract new investment, resulting in the capacity additions that took place in the early 80's. (Fig. 22).

Going forward, increasing capital costs and infrastructure costs will elevate the price and margins required to attract new capacity. And given the large sums of money involved in these investments, investors will have to become comfortable that the price environment is sustainable.

Moving to the sulphur business, Freeport is the largest sulphur producer in the US and operates two Frasch sulphur mines and the largest distribution system in the US. Since 1912, our sulphur business has produced and sold over 100 million tons of sulphur and has evolved into a major market player in the US, particularly in the Gulf Coast market. (Fig. 23).

Let's first examine the demand factors of this business. Up until 1988, world sulphur demand was rising at the rate of one million tons per year, outstripping production in many years by a wide margin. Similar to the fertilizer situation we discussed earlier, the very visible decline in Eastern European sulphur demand from 1988 forward, falling from over 15 million tons in 1988 to under 5 million tons in 1994 significantly impacted markets. As a result, the higher cost tier of sulphur producers were forced to shut down. As illustrated in the production statistics, mined sulphur declined by approximately 9 million tons during the period between 1988 and 1994. About 5.5 million tons were reduced in Poland and Russia and Mexico's industry was shut down. (Fig. 24).

Since the late 80's, we have seen a rise in sulphur production recovered from oil and gas production. Recovered sulphur continues to rise at the rate of nearly one million tons with North America accounting for nearly 50% of the world's total output followed by the Middle East where output of recovered sulphur has more than doubled in the past ten years. (Fig. 25).

This chart reconciles the previous two charts and shows the inventory build situation that has taken place over the past five years. Most of the change in world stocks has taken place in Canada where stocks are currently approaching 10 million tons. Aside from Canada, the bulk of vatted sulphur is held in France and Germany, as well as in the FSU were new production from sour gas is being poured to block given the absence of shipping facilities to move the material to market. (Fig. 26).

For sulphur marketers, trade is the element that dictates price direction. This chart not only illustrates how trade fell off from 1988, but how significant the impacts were on Poland. Ten years ago, the Soviet Union imported nearly 1.7 million tons of sulphur, about one-half from Canada and half from Poland. Last year, the FSU exported 1.6 million tons. We have also seen Western Europe swing from a net importer of sulphur to a net exporter while sulphur exports from the Middle East have continued to rise. (Fig. 27).

The next slide is a list of the players in world sulphur trade. The real meaning in this table is how the number of sellers vastly outweighs the buyers. On the left side, there are probably 40 major suppliers of sulphur internationally while the top ten international buyers comprise 60% of the sulphur traded. (Fig. 28).

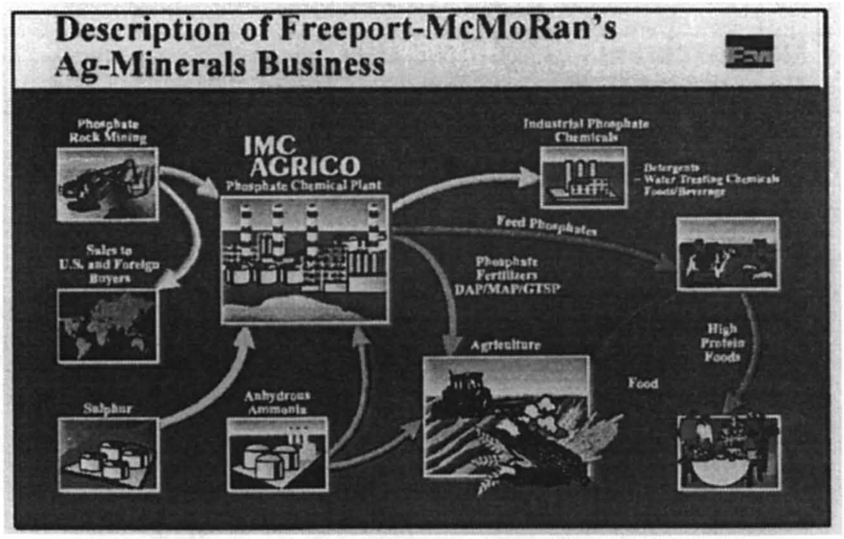
Major suppliers in Canada and the Middle East have recently found reason for optimism. In the case of the Middle East, the increase in phosphate subsidies in India had an immediate impact on sulphur purchases where more than 75% of this country's imports originate from the Middle East. Canadian sulphur maketers also benefited from the Indian subsidy changes, but more significantly from the emergence of China as an importer of elemental sulphur. Canadian exports to China in the first nine months of this year have totaled nearly 500,000 metric tons. Overall, Vancouver exports are running 10% above year-ago levels, while rail shipments into the US are down year over year.

Poland continues its retreat from the sulphur marketplace and announced a further rationalization program in the mining sector that will continue this trend. (Fig. 29).

The next chart illustrates the resulting impact on price of the changes in the global supply/demand situation that we have reviewed in the past several slides. We have seen a slight upturn in international sulphur market prices over the past couple of months and some fourth quarter business has been concluded at prices $2-3 per ton over last quarter's price. (Fig. 30).

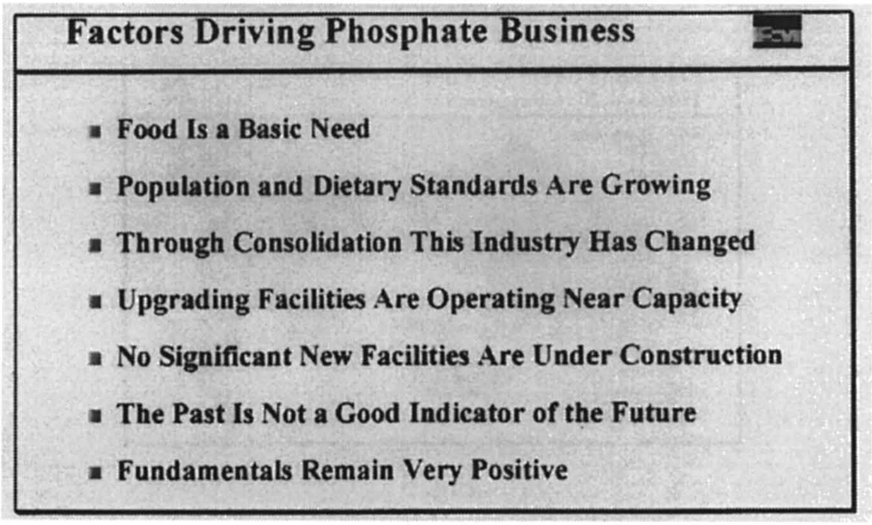
As we look at the projected surplus of sulphur over the next several years, we should remember that projecting a supply/demand balance for sulphur is a dynamic process. This chart does not capture a reduction in supply from discretionary sources logically forced from the marketplace nor does it include additional sulphur sources that will be required to meet the projected increases in phosphate demand. While I am not suggesting that a sulphur shortage is on the immediate horizon, this chart should not imply a hopeless future for the industry. Economic reality will cause a further reduction in discretionary supplies while pouring to block should continue in the absence of alternatives that make economic sense. (Fig. 31).

In summary, we believe the outlook for our business is very strong. The fundamentals of our phosphate business could hardly be more positive and we believe that price levels will rise to a level required to attract new capacity, providing a period of sustained high operating margins for existing producers.



Description of Freeport-McMoRan's Ag-Minerals Business

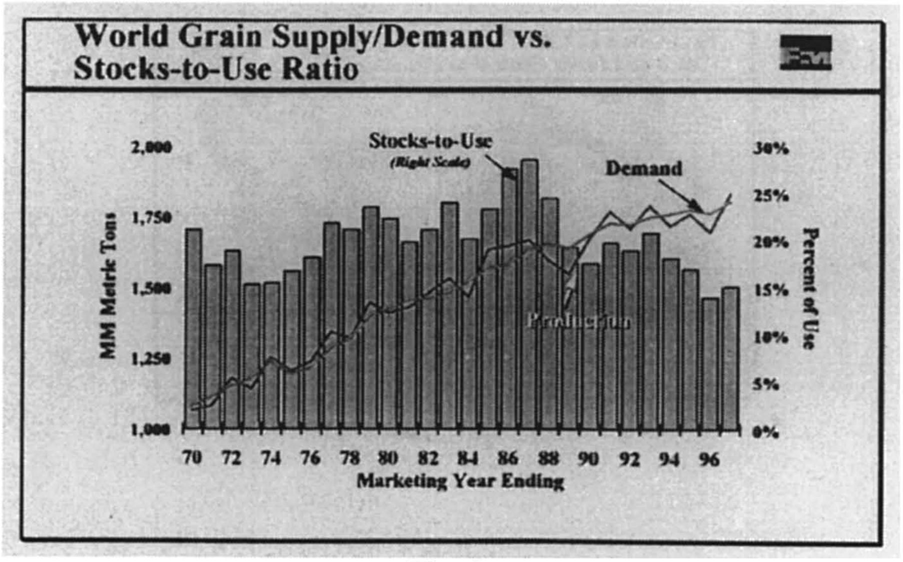
Fig. 1



Factors Driving Phosphate Business

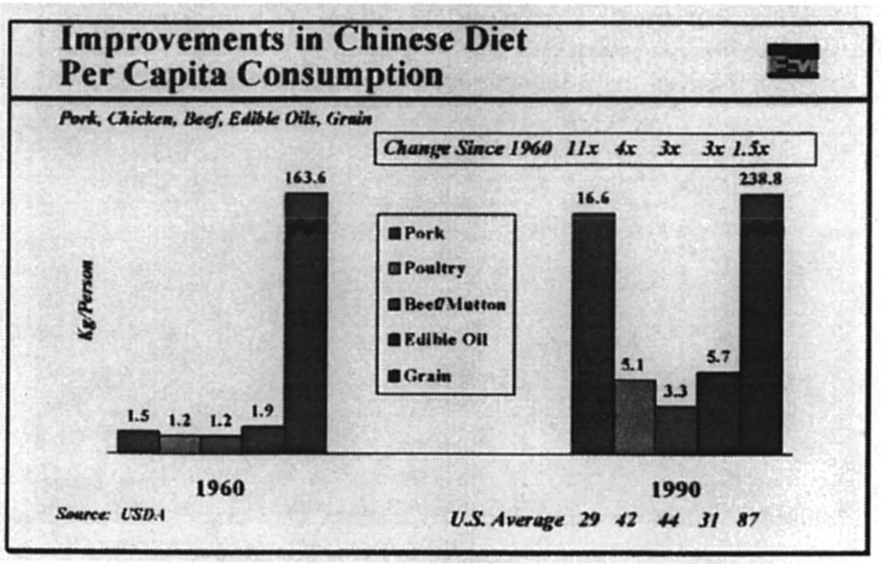
- Food Is a Basic Need
- Population and Dietary Standards Are Growing
- Through Consolidation This Industry Has Changed
- Upgrading Facilities Are Operating Near Capacity
- No Significant New Facilities Are Under Construction
- The Past Is Not a Good Indicator of the Future
- Fundamentals Remain Very Positive

Fig. 2



World Grain Supply/Demand vs. Stocks-to-Use Ratio

Fig. 3

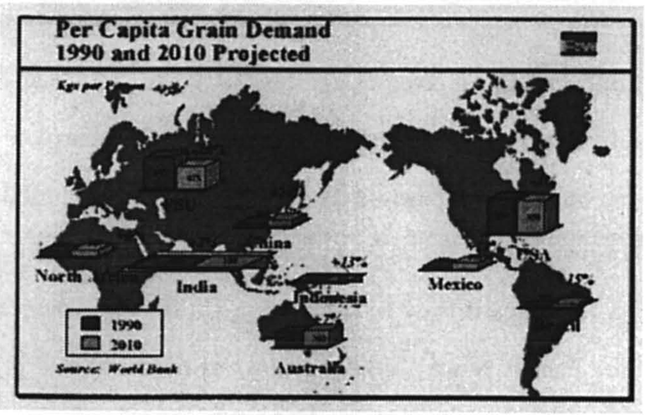


Improvements in Chinese Diet
Per Capita Consumption

Pork, Chicken, Beef, Edible Oils, Grain

Source: USDA

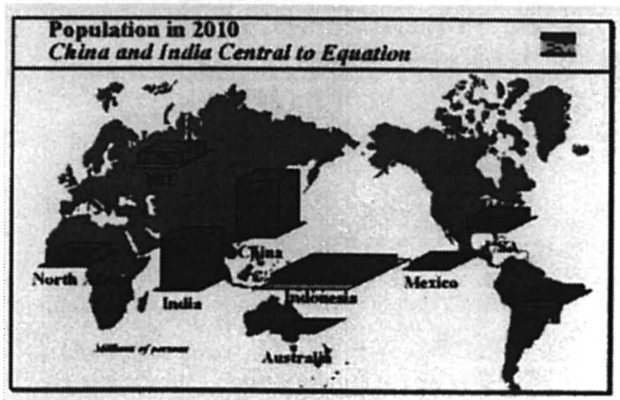
Fig. 4



Per Capita Grain Demand
1990 and 2010 Projected

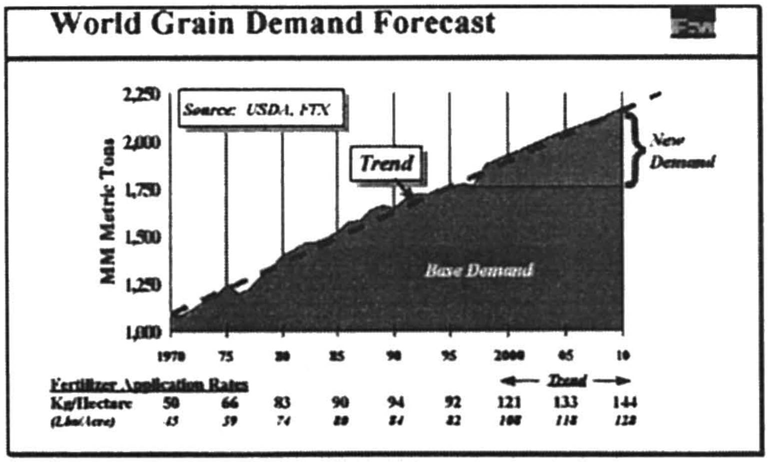
Source: World Bank

Fig. 5



Population in 2010
China and India Central to Equation

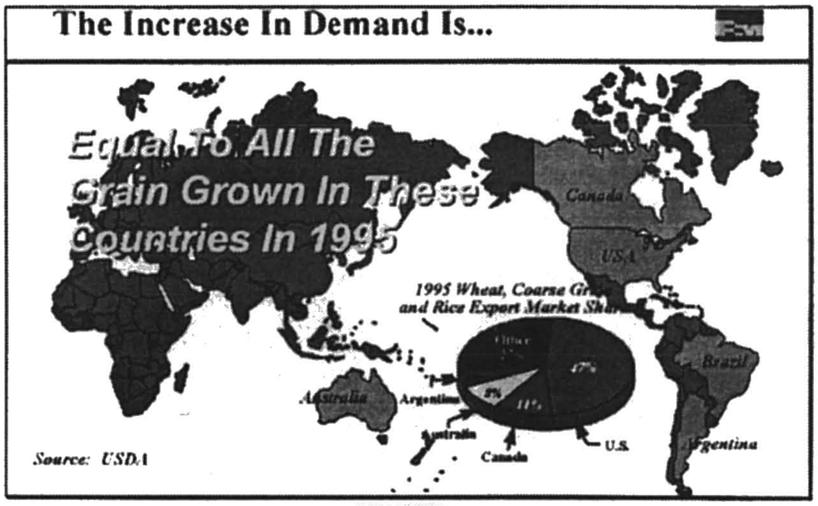
Fig. 6



World Grain Demand Forecast

Fertilizer Application Rates						←	Trend	→
Kg/Hectare 50	66	83	90	94	92	121	133	144
(Lbs/Acre) 45	59	74	80	84	82	108	118	128

Fig. 7

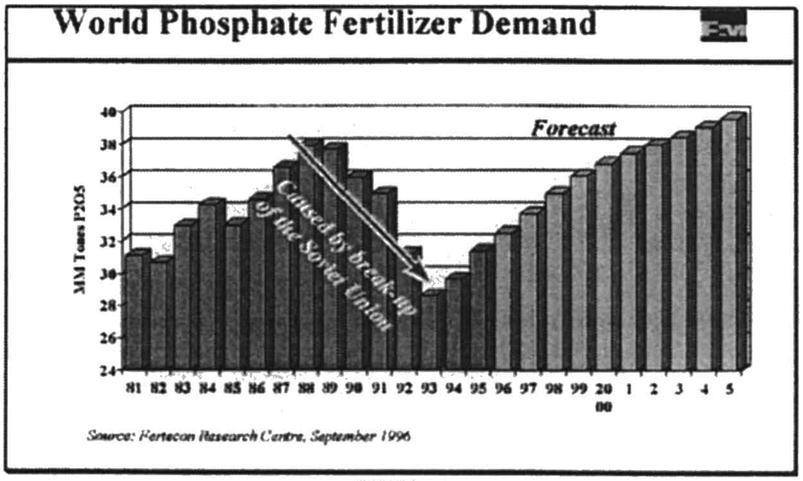


The Increase In Demand Is...

Equal To All The Grain Grown In These Countries In 1995

Source: USDA

Fig. 8



World Phosphate Fertilizer Demand

Source: Fertecon Research Centre, September 1996

Fig. 9

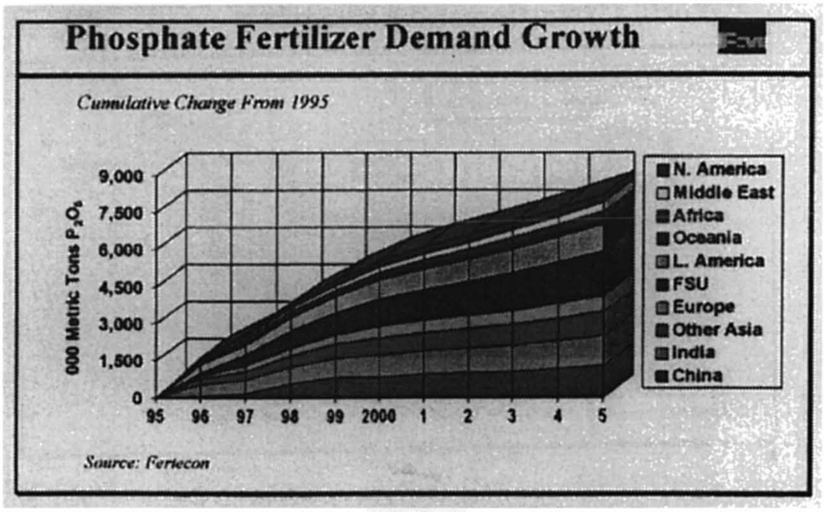


Fig. 10

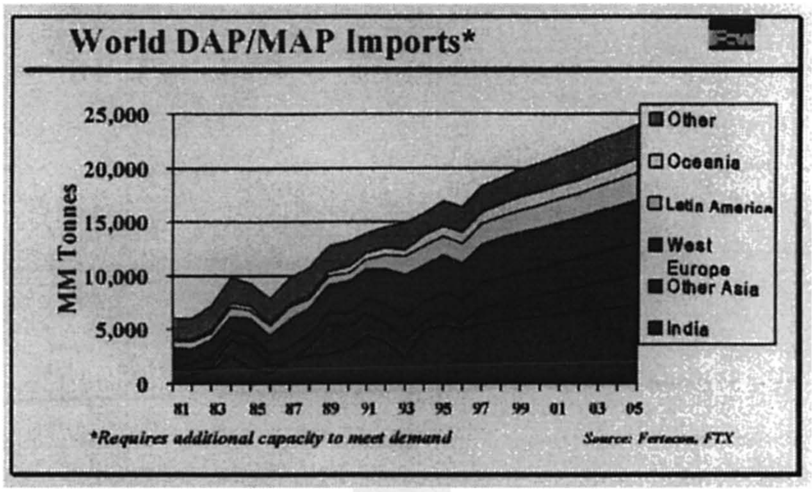
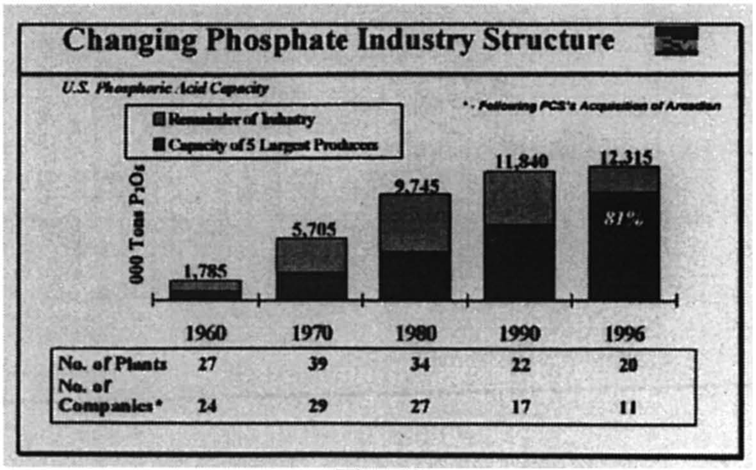
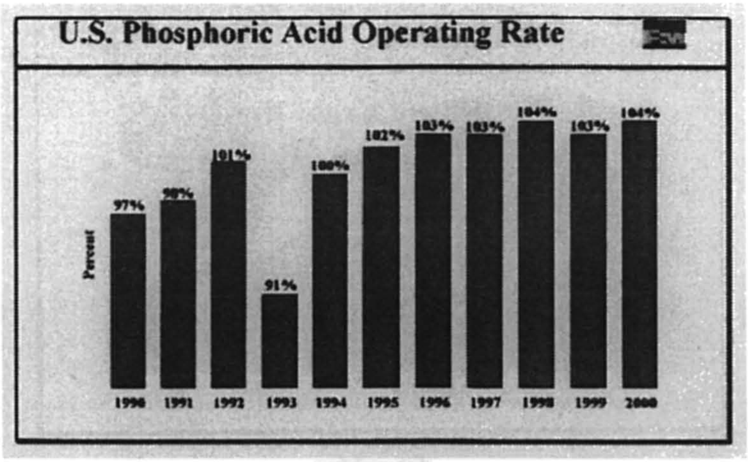


Fig. 11



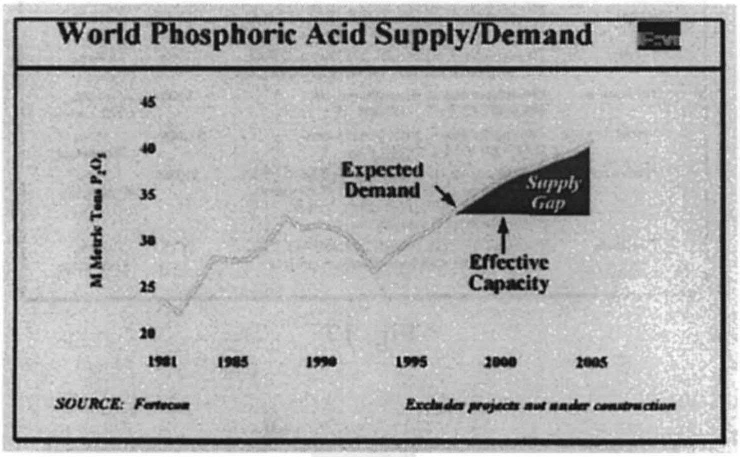
	1960	1970	1980	1990	1996
No. of Plants	27	39	34	22	20
No. of Companies*	24	29	27	17	11

Fig. 12



U.S. Phosphoric Acid Operating Rate

Fig. 13

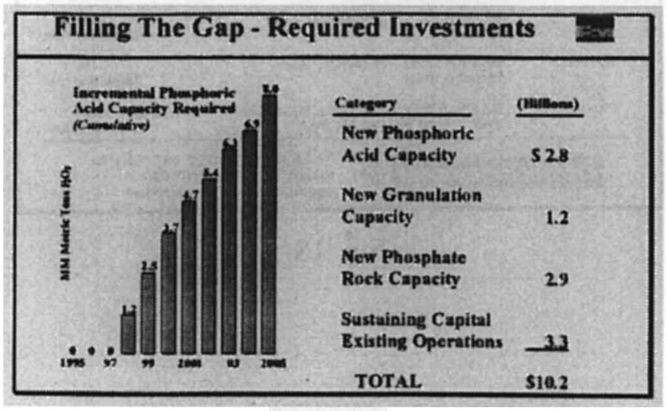


World Phosphoric Acid Supply/Demand

SOURCE: Fertecon

Excludes projects not under construction

Fig. 14

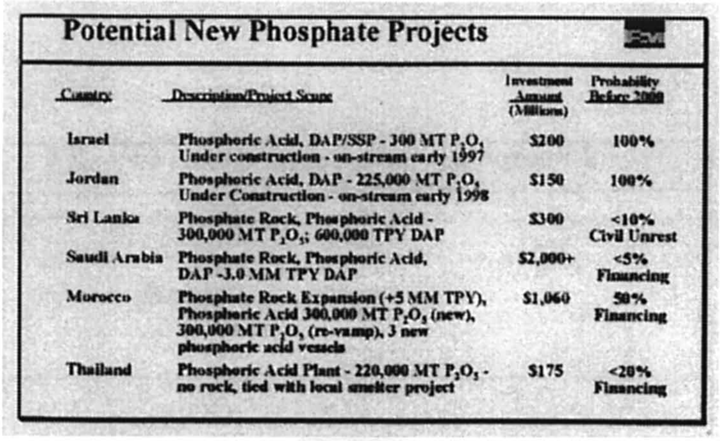


Filling The Gap - Required Investments

Category	(Billions)
New Phosphoric Acid Capacity	$ 2.8
New Granulation Capacity	1.2
New Phosphate Rock Capacity	2.9
Sustaining Capital Existing Operations	3.3
TOTAL	$10.2

Fig. 15

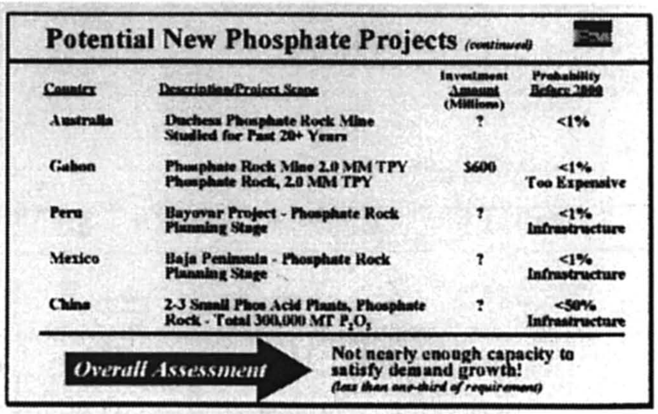
Fig. 16



Potential New Phosphate Projects

Country	Description/Project Scope	Investment Amount (Millions)	Probability Before 2000
Israel	Phosphoric Acid, DAP/SSP - 300 MT P_2O_5 Under construction - on-stream early 1997	$200	100%
Jordan	Phosphoric Acid, DAP - 225,000 MT P_2O_5 Under Construction - on-stream early 1998	$150	100%
Sri Lanka	Phosphate Rock, Phosphoric Acid - 300,000 MT P_2O_5; 600,000 TPY DAP	$300	<10% Civil Unrest
Saudi Arabia	Phosphate Rock, Phosphoric Acid, DAP -3.0 MM TPY DAP	$2,000+	<5% Financing
Morocco	Phosphate Rock Expansion (+5 MM TPY), Phosphoric Acid 300,000 MT P_2O_5 (new), 300,000 MT P_2O_5 (re-vamp), 3 new phosphoric acid vessels	$1,060	50% Financing
Thailand	Phosphoric Acid Plant - 220,000 MT P_2O_5 - no rock, tied with local smelter project	$175	<20% Financing

Fig. 17



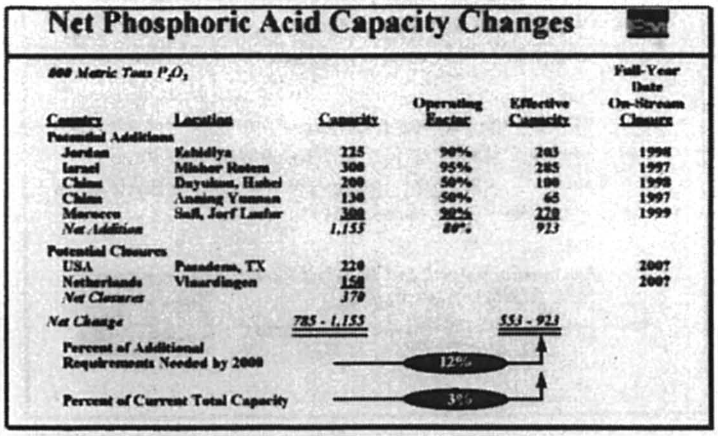
Potential New Phosphate Projects *(continued)*

Country	Description/Project Scope	Investment Amount (Millions)	Probability Before 2000
Australia	Duchess Phosphate Rock Mine Studied for Past 20+ Years	?	<1%
Gabon	Phosphate Rock Mine 2.0 MM TPY Phosphate Rock, 2.0 MM TPY	$600	<1% Too Expensive
Peru	Bayovar Project - Phosphate Rock Planning Stage	?	<1% Infrastructure
Mexico	Baja Peninsula - Phosphate Rock Planning Stage	?	<1% Infrastructure
China	2-3 Small Phos Acid Plants, Phosphate Rock - Total 300,000 MT P_2O_5	?	<50% Infrastructure

Overall Assessment

Not nearly enough capacity to satisfy demand growth!
(less than one-third of requirement)

Fig. 18



Net Phosphoric Acid Capacity Changes

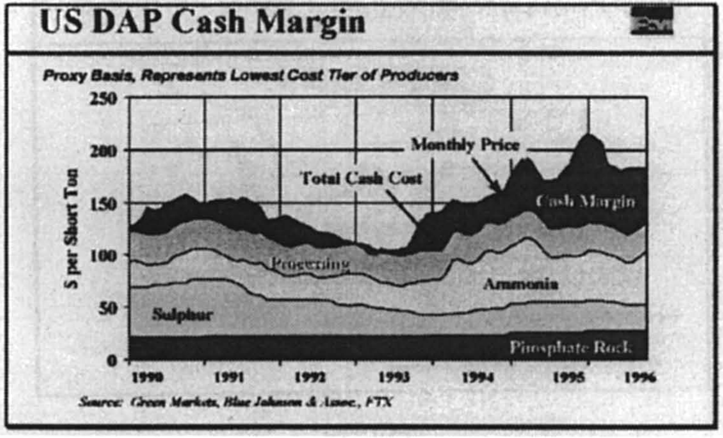
000 Metric Tons P_2O_5

Country	Location	Capacity	Operating Factor	Effective Capacity	Full-Year Date On-Stream Closure
Potential Additions					
Jordan	Eshidiya	225	90%	203	1998
Israel	Mishor Rotem	300	95%	285	1997
China	Dayukou, Hubei	200	50%	100	1998
China	Anning Yunnan	130	50%	65	1997
Morocco	Safi, Jorf Lasfar	300	90%	270	1999
Net Addition		*1,155*	*80%*	923	
Potential Closures					
USA	Pasadena, TX	220			200?
Netherlands	Vlaardingen	150			200?
Net Closures		*370*			
Net Change		*785 - 1,155*		*553 - 923*	

Percent of Additional Requirements Needed by 2000 — 12%

Percent of Current Total Capacity — 3%

Fig. 19

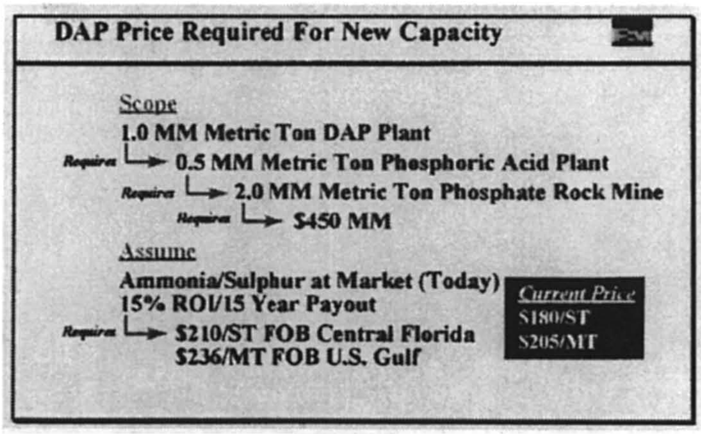


US DAP Cash Margin

Proxy Basis, Represents Lowest Cost Tier of Producers

Source: Green Markets, Blue Johnson & Assoc., FTX

Fig. 20



DAP Price Required For New Capacity

Scope

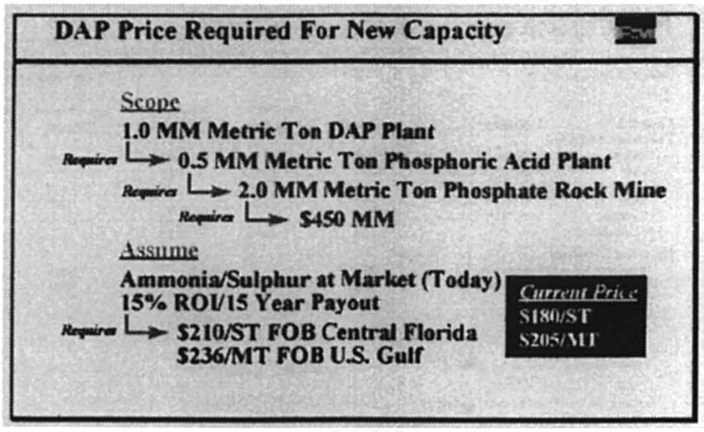
1.0 MM Metric Ton DAP Plant
Requires → 0.5 MM Metric Ton Phosphoric Acid Plant
Requires → 2.0 MM Metric Ton Phosphate Rock Mine
Requires → $450 MM

Assume

Ammonia/Sulphur at Market (Today)
15% ROI/15 Year Payout
Requires → $210/ST FOB Central Florida
$236/MT FOB U.S. Gulf

Current Price
$180/ST
$205/MT

Fig. 21



DAP Price Required For New Capacity

Scope

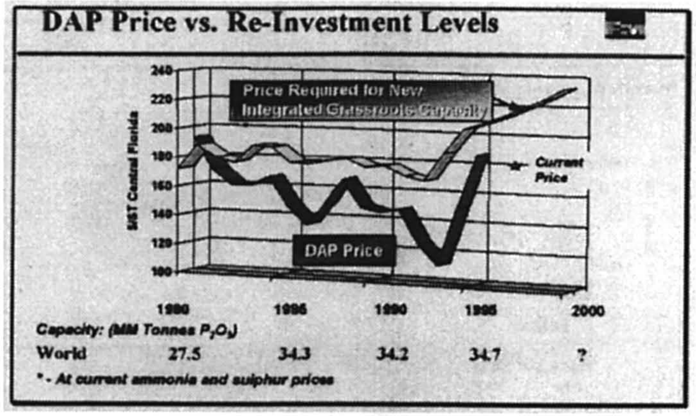
1.0 MM Metric Ton DAP Plant
Requires ↳ 0.5 MM Metric Ton Phosphoric Acid Plant
Requires ↳ 2.0 MM Metric Ton Phosphate Rock Mine
Requires ↳ $450 MM

Assume

Ammonia/Sulphur at Market (Today)
15% ROI/15 Year Payout
Requires ↳ $210/ST FOB Central Florida
$236/MT FOB U.S. Gulf

Current Price
$180/ST
$205/MT

Fig. 21

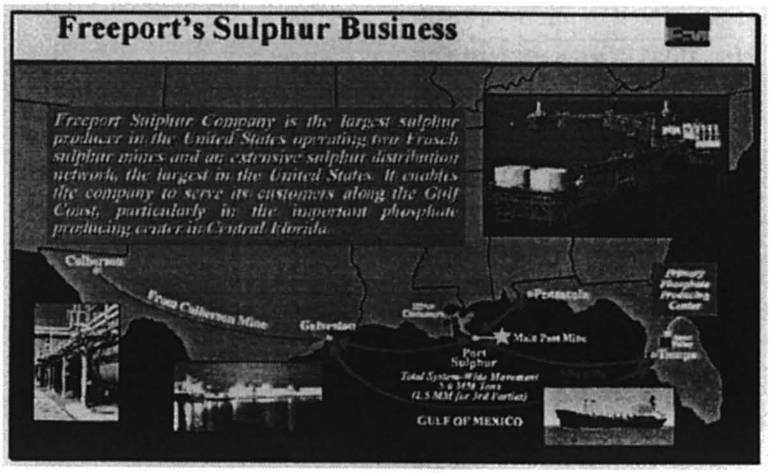


DAP Price vs. Re-Investment Levels

Capacity: (MM Tonnes P_2O_5)	1980	1985	1990	1995	2000
World	27.5	34.3	34.2	34.7	?

* - At current ammonia and sulphur prices

Fig. 22



Freeport's Sulphur Business

Freeport Sulphur Company is the largest sulphur producer in the United States operating two Frasch sulphur mines and an extensive sulphur distribution network, the largest in the United States. It enables the company to serve its customers along the Gulf Coast, particularly in the important phosphate producing center in Central Florida.

Fig. 23

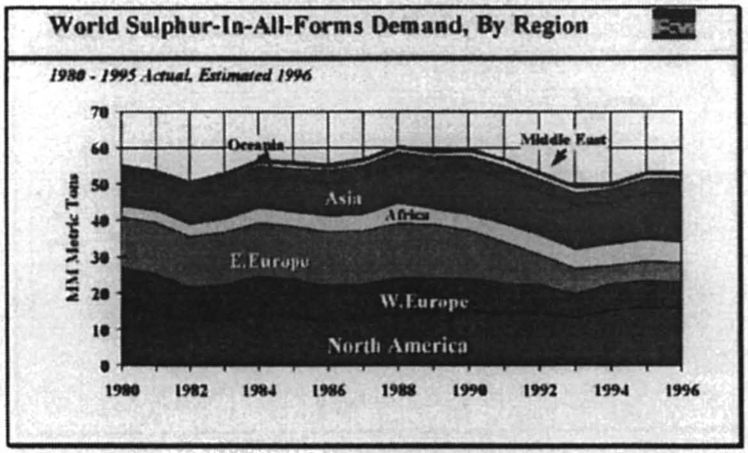


Fig. 23

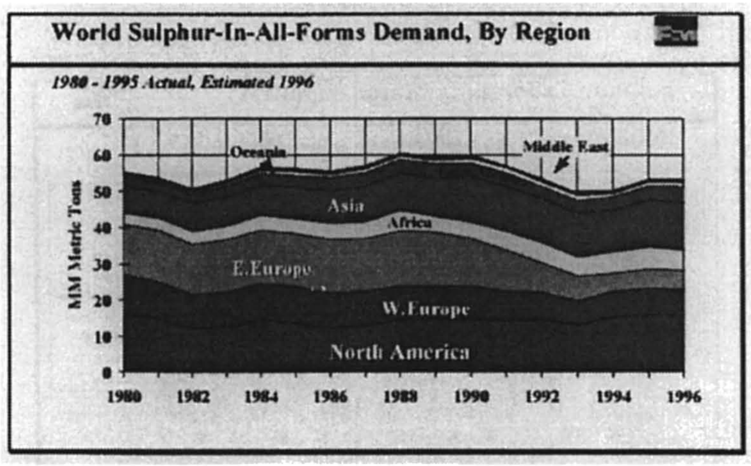


Fig. 24

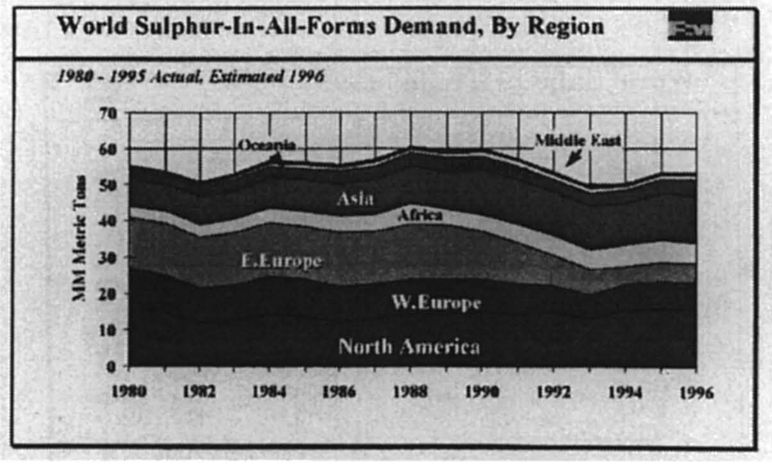


Fig. 25

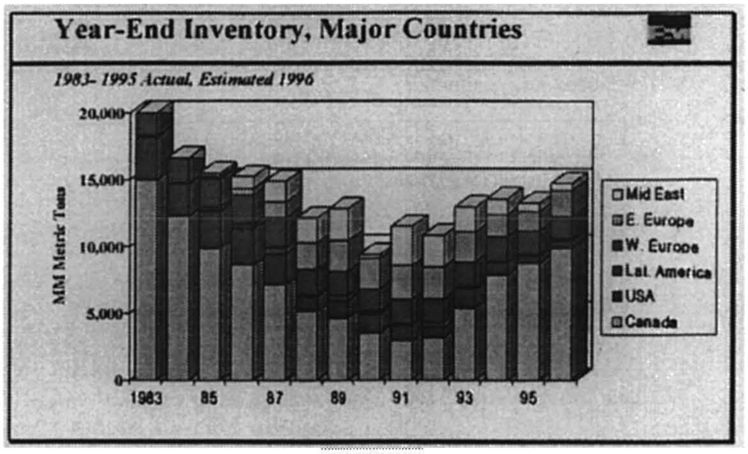


Fig. 26

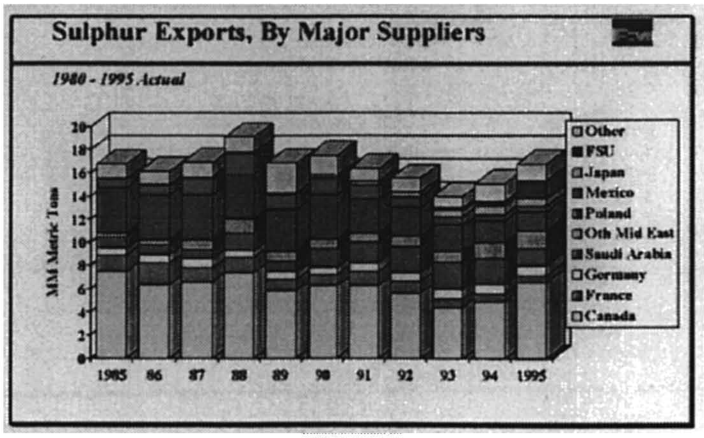
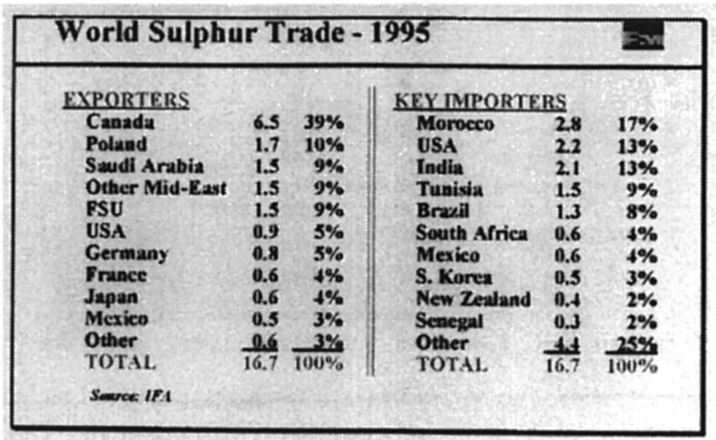


Fig. 27



World Sulphur Trade - 1995

EXPORTERS			KEY IMPORTERS		
Canada	6.5	39%	Morocco	2.8	17%
Poland	1.7	10%	USA	2.2	13%
Saudi Arabia	1.5	9%	India	2.1	13%
Other Mid-East	1.5	9%	Tunisia	1.5	9%
FSU	1.5	9%	Brazil	1.3	8%
USA	0.9	5%	South Africa	0.6	4%
Germany	0.8	5%	Mexico	0.6	4%
France	0.6	4%	S. Korea	0.5	3%
Japan	0.6	4%	New Zealand	0.4	2%
Mexico	0.5	3%	Senegal	0.3	2%
Other	0.6	3%	Other	4.4	25%
TOTAL	16.7	100%	TOTAL	16.7	100%

Source: IFA

Fig. 28

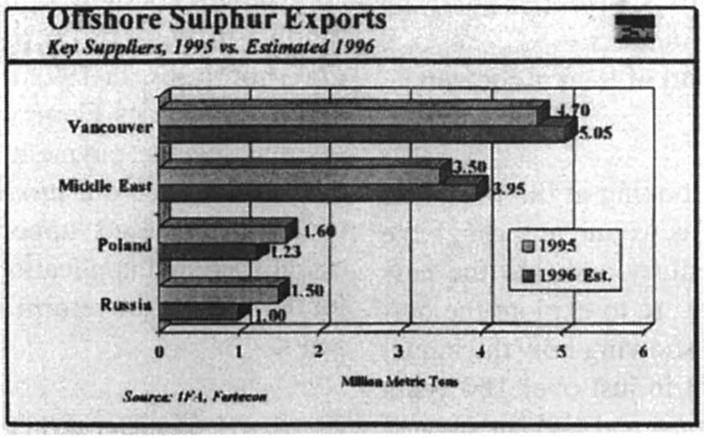


Fig. 29

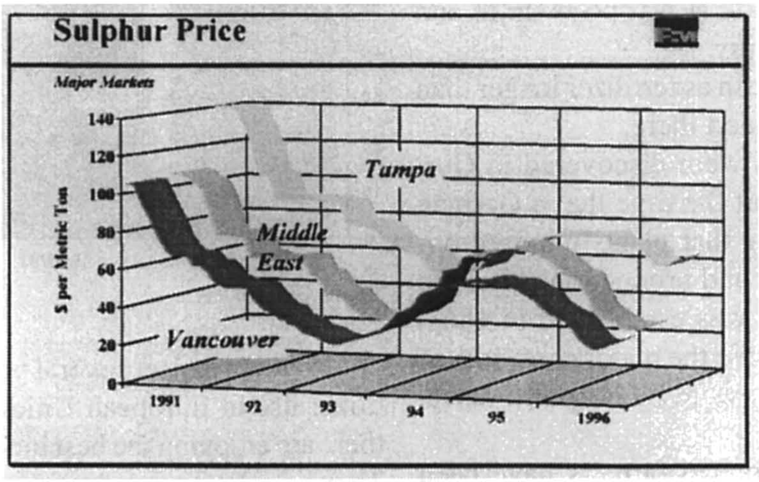


Fig. 30

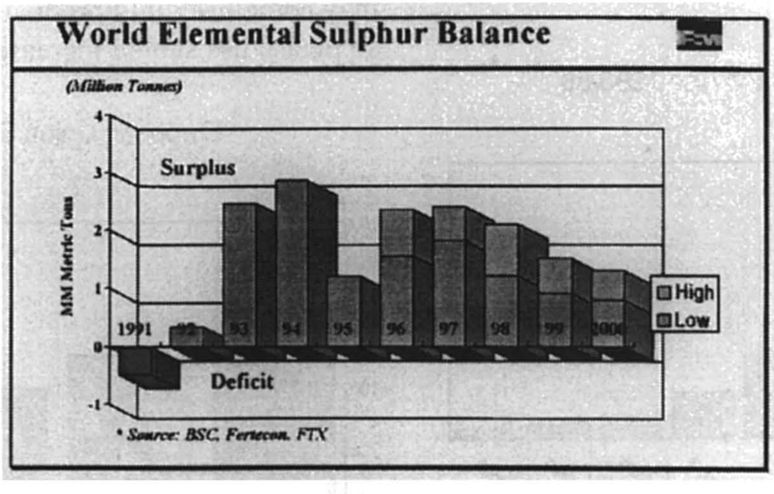


Fig. 31

Outlook For Potash

C.E. Childers
Potash Corporation of Saskatchewan

This Round Table is looking at the prospects for the fertilizer industry as we move through the last years of the 20th century and into the new millennium. It is my pleasure to explore the outlook for potash with you, showing how the industry has grown into a giant in just over 150 years and examining what the past and present suggest about the future.

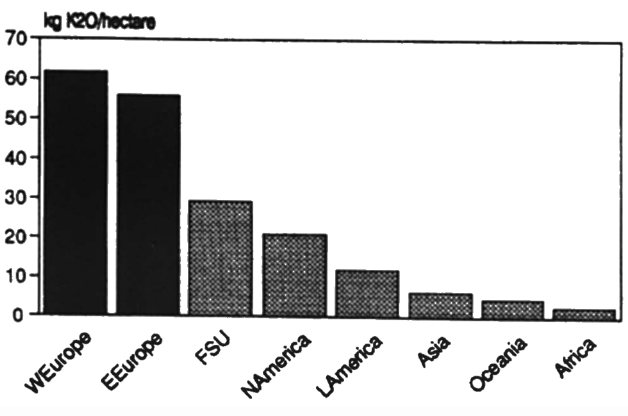
My approach will be to put potash in its historical and geographic context and examine recent developments region by region. From that base, we should be able to look at prospects up to and past the turn of the century.

Europe has used potash as fertilizer longer than anywhere else, so let's start there.

Potash salt deposits were discovered in Germany in 1839, just about the time that a German scientist was concluding that plants required potassium for good health and production. After the first production facility was established in 1861, agriculture quickly became the major consumer of potash. Later, industries were built up in France, Spain, Britain and Italy.

For 125 years, European farmers have been using potash on their relatively small farms. Agricultural subsidies encouraged that use, and in the mid-1980s, application rates in Europe were the highest in the world.

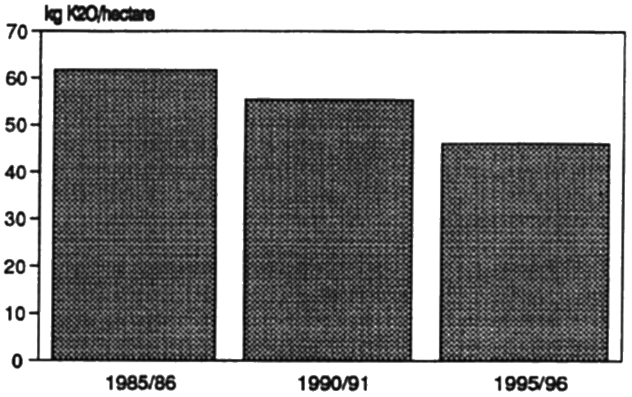
World Potash Use 1985/86



Source: FAO

The costs of these subsidies soon became prohibitive in Western Europe. They also produced grain surpluses. In 1992 the European Union began to reform its Common Agricultural Policy, overhauling the payment system in an effort to control both costs and production. Direct payments to farmers replaced support prices, setasides were established and application rates have fallen, due for the most part to reform and environmental pressures.

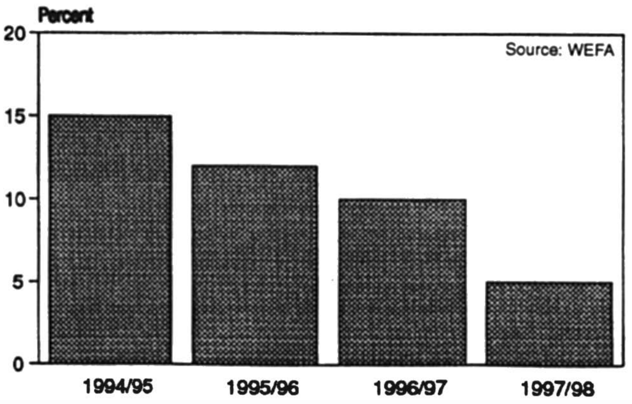
Potash Use in Western Europe



Source: FAO and IFA

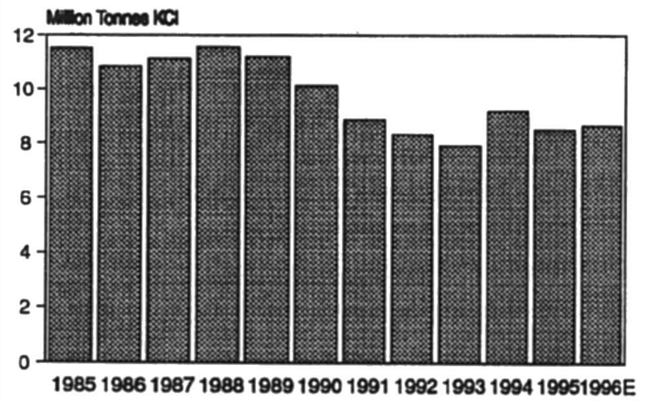
Now we expect several years of increased fertilizer use in European Union countries. Farmers there are enjoying the best incomes in two decades. To increase grain production at a time when world stocks are down, setasides have been reduced to 5 percent for the coming crop year. Industry sources are predicting that as much as 1.7 million hectares may come back into production by next summer, so potash use should increase.

European Union Setasides (%)



Looking into the future, we can see that despite this increase, potash demand in Western Europe is unlikely to return to the highs of the 1980s. European farmers are much more market-driven today. Initiatives to reduce government support have put them more in tune with economics and economic necessity.

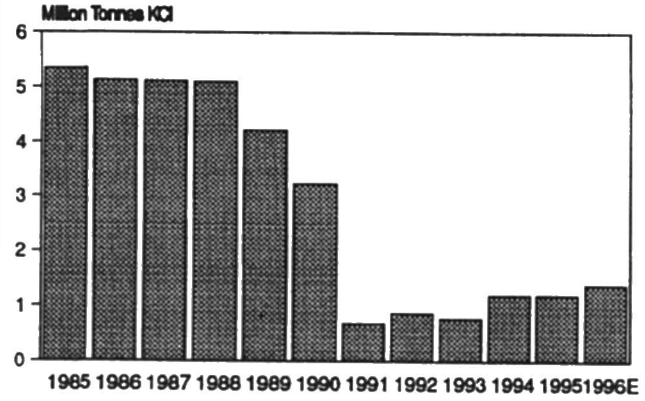
Potash Demand in Western Europe
(includes Former GDR)



Source: IFA, Fertecon and PCS

In Eastern Europe, fertilizer consumption is just starting to come back after the political and economic changes early in the decade. Privatization of land has been slow, and fertilizer application rates that were once almost as high as in Western Europe are now extremely low.

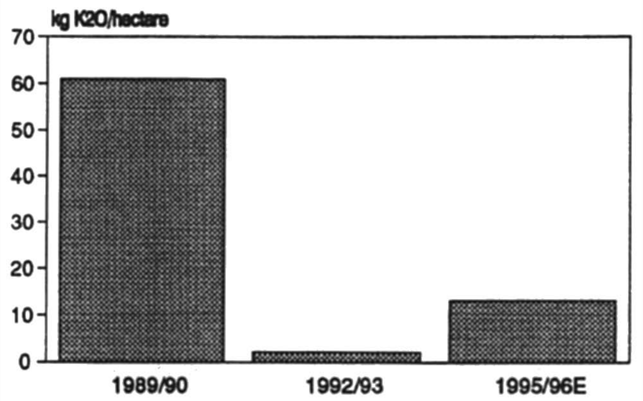
Potash Demand in Eastern Europe
(excludes Former GDR)



Source: IFA, Fertecon and PCS

In Hungary, for example, application rates plummeted in three years from 61 kilograms K_2O per hectare to 2 kilograms per hectare. There has been some small improvement since then, but more fertilizer must be used to restore the productivity of the land.

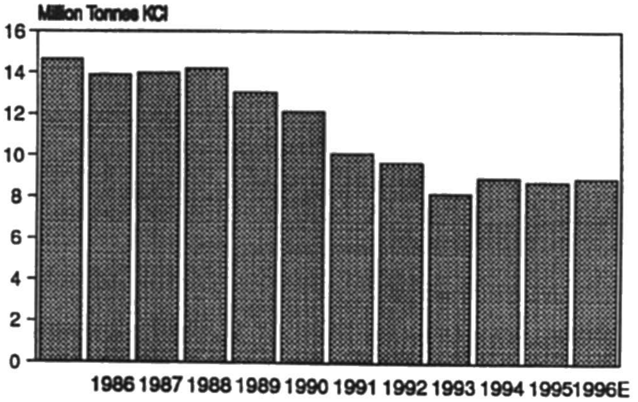
Potash Use in Hungary



Source: IFA, FAO, Fertecon and PCS

Any increase in potash use in Western and Eastern Europe will be welcomed by an industry hurt by the decline in world demand early in this decade. It is a changing industry in which much rationalization has occurred. In Germany, outmoded facilities have been closed and considerable money spent to improve existing mines. The French mines will shut in 2004, and rationalization in Spain will continue. As a result, European production has fallen.

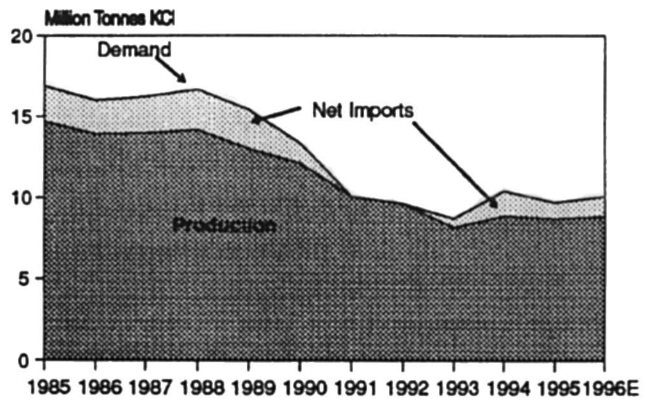
Potash Production in Europe
(excludes FSU)



Source: IFA, Fertecon and PCS

Considering Western and Eastern Europe as one, we can see that this region will have to rely more and more heavily on its remaining local suppliers. It has been a net potash importer for some years. Imports will increasingly fill the gap between supply and demand, as demand recovers in Eastern Europe and European production continues to decline.

Potash Supply/Demand Situation in Europe
(excludes FSU)



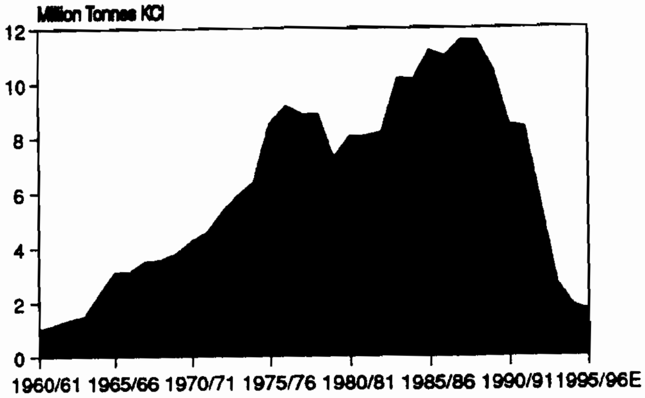
Source: IFA, Fertecon and PCS

Let's turn now to the situation in the Former Soviet Union, where potash was discovered in 1925 in the Ural Mountains. Commercial production began nine years later. Intensive development took place after the Second World War, and the last mine—Berezniki 4—was commissioned in 1992.

Potash Production Locations in FSU

While Russian farmers have been applying potash for 60 years or more, its intensive use as a fertilizer began in the 1960s and peaked in 1988. At its peak, the FSU was the world's largest potash consumer.

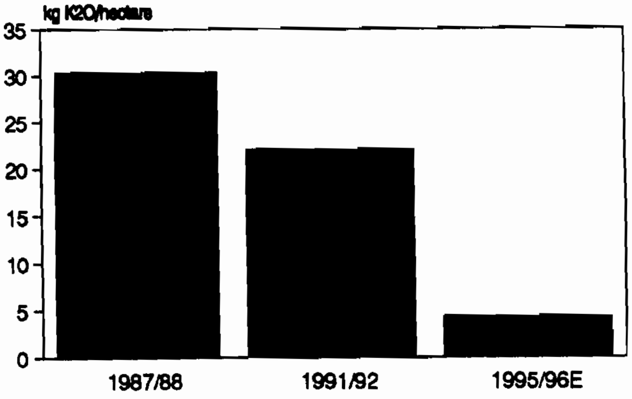
Potash Fertilizer Consumption in FSU



Source: FAO and IFA

Application rates were high since fertilizers were readily available to the large system of state farms. But when subsidies were removed in 1991 with the move to the free market system, the price of fertilizer rose out of reach for farmers with little cash. Application rates have fallen to one-seventh of former levels, so it is not surprising that agricultural production is also down.

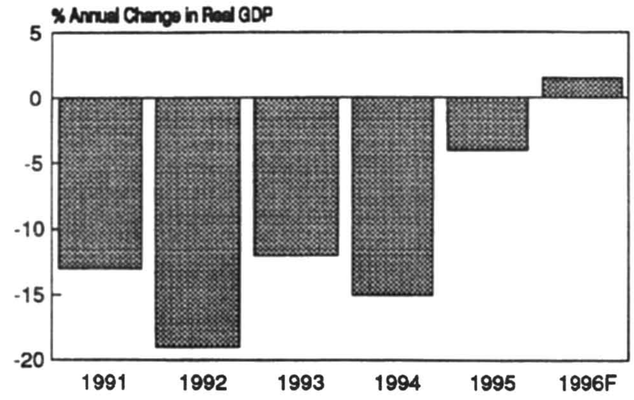
Potash Use in FSU



Source: FAO, Fertecon and PCS

To increase yields, fertilizer application rates must come back, although they are unlikely to reach past levels. The privatization of land has been slow, and farmers don't have the economic base to be able to afford much fertilizer. The national economy is fragile and has experienced negative economic growth for at least half a decade. Only in the current year is positive growth projected.

Economic Growth in Russia



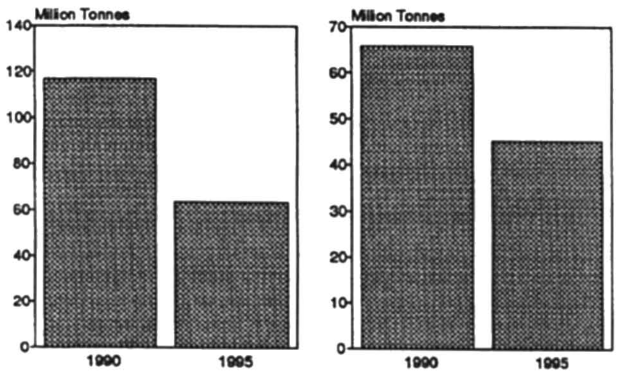
Source: IMF (May 1992) and The Economist

Potash consumption appears to have risen slightly this year after incentives were offered to farmers. Next year could be better because the Russian Ministry of Agriculture is looking to double the subsidy to agriculture. Government leaders are very concerned about falling food production, and want to encourage fertilizer usage.

Food Production in Russia

Grain

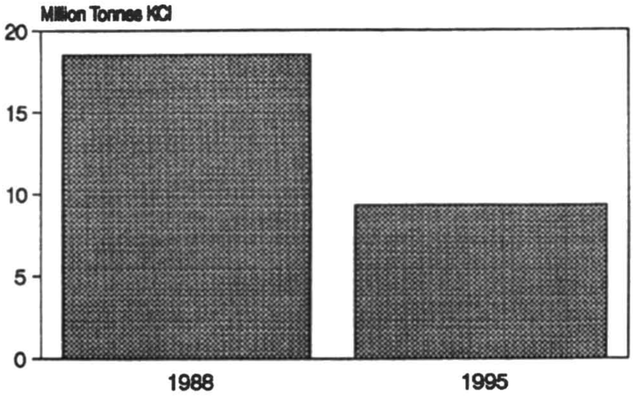
Meat & Milk



Source: USDA

The collapse of communism had a devastating effect on FSU potash production, which fell from 18.5 million tonnes in 1988 to half as much last year. Some production has been shut in while other mines have been converted to salt production. From all indications FSU potash production will be down this year.

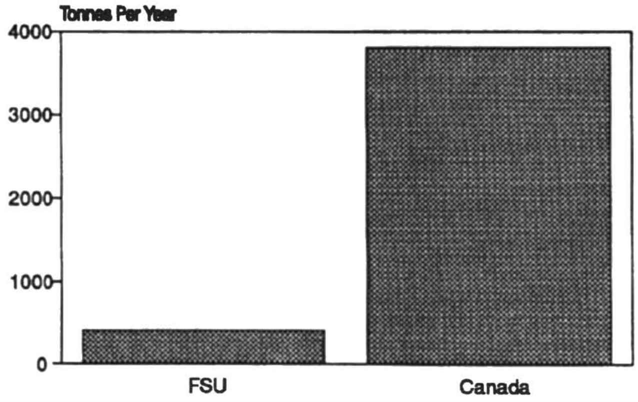
Potash Production in FSU



Source: IFA

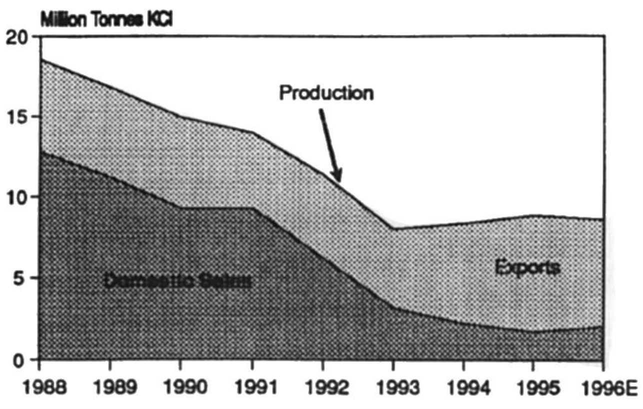
Overhead, debt and inflation eat away at producers' attempts to make a profit. The labor force is enormous and production per employee is one-tenth the Canadian rate. Major restructuring and capital input will be required to restore the industry, which may never again be as large as it once was.

Potash Production Per Employee



The FSU is a major potash exporter, and its exports have risen. However, they have not offset the drastic fall in domestic consumption. The mines in Russia are a long distance from port, which makes transportation a significant and costly problem. Producers who were once concerned only about earning hard currency are now aware of the need to be profitable. Economic forces are playing a much larger role; this spring, for example, FSU producers shut down production to control inventories.

Potash Supply/Demand Situation in FSU



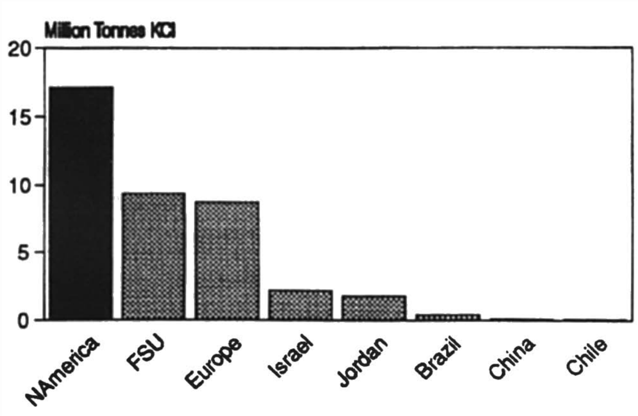
Source: IFA, Fertecon and PCS

Looking into the future, we can expect the FSU to continue to be an exporter. The key element is how much local consumption comes back to absorb its potash. The more potash that is consumed within the FSU, the less there will be in world markets.

Now let's turn to North America, where the potash industry started at about the same time as Russia's. Potash deposits were discovered in New Mexico in 1925, and production began in 1931. This was the only North American source of supply until Saskatchewan's enormous reserves were found in the early 1940s. These proved to be the world's largest and best-quality reserves but it took several attempts to find a way to successfully develop them. The most recent development was the reserves in New Brunswick in the early 1980s.

Today North America is the world's largest potash producer, with the largest reserves, enough to supply global demand for over 100 years.

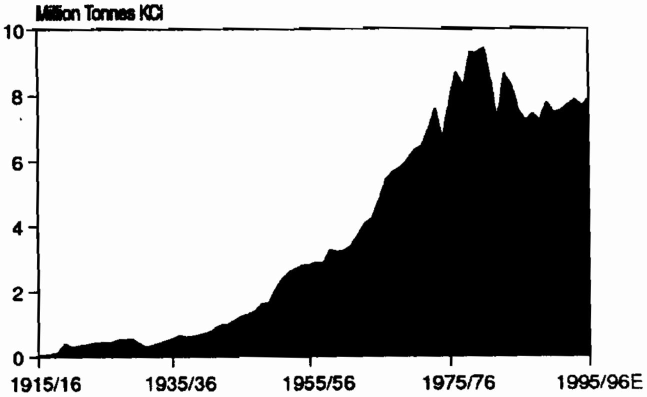
World Potash Production 1995



Source: IFA

The United States makes up the vast share of the North American potash market. Since it began importing German potash early in the century, the U.S. has always been a leader in use of this fertilizer. Consumption rose steadily through the 1960s and the early '70s as plantings increased and application rates rose. After peaking in the late 1970s, consumption fell back due to farm programs which limited production.

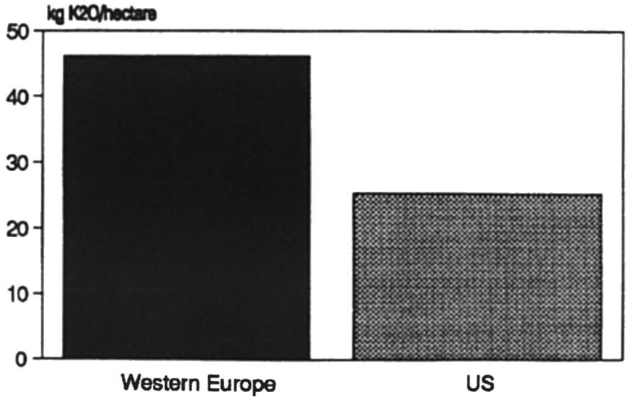
Potash Fertilizer Consumption in US



Source: USDA and PCS

Today's sophisticated U.S. farmers use modern, efficient technology on their large farms, and add the needed inputs knowledgeably. They have benefited from experience elsewhere, but have received less in the line of subsidies than European farmers. Fertilizer application rates are lower than those in Western Europe. American farmers are in tune with farm economics and the principle of a nutrient maintenance program.

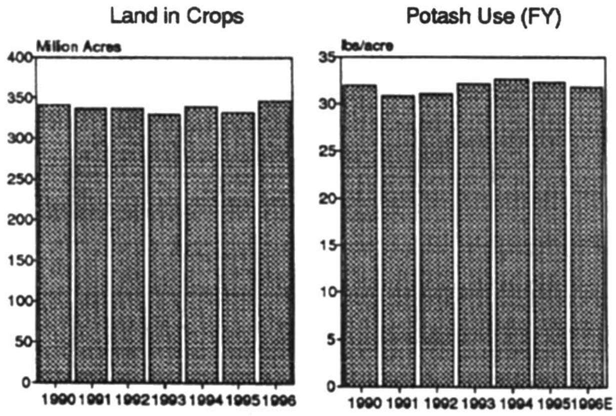
Potash Use 1995/96



Source: FAO, Fertecon and PCS (Estimated)

The U.S. is a mature market where acres and application rates have not changed significantly in recent years. However, the combined effect of Freedom to Farm and strong prices should mean more acres planted and higher application rates next year.

US Cropland and Potash Use

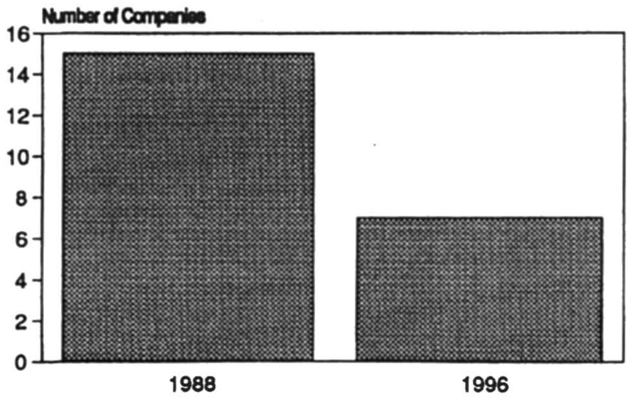


Source: USDA, Doane and PCS

In the longer term, changes in the Conservation Reserve Program will mean more fertilized acres. The United States will continue to be the largest agricultural exporter in the world. Like their peers in Europe, American farmers will be farming more in response to market conditions in the next century.

North American potash producers are recovering from the painful fall in demand early in this decade, and the overbuilt capacity dating from the 1980s. The industry has been consolidated from 15 producers in 1980 to seven today.

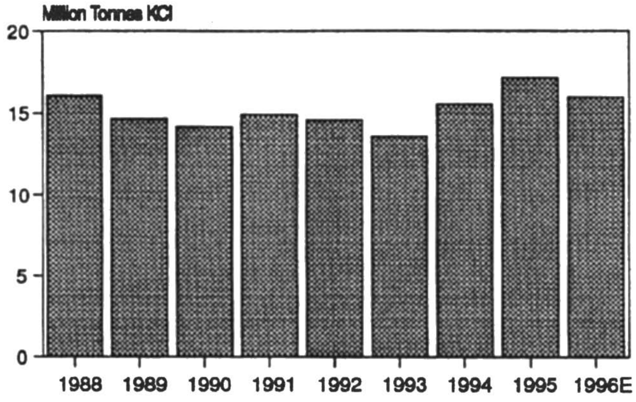
Potash Consolidation in North America



Source: BSC and PCS

New Mexico's reserves are near exhaustion, but incremental new capacity has been added in Saskatchewan in spite of the over-capacity problem. Production will increase over time.

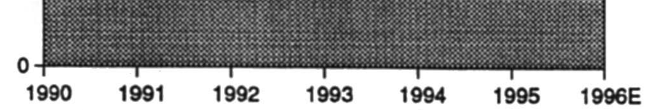
Potash Production in North America



Source: PPI, Fertecon and PCS

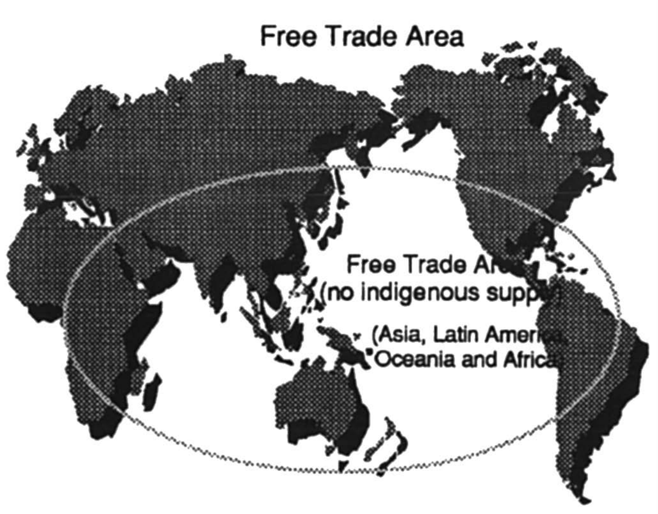
With its large production base and unused capacity, North America will continue to serve a domestic market that is the biggest single market in the world and export large volumes. It's ideally situated to serve most of the growth markets of Asia and Latin America.

Potash Supply/Demand Situation in North America



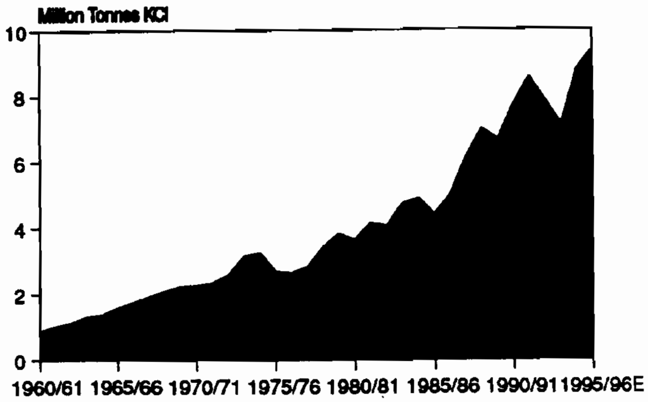
Source: PPI, Fertecon and PCS

Let's look at those growth markets, all of which lie within the Free Trade Area of Asia, Latin America, Oceania and Africa, where there is little or no indigenous supply.



In Asia, the lack of an indigenous supply partly explains why that continent lagged behind other parts of the world in its use of potash. The situation was compounded by a lack of serious government attention to agricultural development. That has changed quite dramatically, and Asia is climbing the agriculture growth curve. It has a large farm population, slowly developing technology and farmers who are coming to understand the benefits of fertilizer. But much application is still by hand.

Potash Fertilizer Consumption in Asia

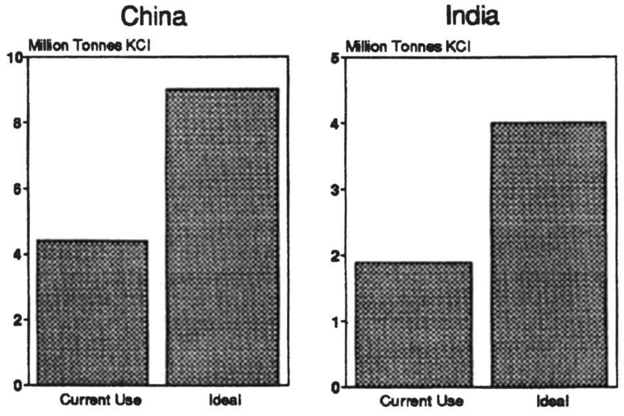


Source: FAO and IFA

Today, governments in Asia are applying their political and economic will to the task of improving agriculture -- as they must if they are to begin to meet their people's demands for more and better food. These are countries with young populations which insist on better, easier lives and diets like those they see on TV. Since food production in Asia does not keep up with consumption, and the land supply is limited, crop production must be improved with fertilizer to even begin to meet these demands.

China and India are already major potash markets, but need to buy even more. China alone needs to apply 4 to 5 million tonnes more potash just to bring its application into balance with the ideal fertilizer ratio of 4:2:1. India's ratio has fallen to 8:3:1. If it applied fertilizer according to the ideal ratio, it would need another 2 million tonnes of potash. For both countries, that ideal ratio does not include any future growth in nitrogen consumption, which is inevitable as demand for food continues to rise.

Largest Potash Consumers in Asia

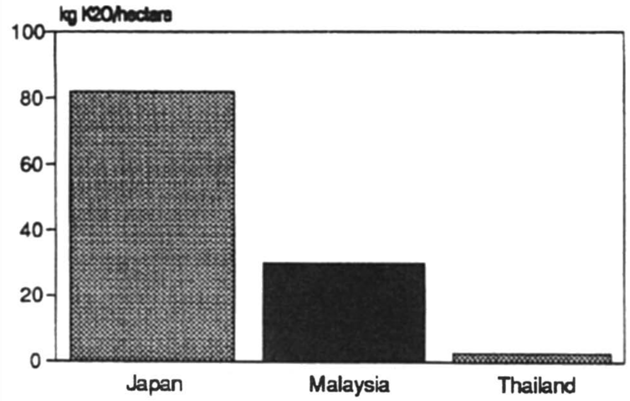


Source: FAO, IFA and PPI

Malaysia and Indonesia are growing markets hungry for potash, and Thailand and Vietnam are emerging markets. Malaysia and Indonesia have a large and expanding plantation sector which use a lot of potash.

But the countries of Southeast Asia lag in the use of fertilizer on food crops. Rice has the most acreage of food crops in Malaysia, but the rate of potash application is less than half of Japan's, which is the standard for Asia. Thailand is the world's largest exporter of rice but its potash application rate on rice is a fraction of Japan's.

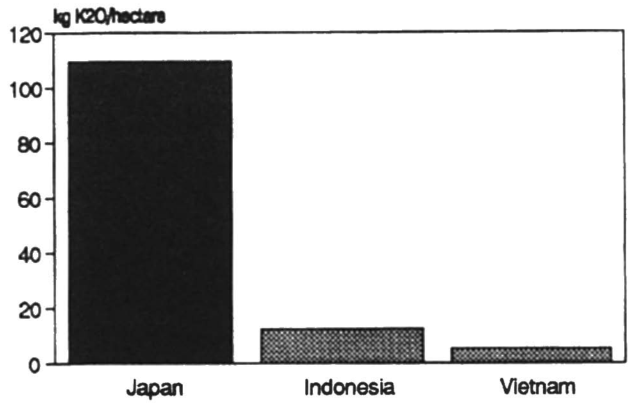
Potash Use on Rice
for Selected Asian Countries



Source: IFA

Indonesia has six to seven times as much land in agriculture as Japan, but uses one-tenth as much potash per hectare. Vietnam uses one-20th of what Japan uses.

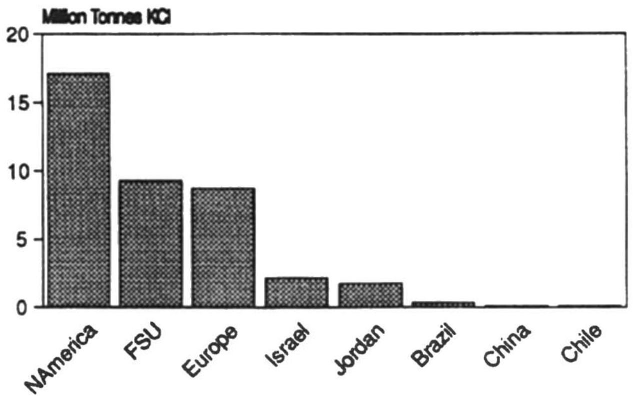
Potash Use on Cropland
for Selected Asian Countries



Source: IFA

Asia has very limited potash resources. China has a small mine that annually produces less than PCS produces in a month at our Rocanville mine. Financing for a new 800,000 tonne per year mine has been approved and the two together would meet 22 percent of China's current use. A new production facility is possible in Thailand but it would not be on stream until the turn of the century, and its success is not assured.

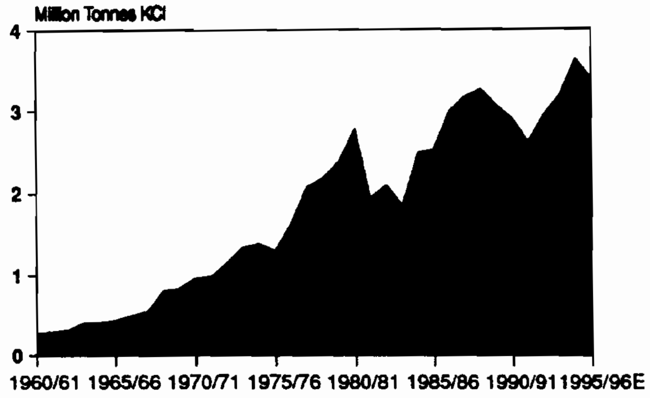
World Potash Production 1995



Source: IFA

Latin America, like Asia, has little indigenous potash supply. Demand is gathering momentum after it was derailed by the debt crisis of the early 1980s and the removal of subsidies in the early '90s. Economies are growing again, and many of the larger countries have become more market-oriented.

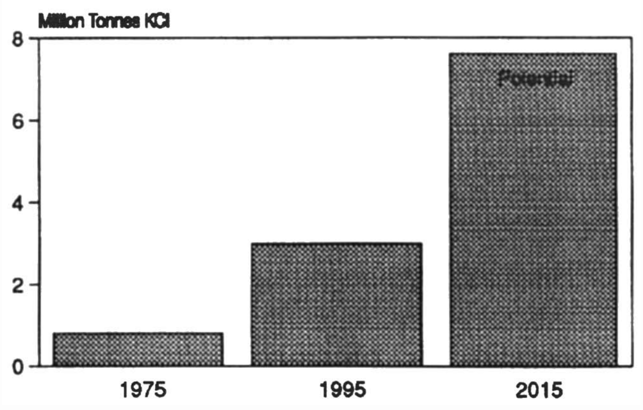
Potash Fertilizer Consumption in
Latin America



Source: FAO and IFA

A large agricultural producer like Brazil, the economic giant of the region, has tremendous potential for potash use. It currently uses 3 million tonnes a year, but a Brazilian expert suggests that in 20 years, demand there could grow to match the current U.S. agricultural level. Brazil has approximately 260 million hectares of land suitable for agriculture; that much land would require 11 million tonnes of potash at an average K_2O application rate of 26 kilograms per hectare.

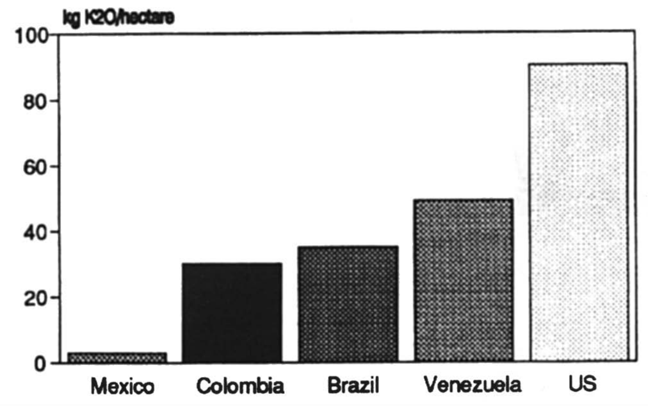
Potash Demand Potential for Brazil



Source: IFA and Potafos

Other Latin American countries such as Mexico, Colombia, Brazil and Venezuela have been constrained by economic and political factors. Their potash application rates are low, for example on corn, an important cereal crop. But agriculture is being deregulated and fertilizer subsidies removed. Once the pain of those changes is over, the prospects for agricultural growth will open up. We can expect increased use of potash in this area.

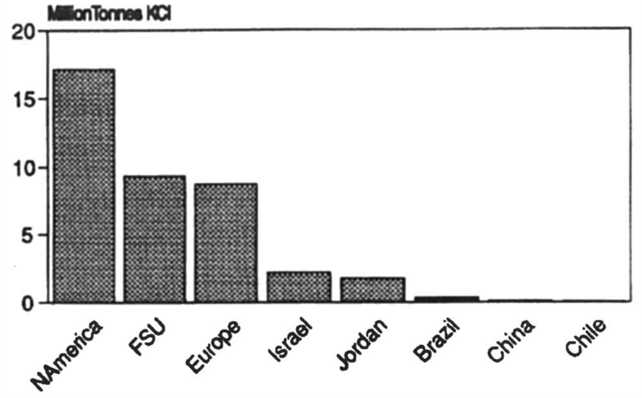
Potash Use on Corn
for Selected Countries



Source: IFA and FAO

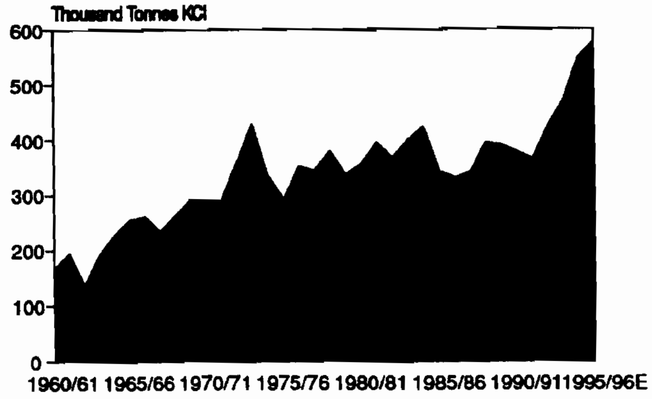
On the production side, Latin America has two producers with very small output that meets only a fraction of the regional demand. Brazil's only mine began producing in the 1980s and has never achieved its design capacity. With its second facility that came on stream in late 1995, Chile has the capacity to produce the same amount as Brazil. Most of it is used in the manufacture of potassium nitrate. Small expansions are scheduled. A proposed potash project in Argentina has been shelved.

World Potash Production 1995



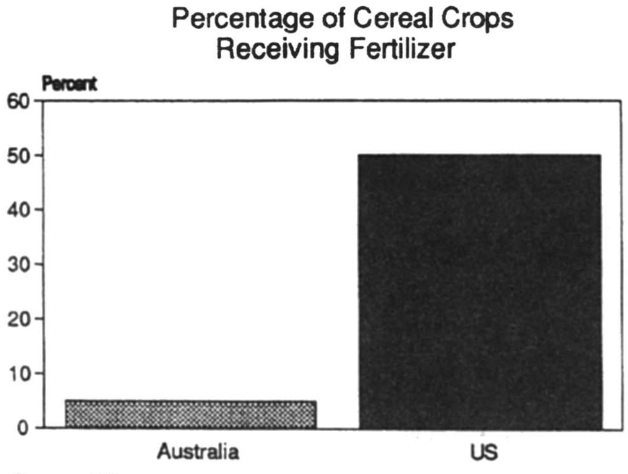
Australia and New Zealand are the main agricultural producers of the area we call Oceania. Both have large, varied and advanced agricultural industries, and are using more potash. Their agriculture is growing and becoming more sophisticated so we can expect the potash consumption trend line to continue to rise.

Potash Fertilizer Consumption in Oceania



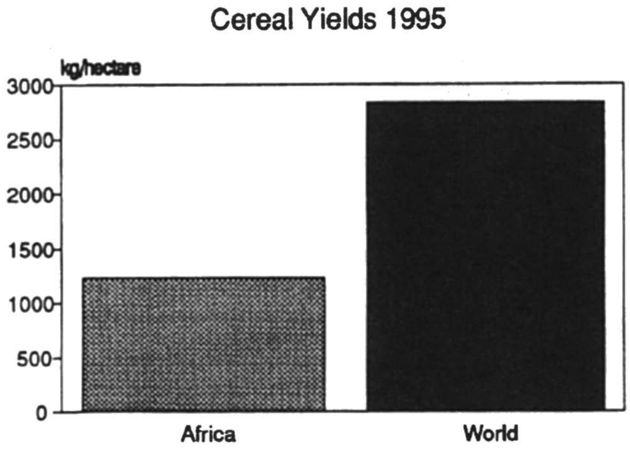
Source: FAO and IFA

Pastureland and legume crops are major users of potash in Australia and New Zealand. Australia is an important wheat producer but fertilizes less than 5 percent of its cereals, compared to 50 percent in the United States.



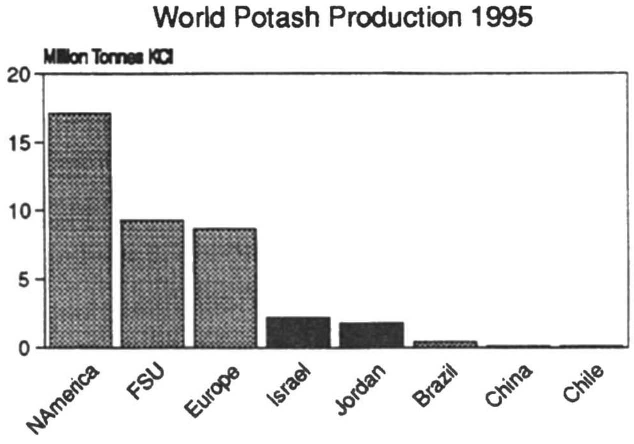
Source: IFA

Africa is still an unknown in the potash industry. With the exception of South Africa, it has not even started to use fertilizer, but it has the capacity to produce much more food than it does. Productivity levels in sub-Saharan Africa are among the world's lowest, according to a 1995 IFA position paper. Cereal yields are less than half the world average. So far, the political and economic will to devote attention, effort and money to improving agriculture has been almost totally lacking.



Source: FAO

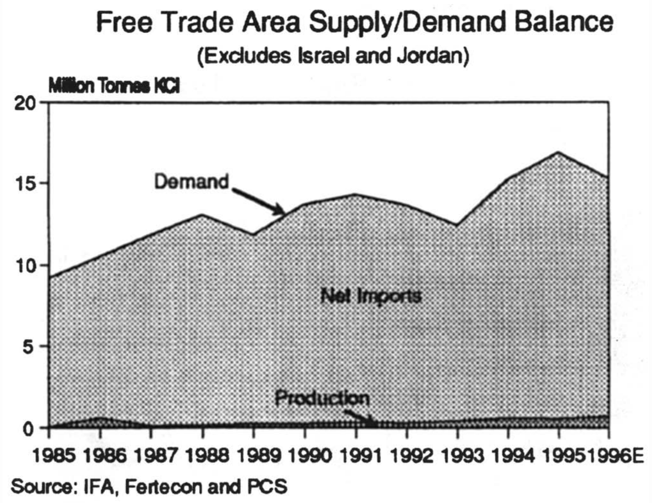
Potash goes into the markets of the Free Trade Area from North America, Europe and the FSU, and from the smaller industries of Israel and Jordan, producing on opposite sides of the Dead Sea. Israel began mining intensively in the 1960s, and now has annual production of 2.2 million tonnes. Production in Jordan began in 1982, and now totals 1.8 million tonnes a year, with plans to add 300,000 to 400,000 tonnes.



Source: IFA

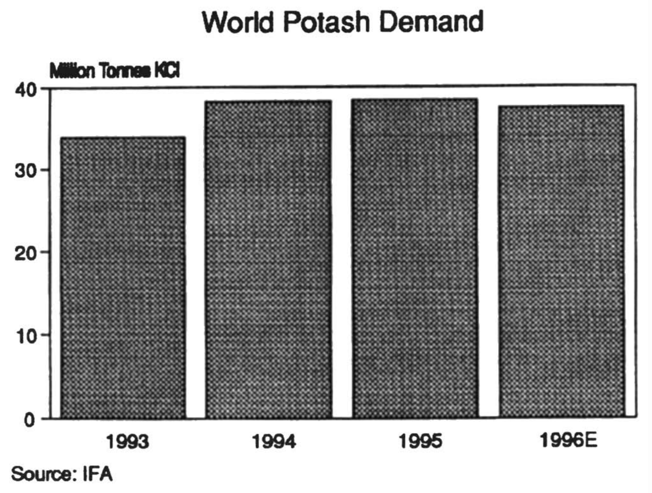
The long supply lines to the various regions of the Free Trade Area make transportation economics important. Canada's west coast is a convenient starting place for potash bound for Asia and Oceania, and shipments to Latin America move from all North American points. The FSU and Germany are major exporters to Asia, but have longer supply lines to the big Chinese market and growing Southeast Asia markets. Israel and Jordan have shorter supply lines for their shipments to Asia. The FSU, Germany, Israel and to some extent Jordan, ship across the Atlantic to Brazil.

Already a big potash market, the Free Trade Area will steadily become more important. This year we expect a downturn due to smaller sales to India and China, but it will be short-term. All indications are that they should bounce back in 1997. The internal supply in the Free Trade Area may grow but demand will greatly exceed it. In 1995, approximately 44 percent of potash sold worldwide went into this area. Since the need for fertilizer is so great in these countries, and many have burgeoning economies, it is not hard to foresee a time in the not-too-distant future when they will take half or more of world potash sales.


Free Trade Area Supply/Demand Balance
(Excludes Israel and Jordan)

Source: IFA, Fertecon and PCS

That is the potash demand and supply situation, region by region, spelling out the opportunities around the world. In 1995, world demand was approximately 38 million tonnes, and we expect 1996 totals to be down slightly, followed by an increase in 1997. Thereafter, as this brief trip around the potash world has shown, we can look for relatively strong growth in demand from the Free Trade Area on top of the mature requirements of North America and Europe. The growth in potash demand is certain but will not always be regular.


World Potash Demand

Source: IFA

We have looked at supply around the world, and seen its limitations and its prospects. We have examined demand, and we have seen where the opportunities are clearest. Potash producers have an array of different markets, each on a different part of the growth curve, but each coming to recognize the need for our vital nutrient. The prospects are bright for those who produce, market and sell this product that the world wants and needs.

Biotechnology: Its Place in Agriculture

Leigh H. English
Research Ecogen Inc.

In this paper I present for you some of Ecogen's experience in Agricultural Biotechnology as it relates to the development and commercialization of biological pest control agents. This paper is not a complete story or an academic review of the subject. While this information may indeed be out there, I recommend to you Ecogen's story as veracious and exemplary.

Biotechnology is the scientific enterprise where genetic information is manipulated for the purpose of creating commercially useful materials from biological organisms and biological processes. It is also a term used to describe the broad collection of scientific disciplines required to manipulate genes, and the products of those genes. More broadly, the term Biotechnology has meant to some the use of the biological sciences as a tool for developing new products.

Biotechnology became a specifically useful term in the early 1980's to differentiate genetic manipulations made possible by gene cloning and restriction enzyme technology from technologies of selective breeding that had been so successfully used since the dawn of agriculture. Biotechnology is the scientific progression from the genetics before gene cloning to the genetic capabilities after cloning. Speaking about it this way, Biotechnology is not a revolution but an evolution. On the other hand the speed with which molecular techniques permit the extraordinary speed for the development of new plants and animals, as well as pest control systems has made the Biotechnology a revolutionary industry.

In agriculture, the importance of genetic manipulations can be easily seen in the development of new plant cultivars and animal varieties specifically designed to fit the agro-ecosystem. New vaccines and disease treatments for animal husbandry, and new pest control systems are available to the agricultural specialist today.

The place that Biotechnology has in agriculture depends on the efficacy, and commercial value offered by the products of this technology. In other words. The answer to the business question: "What do these products offer that is better than an existing product or otherwise solves a problem that people are having that is not addressed by other products, other technologies?" will define the place of biotechnology in agriculture.

The products for agriculture that we have seen and we will see in the marketplace suggest that Biotechnology is only one of the technologies that should be applied in seeking methods to help solve real problems or help make real advances in agriculture. To the extent that the more traditional technologies of plant breeding or synthetic organic chemistry continue to develop and provide new tools for agriculture, depending on the quality of the solution, the agriculturist isn't going to care whether the solution came from a biotechnology laboratory or a child's sandbox.

So what are the unique contributions offered by biotechnology that differentiate the products from other technologies. There are three easily conceptualized and unique contributions in Biotechnology for agriculture.

1. Biotechnology offers the opportunity for enhanced safety to both the agriculturists and the consumers.
2. Biotechnology can offer the potential for a speedy solution and a relatively rapid redress of specific agricultural problems.
3. Biotechnology offers an opportunity to take advantage of new chemistries, macromolecular chemistries, that are only available if produced by an organism.

These unique contributions are then antagonized by the hurdles that must be overcome in order to introduce a product into the market place and receive marketplace acceptance. In general, these hurdles are no different from those presented to any other technology, however, the degree of emphasis on any one issue can be quite different. Some of these hurdles are:

1. Development time, cost of development
2. Regulatory issues
3. Effective marketing and customer acceptance
4. Education for effective use

Since Ecogen's inception we perceived of the company as an Agricultural Biotechnology Company. In 1995, more broad terms such as "Specialty Biotechnology" became appropriate but this was not to the exclusion of the historic emphasis of agricultural biotechnology. Early in the history of the company, Ecogen believed it would be able to use one specific technique in the arsenal of Biotechnology to effectively create strains of *Bacillus thuringiensis* (Bt) with activities that rivaled the naturally occurring Bt. strains. The approach was not a failure but did not prove to be sufficiently different from the technologies already available and marketed very well by competitors Abbott and Sandoz. As our skill base increased, our ability to utilize all of the tools of "recombinant DNA technology" became more readily available for use in Bt's. This technology produced the first recombinant Bt product Raven for Colorado Potato beetle control, introduced just in time to be met by rival chemical technologies. Hence, Raven, while a technologically superior Bt, a product of the finest in Biotechnology, does not today enjoy an dominant position in the market place. This example clearly illustrates the point I made earlier, an excellent technological advancement does not necessarily make a commercially competitive product. The weight of the benefits of a product will still be balanced by the quality of the other products. In this case, the excellent insecticidal activity of the biotechnology product Raven as not superior to the excellent insecticidal activity of other agents. So, the safety of Raven was insufficient to carry the product. Clearly, the safety benefits that biotechnology can provide are today insufficient to carry the market, but tomorrow this issue alone could dominate the decisions governing market dominance. Of course, social and political factors governing environmental regulations and safety regulations will play a role in the need for biotechnology. In this simple statement lies a potent force in the impact of biotechnology on agriculture. How important is applicator, harvester and consumer safety. It is self evident that the same social and political pressures on other technologies will also force them to measure-up on the safety scale, and as these techniques find success in achieving safety milestones, the total market available for biotech-derived products will change. In response to commercial pressure, Biotechnologically-derived products will be able to quickly respond and improve in quality by engineering new active ingredients, demonstrating the second and third of the distinctive contributions of biotechnology. Ecogen's second product produced with the techniques of recombinant DNA technology was CryMax, a revolutionary product for the broad-based control of insect pests on vegetables. In this case, Ecogen was not satisfied with good biological activity with excellent safety, instead we developed a product with superior biological activity and maintained the safety common to Bt products. This product is just being introduced so the history of it has not yet been written.

Just as the small chemical structures common to the Ag-chemical business have the potential of being significantly derivatized, so to the large macromolecular structures common to biotechnology. In fact larger macromolecules have dramatically more possible permutations that can be used to create new active ingredients. Here lies the real power of biotechnology–the chemical nature of the macromolecules provide an essentially unlimited supply of new active ingredients all with their own factory, the living cell itself. Ecogen's newest products including CryMax and Lepinox will be the first to benefit from this technology, however, our genetic resources for insect control will also be used in the development of plants through our relationship with Monsanto Corp. It is worth noting that this is a unique strategy for Ecogen. We will be able to use the very rapid development of our insecticide technology as traditional applied insecticides, and then, after a few more years of development, we will reap the benefits of new plant cultivars harboring these insecticidal proteins.

In Plant application of Bt genes is only one example of how Biotechnology-derived products can be produced. Proteins are large chemicals, macromolecules. At the moment, the size of proteins prohibits synthetic chemical synthesis. Ecogen has learned to take advantage of the microbiological factories that Bt's represent. This property translates into higher margins for the products.

The general and negative factors making an impact on agricultural technology also affect Biotechnology, but to a differing degree. Regulatory issues, for example, have not been as severe as one might believe. Ecogen's products enjoy a regulatory process that takes about one year compared with the several year wait that other chemical technologies require. On the other hand, market introduction can be more severely constrained than traditional chemistry because of the unfamiliarity of the consumer. Clearly additional educational effort expenses are incurred here to achieve market introduction. It is my impression that other negative impacts on products are shared equivalently regardless of the technology.

In consideration of the second half of my definition of Biotechnology, the definition that encompasses the commercialization of biology in general, Ecogen has two other significant and commercialized product lines: biofungicides and pheromones. The biofungicides rely on the ability of naturally-occurring yeast and fungi to control destructive plant fungi. AQ10 a commercial product made from *Ampliomyces quisqualis* is a hyperparasite of numerous powdery mildew fungi. This product is currently being marketed for powdery mildew control on the grape and ornamental crops. Aspire is a commercial preparation of the yeast *Candida oliophila*. This yeast has the desirable property for the colonization of the fruit surface thus excluding the pathogenic blue and green molds. Ecogen also has an extensive list of pheromone-based products for insect control including the NoMate line of fibers, spirals and microencapsulated pheromones.

Our products in development include insecticidal nematodes to be sold under the trade name Cruiser, and a bionematicide. Ecogen is also researching opportunities for the control of soil pathogens.

Monday, October 28, 1996

Session II

Moderator:

Ed Huber, Jr.

Update on Slow Release Fertilizer Methodology

William L. Hall, Jr.
IMC AgriBusiness

I am going to talk about the Controlled Release Task Force, how it was created, why it was created, and what we have been up to. I will start with the history, or evolution, of these products. This evolution had a lot to do with affluence and the ability to do the research to come up with these new products. As influential people tend to be affluent, they want to be controlling people as well; and so they need to be able to control these products. Control officials need to be able to control them as they regulate. Control release manufacturers need to control them in order to make the best use of their product and create an economically beneficial product. And the consumers need to understand what's going on. Right now the consumers are very frustrated because there are a lot of misunderstandings and misconceptions about the products that are out there.

Why do we need controlled release fertilizers? To begin with, the need was really very small. There were not really many tons sold, and as we all know, in the early days fertilizer had much to do with tons. But the margins were quite big because the products that these materials would be used on were very high margin products. Therefore, there could be justification for large research dollars — big research dollars created new products out of all that research.

The trends over the past 40 or 50 years have been from granulation towards bulk blending; from looking at just total or soluble analysis to looking more towards available analysis; and from the lack of control, even on the controlled-release products, to more control and more specification of these products.

In order to control something, you must first measure it, evaluate that measurement, and monitor the production, use and output of that product. The industry has done a pretty good job of being able to do all of these things. Unfortunately, many consumers and control officials cannot do the same thing. The major difference in the controlled release industry in the last 10 to 20 years has been control! We finally have it. The industry can finally make products that can last a specific amount of time. That's great, right? Wrong! With the new technologies, we have gotten new classes of materials that have created new finished blended products. Unfortunately, we also now have the need for new analytical and measurement techniques, which I will show you shortly.

Additionally, new longevity times are produced and also the new claims that new products always bring about. With these new products and claims are new terms. These terms include things like "water soluble slowly available", "coated N-P-K plus minors", "nitrification inhibitors", "urease inhibitors", "release curves", and ways of expressing how products release like "square root of time" and "zero order". All of these terms are very unfamiliar not only to the fertilizer industry, but also to consumers as well.

Each company has done a good job of evaluating its and other people's products. Unfortunately, these were all developed independently as you can see by the information in this matrix chart. We have many different companies on here, but unfortunately they all use different techniques to evaluate their product. Another problem is that most of these evaluations last many days, as many as 200 to 300 days in many cases. This lead to the dilemmas that I am about to describe.

For the control officials the dilemma was the fact that people were making claims that they really could not regulate. Some tried, some did not try at all. From that perspective, what happened to the industry was that you got arbitrary regulation. One bag of product could not be sold with the same claims on it across the United States. This is a major problem when you are printing millions of bags. From the consumer's point of view, there were tremendous amounts of not only confusion, but even frustration. We are not only talking about homeowners here, but also about golf course superintendents, nursery growers and in agriculture. There are just too many terms that consumers have been asked to understand that, without the proper background, they cannot do.

Therefore, we have developed a set of needs. The needs are:

- The state control officials need the regulatory tools to monitor claims for consumer protection.
- The industry needs the ability to make claims accurately describing the benefits of their products.
- The consumer needs simplicity, clarity, and information to make accurate judgements.

Those were the problems. The response took place in June 1993 with the formation of the AAPFCO - TFI Controlled Release Task Force. Their job was basically to reevaluate every aspect of controlled release as it related to each of these groups. Here is a list of the current makeup of the committee and the various areas of expertise that each member brings. As you can see here, my specific area is methodology, and that is what I will discuss during the rest of this talk.

The Methodology group has got to be able to provide the tools for measurement. It will be an AOAC approved procedure and will be available so anybody can use it. From the Enforcement point of view, this should bring about the tools for consistent regulation with an AAPFCO adopted labeling policy. It will make clarity and understanding a high priority and will heighten the consumer awareness of these products if they understand it. Additionally, we will have to address new products and future technologies, so there has to be enough flexibility in what we do to be able to accommodate those sorts of things. We also needed to have some specific direction, so we had to establish policy statements and goals, which we have.

Now without going into all of those areas, I am going to talk specifically about methodology and where we are in this point in time. We have established a number of goals. Those goals are listed here.

In addition to those goals, as you can see, there needs to be categories so we can break these products out into different divisions. These categories are outlined in this table. Every product should fit somewhere on this table.

Among the things that affect controlled release fertilizers are many different variables. I think it is very important that the methodology address and try to control as many of these variables as possible. The variables are listed here. They include time, temperature, solvents, agitation, matrix effects, equilibrium (solvent volume), biological population and type. Other possibilities that might affect release are placement of the fertilizer, sampling and samples size. All of these things can affect the analysis of the product.

Just to give you an example, let's look at temperature for a moment. I am going to show you three graphs at three different temperatures and you can see how temperature affects the release of each of these products. On one axis is the percentage of total N that is extracted in a cumulative sense. The other axis indicates the number of days required for this extraction to take place.

As you can see in the first graph, at 50° C some products release very fast. As an example, the EX-44 released almost completely in eight days, while the NC1768 was only at about 25% after eight days.

If you crank up the temperature to 60° C, the EX-44 is almost completely gone in about three days. And after eight days, instead of being at 25%, the NC1768 is at about 45%.

So we thought we would make one more stab at it and go to 70° C, which is pretty doggone high, especially when you start trying to handle these things by hand. At 70° C, the EX-44 is almost completely gone after two days, while after eight days, the NC1768 is above 60%. At 28 days, it is at about 85%, which is almost totally released. This is 70°C for 28 days. Can you imagine how long that product would last in the field? Probably about 300 days under typical growing conditions of 70°-80° and under normal moisture conditions.

So we tried to develop a method based on temperature being the driving force to increase and accelerate these release curves to the point where we could measure them in a laboratory sense, which is obviously one of our goals. This graph shows some of our early success. Within 48 hours we were able to get about 30% of the plastic coated urea out that under normal circumstances would last about 300 days. Not bad, right?

Unfortunately, we also had some failures. Ureaform was quite variable from lab to lab, as you can see here. It seemed to fall into two separate categories. It appeared that a couple of labs were able to extract almost 80% in 48 hours while others were down in the 40% range.

We have learned a lot from this, and so our efforts are going to continue to try to do the following things.

Try to increase the ruggedness and reproducibility.

Have better, simpler terms and categories not only for the consumer, but so the industry can make claims on the bag that are simpler to understand.

We are going to try to do this with the goal of correlation with agronomic data that shows that this laboratory method has some real life applicability in a real world, in a biological system.

And, just in case we cannot develop something for all of them, we will develop an exceptions list for the products that you can't use and find alternate methods for them.

That is kind of where we are. We met Sunday afternoon and had quite a long session. We have a new list of goals that includes a new round of analytical testing that hopefully should take place in the next few weeks and months. We have had a lot of cooperation and acceptance of what we have done so far by state control officials as well as industry. Everybody realizes that it is a problem and we just have to find a way to attack this, a way that is going to be fair to all parties concerned.

We will continue to work, and hopefully in the next year or two we can bring this to completion.

HISTORY

↓

EVOLUTION

↓

AFFLUENCE

↓

CONTROL

OFFICIALS

RELEASE MANUFACTURERS

CONSUMER FRUSTRATION

WHY?

THE NEED WAS

SMALL

BUT THE MARGINS WERE

BIG

RESEARCH $$$

NEW PRODUCTS

TRENDS

FROM	**Granulation**
TO	**Bulk Blending**
FROM	**Total Analysis**
TO	**Available Analysis**
FROM	**Lack of Control**
TO	**Control**

IN ORDER TO CONTROL YOU MUST

MEASURE

EVALUATE

MONITOR

The Industry Can Do This.

Many Consumers and Control Officials Can't.

MAJOR DIFFERENCE IN THE CONTROLLED RELEASE INDUSTRY IN THE LAST 10 – 20 YEARS IS

CONTROL !

We finally have it.

GREAT!

WRONG!

NEW TECHNOLOGIES

New Classes of Materials

New Products

New Analytical & Measurement Techniques

New Longevity

New Claims

NEW TERMS

Water Soluble Slowly Available

Coated N-P-K + Minors

Nitrification Inhibitors

Urease Inhibitors

Release Curves

Square Root of Time

Zero Order

MATRIX CHART CONTROLLED RELEASE PROCEDURES FOR EXTRACTION AND ACCELERATION

SOURCE/ COMPANY	SCOPE	SOLVENT SYSTEM	TEMP. ° C	SAMPLE/ WATER RATIO	TOTAL SAMP/ WATER RATIO WATER CHANGE	SAMPLE FREQ.	TEST
VIGORO	N-P-K-Mg PC & LS	WATER	~20°	5g/500ml	5g/2000ml Complete	1H/1D 3D/7D	N-P-K MINORS
VIGORO	N-P-K-Mg PC & LS	WATER	40°	5g/500ml	5G/2000 ml Complete	1H/1D 3D/7D	N-P-K MINORS
SCOTT	SCU/PCU	WATER	25°	25g/250ml	25G/1000ml Complete	1H/1D 3D/7D	N
SCOTT	SCU/PCU	WATER	60°	15g/150ml	15g/600ml Complete	1H/1D 3D/7D	N-P-K
SIERRA	N-P-K PC	WATER	ROOM TEMP	4g/300ml	4G/600ml Comp. Sand	3D/10D X7D	N-P-K COND.
SIERRA	N-P-K PC	WATER	HIGH TEMP	20g/170ml	20g/170ml NO	15M/1H 2H	N-P-K COND.
ICI	SCU	WATER	LOW ?20°	12.5g/2500ml	12.5g/2500ml	1D/?	N
ICI	SCU	WATER	HIGH	40g/200ml	40g/200ml	1H/?	DENSITY
FISONS	PC N & N-P-K	WATER	25°	10g/500ml	20g/1000ml Refilling	1D/D	ISE/ICP
FISONS	PC N & N-P-K	WATER	HIGH	10g/200ml	10g/2600ml Complete	1D/7D	N
AGLUCON	PC N-P-K	WATER	LOW	10g/800ml	10g/800ml No	1D/7D	N-P-K & COND.
AGLUCON	PC N-P-K	WATER	HIGH	10g/800ml	10g/800ml No	8H/1D 2D/...	N-P-K & COND.
PURSELL	PC N-P-K & SIZES	WATER	~22°	20g/100ml	20g/100ml No	2H/3D 7D ...	REF. I
PURSELL	PC N-P-K & SIZES	WATER	30°	10g/100ml	10g/100ml No	2H/6H 12H ...	REF. I
PURCELL	PC N & SIZES	WATER	60°	10g/100ml	10g/100ml	2H/6H 12H ...	REF. I

THREE GROUPS - THREE DILEMMAS

CONTROL OFFICIALS	**Claims**
INDUSTRY	**Arbitrary Regulation**
CONSUMER	**Confusion** **Home Owner** **Golf Course Supt.** **Nursery Grower** **Agriculture**

THE NEEDS

A. STATE CONTROL OFFICIALS
Regulatory tools to monitor claims for consumer protection.

B. INDUSTRY NEED
Ability to make claims accurately describing benefits of their products.

C. CONSUMER NEEDS
Simplicity, clarity, information to make accurate judgements.

THE RESPONSE
JUNE 1993
AAPFCO - TFI
Controlled Release Task Force

Reevaluate every aspect of controlled release

CURRENT MAKEUP OF COMMITTEE

AAPFCO	Dr. Wilbur Frye, KY	Chair
	Dr. Dave Turry, KY	Methods
	Dr. Joel Padmore, NC	New Product Labeling
	Dale Duberly, FL	Enforcement
	Gary Braun, MN	Labeling

TFI/INDUSTRY	Bill Hall, IMC Vigoro	Methodology
	Ed Huber, TFI	Methodology
	John Detrich, Pursell	New Products
	Vince Snyder, Scotts	Enforcement
	Alan Sutton, IMC AgriBusiness	New Products
	Whitt Yelverton, TFI	Policy

METHODOLOGY	Tools for Measurement AOAC Approved
ENFORCEMENT	Consistent Regulation AAPFCO Adoption
LABELING	Clarity Understanding Consumer Awareness
NEW PRODUCTS	Future Technologies
POLICY	Establish Direction and Goals

CATEGORY DIVISIONS

GOALS FOR METHODOLOGY

GOALS OF NEW METHOD FOR
<u>EXTRACTION & ANALYSIS OF EFFICIENCY DESIGN FERTILIZERS</u>

1. MUST BE ABLE TO CATEGORIZE MATERIALS TREE STRUCTURE WITH LOGIC FOR COMPUTER EASE.

2. STATUS OF CURRENT MATERIALS WILL NOT CHANGE SIGNIFICANTLY.

3. CAN BE RUN IN AN ANALYTICAL LABORATORY.

4. CAN BE RUN IN SEVEN DAYS, PREFERABLY LESS

5. WOULD BE ABLE TO BE PERFORMED BY TECHNICIANS USING AVAILABLE EQUIPMENT, THUS GAINING WIDE ACCEPTANCE.

6. WOULD BE APPLICABLE TO A WIDE VARIETY OF BLENDED MATERIALS.

7. CAN BE CORRELATED TO AGRONOMIC DATA.

8. MAY BE USED FOR EXTRACTION OF MULTIPLE NUTRIENTS (N-P-K-MINORS).

VARIABLES

VARIABLES EFFECTING RELEASE

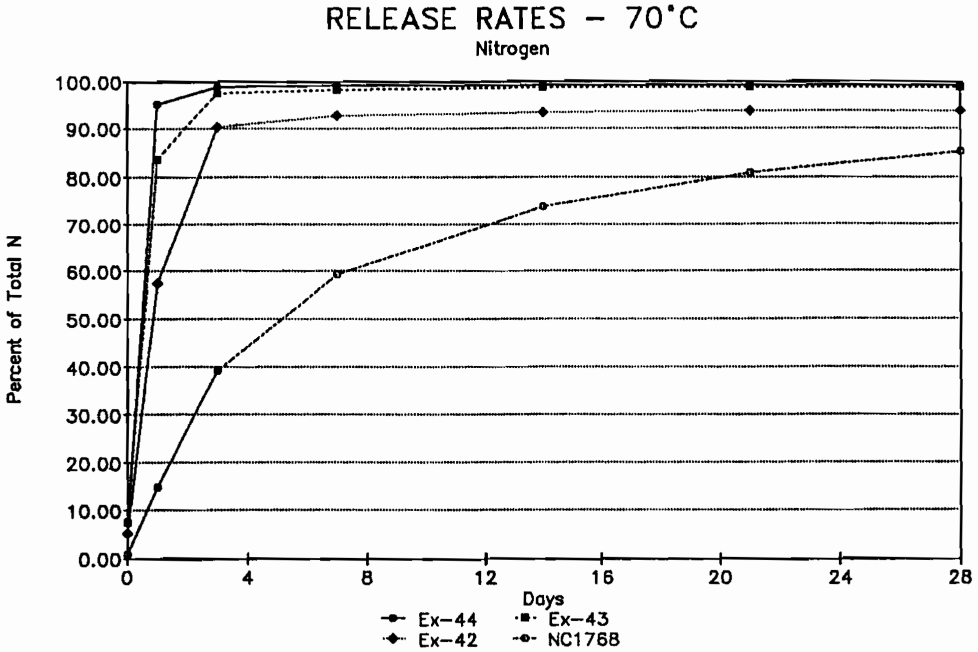
- TIME
- TEMPERATURE
- SOLVENT
- AGITATION
- MATRIX AFFECTS
- EQUILIBRIUM (SOLVENT VOLUME)
- BIOLOGICAL POPULATION & TYPE

OTHER POSSIBILITIES

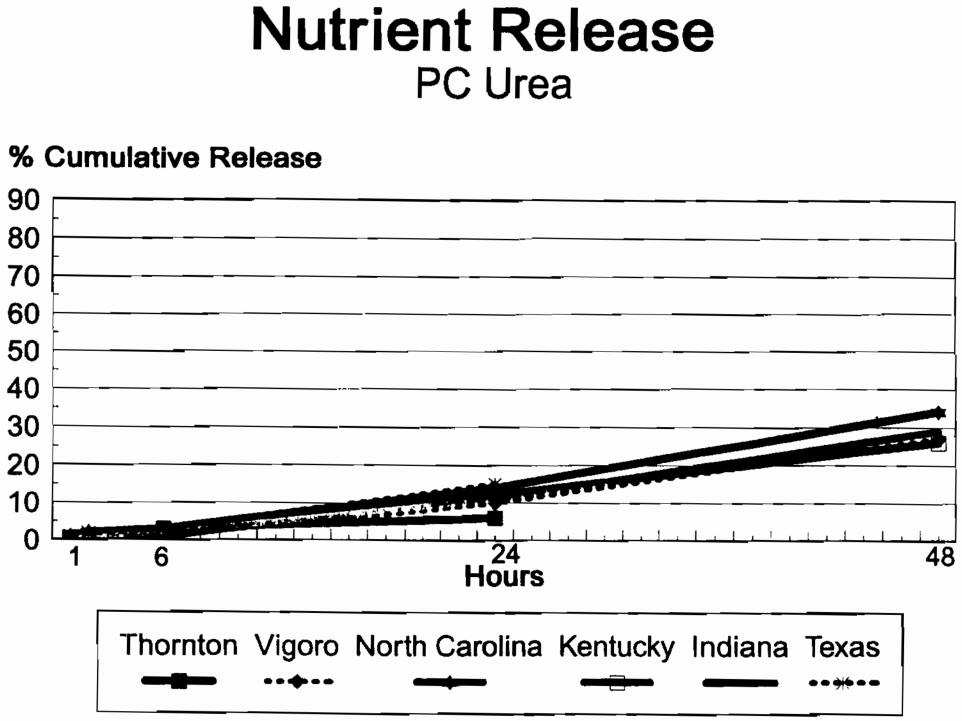
- PLACEMENT
- SAMPLING & SAMPLE SIZE

RELEASE @ 50°
RELEASE @ 60°
RELEASE @ 70°
EARLY SUCCESS
P.C.U.
AND FAILURES
CONTINUED EFFORTS WITH FOCUS ON

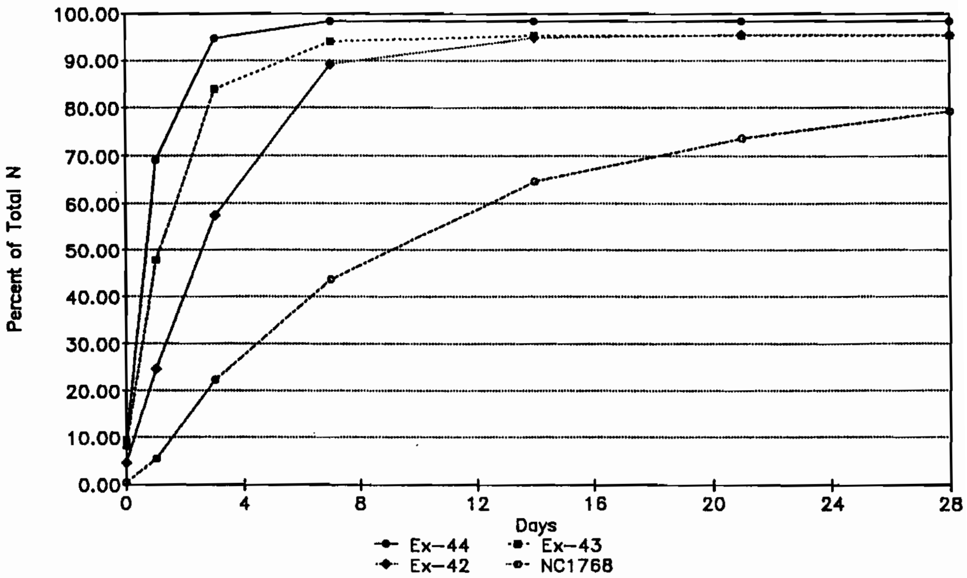
Ruggedness & Reproducibility
Better/Simpler Terms & Categories
Agronomic Correlation
Develop Exceptions List


RELEASE RATES – 70°C

Nitrogen

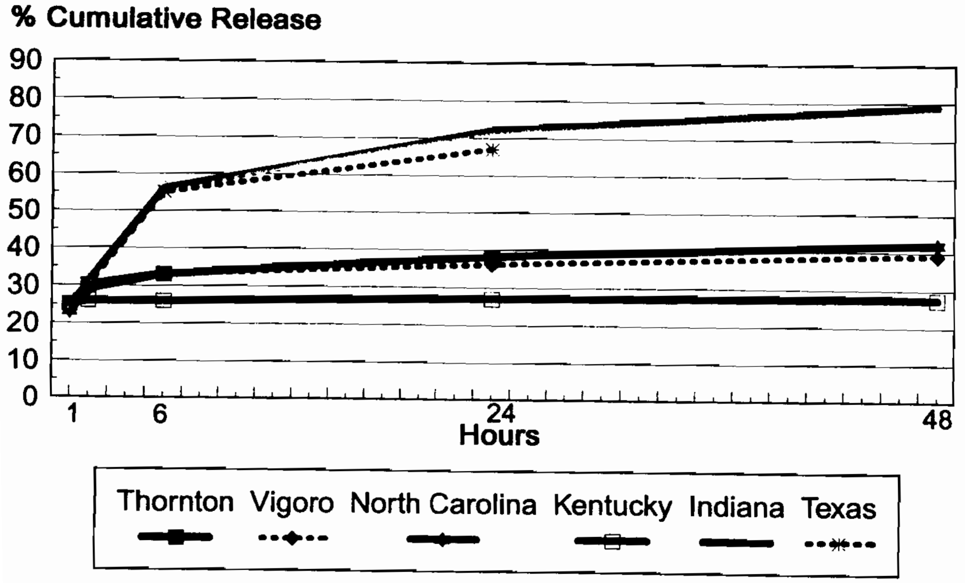

Nutrient Release

PC Urea



RELEASE RATES — 60°C
Nitrogen

Nutrient Release
Ureaform



Advances in the Upgrading of Sludge and Their Importance to the Fertilizer Industry

Vernon B. Meacham
Harmony Products, Inc.

Prior to beginning a discussion of the means and methods of upgrading sludge, I felt that It would be relevant to briefly discuss some of the past and current methods of sewage waste disposal. As we all know, sewage waste has been used as a fertilizer for thousands of years. The Chinese composted the product and referred to it as "Night Soil" and it was prized as a high quality fertilizer. Asian farmers have used sewage waste in rice paddies for centuries. Prior to the twentieth century, indoor plumbing was not common and most sewage waste was disposed of close to its source, by spreading it on the land.

Things changed in the twentieth century with the onset of the industrial revolution. Populations became more concentrated and sewage waste disposal became a municipal concern. Early on, the sewage was generally run into ditches within communities which emptied into nearby waterways. However, by the 1920's and 1930's this method was becoming impractical, populations were growing and these waterways were becoming polluted. Industries were also producing wastes which were needing to be disposed of. So, to deal with these mounting waste disposal needs, the modern water based sewage system was developed. This system included indoor plumbing in most households and industries that lead to elaborate underground pipe systems which conveniently carried everything away to central processing plants. And, this great modern convenience was all the rage.

This leads us to the present, where most of the sewage and industrial wastes generated today are still piped to central processing plants where the wastewater is treated, then separated into liquid and solid fractions. The solid fraction, or sludge cake, goes somewhere for further treatment or disposal, and the liquid effluent is purified and returned to a water system. So, as I proceed with my talk and refer to sludge cake, I am referring to the resultant biomass from the filtration or centrifugation of digested municipal wastewater. This product is usually a 25 to 30% solids cake that is about the consistency of Jell-O Gigglers (apologies to the Kraft Company). This 7 million tons of sludge cake produced in the US receives most of the attention these days. It is also the product who's past, and inevitable future, is in the fertilizer industry.

Current Sludge Disposal Methods

Following is a list of most of the current methods for disposing of sludge cake. Some deal with the cake in the form that it leaves the processing plant (direct disposal methods) and others rely on further processing methods to create a different end product.

Direct Methods of Cake Disposal

Ocean Dumping

Ocean dumping is mostly a thing of the past. We all remember George Bush's campaign speech in the 1988 election where he was standing in front of "the pipe" that discharged Mr. Dukacus's sewage into Boston Harbor. This quickly prompted a 3 Billion dollar clean up campaign that lead to the cessation of this disposal method for the Boston environs. Similar practices were stopped in New York City, off the coast of Britain and many other places around the world.

Ocean dumping is a very convenient and cost effective way of getting rid of large volumes of sewage. It is, of course, an environmental nightmare, not a "beneficial use" of the sludge and very hard to get public opinion on your side.

As an aside—this is a method of getting rid of the prefiltered sewage and not just cake. It is pertinent in that the result of the Boston Harbor clean-up was that the biosolids were dried, and Harmony is now the marketer of this fertilizer. New England Fertilizer Company, the folks that operate this state of the art facility, licensed Harmony's technology for upgrading biosolids and plans to use it in future plants, thus the reason for my talk today.

Landfilling

Another method to dispose of the filter cake is to haul it to the neighborhood landfill. While this is eminently better than ocean dumping, it is not considered a beneficial use.

Economically, the jury is out on whether landfilling is cost effective or not. The industry's thoughts back in the late 80's and early 90's was that landfill costs would increase rapidly through this decade, as land use restrictions would tighten and public opinion would be against "putting one of those things in my back yard". However landfill costs have not significantly increased and it remains a cost effective means of cake disposal for many municipalities compared to further processing. It is a finite solution however, as landfills will eventually "fill" and suitable sites will become harder to find. It is also expensive to haul and pay tipping charges on cake that is 75% water.

Land Application

Similar to landfilling, in some ways, is direct land application of sludge cake. This method become more prevalent in recent years. It is more cost effective than landfilling, in that tipping fees are not generally incurred. Land applying can be considered a beneficial use, as the sludge is used as a soil amendment or fertilizer. However, there is a camp that says the appliers are poisoning the ground water with heavy metals and spreading noxious, disease causing pathogens all over our fields. This is not a black and white issue, as there may be some elements of truth in the later opinion depending on the source of the biosolids and its treatment methods. But there is also truth to the former opinion, that properly processed cake can supply valuable nutrients to the soil.

Further Processing Methods

There are several methods used to process sludge cake that alter the final form of the product. Usually these methods are designed to rid the sludge of pathogens, dilute the heavy metals and reduce the odor. But no matter what process or method used, you still have a product that you must *dispose* of.

Incineration

In the US, 25-30% of sewage sludge cake is incinerated. Incineration is one of the methods of choice to dispose of sludge cake in my area, Hampton Roads, VA. As my sewer bill will attest, it is an expensive step in the disposal process. Its advantages include reducing the volume of end product and complete sterilization of any pathogens that might be present, as well as reducing many of the volatile chemical compounds to inert forms. However you still have ash to dispose of that contains now higher concentrations of heavy metals. Our district has done a great job in finding clever, beneficial means of dealing with the ash, (one of the only areas in the country that does anything besides throwing it in a landfill). One company is making lawn ornaments and concrete for rip-rap in bulkheads on waterfronts . Incineration is a finite opportunity as well; for example, no more incineration permits can be granted in our area, so other means are being explored, including Harmony technology.

Composting

Another method of choice in Hampton Roads and other areas, is composting the sludge cake. The cake is mixed with a carbon source (wood chips), windrowed and periodically turned for several weeks. The process heats the material to temperatures which rid it of pathogens, reduce the odor and form a material that can be used as landscaping mulch. It is a popular product back home and they can actually get a little money back through sale of the material at local garden centers. Composting can be relatively inexpensive, provided the sludge cake is composted near the treatment plant and does not have to be hauled significant distances. It is generally considered a beneficial use. It does however increase the quantity of material that needs to be disposed of and the composting site is space intensive. Land and permitting may be limiting factors to composting in years to come.

Alkaline Stabilization

Another method of dealing with sludge cake is to use alkaline stabilization. This process is similar to composting in many ways in that the sludge is mixed with another product, windrowed and develops and maintains heat (>50°C) for extended periods which pasteurize and stabilize the material. Unlike composting the product is held under high pH's (>12) through the addition of basic materials such as lime or by-products of the lime, cement or utility industries (fly ash). This is an inexpensive process, compared to incineration, and its end-product, a low analysis soil amendment is considered a beneficial use. It's drawbacks include that it increases the volume of material to dispose of and is space intensive. It has been rather slowly accepted as a land application product.

Drying

As an alternative to the methods used above, many municipalities today are considering the process of drying as an alternative. In order to reduce the volume of material required to go to landfills, and reduce the cost of shipping water over the road, drying has emerged as a viable means of sludge treatment. Also, depending on the prior treatment of the sludge and the method of drying, a salable product can be produced to help offset the processing costs.

There are basically two drying methods employed for sewage sludge, direct and indirect. Indirect dryers are typically hollow disc screw mixers, in which a heat medium (steam or oil) is circulated through discs. These dryers are generally smaller in footprint and require less recycle (or none) to be added to the sludge prior to processing than direct methods. They also claim to be more energy efficient than direct dryers. The resultant product can range in size from a fine dusty powder to flakes to granular particles. This depends on the makeup of the sludge and the prior treatment methods. Odor is generally directly related to prior treatment as well.

The most common direct dryer used in sludge drying is a rotary drum. Most are triple-pass and require significant recycle to be mixed with the cake prior to introduction to the drum. Usually, a round granule is produced if the moisture content is correct and the operator is experienced. Like the indirect dryer, the odor is related to prior treatment methods.

Common to both drying methods is that the quantity of sludge is reduced and the end product (depending on its physical properties) may be used as a beneficial use fertilizer or soil amendment. Also, drying can be expensive, particularly if the end product has to be landfilled or shipped for land application.

Definitions

This brings us to the point of my talk, the upgrading of sludge as it relates to the fertilizer industry. To help clarify the differences in drying, upgrading and enhancing sludge, terms I will be using from this point on, I would like to offer a few definitions:

Drying

Removing moisture from sewage sludge cake to approximately 97% solids or more. Methods include both direct and indirect drying. The resultant product may range in physical appearance from a powder to granular form. Can be odorous, depending on the predrying treatments.

Upgrading

Removing moisture from sewage sludge cake while at the same time improving the physical characteristics of the biosolids to a salable form. This usually infers a granular, fertilizer type material of low analysis (2-8 units plant food)

Enhancing

Removing moisture from sewage sludge cake while at the same time improving the physical characteristics and chemical analysis of the biosolids. The resultant product is a granular fertilizer of higher analysis (>8 units plant food).

At this point we can dismiss the idea of ungranulated dried biosolids being used in the normal fertilizer industry. Unless it is used as a substrate for enhancement, it is probably destined for the landfill. With that, we can begin the discussion of using upgraded and enhanced biosolids as fertilizer products.

Why Should the End-User Use Upgraded Biosolids?

Upgraded biosolids, (their most simple salable form) can provide end users, be they professional turf growers, farmers or homeowners, several benefits. These can be classified in two areas, Agronomic Benefits and Environmental Benefits.

Agronomic Benefits

Organic matter

Upgraded biosolids are an excellent source of organic matter. At Harmony, we like to say that our products feed the soil, thereby creating a more beneficial growing environment for the plant. One major aspect of this feeding is supplying proteins and carbohydrates to the micro- and macro-organisms in the soil that make primary, secondary and minor elements available to the plant. Organic matter is also essential in improving the soil's physical characteristics (reducing compaction, increasing water holding capacity, etc.).

Micro nutrients

Biosolids are excellent sources of micronutrients. Iron, zinc, manganese, copper and boron are all found in beneficial levels in biosolids. Most up to date fertilizer programs address the need for these microelements essential for healthy plant growth.

Slow releasing Nutrients

Organics generally release their nutrients more slowly to the plant, feeding them for longer duration's. This supplies the plant with nutrients in a pattern more closely correlated with their uptake.

Environmental Benefits

Beneficial Use

One buzz word being used today in the sludge business is "beneficial use". I have mentioned it several times in this paper and it is really a self explanatory term meaning a method of disposal that is beneficial to the environment. But it is an important term in that it plays a vital role in the waste disposal business. Most companies today spend a significant amount of time and money putting the "beneficial use" spin on what they do. I feel that there are some methods that are more beneficial to the environment than others. The use of biosolids as a fertilizer is probably the best "beneficial use" around.

Non-Leaching

Since the most of nutrients in the biosolids are organic based, there is significantly less leaching potential compared to the soluble chemical fertilizers. This of course reduces the chance of runoff and groundwater contamination.

Reduces Chemical Fertilizer Needs

I realize that this is an insensitive thing to say while addressing a room full of fertilizer people. But as we all know, there is an environmental consciousness out there that is growing more and more guilty all the time. It appears to date that this consciousness does not seem to reach all the way down to peoples wallets, but its getting there. Not long from now, more negative attitudes toward chemical fertilization, costs of biosolids disposal and the practicality of upgrading technology will all grow to the point where the economics will make sense for consumers to buy organically based fertilizers. And with every pound of nitrogen and phosphate sold in biosolids, that much less will be sold as chemical products.

Why Should the Fertilizer Industry Use Upgraded Biosolids?

So, with that said, why should the fertilizer industry use biosolids in their operations.

All the above Reasons

The same reasons that apply to the end users apply here as well. Fertilizer manufacturers should want to use products that make sense environmentally and agronomically. But, this is a business too, and if a product doesn't make sense economically then it is probably not going to find its way into mainstream production. Following are a few reasons why biosolids make sense to the fertilizer manufacturer.

Inexpensive Filler

For the blender and ammoniator making 10-10-10 or other lower analysis grades, biosolids can be used as an inexpensive filler product. Why does it make sense to use $20-$30 limestone in a formula when you could use $25-$35 biosolids that contribute $25-$35 dollars worth of nutrients for $5 more than limestone? This just makes sense.

Organic Component

Not only do the biosolids contribute nutrients, but they provide "chemical" fertilizers with a source of organic matter, which is one of their biggest drawbacks.

Reduces N and P_2O_5 purchases

Again, my apologies to the nitrogen and phos phate producers out there, but using biosolids in formulations will reduce the amounts of N and P_2O_5 purchases. Since biosolids are supplying these nutrients as a filler, more filler can be used in place of nitrogen and phosphate products. This of course means a savings to the fertilizer manufacturer.

Micro-nutrients

Micronutrients seems to be receiving a lot of attention in today's fertilizer markets. Their impact on plant performance has been well documented recently through university and industry research. Biosolids are a good source of micronutrients. Again, why pay more than you need to supplement micros when you can get some for "free" in your filler

Cheap WIN

Another benefit of biosolids use is that the nitrogen it contains is naturally slow release nitrogen. Many formulations for turf or agricultural crops require slow release nitrogen. Synthetic slow release nitrogen products are typically very expensive to include, but you can get some for "free" in biosolids.

Position for the Future

The eventual meeting of the waste disposal industry and fertilizer industry is coming. It is inevitable that a commodity with fertilizer value, such as biosolids, that in many instances costs municipalities a great deal of money to dispose of, will find its way into mainstream fertilizer production. The reasons for its use are sound, both economically and environmentally. That is why we, as a fertilizer producers should be aware of how biosolids can be used, and how we can incorporate them into our operations. The company's that find ways to take advantage of the above now, will have a real advantage in the future.

Why Harmony Enhances Biosolids (and the rest of the Fertilizer Industry should too)!

In order to talk about upgrading sludges, I need to discuss how and why Harmony Products uses biosolids in its product lines, as well as why a biosolids producer, such as New England Fertilizer, is enhancing their biosolids through our patented technology.

Increase Value of Biosolids

To separate themselves from other biosolids drying companies and technologies, NEFCo has joined with Harmony to produce enhanced biosolids fertilizer products. These product are distinguished from typical dried biosolids in the following ways:

Analysis

Obviously, by increasing the analysis of biosolids the value of the product is increased. This also lets us separate our products from the typical low analysis biosolids products in the market. We can tailor formulations to specific markets and customer.

Bulk Density

Typically, all organic products are rather low in bulk density (35-45 lb/ft^3). By enhancing the materials with other fertilizer ingredients, we increase the bulk density and this is advantageous from shipping as well as material handling aspects.

Physical Characteristics

Dried biosolids can vary in form from granular to flaky to a very dusty powder. By enhancing them through the Harmony process, these materials are converted to higher analysis, granular products that are relatively dust free. Otherwise unusable material can be converted into a spreadable, premium, organic based fertilizer.

Inexpensive Organic Substrate

The Harmony technology utilizes the organic substrate (biosolids) as an inexpensive substrate to base a formulation on. In the future, we expect that this substrate will not only be low cost, but negative cost. This will certainly be the case in installations where the upgrading is done at the source of the sludge, the municipal treatment plant. This will be a tremendous advantage for an organic based product. To date, organics have carried the reputation as being extremely expensive to use. This has limited them into a small section of the market where the fact that they are organic outweighs the cost. In the case of Harmony, our major market is the golf course market where performance is critical, and our products have developed a loyal following and good reputation. Given a situation where the organic substrate is at a negative cost, and couple that with the fact that our technical advances in the last five years have decreased the manufacturing costs by a factor of 5, we feel that organics will not only be competitive in the professional and retail markets, but in agricultural markets as well.

How Harmony Enhances Biosolids

If you will allow me to give a brief history of the Harmony upgrading technology, it may be beneficial to the discussion of where the technology is heading. Six years ago, Harmony Products, Inc. was founded around technology developed to upgrade organic waste streams into agricultural products. This is patented technology that was developed by two inventors in southside Virginia. At the time, the primary interest was in upgrading poultry manure, and our initial product lines were manure based. A manufacturing plant was built at great expense that utilized a batch type reactor-granulator that was capable of producing our Bridge® fertilizers at a rate of 1-2 tons per hour. This gives you an idea of one reason our fertilizer was somewhat limited to the professional market, due to price. Another is the fact that we were having to pay for the manure. Nevertheless, this first product was an agronomic success, if not a financial one.

Along the road, advancements were made in the process such that we could manufacture our products in a continuous reactor-granulator. A continuous unit the same size and cost as our batch machine in Chesapeake was installed in a plant we designed for our Ukrainian licensee which produces at a rate of 10-12 tons per hour. Shortly after that development, we found that our products could be manufactured in TVA ammoniators, with a few process variations. Our products have been made in ammoniators at rates of 15-20 tons per hour. The "ammoniator" process was subsequently patented and has been used to produce both biosolids based and poultry based Bridge® products.

All of the materials discussed thus far have been enhanced products starting with dried biosolids or poultry manure. Our resent efforts have been directed toward enhancing biosolids starting with sludge cake. This gives the advantage of upgrading, enhancing and drying in one process train, eliminated the need to dry the biosolids, enhance, then dry the resultant fertilizer. This, we feel, is the future of sludge enhancement.

The Process—Dried Biosolids

I would like to discuss some of the details as to how Harmony enhances biosolids, or any organic waste stream. As I mentioned earlier, Harmony owns the patent rights on some of the methods described, and others are not patented.

Patented Processes

Harmony basically has two patented processes. Both processes involve upgrading organic substrates using aldehyde compounds to form slow release nitrogen compounds. This process forms methylene urea type compounds in-situ, generally from urea formaldehyde related products. In both processes, dry ingredients are continuously fed into the granulating vessel. In the vessel, the urea formaldehyde containing compound (UF) is injected and incorporated with the dry materials. At this point the UF is reacted or condensed by lowering the pH with a mineral acid and the slow release nitrogen compounds are formed. Granulation also occurs at this stage and the product is then discharged to be dried, screened and cooled, as in any fertilizer plant. Following are a few specifics for both of the patented methods of enhancement.

Reactor-Granulator Technology

In the Reactor-Granulator technology the fertilizer is manufactured in a high intensity mixer. The mixer has a horizontal shaft similar to a paddle mixer with plows radiating outward that fluidize the material around the shell, homogenizing the mixture and incorporating the liquids into the dry materials. There are also a series of motorized choppers, similar to Wearing blender blades, that protrude into the vessel. The intense mechanical energy from the plows and choppers react the mixture and form typical fertilizer size granules. The mixer-reactor allows us to utilize a wider variety of materials (from powders to lumps) with a wider range of moisture contents, due to the high energy input into the products. Retention times can be varied somewhat to help regulate particle size, and this technology produces a superior quality greens grade material in significant quantities compared to other methods. This has been a very important aspect of this method of granulation.

Ammoniator Technology

The ammoniator technology is similar to standard ammoniator technologies. The UF compound is injected through the sparger system as a nitrogen solution might be. Acid is also sprayed down the length of the bed through the spargers as well. The dry feeds must to be small particles and free flowing, so this limits the organic material to previously dried products, preferably having little to no dust. Upgraded biosolids from NEFCo have been used quite successfully in the ammoniator.

Conventional Processes

As I mentioned earlier, Harmony owns the patent rights for upgrading organic waste streams with UF based materials using the high intensity reactor-granulator or conventional ammoniator. There are of course, many ways to enhance biosolids through conventional fertilizer technologies. Organic components (such as biosolids) have been used for years in ammoniated fertilizers, particularly tobacco grades in this part of the country. Harmony and NEFCo have marketed biosolids to both ammoniators and blenders to be used as a filler or organic blending base in many of formulations. The granular dried product works well, as its size and appearance is similar to other granular fertilizer ingredients. There is very little odor (in the NEFCo material) and it is not distinguishable in most products.

The Process—Sludge

Most of our current R&D effort is going toward direct enhancement of biosolids sludge cake. Most conventional fertilizer technologies do not handle cake like materials. Therefor, we are developing procedures that will allow us to enhance, granulate and dry in the same process train. This will allow us to save considerable expense by eliminating double drying of the organic base and reducing freight costs associated with moving biosolids from the drying facility to the enhancing facility. We have demonstrated the process with pilot scale equipment and are currently planning to construct a demonstration plant within the next year. Harmony and New England Fertilizer are very excited about this technology and hope to bring the convergence of the waste disposal industry and the fertilizer industry a present day reality.

Regulatory View Toward Organic Waste Fertilizer and Supplements

Darlene H. Blair
Agriculture and Agri-Food Canada

Regulations are, by definition, remedial. They are created and continue to exist because of problems that require a solution or concerns that require resolution. Regulation of fertilizers and supplements is designed to maintain the safety of plants, animals, humans (food and user/bystander), and the environment, and the efficacy and proper labeling of products.

Fertilizers and supplements are the types of products that are regulated under the Canadian *Fertilizers Act.* Fertilizer is defined as any substance or mixture of substances containing nitrogen, phosphorous, potassium or other plant food, manufactured, sold or represented for use as a plant nutrient. Supplement is defined as any substance or mixture of substances, other than a fertilizer, that is manufactured, sold or represented for use in the improvement of the physical condition of soils or to aid plant growth or crop yields.

The *Fertilizers Act* and the associated *Fertilizers Regulations* prescribe mandatory minimum requirements regarding the safety, efficacy, labeling and naming of fertilizers and supplements. It is important to note that other regulatory agencies and voluntary industry standards may also specify requirements for these products. They may be in addition to or more stringent than those contained in and administered under the *Fertilizers Act* and *Regulations*, but they cannot contravene the requirements of this federal legislation.

In the remainder of this paper, there are references to a number of types of standards, such as those for metal content and pathogens. It should be noted that these standards apply to both waste and non-waste products. Also, there are several references to standards that are being proposed by Agriculture and Agri-Food Canada (AAFC). A preliminary consultation on these standards has just ended (deadline for comments was October 16) and the comments are currently being reviewed. The proposals will be revised if necessary and will form the basis for standards to be incorporated into the *Fertilizers Regulations.*

The Organic and Inorganic Waste Streams

The organic designation, from the perspective of the *Fertilizers Act*, is restricted to those products of plant or animal origin. Organic wastes, and a number of inorganic wastes, have been used for some time as fertilizer or supplement products. Organic wastes in particular have been used for centuries.

Recently, there has been a trend, in most jurisdictions, to discourage land filling, incineration and/or ocean dumping of wastes. As the costs and complexity of disposal have increased, many waste producers have turned their attention to application to the abundant North American land base. Many waste products have potential value as fertilizers or supplements and the disposal "crunch" has resulted in an increase in both the amount of traditional waste material that is being proposed for addition to soil and the number of non-traditional products that are being proposed for use. As well, many soil scientists and agronomists with "green" and entrepreneurial inclinations have seized the opportunity to support the beneficial re-use of products that have traditionally been considered to be wastes.

In most discussions of the application of waste products to land, one important question emerges: should land application of wastes be restricted to those products that can provide a benefit to the soil or to the crops that will be produced on the land to which the product is applied, or is it adequate if the waste produces "no net harm" to the application site? This is a difficult question and one that is not resolved in this paper. The discussion in this document is restricted to those products that can be defined as fertilizers or supplements and, therefore, have the potential for beneficial re-use. Although the designation "wastes" has been applied at many points in this discussion, there are a number of other terms that could be used, including by-products or residues. In fact, for materials that can be re-used for beneficial purposes, "wastes" is a misnomer.

Sources, Contaminants and Processes

Knowledge of the origin of a product can help to predict concerns associated with that product and the type of contaminants that it may contain. The attached diagrams show the types of products that are known to be of interest as fertilizers and/or supplements and provide an indication of where these materials come from. The waste products have been broken into four categories, based on their origin: plant, animal, city and industrial.

Knowledge of the stage of the process at which the material proposed for use as a fertilizer or supplement is derived can also yield clues as to potential safety concerns and may alleviate concerns that would be associated with later stages of the process (e.g. pulp and paper wastes from physical pulping versus wastes resulting after chlorine treatment). In addition, examining feedstocks and the process involved in producing the product can give not only some indication of potential safety concerns, but also steps that are already in place to mitigate these concerns (e.g. temperature to destroy pathogens and toxic organics).

Safety concerns with regard to waste products are most commonly associated with the contaminants that they contain. Contaminants may be assigned to one of three categories: physical, biological or chemical.

Physical contaminants

Physical contaminants are primarily a concern at product application or in areas where there is handling of treated soil or plants post-application. Examples of physical contaminants include metal filings and shards, glass shards, syringes and plastic. Many of these may cut, pierce or scrape the skin of someone handling the product or soil or plants that have ben treated with a product. Plastics are a concern because of soil contamination. Most definitions of physical contaminants exclude those materials that do not result from human intervention. Such excluded materials include mineral soils, woody materials and rocks.

Depending on the source of the materials, there is a possibility that a recycled product will contain foreign objects. Several criteria for foreign objects in compost have been developed, some of which are based on product safety and others of which are based on product aesthetics.

To address the safety concerns, Agriculture and Agri-Food Canada is proposing that products that are sold as fertilizers or supplements not contain sharp foreign objects that exceed 3 mm in any dimension.

Biological contaminants

Biological contaminants have the potential to cause disease in plants, animals and/or humans. There is a secondary concern related to the potential to disrupt soil systems such as those related to nutrient cycling or organic matter degradation. Examples of microbial contaminants include bacteria such as fecal coliform and Salmonella.

Concerns regarding the pathogen content of fertilizers and supplements have been a regulatory priority over the past several years. Products that have been the focus of ongoing activities include municipal sewage sludge, other heat-treated animal by-products (e.g. bone meal), composts made from various organic residues of animal and plant origin (e.g. food wastes and animal manures), etc. Other products, such as those consisting of fermentation by-products, represent the less traditional wastes that have also been considered.

As part of the fertilizer monitoring program, AAFC has been sampling and analysing these products for *Salmonella* content for several years. Since 1991, a guideline of "undetectable pathogenic *Salmonella*" has been used as an indication of their safety with regard to *Salmonella per se*, and in some cases with respect to other organisms.

The guideline of "undetectable" *Salmonella* was obtained from USEPA criteria and is necessary because of the potential for multiplication of even one *Salmonella* to significant levels. The use of *Salmonella* analyses as an indication of other pathogens is reasonable given the data generated by/for the USEPA. These data demonstrated the relative resistance of *Salmonella* to treatments to further reduce pathogens in comparison to other potentially pathogenic organisms.

In addition to inspection-related activities, proponents seeking consent from AAFC for the sale of processed sewage-based products and compost-based products have, since 1991, been required to provide analyses demonstrating compliance with our guidelines for *Salmonella* (undetectable) and fecal coliform (less than 1000 MPN per g dry weight), and information on treatment processes aimed at reducing pathogen content. Processes to further reduce pathogens are designed to reduce the numbers of pathogenic organisms to acceptable levels. These processes specify treatment standards for products, such as combinations of temperature or pH treatment and time of exposure. These treatment standards were proposed by USEPA in 1979 and, since then, have been used by many organizations as a substitute for direct analysis of pathogenic organisms

The pathogen content of compost products, with or without sewage sludge, was a prominent feature of deliberations with various stakeholders. Specifications for *Salmonella* and fecal coliform have already been incorporated into the Guidelines for Compost Quality and the National Standard of Canada. AAFC is now proposing adoption of these same two specifications into the *Fertilizers Regulations*. The combination of *Salmonella* **and** fecal coliform specifications is preferred as it provides greater confidence in the safety of regulated products. Furthermore, while treatment processes may be expected to be sufficient to reduce pathogens, this combination of specifications is preferred since safety, and hence compliance, is ultimately determined on the basis of product inspection and actual test results.

Chemical contaminants

Chemical contaminants may be organic or inorganic in nature. They may result in the contamination of food, may pose hazards to product users/bystanders and may threaten the environment. Chemical contaminants include heavy metals and organic pollutants.

Heavy Metals

In 1979, under the authority of the *Fertilizers Act and Regulations*, Agriculture and Agri-Food Canada (AAFC) introduced a series of standards for metals in fertilizers and supplements. They were developed to help to ensure that fertilizers and supplements continue to pose only a minimum risk of adverse effects due to metal contamination. This was a time of particular interest in the use of processed sewage as fertilizer.

The AAFC metal standards are based on generic principles and are generally applicable to fertilizers or supplements applied to land or in crop production. These standards have been used to evaluate and manage all products regulated under the *Fertilizers Act* and for which metal concerns have been raised (e.g. organic fertilizers, processed sewage, compost, phosphate rich fertilizers such as monoammonium phosphate and diammonium phosphate, and recycled inorganic materials). The standards tend to be conservative. This is partly because metals in excess amounts can adversely affect plants, animals and/or humans, and some long term cumulative effects of metals may not be fully understood. As well, significant metal concentrations are already present in soils of some areas, and the degree of plant uptake of metals is affected by factors such as soil acidity, soil cation exchange capacity and plant species.

Between 1993 and 1995, the AAFC metal standards were re-evaluated in response to standard development activities elsewhere (e.g. the USEPA), the variety of by-products being proposed for reuse as fertilizers and supplements, and the progressive depletion of phosphate rock deposits worldwide. It was concluded that the AAFC metal standards remain valid. This fact is perhaps best reflected by their recent adoption into the Canadian Council of Ministers of the Environment (CCME) Guidelines for Compost Quality, and into the National Standard of Canada on Compost.

All fertilizers and supplements:

All fertilizers and supplements, including processed sewage, composts and other by-products must meet the standards for maximum acceptable cumulative metal additions to soil which are shown in Table I.

TABLE I

Maximum Acceptable Cumulative Metal Additions to Soil

(kg/ha)	
METAL	AMOUNT
Arsenic	15
Cadmium	4
Cobalt	30
Mercury	1
Molybdenum	4
Nickel	36
Lead	100
Selenium	2.8
Zinc	370

Note: Please note that the standards in Table I pertain to total cumulative additions to soil over the long term, and that for the purpose of evaluating individual products "long term" is taken to mean 45 years.

In this regard, the metal concentrations of products are evaluated as follows:

> The annual application rate x the metal concentration must be less than the Table I value/45 years.

Note: The application rate and the metal concentration must be presented on the same basis i.e. both dry weight or both as is.

Note also: If the product is to be applied every ***5*** *years, for example, then the* ***5*** *year application rate x metal concentration must be less than the Table I value/****9*** *years. (Tip: the numbers in bold must multiply to give 45.)*

The two metals, molybdenum (Mo) and zinc (Zn) are also plant nutrients. For this reason, higher concentrations than those presented herein may be permitted. Products which contain higher Mo and Zn concentrations may be allowed if they meet all applicable minimum concentration, tolerance, and labelling criteria of the *Fertilizers Act and Regulations*. This includes representation of the element as a plant nutrient and the associated guaranteed analysis.

Processed sewage, compost and other by-products:

The following (Table II) are the maximum acceptable metal concentrations in processed sewage, sewage-based products, compost, compost-based products, and other by-products represented for sale as fertilizers or supplements. (These products include but are not limited to composted manure, municipal waste tankage, garbage tankage, leather tankage, and industrial sewage.)

TABLE II

Maximum Acceptable Metal Concentrations

(mg/kg dry weight)	
METAL	CONCENTRATION*
Arsenic	75
Cadmium	20
Cobalt	150
Mercury	5
Molybdenum	20
Nickel	180
Lead	500
Selenium	14
Zinc	1850

Note: The maximum acceptable metal concentrations in Table II are based on the assumption of a cumulative total application to soil of 200 dry *tonnes per hectare of a product that contains 50% moisture and a total N guarantee of 2.5% (i.e. 5% nitrogen on a dry weight basis). Such a product, applied annually at a rate of 220 kg N/ha (or 4,400 kg dry product/ha) would reach the standards for maximum acceptable cumulative metal additions to soil (Table I) within 45 years.*

* Acceptable metal concentrations increase as the rate of application decreases relative to 4400 kg dry product/ha (e.g. if the rate of application is 2200 kg dry product/ha, this is half of 4400 kg therefore the metal concentrations can be double the values in Table II). Or, when products are applied on the basis of their nitrogen content, acceptable metal concentrations increase proportionally with total %N **on a dry weight basis** and can be calculated using the following equation:

Acceptable metal concentration (mg/kg dry weight) =

$$\underbrace{\text{Concentration in Table II}}_{\text{(Part 1)}} \times \underbrace{\frac{\%\text{N as is}}{5\%}}_{\text{(Part 2)}} \times \underbrace{\frac{1}{(1-\text{ moisture})}}_{\text{(Part 3)}}$$

(Tip: If the product meets Table II concentrations, STOP. If not, include Part 2 of the equation i.e. the N component. If the concentration fails to meet the calculated level, then add Part 3 of the equation i.e. the moisture component. If the concentration still fails to meet the final calculated level, then it definitely exceeds our standards.)

In addition to the 1979 standards that have been reviewed, limits for copper and chromium have been assessed. AAFC is proposing soil loading limits, for copper and chromium, of 150 kg per hectare and 210 kg per hectare, respectively.

Organic Pollutants

The position of AAFC, is that, at this time, the inclusion of organic contaminant limits (e.g. for PCBs), could not be supported or justified by reference to the scientific literature or by data on levels of these substances in compost and sewage. It has been determined, however, that further information on organic pollutants is required and that special attention should be paid to dioxins, furans and pesticides. Thus, the current stance may be modified when scientific advances in the field and new data justify such a modification. In the interim, products continue to be assessed on a case-by-case basis.

Product Efficacy

Product efficacy for fertilizers is most commonly related to whether a product can provide a significant quantity of a required element. The following mineral nutrients are recognized as being essential for plant growth:

primary nutrients: nitrogen, phosphorus and potassium

secondary nutrients: calcium, magnesium and sulphur
micronutrients: iron, zinc, copper, manganese, boron, molybdenum, chlorine and (sodium)

There is some debate about the essentiality of the latter element; therefore, it appears in brackets and requests for its inclusion in a guarantee are reviewed on a case-by-case basis.

Therefore, these are the mineral nutrients that may be guaranteed on a **fertilizer** label. Other elements (i.e. those for which a role in plant growth has not been established) may not be guaranteed.

Guarantees for **supplements** are less straightforward. For supplement products, a guarantee may be made for any substance that has been demonstrated to improve the physical condition of soils, or to aid plant growth or crop yields. Guarantees for other ingredients, for which this role has not been established, may not be made. A manufacturer/registrant is always entitled to demonstrate the value of any active ingredient; this is the basis for the requirement for efficacy data to support supplement registration.

Once an active ingredient has been identified, the amount of that ingredient that would be supplied by the product, when used as directed, is evaluated.

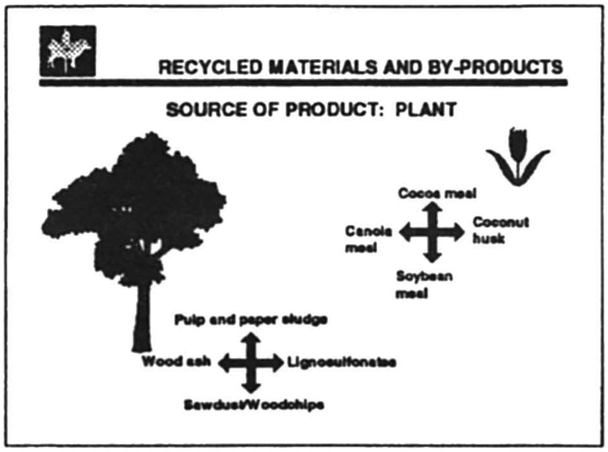
The Assessment Process for "Waste" Products

A typical submission made under the *Fertilizers Act* will describe the type of product that a proponent wishes to sell, and, usually some general information about the derivation of that product. The following list of information is to be provided for the assessment of by-products and other "waste" materials sold as (in) fertilizers or supplements. Once the information is received, a preliminary screening of the safety and efficacy of the product is conducted and any additional requirements are then outlined.

1) Identify and describe the product and its constituent material(s) (by-products or "wastes").
2) Provide a copy of the product label or shipping bill (if sold in bulk).
3) Describe the benefits of using the product, and the recommended rates and methods of application.
4) Identify the product's nutrients or other active ingredients or essential components which account for the benefits. Specify, if known, the form in which these ingredients occur.
5) Identify and describe in general terms the industrial or manufacturing process from which the product and each constituent by-product or "waste" material is derived. A flow-chart diagram of this process would also be helpful.
   Include a description of feedstock for the process, any chemicals or materials added throughout the pathway of the process, and any transformations these undergo as a result of the process.
   Also, identify the point(s) during the process at which the product or the by-product or "waste" is generated.
6) Identify, based on points v) and any available analyses, contaminants which may occur in the material. Specify, if known, the form in which these contaminants occur.
7) Provide any analyses of the product which may be available, accompanied by methods of analysis, detection limits and recovery rates for the methods.
8) Provide copies of scientific reports on the effectiveness of the product, on the human, plant, animal or environmental safety of the product or its constituent materials, and on their environmental fate.
9) Identify whether this material is currently being used in agriculture, or any other uses to which the material is being put.
10) Provide any other information related to the potential effectiveness or safety of the product (eg. related to problems associated with the industrial process from which a by-product is generated).

The Bottom Line

Products that are sold as fertilizers or supplements are required to be safe, effective and properly labeled. Although some products may be derived from or composed of "waste" materials, it is because of their value to soil-plant systems that they are regulated under the *Fertilizers Act*. Therefore, the designation "waste" is probably not appropriate for these products.

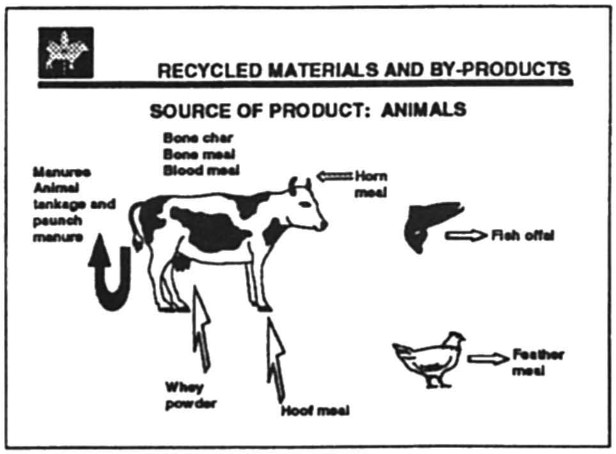


RECYCLED MATERIALS AND BY-PRODUCTS

SOURCE OF PRODUCT: PLANT

Cocoa meal
Canola meal
Coconut husk
Soybean meal

Pulp and paper sludge
Wood ash
Lignosulfonates
Sawdust/Woodchips



RECYCLED MATERIALS AND BY-PRODUCTS

SOURCE OF PRODUCT: ANIMALS

Bone char
Bone meal
Blood meal

Manures
Animal tankage and paunch manure

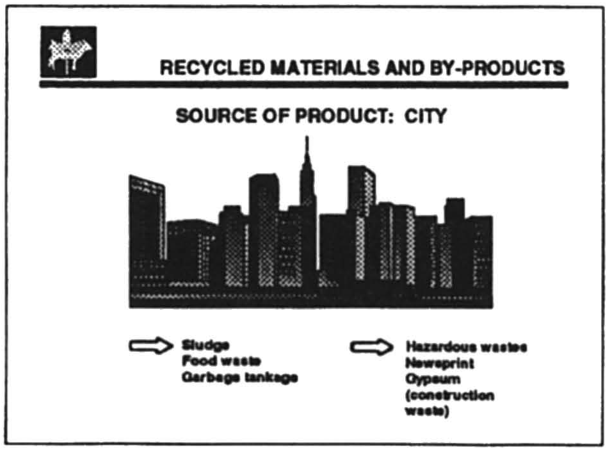
Horn meal

Fish offal

Whey powder

Hoof meal

Feather meal

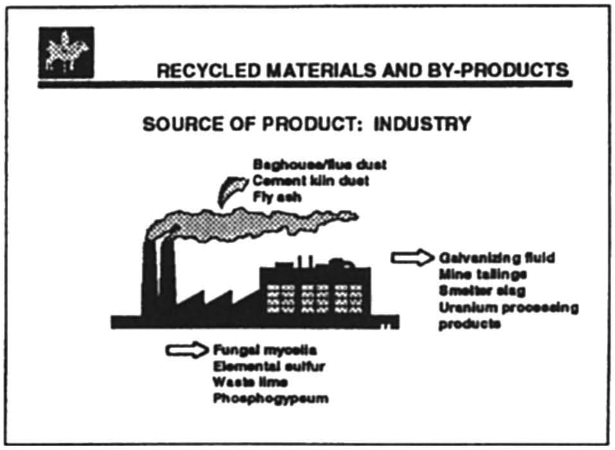


RECYCLED MATERIALS AND BY-PRODUCTS

SOURCE OF PRODUCT: CITY

Sludge
Food waste
Garbage tankage

Hazardous wastes
Newsprint
Gypsum (construction waste)



RECYCLED MATERIALS AND BY-PRODUCTS

SOURCE OF PRODUCT: INDUSTRY

Baghouse/flue dust
Cement kiln dust
Fly ash

Galvanizing fluid
Mine tailings
Smelter slag
Uranium processing products

Fungal mycelia
Elemental sulfur
Waste lime
Phosphogypsum

AAPFCO—Regulatory Update

Lance Hester
Alabama Department of Agriculture and Industries

Introduction

I appreciate the occasion this afternoon of addressing the 46th meeting of The Fertilizer Industry Round Table. As president and on behalf of the Association of American Plant Food Control Officials (AAPFCO), I welcome this opportunity to communicate to you the primary activities of our Association.

In presenting this information, it is my intent that each of you become more knowledgeable about AAPFCO's history, purpose, membership, and structure.

I will not attempt to address all of the Association functions. However, I will relate our activities with regard to committee and task force actions, environmental concerns, and current trends such as precision agriculture. As we examine these issues, I believe it is important that we continually evaluate our roles whether we are regulators, industry, or academia.

History

During the AAPFCO annual meeting this past August, the Association celebrated its fiftieth anniversary. As part of the recognition of this event, several past presidents of the Association addressed the meeting either in person or by letter. These writings and oral presentations serve to remind us of our strengths. For some of us who have not been around that long, the information presented was very enlightening with regard to the initial meeting in 1946 and the progression of the Association through the years. Two major areas of commonality became apparent to me as information was presented that covered each decade of the Association: (1) At any given time, the Association was actively addressing current situations as well as formulating policy to address future concerns. (2) There has always been a very strong synergetic relationship between AAPFCO and the fertilizer industries.

Membership

The AAPFCO is an organization of fertilizer control officials from each state in the United States, from Canada, and from Puerto Rico, who are actively engaged in the administration of fertilizer laws and regulations, and research workers employed by these governments who are engaged in any investigation concerning mixed fertilizer materials and/or their component parts and also the effects of any of these.

With the current trade agreements in place, we anticipate more participation from Mexico and other countries of the North American continent. The importance of AAPFCO in promoting uniformity is magnified as trade barriers fall and product importation and exportation increase. We certainly welcome the assistance of our industry liaison members in establishing, continuing, and improving our communications with other countries involved in trading of fertilizer materials.

Purpose

The Association's purpose is to achieve uniformity by consensus by providing a forum through which members may unite to:

1. Promote uniform and effective legislation-definitions, rulings, and enforcement practices;

2. Encourage and sponsor the adoption of the most effective and adequate sampling and analytical methods for fertilizer;

3. Promote accurate labeling of fertilizers;

4. Exchange information and discuss and cooperatively study issues confronting members of the Association and the Industry regulated;

5. Cooperate with members of the industry to promote the safe and effective use of fertilizers and protection of soil and water resources.

Committee Actions

As I speak this afternoon to specific issues you will realize that I will refer to various AAPFCO committees. The committees are the work force for the Association. The committees are made up of regulatory officials and industry liaison.

Each committee or task force has its own responsibilities. While all are very important, I will address only the highlights that I feel are of significance to this group.

Long Range Planning Committee (LRPC)

Teresa Crenshaw, Delaware Department of Agriculture (AAPFCO President, 1994), initiated the Long Range Planning Committee in 1994. Since that time the committee has established its identity and purpose. Under the chairmanship of Dr. George Latimer, Texas State Chemist (AAPFCO President, 1995), the LRPC has begun to fulfill its purpose. I feel the LRPC has proved to be the vehicle for direction and efficiency the Association has needed for some time. This committee enables a flow of information to and from specific committees to assist in the development of goals that reflect the direction of the Association. Some examples of the LRPC activities are as follows:

1. Required of Environmental Affairs Committee to establish guidelines for use of biosolids and industrial by-products and co-products within two years.

2. Directed restructuring of the Bylaws Committee with responsibility for reviewing membership qualifications.

3. Established a task force to address sampling of minibag and Killibrews.

4. Encouraged the slow release task force to complete its assignment.

5. Instructed the Seminars Committee to complete revision of the inspection manual and to restructure the Inspectors Training Seminar.

Also, as an outgrowth of discussions in the LRPC, I am in the process of establishing a task force to address and/or evaluate regulatory issues regarding precision agriculture.

Bylaws Committee

During the coming year, our Bylaws Committee will be reviewing membership qualifications. We feel a need to recapture some of the academia involvement the Association has enjoyed in the past. Also, the Committee will be clarifying committee structure with regard to industry participation in committee votes and industry serving as chairs.

Education and Information Committee

A Procedures Manual for AAPFCO is near completion by the Education and Information Committee. This manual will serve to provide information on how the Association operates and the mechanisms involved to facilitate a change or amend existing model bills, labeling, definitions, etc.

Also, the Education and Information Committee will be providing training (How to Improve Committee Effectiveness) for committee chairs during our mid-year meeting. Our mid-year meeting is scheduled for February 10-13, 1997, in Lake Buena Vista, Florida.

Good Manufacturing Practices Committee

On behalf of AAPFCO, I want to thank The Fertilizer Institute (TFI) for working with our Good Manufacturing Practices Committee. TFI has sponsored and provided speakers for the GMP workshops throughout the United States for several years. Workshops in Oklahoma, Arkansas, Missouri, and Mississippi were scheduled for this year.

Labeling/Terms and Definitions Committees

The Labeling Committee and the Terms and Definitions Committee continue to meet together. This committee meeting is always the best attended. The committees continue to update, amend, and fine tune definitions and/or labeling requirements.

Seminars Committee

The Seminars Committee is nearing completion of revision of the AAPFCO Inspection Manual. We continue to rotate our Administrators Seminar and this year it will be in Corpus Christi, Texas, November 7-10. We are restructuring our Inspector Training to include training for feed inspection by the Association of American Feed Control Officials.

We are continuing to evaluate sampling tools. A preliminary test with the AOAC bagged trier has indicated a need for a full evaluation.

Slow Release Fertilizer Task Force

Dr. Wilbur Frye, University of Kentucky Division of Regulatory Services and Chair of the Slow Release Task Force, has indicated that work continues and progress is being made. The Task Force is currently devoting most of its efforts towards development of analytical methods for determination of slow release characteristics. Labeling and terminology issues may be dependent upon this development. There has been some change in the make-up of the Task Force due to some members having to step down because of responsibility changes in their employment. The Task Force met yesterday (Sunday, October 27, 1996) and will continue to meet at the mid-year and annual meetings.

Environmental Issues

In several states and probably most states, fertilizer regulatory officials have not been directly involved in environmental issues. Most state fertilizer laws are based on the AAPFCO model, Uniform State Fertilizer Bill. Until very recently, the model bill included only the terms "sale" and "distribution." The Uniform Bills Committee has amended the bill to include the terms "use" and "storage." Also, the adulteration section of the bill has been amended to include provisions that deem a fertilizer product adultered if injurious to animals, humans, aquatic life, soil, or water. Previously, only plant life was considered. These changes have been approved and are in tentative status until next year's annual meeting.

The purpose of these changes is to have a model bill that enables the state fertilizer control officials to consider and address environmental concerns. Of course, in most states the new changes and amendments would require adoption by their legislature or through their rule promulgation process. In Alabama during the past few years, more demands have been placed on my time to address licensing of by-products for use as fertilizer or liming material products. Just this week I met with Alabama Cooperative Extension, Alabama Department of Environmental Management, industry, and consultants to discuss by-product licensing as fertilizer or liming materials. Also, I have been notified of a multimillion dollar lawsuit regarding the mishandling of an industrial by-product that was utilized as a fertilizer.

Concerns regarding by-product issues were at the top of the list in a recent survey conducted by the Association. Therefore, we have established a subcommittee within the Environmental Affairs Committee to address By-products and Recycled Materials. I quote from the August 1996 report of Darlene Blair, Canada Department of Agriculture and Industries and chair of the subcommittee on By-products and Recycled Materials:

> The types of products that have been encountered in various jurisdictions include: sludges, paper wastes, restaurant wastes (food, fats and oils), combustion products (wood, coal, flue residues) processing co-products, chelating/complexing agents from various sources, and anything that could possibly be composted, including discarded, ground housing materials and biomedical wastes. The challenges facing those who must assess these products include product variability, product identification, and the roles of various other agencies in the assessment process.

It is apparent the subcommittee has a difficult task in providing guidelines to assist in uniform by-product evaluation.

Precision Agriculture

Precision agriculture, including grid soil sampling, computer mapping, global positioning systems (GPS) and yield monitors, has grown steadily in midwestern states and is extending into practically all regions. This progression has a growing influence on how fertilizer is sold, manufactured, mixed, and applied.

Dr. Dave Terry, University of Kentucky Regulatory Services, recently conducted a survey concerning "on-the-go" mixing application and variable rate application of fertilizer materials. The results of the survey indicated that we as regulators are uncertain how to address these methods of fertilizer manufacture or mixing.

Therefore, AAPFCO is establishing a Precision Agriculture Task Force to evaluate fertilizer regulatory issues regarding these new systems. The Task Force will be asked to ascertain information on the various equipment and components currently in use, and attempt to determine if and how we as regulators need to address sampling, licensing, and registration.

Summary

I am sure most of us realize our roles have changed over the past few years and will continue to be altered in the years to come. We will continue to deal with some of the same old problems such as particle size, segregation, and fine tuning our sampling techniques and equipment. However, we must have the ability to anticipate change and formulate policy that will carry us into the future.

Meetings such as The Fertilizer Industry Round Table not only allow an opportunity to reflect on the past, but also serve as an invaluable asset in stimulating our vision for the future.

Fertilizer Tonnage Reporting in the US

David L. Terry
University of Kentucky

Introduction

Prior to 1985, fertilizer use statistics in the US were collected by the USDA which used not only tonnage reports from the states but also some of their own estimates. The USDA data are available from libraries that have a complete set of US Government documents. In 1985 TVA, Muscle Shoals, AL, assumed the mission from USDA of collecting and publishing the fertilizer use statistics and continued this up to 1995 when a change in mission caused them to drop the publication of *Commercial Fertilizers*, which is a summary of the national fertilizer use data. At that time AAPFCO and TFI combined forces to continue the publication and TVA agreed to give us all the software and procedures that they had developed for this publication.

The objectives of my presentation are: (1) to describe how the national fertilizer use statistics are collected and published, (2) to outline the characteristics of and warn of the problems associated with the data, (3) to extol the value of the data, and (4) to identify some of the major users of the data.

How the National Fertilizer Use Data are Collected

The UFTRS and What it Does

No discussion of the collection of the national fertilizer use data would be complete without mentioning AAPFCO's Uniform Tonnage Reporting System (UFTRS). As soon as tonnage reporting was discussed the need for uniform reports among the states was cited as very important.

First a little history is in order. Fertilizer tonnage reporting has been around over 100 years and has progressed significantly since the early beginnings being required by almost all state fertilizer laws. New Jersey reported first in 1882 followed by Indiana in 1883 and 36 states were making some kind of tonnage report by 1945. The 4th draft of the AAPFCO Model State Fertilizer Bill that was published in the first Official Publication of the Association of American Fertilizer Control Officials(AAPFCO) had a requirement for reporting tonnage. It required semiannual reporting of tonnage by grade[1]. The current Uniform State Fertilizer Bill has a very similar tonnage reporting requirement. In the very first annual meeting of the AAPFCO one of the papers presented was 'The Use of Fertilizer Tonnage Data' by J. F. Fudge of College Station Texas[2]. Some of his comments are as appropriate today as they were 50 years ago. He noted that tonnage reports allow the determination of: (1) the consumption of N, P_2O_5, and K_2O, (2) the most popular grades and materials, (3) the ratio of mixtures to materials; and, (4) trends in fertilizer use when followed over several years. Another important aspect of tonnage reporting is the collection of an inspection fee that goes to support the regulatory program.

The initiative for developing uniformity in tonnage reporting came in 1964 when W. L. Baker of MO, President of AAPFCO, appointed a committee to begin the work for a uniform system[3]. In 1965 the AAPFCO passed a resolution supporting a uniform tonnage reporting system[4] and in 1967 the committee recommended a standard format for the data and a monthly-county-invoice system. With some slight modification that format is the same as currently recommended under the UFTRS. Of course, the ADP equipment at that time was the mainframe IBM computer that used 80 column punched cards. When I came to Kentucky in 1974 we used punched cards and every month we would use our pick-up truck to haul the many boxes of cards to the UK Computing Center. Nevertheless, the standardization of how companies should report their tonnage to the control official was a boon to accurate and timely tonnage reports. USDA, NPFI (now TFI), NASDA, and ASFFPCO immediately endorsed and AAPFCO began to promote the system soon after its adoption.

That is the beginning of the UFTRS and it remained basically the same until Norman Hargett of TVA spearheaded the development of the UFTRS computer program for IBM PC's. The first version of the UFTRS software was released in 1986[5]. It was a joint project among TVA, AAPFCO and TFI. TVA provided some funds in addition to the personnel to promote the program and TFI provided funds to purchase the software used by the program. It was met with enthusiastic support and was adopted by several states immediately. Norman Hargett, Janice Berry and their programmers promoted the software in what became Norman's traveling UFTRS show. They would go to the fertilizer regulatory office in a state, set up the software, demonstrate its abilities, train the state's personnel to use it and in some cases supply matching funds to purchase a PC. Periodic training sessions were held for UFTRS users funded partially by TVA. At last count there were 35 states utilizing the UFTRS software as their tonnage reporting engine.

With that background on how UFTRS came in to being I want to describe how the data you find in the national fertilizer database get there.

The Operational Procedure

Each fall beginning around October 1, a notice is sent to each state control official requesting that their state's tonnage data from the previous fertilizer year be sent to the AAPFCO secretary's office. All the data are now sent as electronic files on diskettes. The fertilizer year is July 1-June 30. For example, FY96 is July 1, 1995-June 30, 1996. All states except ND, SD, and TX report their tonnage this way.

Once received the databases from each state are edited, summarized and published.

Editing the Data

Edit programs provided to us by TVA are used to correct various coding errors and to provide uniformity among the states' data for later summarization. There is an edit program designed for the uniqueness of each state's data which TVA designed from experience with each of the states. If the edit program discovers a problem with a state's data, the state control official is called and the problem resolved. We have a good working relationship with each of the control officials and are usually able to resolve the problems.

Summarizing the Data

We have continued the format of *Commercial Fertilizers* as developed and used by TVA. We have not received any comments at this time on the TVA format; however, we would welcome any suggestions for changes or additions to the content of the publication. Other formats or tables with different fields could easily be included.

Publishing, 'Commercial Fertilizers'

The national fertilizer use data are published in two ways: a 41 page hard copy publication, *Commercial Fertilizers*; and, in two electronic formats: ASCII text and Lotus.

The Hard Copy

Commercial Fertilizer 1995 was the first issue of this publication by the AAPFCO-TFI joint project. There are two steps to this publishing process. First, AAPFCO (Secretary's office) collects the data from the various control offices, massages it as described, and produces a camera ready copy of *Commercial Fertilizers*; and, then, TFI takes the camera ready copy and publishes it. The first issue of *Commercial Fertilizers* under this arrangement was published around January 20, 1996.

The distribution of the publication is also handled by TFI so all orders are forwarded to TFI who invoices and mails them. Gratuitous copies are sent to each control office and a limited number to the USDA and to certain other agencies where mutual assistance is helpful. *Commercial* fertilizers is sold for $25 per copy which allows us to pay for our costs plus a little extra for other projects.

Electronic Copies

In addition to the *Commercial Fertilizers* hard copy publication, we generate electronic files in ASCII text file and Lotus formats which we sell for $150 per year.

The ASCII text format has the complete data set. Each record in the database has the following fields: fertilizer year, state, county, reporting period(July-December or January-June), tons, fertilizer code, container, use, and grade. Use of the ASCII text file requires user supplied software, such as, Statistical Analysis System(SAS) or MS Excel that is capable of reading the ASCII data. This means that you can summarize the entire data set by any of the fields mentioned above. Thirty four of the states have county data

The Lotus data set is easy to use if the user has the Lotus software or software that can read the Lotus format; but, it does not include all the data. There are four files in the *.wk1 format: SINGx, MULTGx, MULTx, and NUTRx. Each of the files is described below. Note that in all the files x=data year.

SINGx: Consumption of the most common single nutrient NPK materials by state and county.

MULTGx: The top 12 mixed fertilizer grades are listed for each state in the US including PR. Note that only the grades are listed not the tons.

MULTx: The tons of the top 12 grades are listed by state and county.

NUTRx: The data are summarized by state and county and include tons of NPK from single and multinutrient materials, total NPK tons, total tons of organic and secondary and micronutrient materials, and total tons of all fertilizers.

Characteristics of and Problems Associated with the Data

The *Commercial Fertilizers* publication has a section titled 'Data Sources' which details the characteristics of the tonnage data in the publication and should be consulted before using the data. Some of those characteristics are discussed here.

Alaska, Hawaii, and Wyoming have no tonnage reporting requirement. Alaska does a survey each year to estimate the tonnage and we use that estimate adjusted in relation to any other relevant information. Hawaii and Wyoming have no tonnage reporting requirement so their data are strictly educated guesses after consultation with agricultural officials in each of these states and, for WY, after looking at the tonnage reported in the surrounding states. Puerto Rico reports tonnage by materials and grades on an annual basis and we receive the data about one year late so the PR data are estimated for the current year and are fairly firm for the previous year. WI collects tonnage data but at present is unable to provide it to us for technical reasons; therefore, WI data are estimated based on tonnage reported in the surrounding states and after consultation with WI officials. GA does not report the analyses of mixed grades so we have to use estimated analyses and CA does not report the analyses of their specialty products so an estimate is used. All other states collect and report tonnage in some fashion. There are 34 states that report county data.

Several states have reported budget problems and the lowering of the priority of reporting the tonnage data. AAPFCO tries to help these states as best we can but all the states need support from the industry to continue and to improve their tonnage reporting effort.

Questions about the interpretation of the data on materials and mixtures have been with us for a long time. My best answer is that some states report as materials both those that are used straight and those that are subsequently sold in mixtures, some report materials only when used straight, and some do both. Therefore, the tons of a specific material reported does not necessarily represent the tons of that specific material that were applied straight because some would have been used in mixtures. Also, the tons of a specific material reported used does not represent all the tons of that specific material that were used because some would have been used in mixtures. Custom blenders frequently report the materials that they use in their custom blends rather than the individual custom mixes.

Capturing the usage of secondary and micronutrients is just as difficult as that of the NPK materials. If a company buys a secondary/micronutrient mix and adds it to a registered NPK mixture then the amount of the secondary or micronutrient used in the mixture is lost. If the individual materials used in the mixture are reported then the secondary/micronutrient tonnage is captured.

I am not aware of any effort at this time to improve on these specific situations. The UFTRS system is designed to allow reporting of the secondary and micronutrient guarantees in mixtures but as of this date that feature is not being utilized.

Value of the Data

- Industry Stability—The use of fertilizer by state and region allows companies to plan and invest to supply future needs and is a service to the regulated industry.
- Improved Decision Making—Trends in fertilizer use by county, state, and region provide a firm basis for companies to make business decisions and for agricultural professionals to evaluate how well farmers are following recommendations for fertilizer use.
- Part of National Database—It continues one of the oldest agricultural databases.
- Annual Publication in *Commercial Fertilizers*
- Ensured Adequate Supply to Each Farm—It helps balance supply and demand.
- Environmental Applications
- Identify Potential Areas of Concern—County data are especially useful in evaluating the presence of nutrients in surface and subsurface waters.
- Improve Efficiency of Policy
- Track nitrogen, phosphate, and potash use

Who Uses this Information?

- Local Dealers
    - Δ Track Sales
    - Δ Determine Warranted Changes
    - Δ Evaluate Sales in Other Areas
    - Δ Provide Data for Investment Capital
    - Δ Support Studies for Orderly Growth and Effective and Efficient Capital Investment

- Fertilizer Industry Market Analysts
    - Δ Determine Market Penetration
    - Δ Develop Trend Analyses
    - Δ Study Regional and National Market Conditions
    - Δ Improve Distribution

- Universities, Institutions, and Governmental Agencies
    - Δ Determine Potential Distribution and Use Problems
    - Δ Improve Consistency of Recommendations
    - Δ Evaluate Effectiveness of Soil Test Recommendations
    - Δ Advise on Efficient Use
    - Δ Develop Environmental Studies
    - Δ Determine Trends in Types and Usage of Materials
    - Δ Identify High Payoff Areas for Research
    - Δ Verify Effectiveness of Regulation/ Policy
- Financial institutions—Evaluate Operating/ Investment Loans
- Transportation Systems—Identify Efficient Systems/Routes
- Producers
- Extension Specialists
- Control Officials
    - Δ Track movement within the state
    - Δ Collect accurate tonnage fees
    - Δ Develop Inspectional Programs so sampling is proportional to distribution

What other kinds of Information from the reports is used?

- County Data
- Materials and Mixed Grade Use
- Farm/Nonfarm
- Bag, Bulk, or Fluid

Fertilizer Tonnage Data are Valuable to:

- Farmers and Ranchers
- Market Analysts
- Dealers
- Producers
- Environmental Study Groups
- Extension Specialists
- Other Input Suppliers
- Financial Institutions
- Accurate Fertilizer Tonnage Data is Basis of Sound Business Decisions.
- Record Keeping is Good Business!

Summary

Fertilizer data are available.
Fertilizer data are valuable.
Fertilizer data are used.
Fertilizer data are fragile.

---

[1] Official Publication, 1947, Association of American Fertilizer Control Officials, (p7 of Model Bill).

[2] Official Publication, 1947, Association of American Fertilizer Control Officials.

[3] Official Publication No. 18, 1964-65, Association of American Fertilizer Control Officials, p104.

[4] Official Publication No. 19, 1965-66, Association of American Fertilizer Control Officials, p 85.

[5] Official Publication No. 40, 1987, Association of American Plant Food Control Officials, p130

User's Prespective of Fertilizer Data Needs

David Asbridge
CF Industries, Inc.

The fertilizer industry in the U.S. has been blessed with one of the best data reporting systems in the world. Data users have been able to do a much better job of planning than would otherwise have been possible without this good data. I would like to take a few minutes to discuss some of the uses for this data and then look into the future and see how it might be made even better.

Economists such as myself have always had the need for good data sources in order to carry out our work. We use the data to track items such as market growth, market saturation or maturation, market share and other objective measurements of how our business is doing, either in its own stead or in comparison with other companies. Without this data, and these resulting data studies, it would be much harder for a company to know how it is doing. Profitability is, of course, still extremely important as a measure for success, but if a company wants to grow, it needs to know potential. This potential can only be known when there is data available to show what the possibilities are in the entire market segment, not just where we are doing business now.

Of course economists are not above "estimating" data that is not available, but we much prefer a more reliable source that we can reference. This gives our studies a sometimes much needed boost in credibility. Not that we economists lack credibility, but government statistics are regarded much more highly than the "educated guesses" of most economists. Even using good data does not always give an economist a high level of credibility, but is sure helps.

USDA has always been a good source of agricultural data. With cutbacks in funding, however, data collection and dissemination has sometimes had to be done by other sources. Dr. Terry, and TVA before him, are good examples of how an industry with a need for data will sometimes have to develop new ways to get that data. When faced with the loss of USDA-reported fertilizer data in the U.S., the industry decided that we needed to continue reporting this data. It kept pushing until other ways to keep the data flowing were developed. This has led to the system that we have today.

There can, of course, always be improvements. We would like to get the data much quicker and in even more detail, such as how much urea is used in blends, etc. We realize, however, that there are certain laws of nature and funding that we have to be aware of, so we take what we can get and, in fact, are very grateful for it.

I want to talk a little now about how we use the data that we get. I will start at the top and talk about U.S. level data first. Then I will work down to state and then district or county data.

At the U.S. level, the data we get keeps us informed on how we are doing in terms of our competitors. We are able to track what our market share is doing on an annual and even six-month basis. This shows us what product areas we are doing well in and what areas we need to adjust in order to remain competitive. Being a co-op, CF also has the advantage of our members telling us what we need to do to stay competitive. And believe me, our members are not shy about letting us know what we can do better, especially as it relates to their areas.

As important as national data is to us, state data is also very important. This is where we can really begin to see how our marketing activities are working. Since we are organized on a regional basis (based on our members' marketing areas), we have a great deal of need for data that can be aggregated to tell us how we are doing in each of our different regions. We can look at this data and tell if we are gaining or losing in each region. Then we have the data to help us decide if we want to make a bigger effort in that region or if it is not worth any additional effort to take more of that market.

The state data is also helpful to our transportation department as they plan movement of our products from plant to distributor and in some instances to end user. They need to know if usage patterns are changing so they can begin to make arrangements for different modes of transport. This may be in the product itself such as ammonium nitrate to urea or in the form of the product such as from dry to liquid. There are many factors that need to be evaluated as consumption patterns change.

State level data also helps us as we determine where to locate terminals and warehouses. We can plot the data and see if we are short of storage in certain areas and begin to plan to beef up our presence in those areas. We will cross-tab this with transportation sources to see if we should be lining up more rail cars or more barges.

The availability of even more detailed data is a luxury that we get from only a few select states. In those areas, we are able to fine tune our analyses to see how fertilizer moves in district or sometimes even county levels. This type of detailed data becomes extremely important as we can look at wholesale and even retail facilities to see if they are being competitive in terms of fertilizer sales and try to use the data to see what product mix should be in relation to that specific market.

The members can make use of this data as they plan their expansion into adjoining areas of their own locals. They are also able to look at the total product movement to see if it justifies keeping both facilities open for all types of products.

As to future improvements for data, I am not too optimistic about additional data sources. If past trends continue, we are probably going to see less availability of the type of data that we are seeing now. That does not mean less data, just less of the type that we are seeing now. Let me explain what I mean by that.

I have seen the future and it ties into satellite transmissions. I have a colleague that is currently taking the available data and layering it into a computer program that can then take data from a satellite and "color" in a chart of exactly where the crops in that area are being grown. This crop data can then be manipulated to help spread the fertilizer data to a more detailed level than was previously available. We still need the most detail we can get from the actual fertilizer data source, but we can take the data we have and assign it to the known crops being grown to see exactly where the fertilizer is going.

This level of detail will show us if the fertilizer product is going to the top of the district or county or to the bottom or spread out across the entire area. This can help us place that facility were transportation costs is the most economical.

I hope this helps you realize how important this data is to us users. Without you and others like you, data generation would be left up to people like myself, and that is a scary thought!

Tuesday, October 29, 1996

Session III
Moderator:

Frank P. Acorn

Graphite—A Suitable Material for Phosphoric Acid Evaporators

Gerd L. Meier
Presented by Lance Smith
SGL Carbon Group

For decades, graphite has been used as a material tor phosphoric acid evaporators because of the excellent corrosion resistance and good heat transfer rate. However, there are mixed results against mechanical damage. Some of the graphite heat exchangers suffer from the rigid operation conditions in a phosphate plant. A few pictures demonstrate the problems experienced in the past.

The failure of a graphite heat exchanger can be caused by various reasons. (Fig. 1).

Each tube failure or block crack results in a plant shut-down, loss of production, acid contamination of the condensate, repair costs, assembly and disassembly time and costs.

The objective of this paper is to describe ways how to increase the production rate of phosphoric acid evaporators and to cut the maintenance budget.

Manufacturing process and properties of graphite used in chemical equipment

In manufacturing synthetic graphite, all the following steps are important for quality: selection of raw material mixing, baking, graphitisation and impregnation. (Fig. 2).

Chemical properties

One of the reasons to use graphite for chemical equipment is the excellent corrosion resistance (Fig. 3).

Graphite is best suited for phosphoric acid application at any concentration up to the maximum allowable operating temperature for graphite material. The chlorine and fluorine content in the acid does not affect the impregnated graphite.

Physical properties

In table 1 the important properties for impregnated and non-impregnated graphite are listed in comparison to other materials used for chemical equipment. The low strength of graphite and the ceramic-like character of the material has to be considered in the engineering of the evaporators. What impact has the equipment manufacturer and the repair shop to improve the performance of the evaporator?

Material selection

The best suitable material grade has to be selected for the application of the graphite pans in reference to the material strength, pore size, pore distribution, grain size and the suitability for resin impregnation.

Resin impregnation

The key properties of corrosion resistance, strength and maximum operating temperature are determined by the proper impregnation of the porous graphite material with a synthetic resin. Resin properties, details of the impregnation process, and the curing parameters all have to be carefully considered. The quality of the impregnation can best be seen in a micrograph picture.

The resin must link to the graphite matrix, i.e. there should be no gap between pore wall and the resin. The impregnation process has also the advantage that the strength of the material increases by a factor of 2 to 3 (Fig. 4). Selecting the right graphite material combined with the proper impregnation results in the best material strength.

Joining technology

Graphite parts can be jointed together by using a cement consisting of graphite powder and resin. The joint factor depends on the thickness of the cemented joint. The optimum thickness for DIABON material is at .0 01 inch. This optimum however can change with other graphite grades (Fig. 5). The quality of tube/tube pints is influenced by the cement thickness, the shape of male/female connection and the length of the overlap (Fig.6).

The development of the optimum joint tube/tube sheet is shown below (Fig.7–9).

Design a) results in a low flexural and tension strength and sometimes in leakage of the joint after assembly. Design b) is a better solution because the cement is compressed and the excess cement is extruded out of the joint. Design c) is a patented shape of SIGRI and has a tapered end and a cylindrical section. In the conical pan the cement is pre compressed and the joint thickness exactly defined. The cylindrical surface of the tube end is specially prepared to avoid any bond of the cement to the tube, i.e. the tube is only supported by the cement. Any shrinkage stress of the cement as well as stress peaks on the transition tube/tube sheet is avoided. Therefore the flexural strength of the joint increases to approximately 90 % of the tube strength.

SIGRI reliability concept improves operational dependability

Graphite is a fragile material with a low breaking elongation of approximate 0.2%. Any fiber used to reinforce the graphite should have the following properties:

- very high modulus of elasticty
- very high tensile strength
- very low coefficient of thermal expansion
- same corrosion resistance as graphite

Carbon fiber reinforced graphite tube DIABON HF1

The DIABON HF1 tube is a standard graphite tube which has been wrapped nettedly under high pretension with carbon fiber (Fig.10.).

The saucer-type fracture of the standard tube will leak large quantities of acid into the condensate, whereas the DIABON HF1 tube always has a longitudinal crack and releases only small quantities at higher pressure.Below 40 to 50 psi the fiber wrapped tubes will remain impervious (Fig. 11).

On the tube ends as well as on the tube/tube joint an additional longitudinal reinforcement is applied to increase the strength. Owing to the carbon fiber negative coefficient of thermal expansion, the reinforcement is pretensioned further with increased temperature. As a result, the bursting pressure and the maximum impermeability retention pressure are higher. The DIABON HF1 tube is insensitive against steam hammer and inadmissible excess in operating pressure because of the 40 to 50 % higher bursting pressure. The physical properties of the DIABON HF1 tube compared to the standard tube DIABON NS1 are listed in table 2.

The heat transfer rate of an phosphoric acid evaporator with fiber-wrapped tubes is theoretically 5 % lower compared to the standard graphite tube. However, exact comparison tests in the field did not show any difference in performance. Especially important for the operation is the completely different appearance of a fracture of the DIABON HF1 tube (Fig.12).

Reinforcement of tube sheets and exchanger blocks

Tube sheets and blocks should be manufactured from a monolithic graphite piece to avoid a strength- reducing cement joint. The risk of cracking a big graphite part cannot be completely ruled out if various unfavorable factors occur simultaneously. Investigations have clearly shown that the force causing the cracks are tangential stresses. Highly pre-tensioned carbon fibers wrapped around the circumference area develop powerful counteracting forces which prevent cracking (Fig.13).

The evaporator can continue to operate without interruption until the next scheduled plant shutdown. Each cracked fiber-wrapped tube can be replaced individually or the heat exchanger completely retubed. The HF1 tube bundle can be cut with a saw. The carbon fiber on the tube will not unwrap. Good used HF1 tubes can be rejoined. A layer of carbon fiber tape on each end of the cut tube end secures the fiber-wrapping, the ends can be machined and the tubes cemented together again (Fig.14).

Wear protection for graphite evaporating units

Tube sheets and exchanger blocks are exposed to erosion damage due to high velocity of solid particles in the phosphoric acid. The objective of the operation is to have the highest allowable acid velocity to avoid or reduce scaling. A ceramic oxide coating together with an optimized flow geometry for the inlet and outlet increases the lifetime of the graphite parts substantially. (Fig.15 &16).

For shell and tube heat exchangers only the front face of the tube sheet requires the coating, whereas for block heat exchanger both end faces of each block have to be coated because of the gap between the blocks and the machining tolerance of the holes. The coating is absolutely corrosion-resistant and does not reduce the heat transfer rate. The good link of the coating to the graphite material can be seen in a micrograph picture (Fig 17).

Removal of incrustations

Incrustations in heat exchangers always represent a problem for the operator. The efficiency of the evaporator goes down, the pressure drop increases and, under certain circumstances, this results in mechanical failure. Therefore the incrustations should not exceed 1/8 inch thickness in the graphite tube.

a) Removal with hot water

This is a simple method which can be successfully used it the incrustation is relatively thin and soft. The water velocity in the tubes should be as high as possible (more than 9 ft/sec).

b) Chemical cleaning

Owing to the excellent corrosion- resistance of the graphite material the unit can be cleaned using a suitable chemical. The chemical resistance of graphite must be taken into account (Fig.18).

c) Cleaning with high water pressure

Graphite tubes can be cleaned with high water pressure up to 4000 psi At this pressure the water velocity already reaches the erosion point. This method for the removal of incrustations causes the most tube damages, if the water pressure, the handling and the system used are not selected for the graphite unit. A solid rod with the water nozzle on the tip causes the most tube breakages because the cleaning people can ram the nozzle into the blocked tube. Our recommendation is a self- pushing nozzle with a flexible hose connection (Fig.19).

Summary

Graphite is a fragile material However, a offers one of the most economical solutions to the problems of corrosion in the phosphoric acid evaporators. The mechanical weakness of the material can be overcome through the selection of a suitable grade of graphite, stabilized impregnation, and the mechanica design of the equipment. Two new technologies by SIGRI, carbon fiber wrapping of graphite tubes and tube sheets, and ceramic oxide coating on the face of blocks and tube sheets, greatly enhance the mechanical strength of graphite, therefore improve the reliability and life of phosphoric acid evaporator. The superior performance of heat exchanger with DIABON HF1 tubes has been proven in many phosphate plants (in the US: Texasgulf) around the world. The carbon fibertube unit requires15 to 25 % additional capital investment as compared with the standard unit. Wth reduced down time and maintenance cost, the payback period on the additional investment is mosdy less than one year.

		Graphite		
		tubes	tube sheets	blocks
Manufacturer & repair shops	Poor impregnation	X	X	X
	Wrong strength calculation	X	X	X
	No material specific design	X	X	X
	Assembly mistakes		X	X
	Poor cemented joints	X		
	Vibration	X		
Operation	Pressure shocks (steam hammer)	X	X	X
	Overheating	X	X	X
	Temperature shocks		X	X
	Condensate drain	X		X
	Low liquid level in flux tank	X		X
	High acid velocity (erosion)		X	X
	Incrustation	X		X
	Blockage by floating lumps	X		X
	Wrong start-up and shut-down procedure	X		X
Cleaning & handling	High pressure water cleaning	X		X
	Chemical cleaning	X	X	X
	Overtorque of the tie rods	X	X	X
	Mechanical damages of gasket area		X	X

Reasons for graphite failure

Figure 1. Reasons for Graphite Failure.

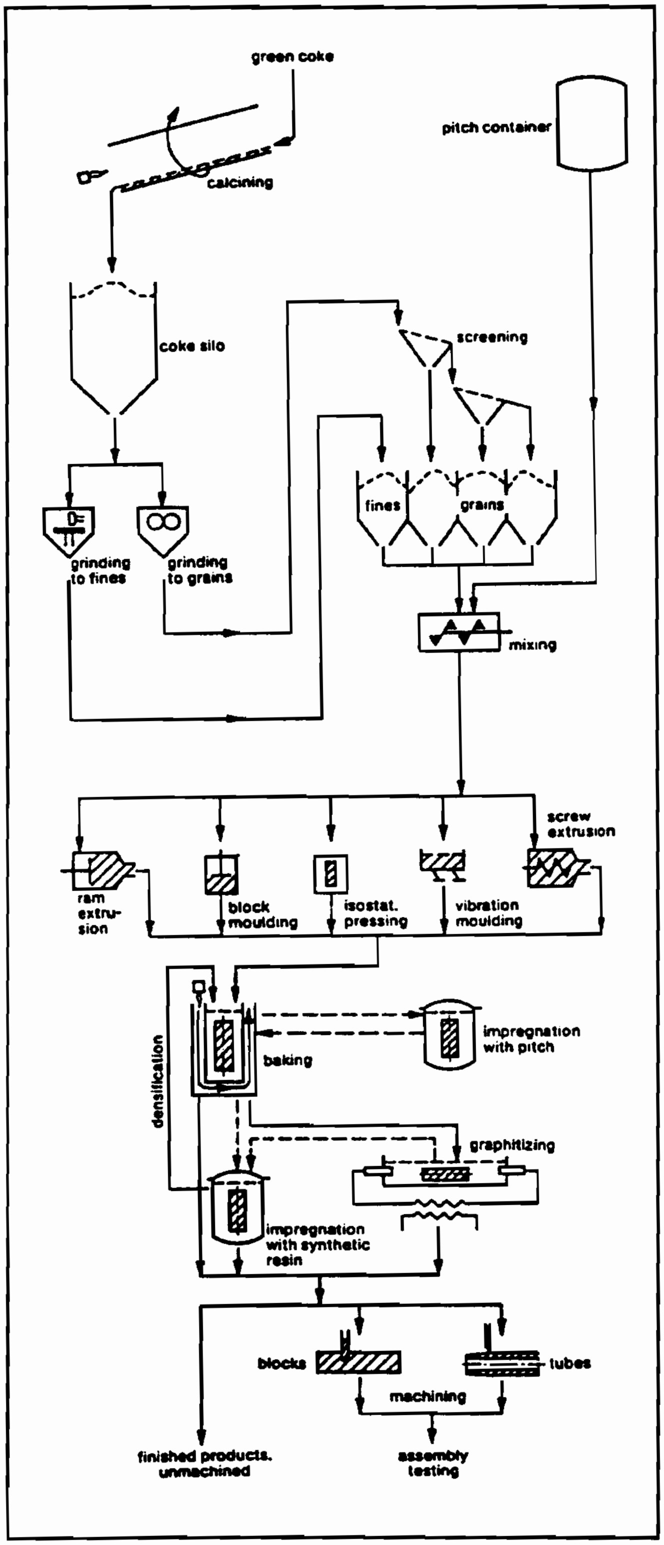


Figure 2. Manufacture of DIABON Process Equipment Graphite.

Medium	**Concentration**	**Temperature**
INORGANIC ACIDS		
Hydrofluoric acid	0-60%	boiling point
Phosphoric acid	all	330° F
Hydrochloric acid	all	boiling point
Sulphuric acid	0-70%	330° F
Sulphuric acid	70-80%	330° F
Sulphuric acid	80-96%	330-65°F
ORGANIC ACIDS		
Chloroacetic acid	all	boiling point
Acetic acid	all	boiling point
Sulphonic acids, such as benzene/ sulphonic acid	all	330°F
SALT SOLUTIONS		
Acetic Chloride Fluoride Sulphate Sulphite all common metals	all	330°F
Calcium Lypochlorite	all	
Sodium hypochlorite	all	
VARIOUS SUBSTANCES		
Hydrogen chloride (gas)	100%	330°F
Hydrogen fluroide (gas)	100%	330°F
Sulphur dioxide (gas/liq)	100%	330°F
ORGANIC COMPOUNDS		
Chlorobenzene		
Dichlorobenzene	100%	330°F
Cyanogenic chloride		
Cyanuric chloride	100%	330°F
Halogenated hydro-carbons (Freons)	100%	330°F
MIXTURE OF SUBSTANCES		
Calcium bisulphate sol.	100%	330°F
Hydrochloric acid & Sulphuric acid	100%	330°F
Pickling & nickel plating bath		
Sulphuric solutions (precipitating bath)	100%	330°F

Figure 3. Chemical Resistance of Graphite.

Properties at 68°F	Units	Material				
		Graphite *		ASTM	Tantalum	Glass
		non - impreg.	resin impreg.	A 322 - 82		
Tensile strength	psi x 10^3	0.7 - 3.2	2.3 - 5.1	116 - 138	36 - 73	8.7 - 14.5
Flexural strength	psi x 10^3	1.0 - 4.3	3.6 - 8.7	—	—	7.2 - 8.7
Compression strength	psi x 10^3	2.2 - 9.5	9.5 - 19	—	—	87 - 145
Modulus of elasticity	psi x 10^6	1.0 - 1.5	2.2	3	2.7	0.7 - 1.2
Breaking elongation	%	0.15- 0.3	0.15- 0.3	14	15 - 25	—
Thermal conductivity	BTU/ft/hr/°F	46 - 75	46 - 75	25	31	0.3 - 0.8
CTE	1/°F x 10	0.5 - 1.5	1.5 - 4.4	6	3.7	1.7 - 4.4

* Properties of low and high quality grade

Table 1. Comparison of Important Properties of Materials Used for Chemical Equipment.

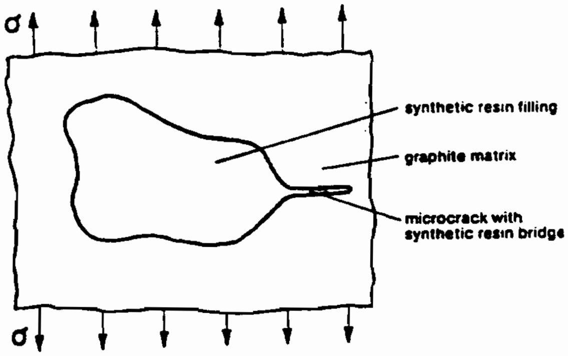


Figure 4. Sketch Showing a Resin-Filled Pore With Microcrack.

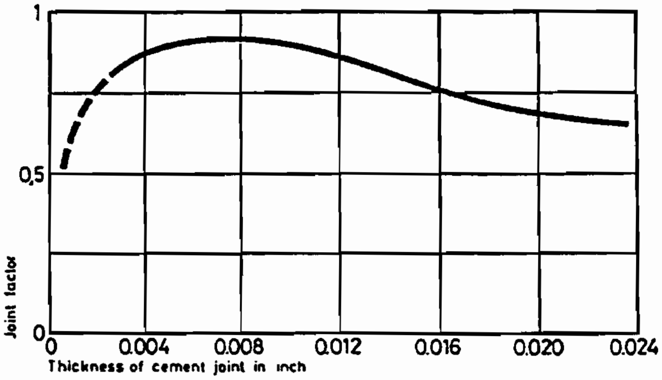


Figure 5. Relationship Between Joint Factor and Thickness of a Cemented Butt Joint.

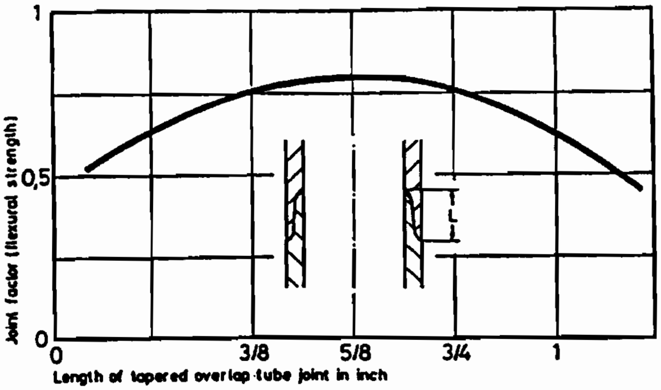


Figure 6. Relationship Between Joint Factor and Length of Tapered Overlap Tube Joint in Inches.

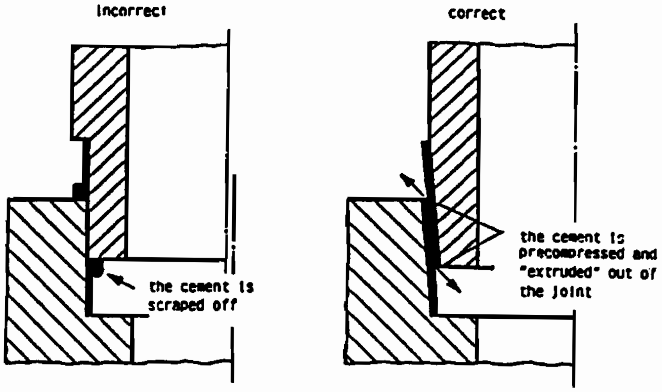


Figure 7. Designing Tube/Tube Sheet Joint.

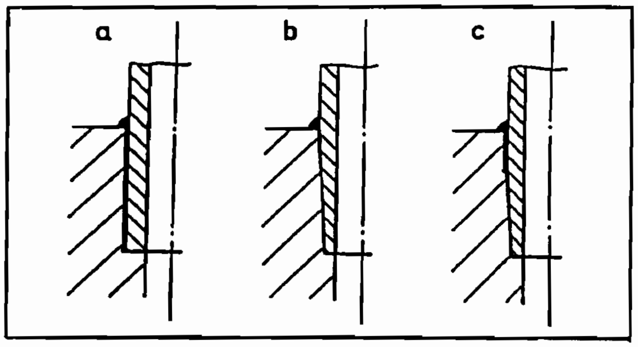


Figure 8. Development of the Tube/Tube Sheet Joint .

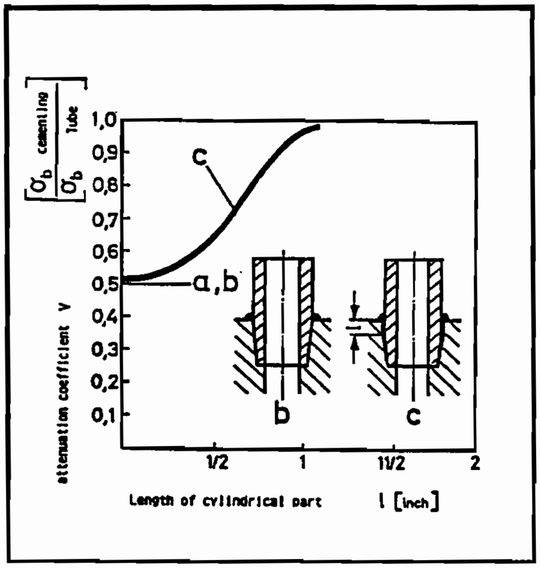


Figure 9. Development of the Tube/Tube Sheet Joint .

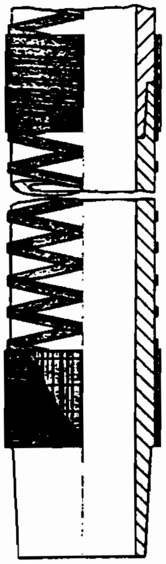


Figure 10. DIABON HF1 tube.

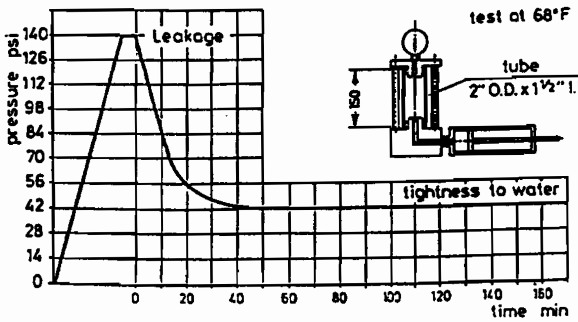


Figure 11. Pressure Behavior of a Cracked DIABON HF1–Tube.

Graphite Tubes
Physical Properties

		DIABON NSI (standard tube)	DIABON HFI (carbon fiber reinf. tube)
Flexural Strength	psi	7250	8700
Burst Pressure 68°F	psig	1070	1425
302°F	psig	1000	1565
Strength of Shock Pressure (steam hammer)	relative%	100	250
Leakage Pressure on a crack tube water pressure inside	psig	0	142
Thermal Conductivity I	BTU/ft²/hr/°F	46.4	29
Thermal Conductivity II		87	87
Max. Recommended Operating Temperature	°F	392	392
Thermal Coefficient of Expansion (68-338°)	in/in/°C	3.5×10^{-6}	3×10^{-6}
Flexural Strength of Tube/Tube Joint	psi	5800	7975
Flexural Strength of Tube/Tube Sheet Joint	psi	6525	7975

Note: The above information is subject to change and does not constitute a warranty.

Table 2. The Physical Properties of the DIABON HF1 Tube Compared to the Standard Tube DIABON NS1.

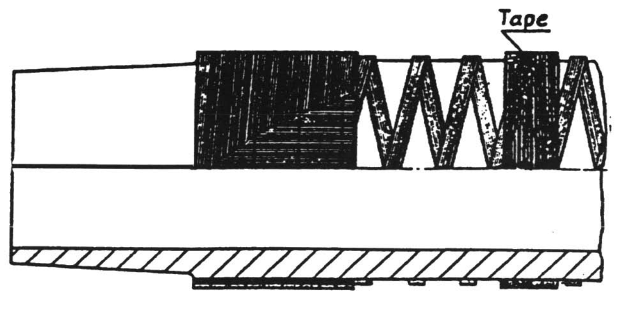


Figure 14. Section Showing Carbon Fiber Tape.

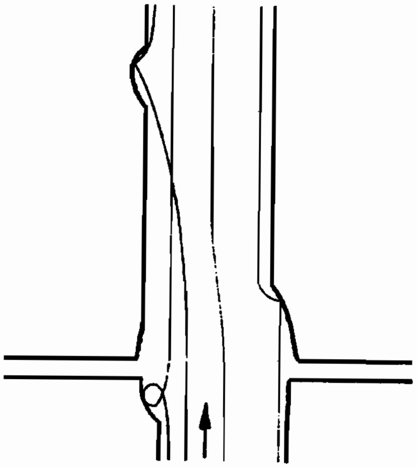


Figure 15. Erosion Damage in the Transition Zone Between Two Blocks.

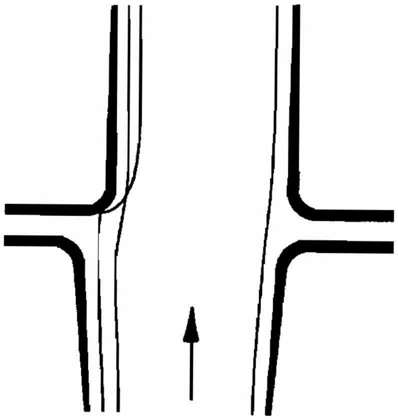


Figure 16.Optimum Flow Geometry in a DIABON Block Heat Exchanger.

Figure 17.

DIABON® is NOT resistant against
- highly concentrated alkalis
- high oxidize products like
  - Nitric acid
  - Sulphuric acid
  - Elementary bromine
  - Elementary iodine

DIABON® is resistant aganist
- Hydrochloric acid
- Sulfuric acid up to 80%
- Phosphoric acid
- Hydrogen fluoride
- Salt and salt solution
- Sea water
- Hydrocarbon
- Organic acids

Figure 18. Chemical Resistance of Graphite.

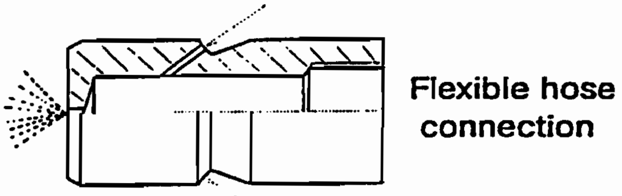


Figure 19. Cleaning Nozzel.

Ammonia Technology for the 1990's and Beyond

J.R. LeBlanc
M.W. Kellogg Technology Co.

Introduction

Manufacture of anhydrous ammonia began in 1913 at BASF's plant in Ludwigshafen-Oppau, Germany. Feedstock was coal derived gas. Plant capacity was 30 metric tons per day.

From those beginnings to today, there have been significant changes in this industry. Some of the more salient characteristics of today's industry are:

- Natural gas is the dominant feedstock
- Single train plant capacities are approaching 2000 MTPD
- Ammonia production is practiced on a global basis

Technology has played a significant part in advancing this industry to where it is today and where it will go tomorrow.

Current Practice

The forerunner of today's modern single train ammonia plant was introduced by the M. W. Kellogg Company in the mid 1960's. The major process operations are shown in the block flow diagram of Figure 1.

Modern ammonia plants in operation today essentially follow the same processing scheme.

In brief, the feedstock, typically natural gas is desulfurized to remove poisons which would cause problems to the downstream operation. The desulfurized feed is mixed with steam and reformed in two steps. In the primary reformer the steam and gas are reacted over a nickel catalyst inside tubes in a fired heater. The effluent from this step is passed to the secondary reformer, in which air is introduced to furnish the nitrogen needed for ammonia synthesis. In the secondary reformer operation, which is highly exothermic, raw syngas is produced containing H_2, N_2, CO, CO_2, residual CH_4 and unreacted steam. Additional H_2 is made in the down stream shift conversion system, wherein CO is converted to H_2. Next, CO_2 is removed and the resultant gas is passed to the methanator to reduce CO and CO_2 to the low ppm level.

The purified synthesis gas, at about 3/1 H_2/N_2, is compressed to synthesis pressure, mixed with recycle gas and passed to the ammonia converter wherein the H_2 and N_2 is reacted to produce ammonia. The ammonia produced is recovered in the refrigeration system, with the uncondensed gas, after purge, serving as recycle gas.

In recent years there have been significant advances in the steam reforming and ammonia synthesis sections of the plant.

In this paper, an overall view of these significant developments brought to commercialization by Kellogg will be reviewed.

Steam Reforming

The classical approach to steam reforming has been to use a fired primary reformer followed by a fixed bed adiabatic secondary reformer.

Available primary reformer designs differ in arrangement of tubes and burners, tube material, feed distribution and reformer gas collection system. Figure 2 is a picture of a fired primary reformer and secondary reformer in a Kellogg designed ammonia plant.

Steam reforming has been in commercial practice for more than 50 years. Improvements have been made over the years, but the basic unit has consisted of firing fuel in the radiant box to furnish the heat for the endothermic reaction of steam reforming, which takes place in the catalyst filled tubes.

In October 1994, Kellogg put into commercial service the Kellogg Reforming Exchanger System (KRES) at the Pacific Ammonia plant at Kitimat, British Columbia, Canada.

Figure 3 gives an overview of KRES. The desulfurized natural gas and steam stream is split into two steams and heated in a fired heater. After preheating, the mixed feed is routed to the reforming exchanger and autothermal reformer, which operate in parallel.

To satisfy both the stoichiometry and thermodynamics, this design uses enriched air in the autothermal reformer, the enriched air typically containing about 30% oxygen. The hot effluent from the autothermal reformer flows to the reforming exchanger shell side.

The mixed feed routed to the reforming exchanger flows inside the tubes. The tubes contain conventional nickel catalyst. The heat required for the endothermic reforming reaction in the tubes is provided from the shell side gases, which consist of the effluent from the open tubes in the reforming exchanger and the effluent from the autothermal reformer. The shell side gases exit the exchanger for further processing.

As shown in Figure 4, the reforming exchanger in the KRES unit is of the open tube design. The catalyst tubes are suspended from a single tube sheet located at the cold end of the exchanger. With the open tube configuration, each tube is free to grow without restriction.

Figure 5 is a picture of the KRES unit at Pacific Ammonia.

The KRES technology was developed to serve the full range of plant sizes, including today's sizes of 1850 MTPD capacity.

The operation of KRES at Kitimat has been a success in every measure. The performance of KRES has exceeded flowsheet expectations. The operation has been smooth and very user friendly.

Ammonia Synthesis

In the first BASF ammonia plant started in 1913, iron was used as the catalyst to synthesis ammonia from reacting hydrogen and nitrogen. Up until 1992, the basic catalytic material in commercial ammonia plants has been iron. Various promoters have been used to enhance activity, but the fundamental catalytic material had not changed. In 1992, Kellogg put into operation at the Pacific Ammonia site in Kitimat, the Kellogg Advanced Ammonia Process (KAAP).

Figure 6 is a picture of the KAAP ammonia converter at Pacific Ammonia.

KAAP is unique in that it employs a new and highly active ammonia synthesis catalyst. The KAAP catalyst uses a precious metal, ruthenium, on a high surface area graphite support. KAAP catalyst is up to 20 times more active then the conventional iron catalyst. Additionally, the KAAP catalyst operates very effectively at relatively low temperatures and pressures, when compared to conventional iron catalyst.

The Pacific Ammonia KAAP unit was added to an existing plant to allow for increasing capacity some 40%. The unit has met and exceeded all flowsheet expectations. Both KAAP and KRES have been used to increase the Pacific Ammonia Plant operating capacity from 500 MTPD to over 800 MTPD.

Operation at Pacific Ammonia has shown that the KAAP catalyst is at least as robust as the iron catalyst. The KAAP catalyst at Pacific Ammonia has seen excursions wherein poisons were introduced at a level of some 4000 ppm of equivalent carbon monoxide. After an initial period of reduced catalyst activity and subsequent removal of the poisons from the system, the KAAP catalyst regained full activity.

Figure 7 shows the KAAP synthesis loop configuration in a grassroots configuration. The single case synthesis gas compressor compresses make up and recycle gas and routes the mixed flow through a feed/effluent exchanger to the 4 bed radial flow KAAP converter. The effluent from the converter, at about 1300 psig, contains in excess of 20% ammonia. Heat is recovered from the converter effluent through generation of high pressure steam. After heat recovery, the converter effluent is passed to the ammonia recovery operation which uses mechanical refrigeration to condense the ammonia product. The gas resulting from the ammonia recovery operation, after interchange to recover refrigeration, is split. A small portion of the gas is fed to the purge gas recovery unit which recovers both hydrogen and nitrogen, and then joins with the remaining gas to become the recycle gas feeding the synthesis gas compressor.

Since taking the position of offering KAAP technology commercially world wide in the latter part of 1994, contracts for two retrofits and two grassroots plants have been undertaken. The new KAAP plants are for name plate capacities of 1850 MTPD.

Integrated KAAP and KRES Plant

With the successful commercialization of both KAAP and KRES, Kellogg's current commercial offering for ammonia incorporates these technologies in an integrated flowsheet. Figure 8 shows the overall processing scheme integrating KAAP and KRES.

The major features of this process scheme include:

- Application of KRES and the elimination of the fired primary reformer
- Application of KAAP
  - – use of a single case synthesis gas compressor
  - – use of a four bed radial flow KAAP converter
  - – purge gas recovery of hydrogen and nitrogen
- Reduction in total steam generation
- Equipment packaging to reduce item count and capital cost
- Compact plot arrangement to minimize plant real estate requirements

The benefits afforded to the ammonia plant operator in this technology include:

- Reduction in capital cost
- Efficient energy consumption
- Environmentally friendly operation
- Reduction in operator attention
- Reduction in maintenance and improved serviceability
- Improved reliability

This new integrated flowsheet was brought to a position of commercial offer in late 1995. Although the new flowsheet is a significant departure from conventional practice, the benefits for the ammonia operator are real and significant. In 1996, two projects have selected this KAAP/KRES integrated flowsheet, each plant having a name plate capacity of 1850 MTPD.

The KAAP/KRES integrated flowsheet is ammonia technology for the 1990's and beyond.

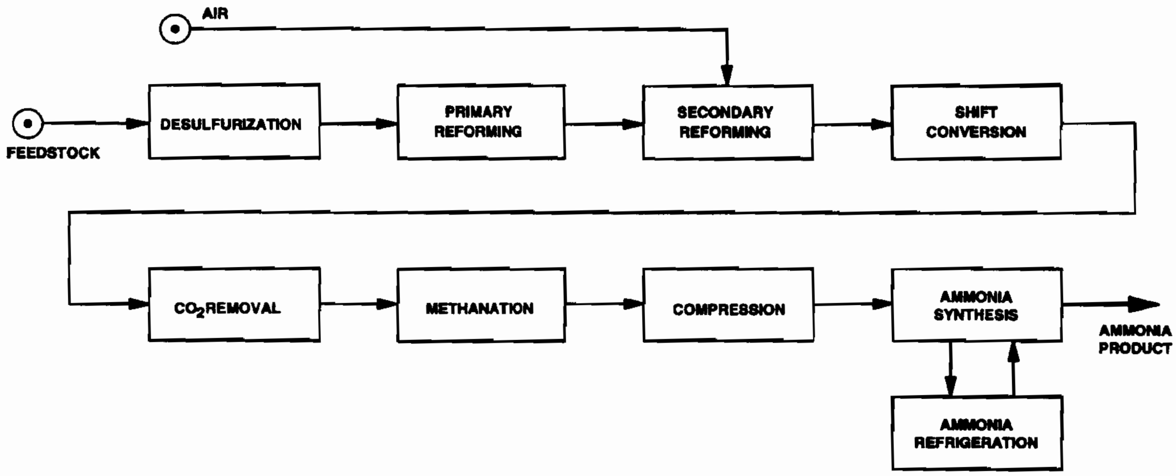


Figure 1. Block Flow Diagram for Ammonia Production

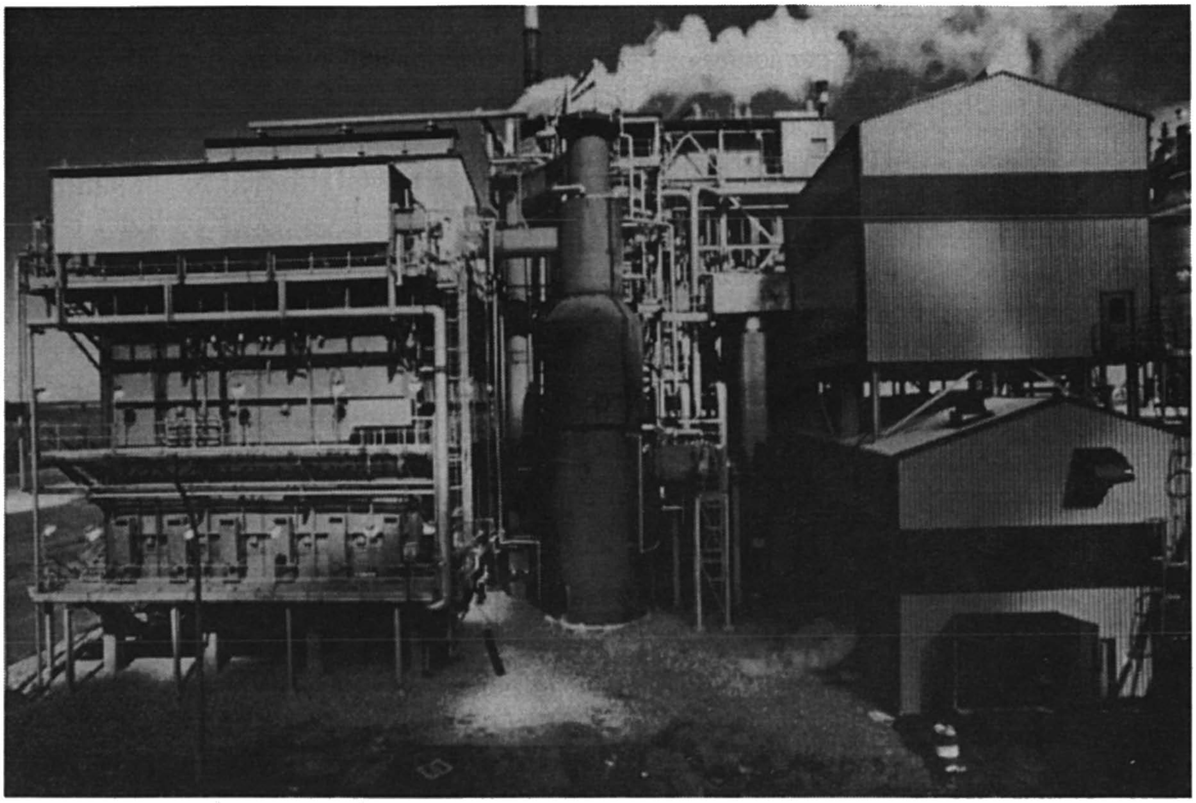


Figure 2. Primary/Secondary Reforming

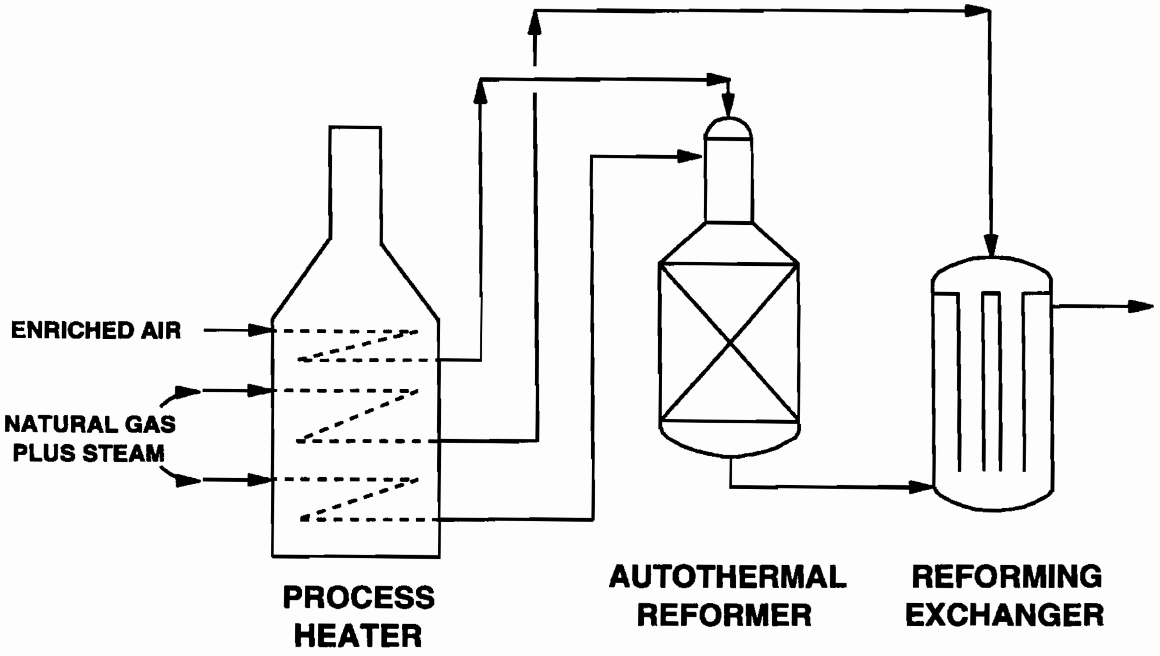


Figure 3. KRES

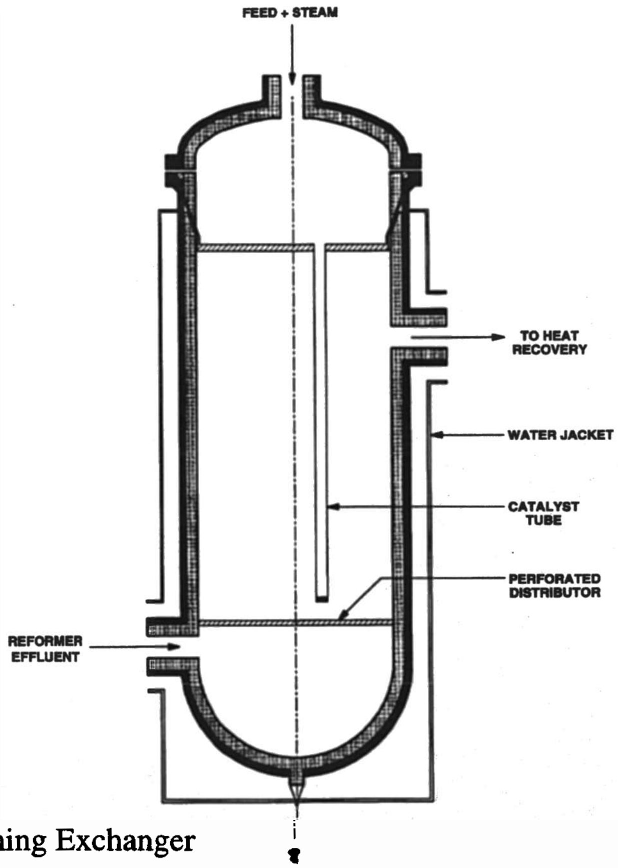


Figure 4. Open Tube Reforming Exchanger

Figure 5. KRES Unit at Pacific Ammonia

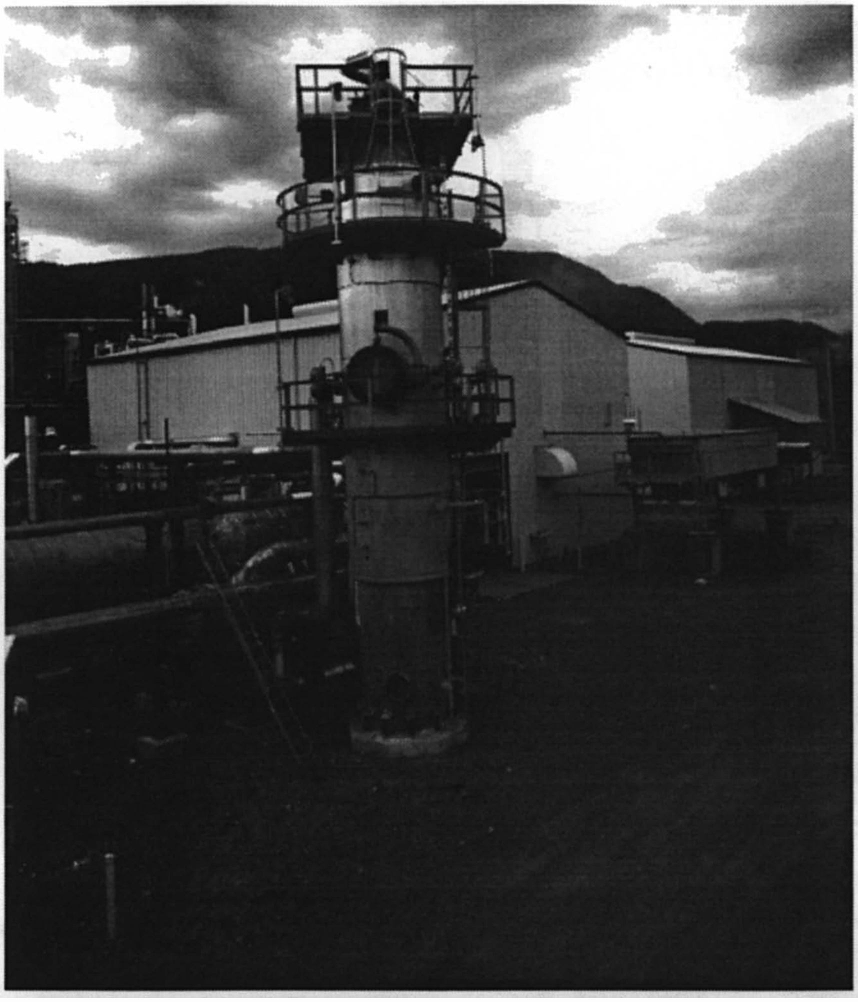


Figure 6.KAAP Ammonia Converter at Pacific Ammonia

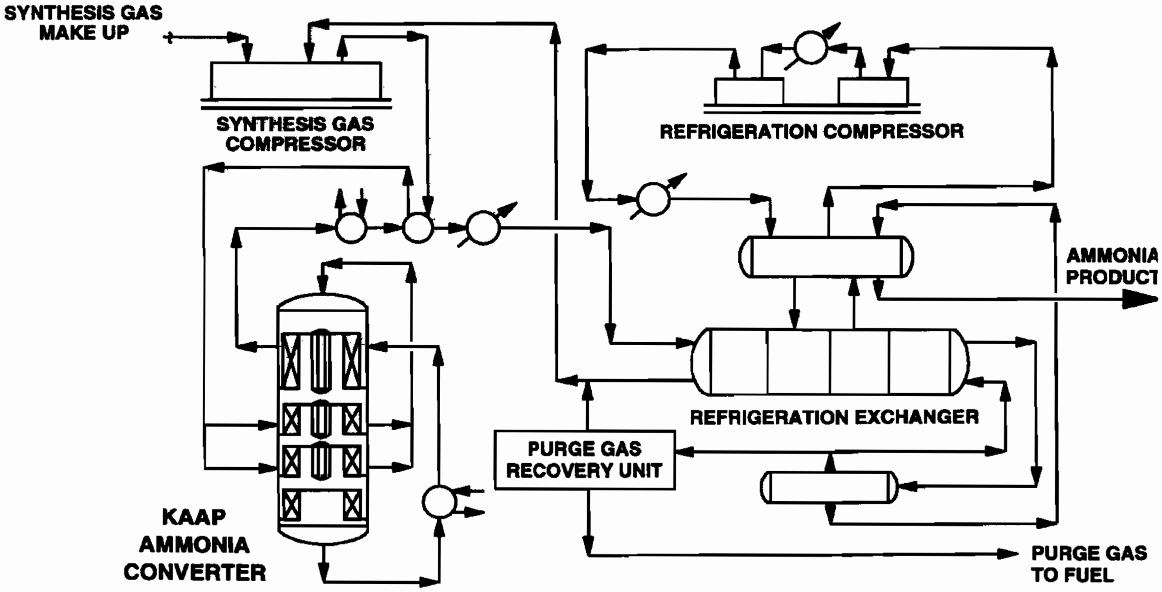


Figure 7. KAAP Flow Chart

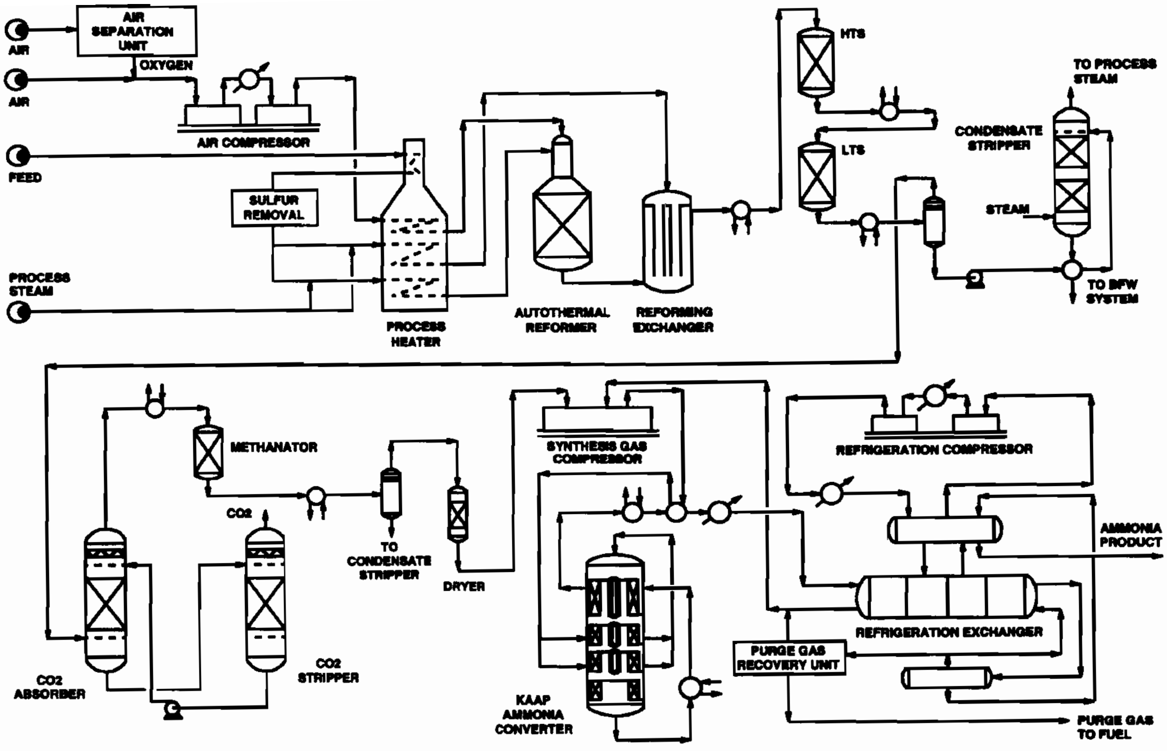


Figure 8. Integrated KAAP/KRES Process

Micronutrient Focus in Modern Farming II

Roy M. Stephens
Arise Research and Discovery

In November, 1994, the paper Micronutrient Focus in Modern Farming was presented to the Fertilizer Roundtable. The paper and concepts were well received with encouragement to investigate the data analysis into a continuing study. Further encouragement to investigate other crops was accepted. Therefore Micronutrient Focus in Modern Farming II. A Sequel is presented.

Continued growth of the Micronutrient Industry has brought new focus to the use of micronutrient formulas in Modern Farming and Precision Agriculture. Balanced fertility has long been a discussion point with universities, fertilizer companies, private consultants, farm management companies and growers. Nutrients improperly balanced are not cost effective or environmentally friendly.

Soil sample collection and testing for chemical analysis has been and is still being used as a guide for fertilization. Without such information, economical recommendations cannot be made for balancing nutrients. Soil testing labs, fertilizer dealers, universities and crop consultants all make varied types of recommendations for balancing nutrients.

"The process of making fertilizer recommendations should consider, the technical aspect of soil chemistry, nutrient response, plus the economic and personal concerns of the grower."[1] Micronutrients are small "but mighty" in the recommendation process. New technology focuses on small grids in the field with the potential to make prescription fertilization for a particular grid a more viable good management practice.

---

[1] Mengel, Purdue University, *Fertilizer Recommendations, Fact or Fiction*, p.75, Proceedings of the Twenty Fourth North Central Extension-Industry Soil Fertility Conference. October 26-27, 1994.

Introduction

Arise Research and Discovery, Inc. in conjunction with Cameron Chemicals of Chesapeake, Virginia and Sims Ag of Mt. Gilead, Ohio set about the task to enforce the validity of micronutrients and the role of micronutrient formulations with Modern Farming Techniques and Precision Agriculture. The five year study encompasses a number of crops with specific fertility requirements during a growing season. The selected verification crops were Field Corn, Soybeans, Soft Winter Wheat, Alfalfa and Pumpkins. Each crop has nutrient requirements of a different physiological metabolic process and need nutrient assessment (NNA) during different periods of time in their respective growing season.

Methodology

The procedures used to test validity and evaluate the role of rnicronutrient formulations in Modern Farming and Precision Agriculture were as follows:

1. Define the relationship between yield increase (ie. the yield with rnicronutrient formulas minus the yield without micronutrient formulas), soil test, and rate of fertilizer applied for the case of zero spatial variability. The relationship must give actual yield increases and not relative increases. (The equation used determines the relationship of treatment vs. no treatment.)

2. The plot site is an Illinois Glaciated Soil in the Cisne Association. Cisne soils are highly weathered, old soils, with a low CEC of ten or less, very poorly drained internally but have good surface drainage with a slight slope. High fertility test plots were selected to limit nutrient variability. All soil tests in this trial were well above the economic levels to apply maintenance fertilizer in accordance with the University of Illinois Agronomy Handbook. The high soil tests allow for an inverse view of the micronutrient formulations.

3. Four test controls were used for measuring actual yield response.

   Control 1: No Fertilizer Control.
   Verification 1: No Fertilizer Control Plus Micronutrient Formulation.

   Control 2: Nitrogen only Soil Productivity Rating
   Verification 2: Nitrogen only Soil Productivity Rating plus Micronutrient Formulation.

   Control 3: University of Illinois N,P,K. and Pelletized Lime Recommendations.
   Verification 3: University of Illinois N,P,K, and Pelletized Lime plus Micronutrient Formulation.

   Control 4: University of Illinois N,P,K, and Pelletized Lime Recommendations at 25 bushel corn increments.
   Verification 4: University of Illinois N,P,K, and Pelletized Lime Recommendations at 25 bushel corn increments plus Micronutrient Formulation.

4. Crops: The verification crops encompass the complete growing season All crops, with the exception of field corn and soybeans, were planted within economical planting dates as indicated in the Illinois Agronomy Handbook and Vegetable Growers Guide from the University of Illinois. Field corn was planted on June 12 and soybeans on June 14. Both crops reached physiological maturity before harvest.

5. Weather: Weather during the 1996 growing season was below normal in temperature, growing degree days and rainfall. Irrigation was applied during July and August to facilitate normal crop development. Environmental conditions for winter wheat production were the most unfavorable in 50 years leading to extensive winter kill.

6. Soil: Seedbed was excellent with no extenuating circumstances to cause poor germination or development. Soil conditions were not considered a limiting factor in this experiment.

7. Product Sources: Micronutrient Formulations and product were acquired from Sims Ag in Mt. Gilead, Ohio. The pelleted lime was acquired from Allerton Supply Company, Allerton, Illinois. All other nutrients were acquired from a local fertilizer dealer.

8. Data: Data was collected and analyzed into a per acre basis. Units were set at bushels per acre, tons per acre and cwt per acre. All crops were harvested in a timely fashion.

Results and Discussion

Table 1 encompasses the average range of the soil tests taken in the plot area. The tests are excellent with all soil test levels above buildup ratings with the exception of pH. By using a highs test area, no response to P or K would be expected with any of the crops in the trial. This eliminates the masking of symptoms of other nutrients and brings focus to the micronutrient formula used. The micronutrient formula differed with each crop.

Table 2 gives the yield data for the controls and the verification experiments. The results indicate little influence from other elements in the trial. Economic responses were noted with pelleted lime and the micronutrient formula used. A combination of the two indicate a strong economic advantage by a "bundling of the two" for soils with high fertility tests.

Table 3 examines the economic gross return per acre of each control and verification crop. Data indicates a higher gross margin with the verification studies. Put to a cost basis, micronutrient formulations and pelleted lime are key players for Maximum Economic Yield.

Observations of the five control crops during the gro~nng season:

Field Corn: Subnormal growing season. Limited environmental stresses due to irrigation. Corn yields were superior for the geographical area of the trial. A Pioneer number was selected with a second ear characteristic noted to be actively involved in yield. The second ear was noted throughout the growing season as being more developed in the verification studies than the controls. Root masses were examined during the growing season numerous times. Root mass was more prevalent in the verification trials than the control. Visual differences in height and leaf structure were noted with the verification studies. Extended leaf height favored the verification studies.

Soybeans: An indeterminate soybean variety for narrow rows was selected. The growing season was below normal but few environmental stresses were noted. Visual differences were noted in this trial as to height, pod count, etc.

Wheat: "The Winter Wheat growing season was the worst in 50 years!"2 Winter kill along with severe heaving devastated the yield potential of this trial. The fertilized plots yielded more and exhibited better plant health. Data was inconclusive.

Alfalfa: Considerable heaving was noted in all plots but recovery was enhanced by April and May weather conditions. In protein analysis, significant differences were noted in TDN and CP in the micronutrient and pelleted lime formulations.

Pumpkins: Accelerated users of nutrients with rapid plant growth, this crop produced prominent visual observations during the growing season. The crop did not suffer moisture stress. Verification study pumpkins noted a deep color with excellent weight and stem qualities.

Summary

The Micronutrient Industry has increased in size and production dramatically since 1978. Industries contacted openly state a lO per cent increase in sales each year for the last ten years. Since the development of fertilizer recommendations and the advent of new technology, grower management schemes have evolutionized from every seven years to every 90 days; the end product being: BMPS→MEY→Sustainable Agriculture.

Factual data, as indicated in this multiple year experiment aborts some philosophical recommendations by governings not associated to the Micronutrient and Pelletized Lime Industry.

---

[3] Nafziger, Emerson, University of Illinois, *Illinois Aari News*. May 1996.

Global Positioning and Variable Rate Technology begin with a grower's library for each field. Nutrient recommendations will address the Nutrient Needs Assessment approach sometimes called the Nutrient Sufficiency approach. The recommendation must be correlated to the technical aspects of soil chemistry, plant nutrient response and the economic and personal concerns of the grower. Different nutrient goals and objectives should be reflected with the crop to be grown. Soil test sustainability and correlated yields lead to nutrient efficacy.

Equipment controllers will bring about higher levels of grower management within a field. Once a field library is developed, economic status of grids and nutrients may be analyzed and precision applications made. This management scheme proves to be environmentally friendly as well as a relief to societal pressures.

Balanced micronutrient formulations along with other elements will produce a more efficient use of $ inputs in Modern Farming.

Micronutrient formulations should be focused to the soil environment for narrower rowed crops, higher plant population, changing nutrient demands and increased economic environmentally sound yields.

Presenter Note

Legality prevents the disclosure of the micronutrient formulations being used in the study.

Disclosure of such information must be given by Sims Ag.

References

Jones, J. B., B. Wolf and H Mills. 1994. *Plant analysis handhook* Micro-Macro Publishing, Inc. Athens, Georgia

Mengel, D. and S. Hawkins. 1994. *Fertilizer recommendations, Fact or fiction.* Proceedings of the Twenty Fourth North Central Extension Industry Soil Fertility Conference.

Sawyer, J. E. 1994. *Grid sampling: The worth of information.* Proceedings of the Twenty Fourth North Central Extension Industry Soil Fertility Conference.

Webster, R. and M. A. Oliver. 1990. *Statistical methods in soil and land resource survey.* Oxford University Press. New York, NY.

SOIL TEST	RANGES	MEASUREMENT
pH	5.4 - 5.9	NEG LOG of H Active
P	120 - 160	LBS/A
K	230 - 400	LBA/A
Ca	1900 - 2640	LBS/A
Mg	99 - 105	LBS/A
OM	1.2 -2.0	%
CEC	8.3 - 10.3	Meq/100 g Soil
Ca	47 - 58	%
Mg	4.6 - 5.0	%
K	3.3 - 7.3	%
H	32 - 41	%
S	43 - 53	LBS/A
Zn	22 - 50	LBS/A
Fe	269 - 345	LBS/A
Mn	145 - 232	LBS/A
Cu	0.9 - 1.1	LBS/A
B	6 - 15	LBS/A

Table 1: Replicated Average Pretrial Tests.

Treatment	Field Corn Bu/A *	Soybean Bu/A *	Alfalfa T/A *	Wheat Bu/A	Pumpkins CWT/A *
NFC	119	31	2.7	17	211
NFC + M	127	36	3.2	22	219
SPR + N	151	34	3.0	12	220
SPR +N +M	172	41	3.7	18	226
NPK + PL	175	38	6.7	21	239
NPK + M	169	42	7.9	19	261
NPK +PL+M	174	46	11.2	31	264
NPK (U of IL)	161	38	5.4	26	234

No Nitrogen was applied to legume plants. * Irrigation applied.

Table 2: Yield Results Year of 1996 – Year 3 of 5.

Treatment	Field Corn Bu/A $2.80	Soybean Bu/A $6.80	Alfalfa T/A $110.00	Wheat Bu/A $4.25	Pumpkins CWT/A $12.50
NFC	$333.00	$211.00	$297.00	$72.00	$2638
NFC + M	$356.00	$245.00	$352.00	$94.00	$2738
SPR + N	$423.00	$231.00	$330.00	$51.00	$2750
SPR +N +M	$482.00	$279.00	$407.00	$77.00	$2825
NPK + PL	$490.00	$258.00	$737.00	$89.00	$2988
NPK + M	$473.00	$286.00	$8692.00	$81.00	$3263
NPK +PL+M	$487.00	$313.00	$1232.00	$132.00	$3300
NPK (U of IL)	$451.00	$258.00	$594.00	$110.00	$2925

Table 3: Dollar Economic Gross Year of 1996.

Unique Process for Production of Ammonium Sulphate

Gregory N. Brown
General Electric Environmental Systems

Abstract

GE Environmental Systems (GEESI) has developed and patented a unique process which produces high quality ammonium sulphate from utility boiler flue gas. Most utility boilers have significant levels of sulphur dioxide (SO_2) which reacts with water in the atmosphere to form sulfuric acid. Throughout the world, environmental protection agencies are requiring utilities to minimize their SO_2 emissions. The new GEESI process combines our worldwide leadership in SO_2 control technology with a patented process for the simultaneous removal of SO_2 and production of ammonium sulphate.

The process reacts unwanted sulphur oxides with ammonia to form ammonium sulphate. In addition, this energy efficient process uses the waste energy from the boiler flue gas to evaporate excess water and crystallize the product. Thus, two of the three required elements in the production of ammonium sulphate are free in the GEESI process. The first commercial Ammonium Sulphate Forced Oxidation system (ASFO) is being installed at the Dakota Gasification Company's (DGC) Great Plains Synfuels Plant near Beulah, ND, USA. This plant is designed to produce nearly 600 tons per day of granular ammonium sulphate.

This process produces the highest quality ammonium sulphate product while simultaneously cleaning the air of unwanted sulfur oxides. This paper discusses the process, the first commercial plant, the quality and quality controls for the product and economics for the production of ammonium sulphate.

Introduction

The presence of sulphur oxides (SO_2, SO_3) in a boiler flue gas has been identified and recognized by most environmental protection agencies around the world as a source of "acid rain". Acid rain results when sulphur oxides react with water to form sulphuric acid and then return to the earth with the rain. This has had detrimental effects in many areas world wide. As a result, specific technologies have been developed to capture the sulphur oxides and convert them to byproducts, typically gypsum or calcium sulphite. Gypsum has a relatively low value in the wall board and cement manufacturing industry, and calcium sulphite has little or no value. Both products are generally landfilled as a waste product.

In 1987, GEESI was awarded a patent for the removal of sulfur oxides from gases and the simultaneous production of ammonium sulfate. In 1991, GEESI and DGC installed a 3 MW equivalent process demonstration plant on a slip stream from the DGC boiler flue gas. The purpose of the pilot plant was to demonstrate the following:

- Greater than 95% SO_2 removal
- Less than 10 ppm ammonia slip
- No increase in opacity when compared with a limestone operation
- 95% pure ammonium sulfate production

The results of the process demonstration plant, detailed below, were outstanding:

- Greater than 99% SO_2 removal
- Less than 10 ppm ammonia slip
- No increase in opacity
- Greater than 99% pure ammonium sulfate

After more than a year of operation, testing in the process demonstration unit was discontinued and the unit was dismantled to install the commercial flue gas desulfurization system.

Commercial Order

As a result of the performance of the process demonstration plant and the quality of the ammonium sulfate byproduct produced, General Electric Environmental Services, Inc., Morrison Knudsen Corporation (MK) and the Dakota Gasification Company entered into a contract to design, procure, install, start-up and test the first ammonium sulfate system at DGC's Great Plains Synfuels plant located near Beulah, ND. The project was awarded in March of 1994 and first flue gas was passed on June 29, 1996.

Process Chemistry

The chemistry for the production of ammonium sulfate from boiler flue gas is simple. The sulfur dioxide, SO_2 from the flue gas, is absorbed in an open spray tower by water according to the following equation:

$$SO_2 + H_2O \longleftrightarrow H_2SO_3 \qquad \text{EQ. (1)}$$

The H_2SO_3 is then reacted with ammonia to form ammonium sulfite according to the following equation:

$$H_2SO_3 + 2NH_3 \longleftrightarrow (NH_4)_2SO_3 \qquad \text{EQ. (2)}$$

The ammonium sulfite further reacts with H_2SO_3 to form ammonium bisulfite according to the following equation:

$$H_2SO_3 + (NH_4)_2SO_3 \longleftrightarrow 2(NH_4)HSO_3 \quad \text{EQ (3)}$$

The ammonium sulfite is also oxidized in the absorber to form ammonium sulfate according to the following equation:

$$(NH_4)_2SO_3 + 1/2\ O_2 \longleftrightarrow (NH_4)_2SO_4 \qquad \text{EQ. (4)}$$

Similarly, ammonium bisulfite is also oxidized in the absorber to form ammonium bisulfate according to the following equation:

$$(NH_4)HSO_3 + 1/2\ O_2 \longleftrightarrow (NH_4)HSO_4 \quad \text{EQ. (5)}$$

The ammonium bisulfate then can be further neutralized in the presence of ammonia and water to form ammonium sulfate according to the following equation:

$$(NH_4)HSO_3 + NH_3 + H_2O \longleftrightarrow (NH_4)_2SO_4 \qquad \text{EQ (6)}$$

All of these reactions take place in the absorber vessel. The ammonium sulfate is recovered through crystallization when the excess water is evaporated in the prescrubber at the absorber.

Basic Process Review

The basic process design for an ammonium sulfate process is shown in Figures 1-2. The flue gas leaving an electrostatic precipitator is processed by a prescrubber and absorber. The flue gas enters the counter current prescrubber just above liquid level. The hot flue gas is contacted with a recirculating spray of ammonium sulfate slurry. In this vessel, the flue gas becomes saturated by evaporation of water from the recirculating slurry. The saturated flue gas leaves the prescrubber through a mist eliminator designed to remove slurry entrained in the flue gas.

After leaving the prescrubber, the flue gas enters a counter current absorber where it is contacted by a recirculating solution of subsaturated ammonium sulfate liquor. Ammonia is added with the oxidation air to maintain the recycle liquor at a pH of 5.2-5.8, thus ensuring the desired SO_2 removal is achieved. The cleaned flue gas then passes through two stages of high efficiency mist eliminators to remove any entrained droplets.

The process functions of SO_2 absorption and oxidation are separated from the function of ammonium sulfate crystallization. SO_2 absorption and oxidation take place in the absorber while ammonium sulfate crystallization takes place in the prescrubber. The process functions of SO_2 absorption, reaction with ammonia, oxidation to ammonium sulfate and crystallization can occur simultaneously in a single vessel. However, it is more cost effective to separate these two functions when the fuel sulfur content is greater than 3-4 wt% sulfur.

At the DGC plant, the design fuel sulfur content is over 5 wt% and the maximum fuel sulfur content exceeds 7 wt%. The nature of the DGC fuel made installation of the prescrubber the most cost effective alternative.

The thermal energy associated with the flue gas is used to evaporate water from the prescrubber slurry as the flue gas is saturated. The evaporation of water causes crystallization of ammonium sulfate product and liquid level reduction in the prescrubber vessel. The subsaturated ammonium sulfate solution in the absorber is used to wash the prescrubber mist eliminator and maintain the prescrubber vessel liquid level. As a result, subsaturated ammonium sulfate solution is introduced into the prescrubber where the excess water is evaporated and crystallization of product occurs.

In the absorber, the SO_2 is removed and reacted with ammonia. The ammonia is introduced into the absorber with the oxidation air. The process can use either anhydrous or aqueous ammonia. If anhydrous ammonia is used, the ammonia is stored in a pressurized or refrigerated vessel and pumped as a liquid to a vaporizer. The vaporizer typically uses steam to vaporize the ammonia prior to introducing it into the oxidation air. If aqueous ammonia is used, the ammonia is stored in a tank and pumped to the absorber directly. With either form of the reagent, the ammonia is added to the absorber to control pH.

Oxidation air is introduced into the absorber to oxidize the ammonium sulfite to ammonium sulfate. Ammonium sulfate solution (10-25 wt% dissolved solids) is bled from the absorber to the prescrubber to maintain level in the prescrubber tank. The fresh make up water required by the process is added to the absorber reaction tank to maintain tank level.

Slurry is bled from the prescrubber to a dewatering hydroclone which increases the slurry density from 10 wt% slurry to 50 wt% slurry. The underflow is fed directly to a centrifuge. A tank can be installed for surge capacity if there is a desire to separate the absorber and dewatering areas. The overflow of the hydroclone is returned to the prescrubber. The hydroclone underflow slurry is dewatered to 99% solids using a centrifuge.

To maximize the byproduct value in the U.S., the ammonium sulfate material in the storage silo is converted from sugar like crystals to the larger granular crystals. To accomplish this, the raw unprocessed ammonium sulfate material is fed from an intermediate storage system to the compaction system where it is mixed with recycle material and fed to a compactor. The compactor presses the material at a high force producing large flakes of ammonium sulfate. This flake is ground in sizing mills, screened and dried. The final on-size product is sent to a large storage dome. All of the compacted product that does not meet the required quality is recycled to the beginning of the compaction process and mixed with fresh feed material. This provides for a closed loop system.

Product Quality

The quality and thus the value of the ammonium sulfate byproduct is subject to four basic physical criteria; purity, size, moisture and hardness. The following represents the quality of the ammonium sulfate produced in this unique process.

Purity	99.0 %
Size	
Granular Grade Particle Size	1.0 - 3.5 mm
Standard Grade Particle Size	0.1 - 0.8 mm
Residual Moisture	< 1.0 wt%
Hardness	Less than 5% loss

Purity

The purity of the ammonium sulfate is a function of the purity of the various feed stocks. In the GEESI process, no additives or other compounds are added in the production of ammonium sulfate. The GEESI process can use ammonia in any form. The commercial unit in North Dakota will be using anhydrous ammonia because it is available at site. The process is equally effective when using aqueous ammonia containing various concentrations of ammonia in water. The process consumes water by saturation of the flue gas. The water in the aqueous ammonia simply displaces a portion of the required make-up water to the system. This flexibility in reagent use allows the producer of the ammonium sulfate the greatest economic benefits from the selection of the feed stock.

In the GEESI process, the sulfur required to produce ammonium sulfate is recovered as unwanted sulfur dioxide in the boiler flue gas. The SO_2 is removed with ammonium sulfate solution and reacted with excess ammonia and air to form ammonium sulfate. The presence of other impurities in the make-up water and/or the flue gas are the only sources of impurities in the final product. Typically flue gas will have trace amounts of hydrochloric acid (HCl) and fine particulate ash. The make-up water will also typically contain some low level chloride ions and other trace salt compounds.

The HCl in the flue gas is readily removed in the prescrubber and reacted with ammonia to form ammonium chloride (NH_4Cl). For most fuels the chloride concentration is considerably lower than the sulfur concentrations. In this process, the chloride species is allowed to increase in the process liquor until it co-precipitates with the ammonium sulfate. Typically this results in a residual ammonium chloride concentration of less than 0.5 wt% of the total product. In a rare occurrence where a relatively low sulfur coal has a high chloride content, the resulting ammonium sulfate product may be 97.5 wt% ammonium sulfate and 2.5 wt% ammonium chloride. This results in a product that is 21.3 wt% N, 23.7 wt% S and 1.5% CL. Thus, the presence of ammonium chloride actually increases the nitrogen content of the final product.

The particulate in the flue gas may vary based on boiler and ESP performance. Typically during normal operation of a modern precipitator system, not enough ash is present to significantly impact the purity of the ammonium sulfate byproduct. Table 1 shows the byproduct purity of various high quality ammonium sulfate. The presence of trace metals in the food and reagent grade are important in the manufacture of ammonium sulfate. During boiler and or ESP upsets, ash content in the flue gas may dramatically increase thus negatively impacting the purity of the ammonium sulfate. (See Table 1.)

The GEESI system uses a solids waste removal system to remove captured particulate from the ammonium sulfate slurry prior to dewatering, thus maintaining the product purity. Typically, removing particulate matter takes on a two step process. In the first step, the particulate impurity is separated from the ammonium sulfate slurry in a device called a hydrocyclone. The hydrocyclone functions as a particulate separation device based on particle size. Typically, the ammonium sulfate particles at this stage of the process are 100-900 microns. The ash particulate removed from the boiler typically range less than 10 microns. The hydrocyclone uses centrifugal action which causes the smaller lighter particles to move to the hydrocyclone overflow and the larger heavier particles to move to the hydrocyclone underflow. In this way, the smaller impurity particles are separated from the larger product particles.

The second step of this process is to take the hydrocyclone overflow, which is rich in impurity particles, and process it with a higher pressure filter press (see Figure 3). The dilute slurry (1-3 wt% suspended solids) is fed to a filter press directly from a filter press feed tank which takes its feed from the hydrocyclone overflow. From the filter press feed tank, slurry is pumped at higher pressure through a multi-stage filter press which allows the liquor to pass through while capturing the solids. When the filter feed pump discharge registers a high pressure, the filter cake which is formed is washed with clean water and pressed dry (~50-60 wt% solids). The cake is then discharged into a waste bin to be disposed of with the boiler ash.

In the event that undesirable metal species are soluble at the operating pH, the pH of the slurry in the filter press feed tank can be raised to precipitate out the metal ions as metal hydroxide prior to the filtering step. This pH adjustment precipitates the heavy metals which are then removed by the filter press. (See Figure 4)

Table 2 shows the purity of the ammonium sulfate byproduct produced in the process demonstration unit in North Dakota. The actual plant flue gas and available reagent were used to produce this byproduct. In this small unit, all of the impurities in the system were allowed to co-precipitate with the final product. No steps were taken to improve the product purity with a filter press or similar device. The flue gas at the DGC plant is relatively free of chlorides and ash so the impurities in the feed stock were low. However, on two occasions the boiler system had a major upset resulting in larger amounts of ash being absorbed in the FGD system. With no way to remove the ash from the slurry, the concentration of fine particulate in the hydrocyclone overflow was high. As can be seen from Table 2, the product purity did not suffer significantly. (See Table 2.)

Size

Size is also a major criterion of the ammonium sulfate byproduct value. There are essentially two grades of ammonium sulfate particles that can be generated by the GEESI process. The first grade is "standard" grade ammonium sulfate that ranges in particle size from 0.1 mm to 0.8 mm. Figure 5 shows the particle size distribution from this process. This is the distribution of the solids as they are recovered from a centrifuge and dried. This particle size distribution requires no additional cost to generate.

Typically, the U.S. markets blend ammonium sulfate with other nitrogen, phosphorous, and potassium compounds. Blending processes require that all of the particles from each of the sources be essentially the same size. This minimizes the segregation of the blends during storage, transportation and application. Most blended products require the individual compounds to have a particle size range such as 1.0 - 3.5 mm. This size ammonium sulfate is commonly referred to as a granular grade ammonium sulfate.

When a granular product is required, the GEESI process uses a compaction system that takes the dewatered and dried standard grade ammonium sulfate and processes it with a roll press compactor (see Figure 6). In this process, the fresh feed ammonium sulfate material is mixed with the fine particles from the compaction process which are recycled to the front of the process. The recycle and fresh feed ratio are controlled to produce the ammonium sulfate product with the hardest particle characteristics. The fresh feed and recycle ammonium sulfate are mixed in a pug mill mixer to insure the recycle and fresh feed material are fully mixed prior the compactor.

The material is fed to a compactor feed screw system that feeds the compactor rolls at high force. The material is forced between the rolls that press or compact the solids into a hard flake which is discharged into a flake breaker. The flake breaker granulates the large flakes into smaller pieces which can then be sized in a series of sizing mills. The sizing mills use hammers and/or chains and specifically sized screens to generate a larger fraction of the material between one and three millimeters in diameter. After being discharged from the mill the particles are screened with all particles less than one millimeter being recycled to the beginning of the process. The particles greater than one millimeter are sent to a dryer where the residual moisture is dried to less than one weight percent.

After being dried, the material is cooled to minimize the amount of moisture adsorbed during storage and handling. The cooled product is screened in a two stage screening process with the material over three millimeters returned to the sizing mills and the material less than one millimeter recycled to the beginning of the process. The final on-size product is transported to the storage dome. In this way the size distribution of the granular product is controlled very closely.

Moisture

It is important to maintain the moisture of the final product as low as is possible. Ammonium sulfate is highly hydroscopic and will have a tendency to set up or bridge in storage. To minimize this potential, the GEESI process uses three specific processing steps to control moisture in the final product.

First, the product is discharged from the centrifuge at approximately 1 wt% moisture. This material is dried immediately to less than 1 wt% moisture using a rotary drum dryer. This makes the moisture of the fresh feed material less than 1 wt% moisture which is important in the control of the hardness of the compacted flake that is produced.

During the process of initial compacting, sizing and screening the material has a trace amount of moisture added to enhance the hardness of the compacted flake. This and any residual moisture is then removed in the final product dryer. The purpose of the second product dryer is to dry any residual moisture from the compacted material to ensure that the final moisture requirements are met.

Finally, as an added measure, the material is cooled to less than 40 °C before being sent to storage. Cooling the product prior to storage minimizes the potential for the ammonium sulfate to absorb water from the air. This helps prevent the bridging phenomenon.

Hardness

The hardness of ammonium sulfate is particularly critical for the granular grade material. The granular material can not be too soft or too brittle or it will not be able to stand up to the rigors of transportation, handling and ultimately blending. During a number of steps in the process, the material has a trace amount of moisture added to the particles to soften and then re-crystallize the surface of the particles. This re-crystallization of the particle surface adds great strength and hardness to the particle.

The hardness is measured by a specific test which involves combining a known weight of steel balls and a known amount of ammonium sulfate on a series of sieves. The entire apparatus is shaken for a set length of time. The amount of material that passes a one millimeter screen during this test is an accurate reflection of the hardness of the material. Typically, the material is deemed acceptable if less than five percent of the original sample passes a one millimeter screen as a result of this test. The material produced in the GEESI process typically averages 1-2 % attrition.

Process Economics

The economics of this process are very important. As with most other forms of manufacture of ammonium sulfate, the GEESI process produces ammonium sulfate as a byproduct. In this case, the production of ammonium sulfate is a byproduct of cleaner air and energy. Typically, the utility or industrial customer are under regulatory compliance to remove SO_2 from the gas exiting their stack.

For a typical 500 MW boiler burning 3 % sulfur fuel, the utility may be required to reduce the SO_2 emissions to 5% of the uncontrolled emission. Traditional technologies will cost the utility approximately $240/ton of SO_2 removed. To make standard grade ammonium sulfate using the GEESI process will cost approximately 20% more capital than traditional technologies. Assuming $180/ton for ammonia consumed by the process, the utility or industrial producer would need to sell the standard grade ammonium sulfate at $38/ton to equal the life cycle economics of the traditional control technologies.

To produce granular ammonium sulfate an additional 20% capital investment for the compaction granulation system is required. For this added investment, the sale price of the ammonium sulfate would need to be $48/ton to have equivalent life cycle economics with traditional technologies. Selling either the standard or the granular grade ammonium sulfate above these threshold values makes the utility or industrial producer more cost effective. For example, at $90/ton for ammonium sulfate in the same economic model, the utility or industrial producer will reduce his cost of environmental compliance by 55% of that using traditional technologies.

With this type of economics for production, the ammonium sulfate made in this process becomes competitive with other nitrogen fertilizers solely on a per ton of nitrogen basis.
(See Table 3.)

There are additional beneficial effects of the ammonium sulfate that other nitrogen fertilizers do not have and thus make the value of the ammonium sulfate far greater than simply for its nitrogen content alone.
(See Table 4.)

As the world requires increasingly stringent controls of air quality, the sources of sulfur in soils are diminishing. Studies in the U.S., Europe and Asia show a steady decrease of sulfur in the soil on each of these continents. Since many crops greatly benefit from sulfur and nitrogen in non-volatile release form, the use of ammonium sulfate as a high valued fertilizer is steadily increasing.

The GEESI process provides an additional source of high quality, high purity ammonium sulfate at competitive prices while simultaneously reducing the emission of harmful acid gasses to the environment.

Conclusion

- The GEESI ammonia scrubbing system was successfully demonstrated at a 3 MW scale with the Dakota Gasification Company. The GEESI system was selected for installation on a 300 MW equivalent steam generating boiler at Dakota Gasification Company's Great Plains Synfuels plant.

- The GEESI process produces a very high quality, high purity ammonium sulfate byproduct in both standard and granular grades.
- The economics of this unique system allow for production of a low cost ammonium sulfate byproduct which is competitive with other nitrogen fertilizers on a per ton nitrogen basis.
- In addition to its nitrogen value, the ammonium sulfate byproduct also provides crops with the needed micro-nutrient sulfur.
- Decreasing sulfur levels in the soils throughout the world ensures the sustained long term growth of ammonium sulfate use.

Table 1: Various Grades of Ammonium Sulfate

	Fertilizer Grade	Food Grade	Reagent Grade
Ammonium Sulfate	99.3%	99.3%	99.7%
Insoluble Matter	NM	0.3%	0.005%
Free Sulfuric Acid	0.05%	0.01%	0.005%
Moisture	1.0%	0.15%	0.15%
Arsenic	NM	0.5 ppm	0.5 ppm
Iron	27 ppm	15 ppm	5 ppm
Selenium	NM	5 ppm	5 ppm
Other Heavy Metals	10 ppm	8 ppm	3 ppm

NM = Not measured

Table 2: FGD Ammonium Sulfate vs. Various Grades of Ammonium Sulfate

	DGC Ammonium Sulfate	Fertilizer Grade	Food Grade	Reagent Grade
Ammonium Sulfate	99.6%	99.3%	99.3%	99.7%
Insoluble Matter	0.03%	NM	0.3%	0.005%
Free Sulfuric Acid	0.01%	0.05%	0.01%	0.005%
Moisture	< 0.1%	1.0%	0.15%	0.15%
Arsenic	< 1.0 ppm*	NM	0.5 ppm	0.5 ppm
Iron	33 ppm	27 ppm	15 ppm	5 ppm
Selenium	< 1.0 ppm*	NM	5 ppm	5 ppm
Other Heavy Metals	4 ppm	10 ppm	8 ppm	3 ppm

* Detectable limit of the instrument

Table 3: Price Comparison of Ammonium Sulfate with Other Nitrogen Fertilizers

Fertilizer	$/Ton	$/Ton N
Urea	$ 200	$ 429
Ammonium Nitrate	$ 160	$ 457
Ammonium Sulfate	$ 90	$ 424

Table 4: Benefits of Ammonium Sulfate

- Non volatile nitrogen source
- Sulfur is an ideal micro-nutrient for many crops
- Non-explosive
- Compaction system ideal place for slow release polymer addition

Figure 1: GE Ammonium Sulfate Process Absorber Island

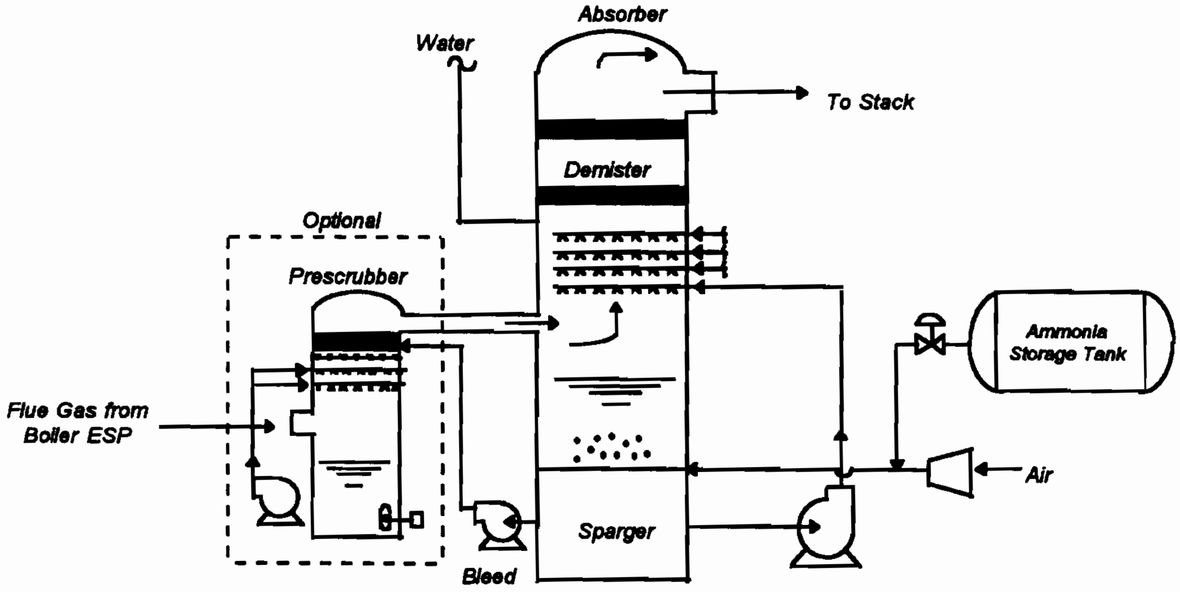


Figure 2: GE Ammonium Sulfate Process Dewatering System

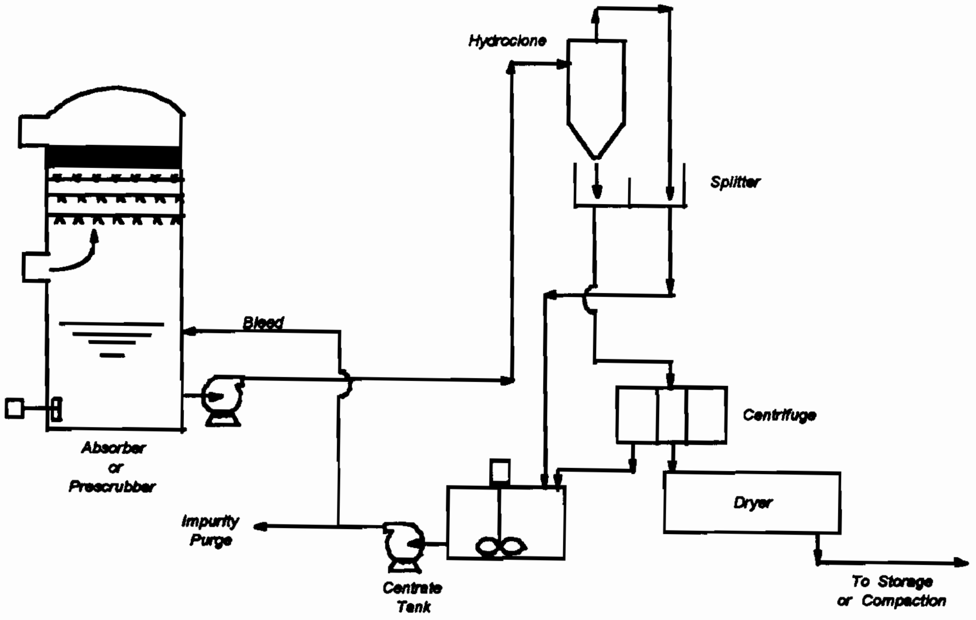


Figure 3: Suspended Impurities Removal

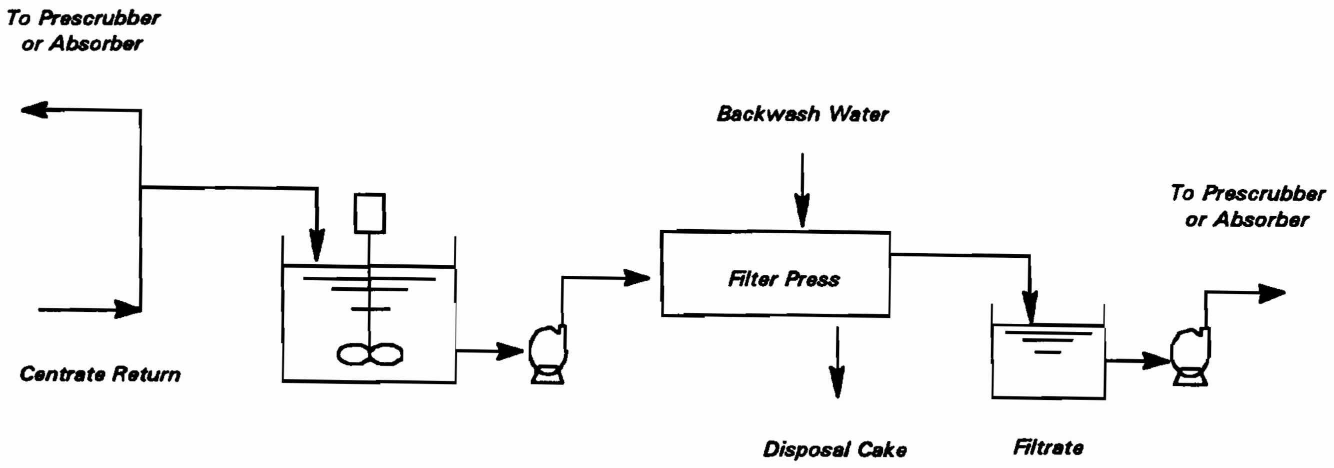
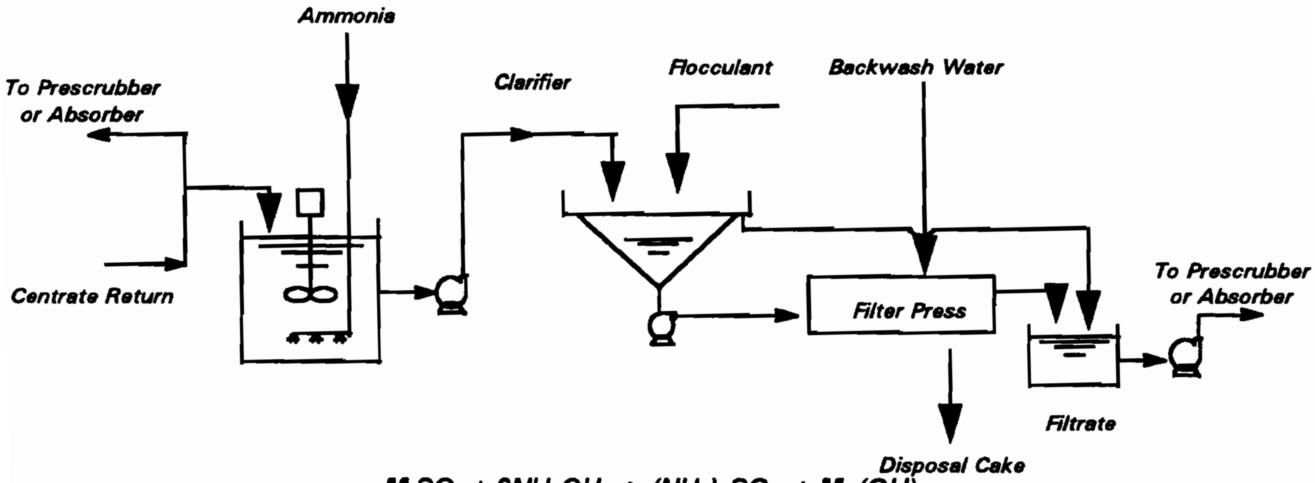


Figure 4: Impurities Purging Slipstream



$M\,SO_4 + 2NH_4OH \dashrightarrow (NH_4)_2SO_4 + M\,(OH)_2$

M = trace metals

Figure 5: Particle Distribution for FGD Ammonium Sulfate

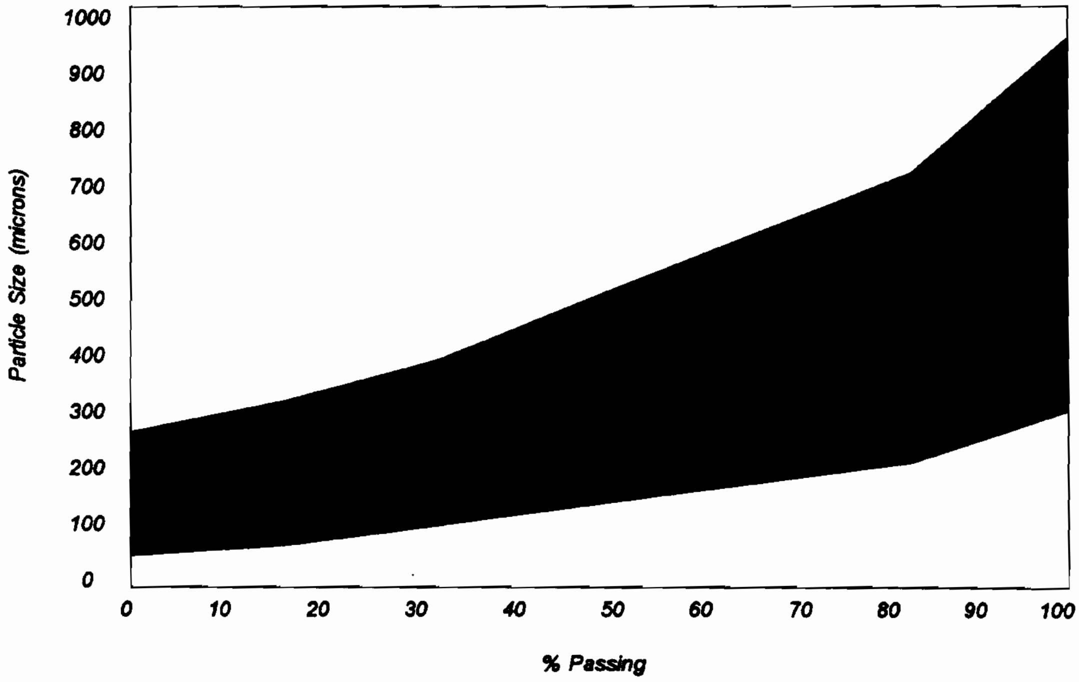
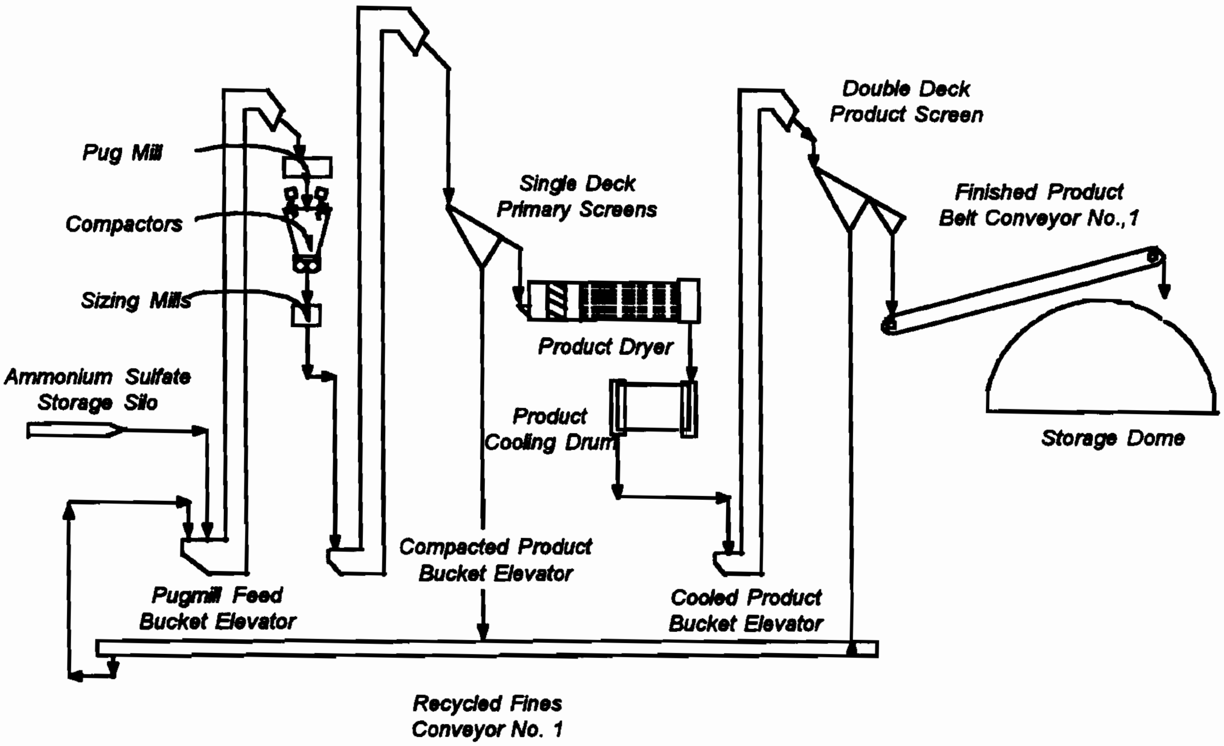


Figure 6: GE Ammonium Sulfate Compaction Granulation System Process Flow Diagram



Wednesday, October 30, 1996

Session V

Moderator:

Michael Hancock

DAP Production Quality Improvements

Randy Charlot
CF Industries, Inc.

In the last decade a variety of factors combined to create the need for DAP product quality improvements at the Plant City Phosphate Complex. Product size, "caking"/handling, dust generation characteristics and nutrient grade enhancement have been improved through a combination of capital projects and operating practice. The following is a discussion of these improvements.

The Evolution of Product Size Within CF Industries

In the early 1980's the term Size Guide Number (SGN) was only beginning to surface in the US Fertilizer Industry. The SGN is the calculated diameter of the median particle size expressed in millimeters then multiplied by 100. For example, a SGN of 200 simply means the median particle size is 2.00 millimeters.

During the early 1980's the Plant City Phosphate Complex produced a fertilizer product with a SGN of 180. This SGN was typical of the dry fertilizers at this time.

In 1984, CFI began exporting a portion of its fertilizer products to the European market. However, the European market required a larger product size of 85% 200 SGN to 400 SGN or approximately 85% -5 Tyler mesh to +9 Tyler Mesh.

With more rigorous process control and minor equipment changes the product size evolved from a 180 SGN to a 230 SGN to satisfy the European market (see Figure 1). This larger product size material was also delivered to the domestic market and CFI members.

The small increase in product size favorably impacted several product quality issues in the domestic market. First, the CFI members preferred the larger product because of "appearance" and the "ease of handling." Second, a reduction in fugitive dust and fines was evident both in house and throughout the distribution facilities. Third, a reduction in member complaints about segregation and nutrient deficiencies was also observed with the increased product size. For these reasons, CFI continued to produce the larger ammoniated phosphate fertilizer after the agreement with the European market was complete.

In the late 1980's the typical NPK raw materials used in the blending process by CFI members had the following SGN's: granular Potash was 265, DAP was 230 and granular Urea was 200.

It was becoming more apparent to CFI from industry literature and internal observations that raw NPK materials with a similar SGN tended to blend more efficiently with less segregation. This is important because it provides a uniform nutrient value being applied to the land and reduces penalties for nutrient deficiencies. This concept infers that all the raw NPK material should be produced with similar SGN's. However, what SGN was the appropriate one for CFI?

An internal decision was made to increase DAP and granular urea product sizes towards the larger 265 SGN of granular potash. The basis for this decision was established from observations surrounding the first size increase. CFI members were receptive to the larger DAP product size; therefore, increasing DAP to the 265 SGN was perceived to be the correct move. Also, the previous small increase in DAP product size clearly showed a reduction in fugitive dust and fines. Consequently, a further increase in DAP product size could possibly result in less fugitive dust and fines. The granular urea SGN was increased in order to maintain the lower probability of segregation in the bulk blending process.

Currently, the CFI members have available to them all NPK raw materials with a SGN of 265 (see Figure 1). The resulting product quality improvements with the larger product size have been customer satisfaction, less segregation, and a reduction in fugitive dust and fines.

"Caking" and Handling Improvements

Within the last decade, DAP production rate increases and changes in shipping patterns have caused product to be shipped from the Plant City Phosphate Complex at higher than desirable temperatures. The shipping of higher temperature DAP products resulted in both product bridging and moisture condensation or "caking." These are product quality issues that cause product degradation and problems in the unloading process.

Product bridging tends to occur when DAP is loaded into railcars or barges at temperatures greater than 140 °F. The moisture content and the elevated temperature cause the formation of agglomerates and lumps through a process of surface dissolution and recrystallization. When DAP temperatures are much greater than 140 °F and the material loaded into airtight compartments, such as railcars, moisture condensation tends to occur at the top and along the walls of the compartment. Contact between the condensing moisture and the water soluble DAP causes degradation of the product or "caking." To reduce the probability of these product quality issues from occurring, the "hot" product requires cooling. The loading temperatures for DAP are typically less than 120 °F.

To better understand how the product cooling issue has become important in the last decade some general background is necessary. The Plant City Phosphate Complex has four granulation units, referred to as "A", "X", "Y" and "Z" trains. The "A" and "Z" trains were originally built to granulate DAP and are equipped with product cooling capabilities. The "X" and "Y" trains were originally designed to granulate GTSP and were constructed without product cooling capabilities.

The method used by most DAP manufacturers to avoid the shipment of hot DAP is to cool the product as it leaves the process going to the storage facility. DAP passes through a rotary drum product cooler that uses cool air to remove heat from the product (Figure 2). Some manufacturers use air chillers to cool the air to less than ambient temperatures before it is used in the product cooler. "A" train's cooling capabilities consisted of a fluidized bed type cooler with no air chiller. "Z" train had a rotary drum cooler without an air chiller.

DAP production increases were achieved over a period of time by converting the "X" and "Y" trains from GTSP production to a DAP/GTSP production. In addition to the conversion of these two plants, various small debottlenecking projects resulted in rate increases. Consequently, DAP production increased from 800,000 tons in 1980 to 1.3 MM tons in 1984, and to 1.9 MM tons in 1988. At the original design rates, the loading temperatures of DAP product from "A" and "Z" were approximately 110 °F to 120 °F. With the increase in rates, the loading temperatures increased to 130 °F to 140 °F. The loading temperatures of DAP product from "X" and "Y" were approximately 160 °F to 170 °F.

In the mid-1980's, a majority of the DAP product was shipped on transport vessels across the Gulf of Mexico, off loaded on river barges, and transported to warehouses along the Mississippi River. This provided the Plant City Phosphate Complex with a distribution strategy of shipping "hot" DAP product via the river barges and the cooled product via railcar.

The loading and off loading of product several times from ships to barges then to warehouses, together with the increased transportation time, allowed the "hot" DAP from "X" and "Y" trains to cool considerably. This helped minimize problems associated with bridging and condensation.

In 1988, the railroads began to recapture their historic share of the phosphate transportation business through programs designed to compete head-on with barge and truck modes. Thus, the combination of the market's renewed interest in rail shipments and the Company's reliance on Plant City as its primary source of DAP, resulted in increased pressure on Plant City's railcar shipping capabilities. Consequently, incidents of product bridging and condensation were more likely to occur as the shipments of "hot" DAP via railcar began to increase.

It was clear that the Plant City Phosphate Complex required additional product cooling capacity in order to resolve product quality problems. To accomplish this, CFI developed a program of product cooling capital improvements which involved three separate projects. In 1989, "Z" train's existing product cooler was equipped with an air chiller and "A" train's fluidized bed cooler was replaced with a rotary drum cooler and air chiller. In 1990, a rotary drum cooler and air chiller were installed on "Y" train and the same product cooling capabilities were installed on "X" train in 1993 (see Figure 3).

Along with the capital improvements, product cooler performance was improved through several cooler optimization projects. In one project the lifting flights in the rotary drum cooler were modified to increase lifting capacity and improve distribution in the cooler. To complete this modification a fourth 2-3/4" segment was welded to a three segment lifting flight. A computer program was developed to model the effects of flight modifications on DAP distribution and lifting capacity. One of the goals was to distribute DAP completely across the diameter of the drum to prevent air tunneling. The other goal was to increase the density of DAP falling near the center of the drum where it has the longest contact time with air. The project increased the lifting capacity by 43% and decreased the product temperature by an average 8.2 °F (see Figure 4).

Improvements in product cooling capabilities on all four granulation plants have enabled the Plant City Phosphate Complex to supply its members with approximately 2.1 MM tons per year of dry fertilizer products with an average loading temperature less than 120 °F. The cooler loading temperatures significantly reduced problems associated with product handling and "caking" to maintain a high product quality standard (see Table I).

DAP Dust Characteristics and Control

Over the last two decades safety, health, and environmental concerns have led North American fertilizer producers to be more conscious of product dust problems and the increasing importance of anti-dust agents.

In phosphate based fertilizers dust is produced during the manufacturing and handling processes. Dust is created when minute particles, generally <50(km, are broken from the surface of granules as they tumble through rotary drum granulator, dryers and coolers. Dust is also generated during screening, conveyor transfers, elevator transport, and during loading/unloading operations. The formation of fine crystals on the surface of granules during the granulation process can also be a major source of dust particles. Dust suppression can be accomplished through modifications in the manufacturing process and by applying anti-dust agents before storage or shipping.

At CF Industries Inc., dust suppression in the DAP manufacturing process is accomplished through control of ammoniation, control of product size and uniformity, and with the addition of lignin. Ammoniation is shifted more heavily toward the prenuetralizers and away from the granulator where over ammoniation can result in the growth of fine crystals inherent to dust generation. Typically, the ratio of granulator to prenuetralizers ammonia rates should be maintained below 40%.

Increasing product size and uniformity while producing a nearly spherical granule is an important manufacturing tool to reduce dust generation. Increasing particle size and uniformity reduces the surface area thereby limiting dust generating surfaces. For example, increasing the product size from 180 SGN to 265 SGN reduces the surface area by 32%.

A lignin, typically supplied as a viscous calcium lignosulfonate, is added in the granulator at an application rate of 0.25%. The wood derived lignin helps suppress dust by binding to the granular surface and producing a more stronger fracture resistant granule. The lignin also promotes improved DAP product quality by helping to produce a darker more aesthetically pleasing DAP product. In reality, adequate control of product dusting is not attainable through production controls alone and a dust control agent is normally required.

Several types of dust control agents have been tested or used in phosphate fertilizers including: vegetable and petroleum oils, natural and petroleum based waxes, petrolatum's, and emulsions. However, currently used dust control agents are primarily petroleum hydrocarbons. These oils control dust by coating the particles with a thin high surface tension film. The oil coating film binds small dust particles to larger particles or agglomerates several dust particles together resulting in particles too heavy to become airborne. A 1995 industry survey, courtesy of KEMWorks Technology, Inc. (see Table II), shows that all phosphate fertilizer manufactures polled, except for one company, were using petroleum based oils.

Anti-dust coating agents were reported to be used at CF as early as 1966. At CF coating oil was applied by sprays in ladder chutes just prior to shipping. In 1993 CF installed ribbon blenders to apply coating oil prior to shipping (see Figure 5).

The ribbon blender improved the distribution of oil on the DAP granules. Paddles on the blender are adjustable to increase or decrease the intensity of the mix. Adjusting the paddles will also adjust the fill height in the mixer. Figure 6 shows the screw shaped ribbons and paddles located in the mixer. A slight drop in oil usage rates was experienced following installation of the ribbon blenders. Tunnel dust testing on DAP before and after the ribbon blenders were installed indicated that dust generation levels dropped marginally.

DAP Grade Enhancement

Over the last decade CF has increasingly had to deal with lower BPL and higher metals in the phosphate rock. This factor along with substantial increases in production rates has made it harder to achieve a DAP grade of 18-46-0. In addition CF operates two 1200TPD single absorption sulfuric acid plants that use ammonia scrubbing and produce a byproduct stream of ammonium sulfate liquor. The liquor is consumed in DAP production where it acts as a P2O5 diluent and minor nitrogen grade enhancer.

When the metals to P2O5 ratio, MER, for wet rock is compared to the DAP nitrogen grade a good correlation is usually found. At CF Plant City a linear regression for MER and DAP Nitrogen grade for the first 9 months of 1996 gives a correlation with an R^2 of 94% (see Figure 7). This correlation can be shifted up by improving clarification or by adding a DAP nitrogen grade enhancer.

Solids in the 26% DAP feed acid have steadily been increasing since 1985 and are attributed to substantial increases in production throughput and the mothballing of a uranium extraction process in 1992 (see figure 8).

To help improve clarification and reduce the acid solids, CF is in the process of reconfiguring the 28% and 40% clarification systems. Currently all 40% acid is clarified in either a 54' diameter rake tank or a lamella clarifier. The 40% sludge is currently mixed with #1 filtrate. The #1 filtrate is clarified in two 80' diameter rake clarifiers. Acid sludge from these clarifiers is filtered on a belt filter.

In the reconfiguration project the primary 40% clarification will be done in one of the two 80' rake clarifiers. The second 80' clarifier will be used to clarify only 26% DAP feed acid. The 26% and 40% acid sludge will be combined and filtered on the belt filter. The reconfiguration will increase 40% aging from 16hr to 39hr and reduce clarifier throughput by 24%. The 26% Acid aging will increase from 14.5hr to 20hr and the clarifier throughput will reduce by 20%. The estimated impact from the reconfiguration project is a 0.2% boost in DAP nitrogen and 0.5% boost in DAP P2O5 grade (see Figure 7).

Several DAP nitrogen grade enhancement additives have been tested at CF Plant City including sulfuric acid, ammonium sulfate, nitric acid, urea solutions, granular urea, and UAN-32%. The recovery of nitrogen from these additives was 90% or greater except for some of the urea tests which had recoveries as low as 60%. Spraying urea solutions in the product cooler resulted in a low recovery of nitrogen. The poor recovery was attributed to dust formation from the urea coating on the DAP. A comparison of the economics shows that UAN-32% offers the lowest cost per ton of DAP product, (see Figure 9). The UAN-32% is currently the choice additive at CF Plant City that is being added to the suction of the preneutralizers slurry pumps at a rate of 1-2 gallons per ton DAP production.

Summary

Improvements in DAP product quality have been achieved through a combination of capital projects and process changes. Increasing the product size, providing adequate DAP cooling capacity, improving product oil coating, improving clarification and using grade enhancement additives have combined to improve the company's reputation for producing and shipping a high quality fertilizer product.

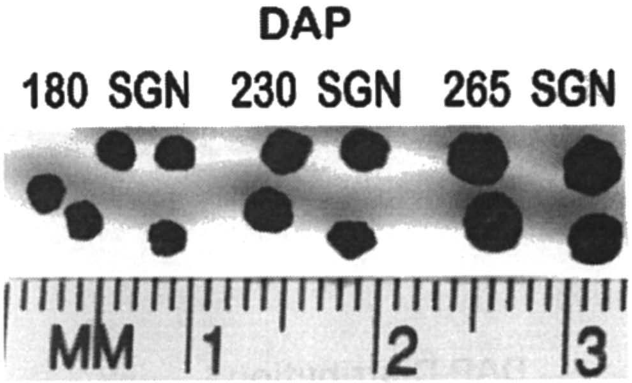


Figure 1. Size comparison of 180, 230, and 265 SGN of DAP particles.

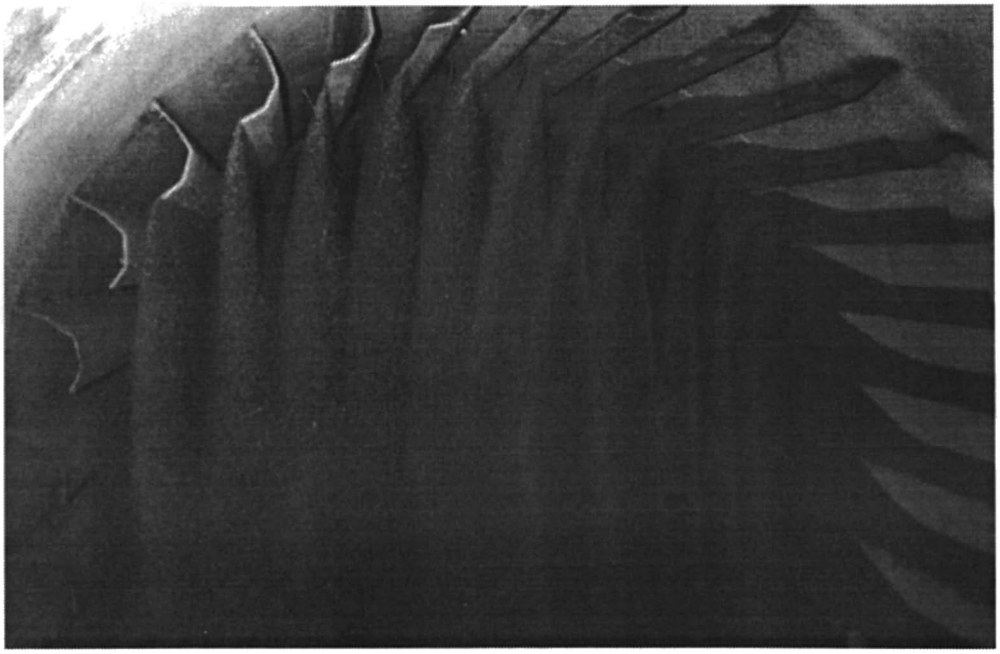


Figure 2. Curtain of DAP inside Product

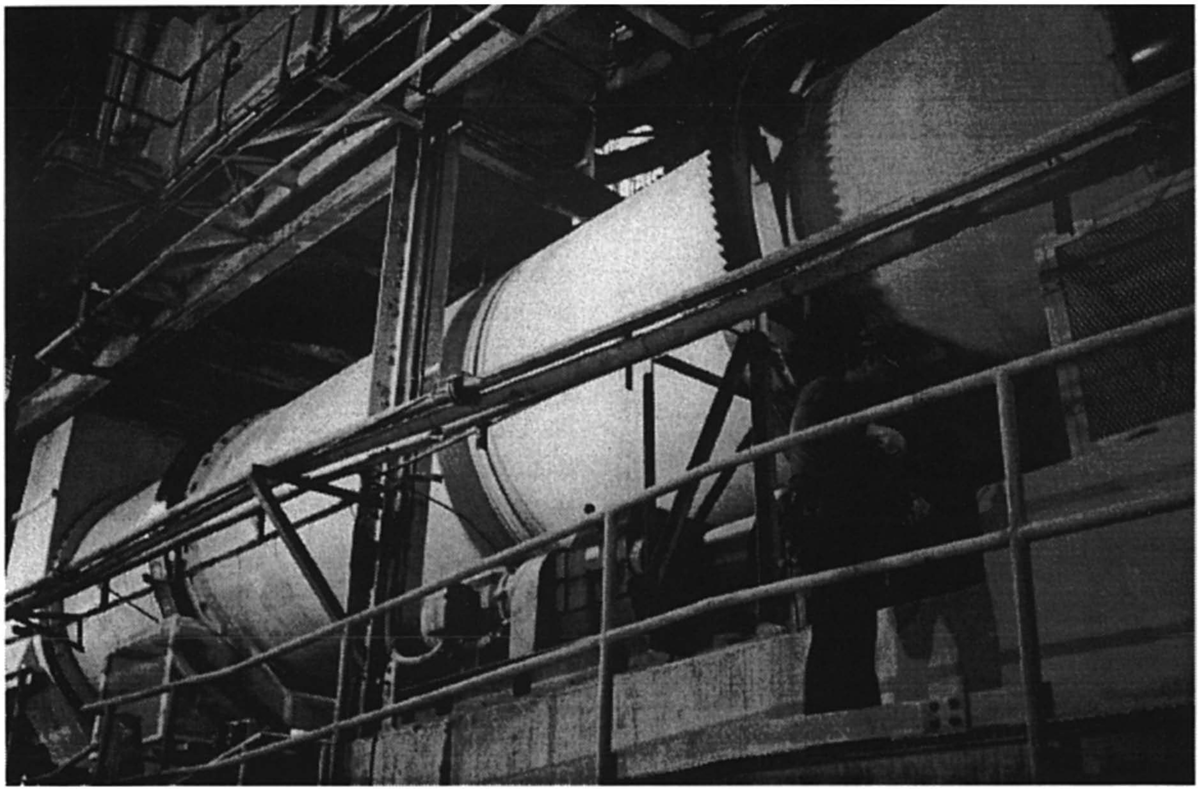


Figure 3. “Y” train’s Product Cooler.

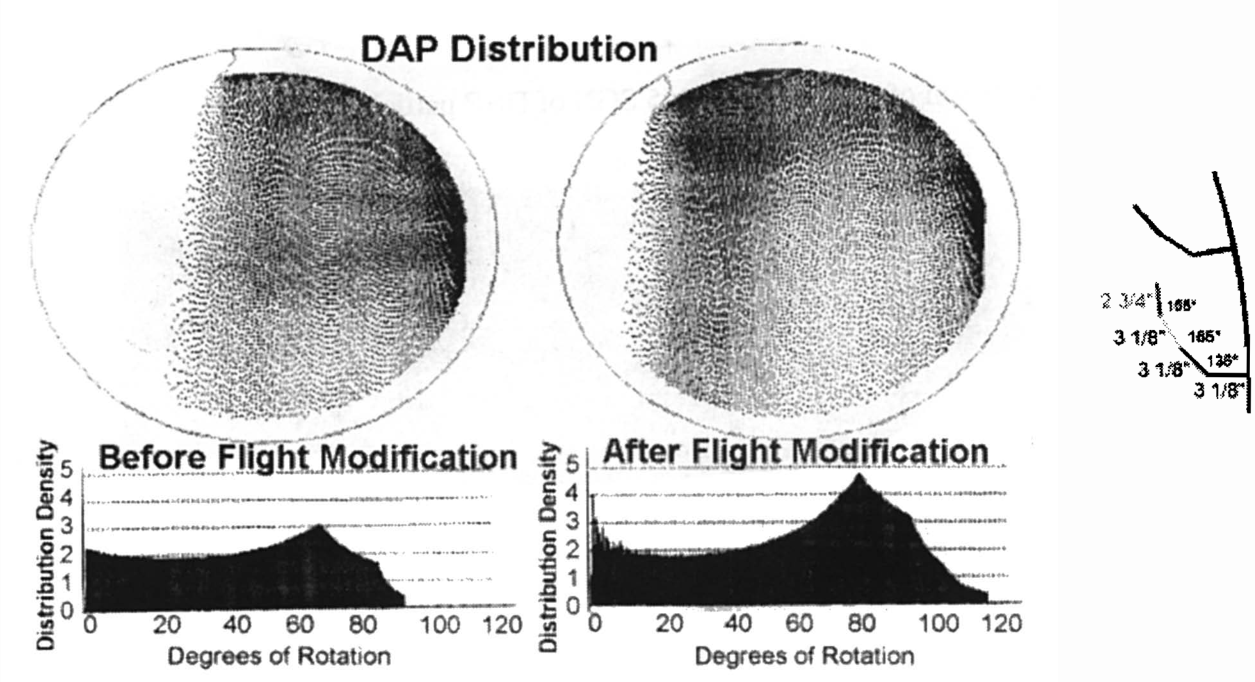


Figure 4. Product Cooler Distribution and Flight Modifications.

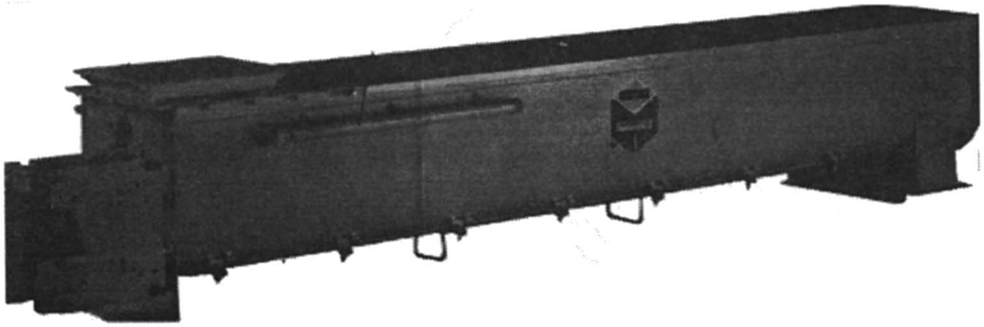


Figure 5. Scott Ribbon Blender.

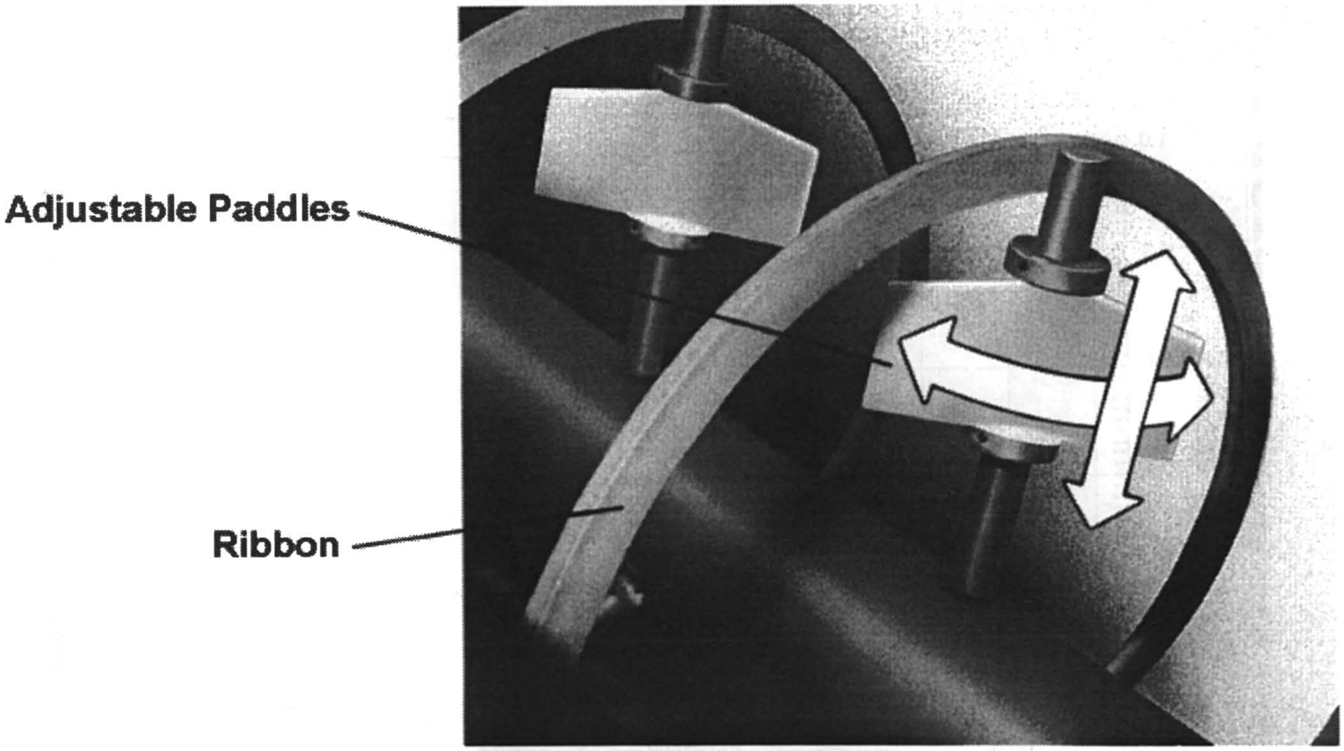


Figure 6. Screw Shaped Ribbons and Paddles Located in Mixer.

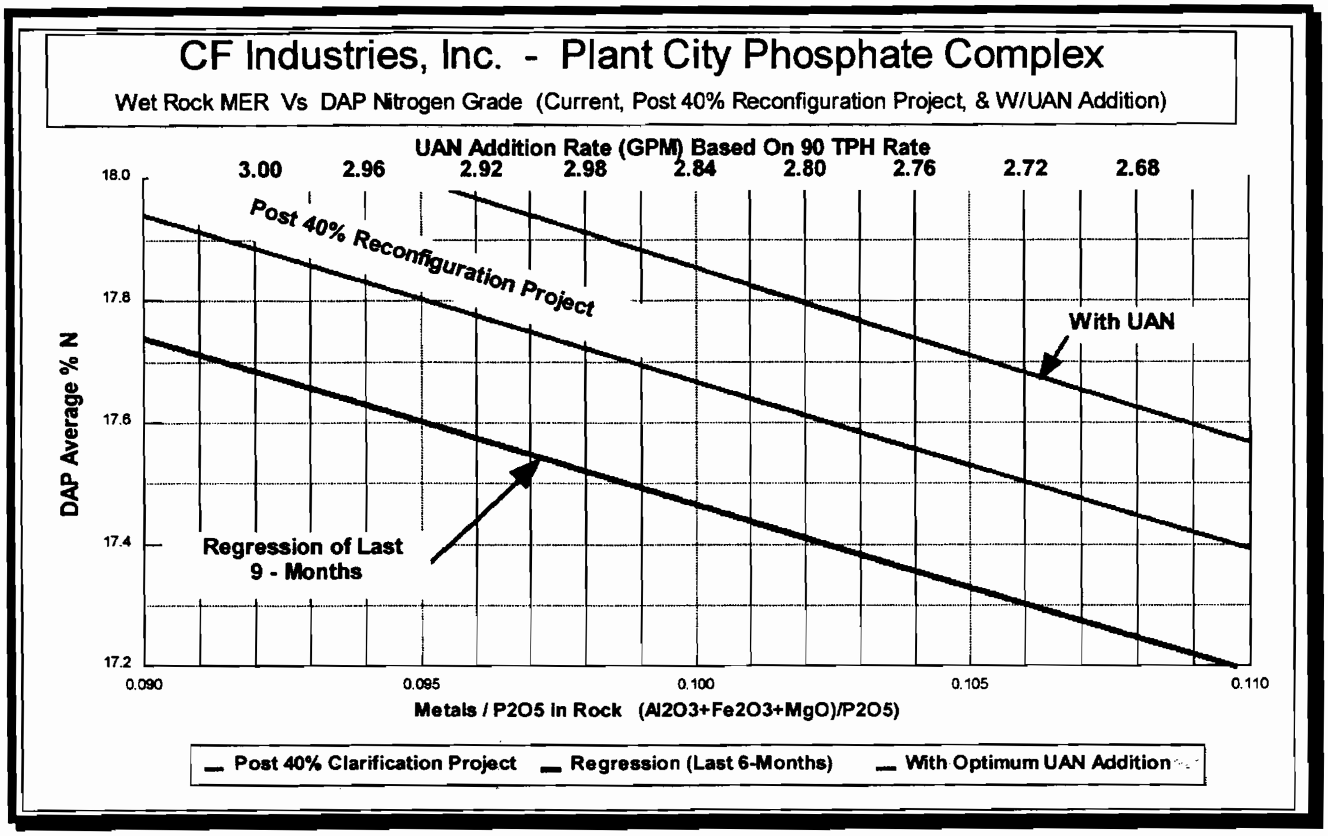


Figure 7. Linear Regression for MER and DAP Nitrogen Grade.

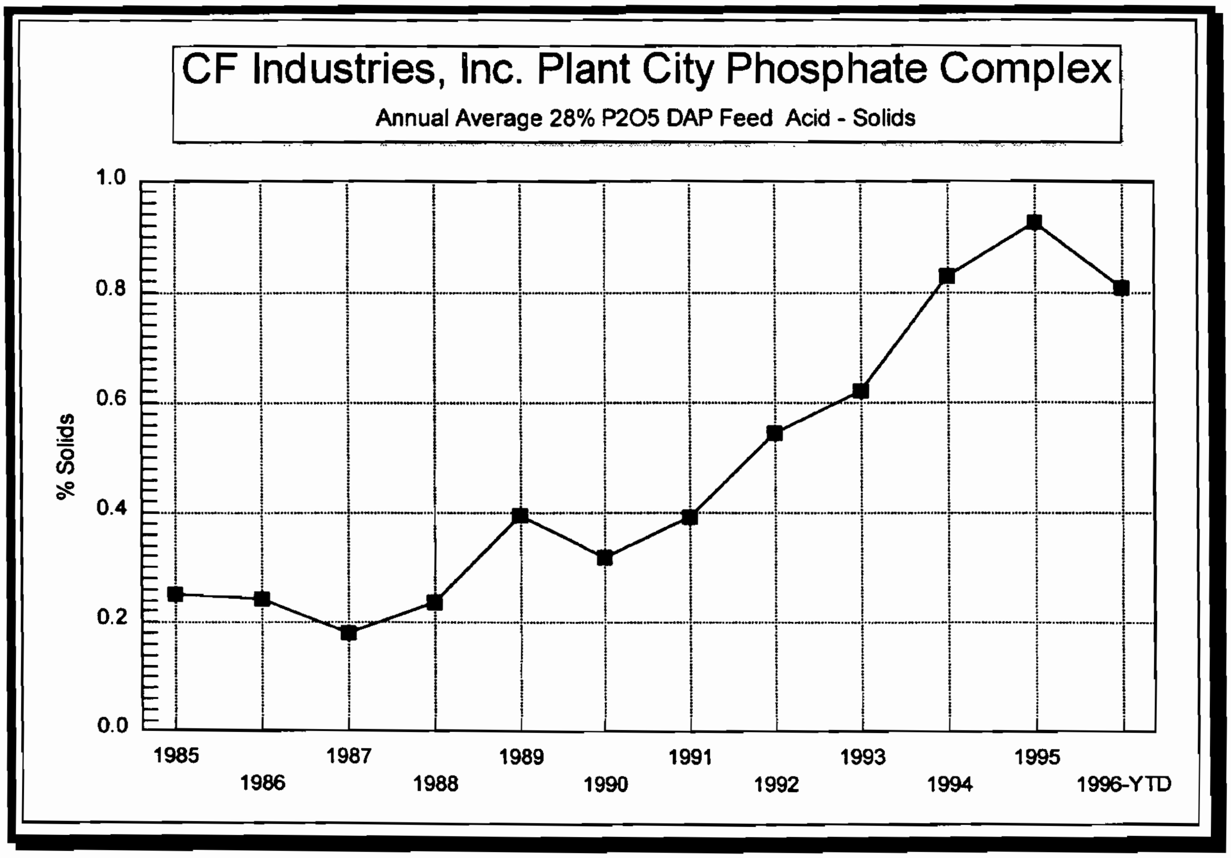
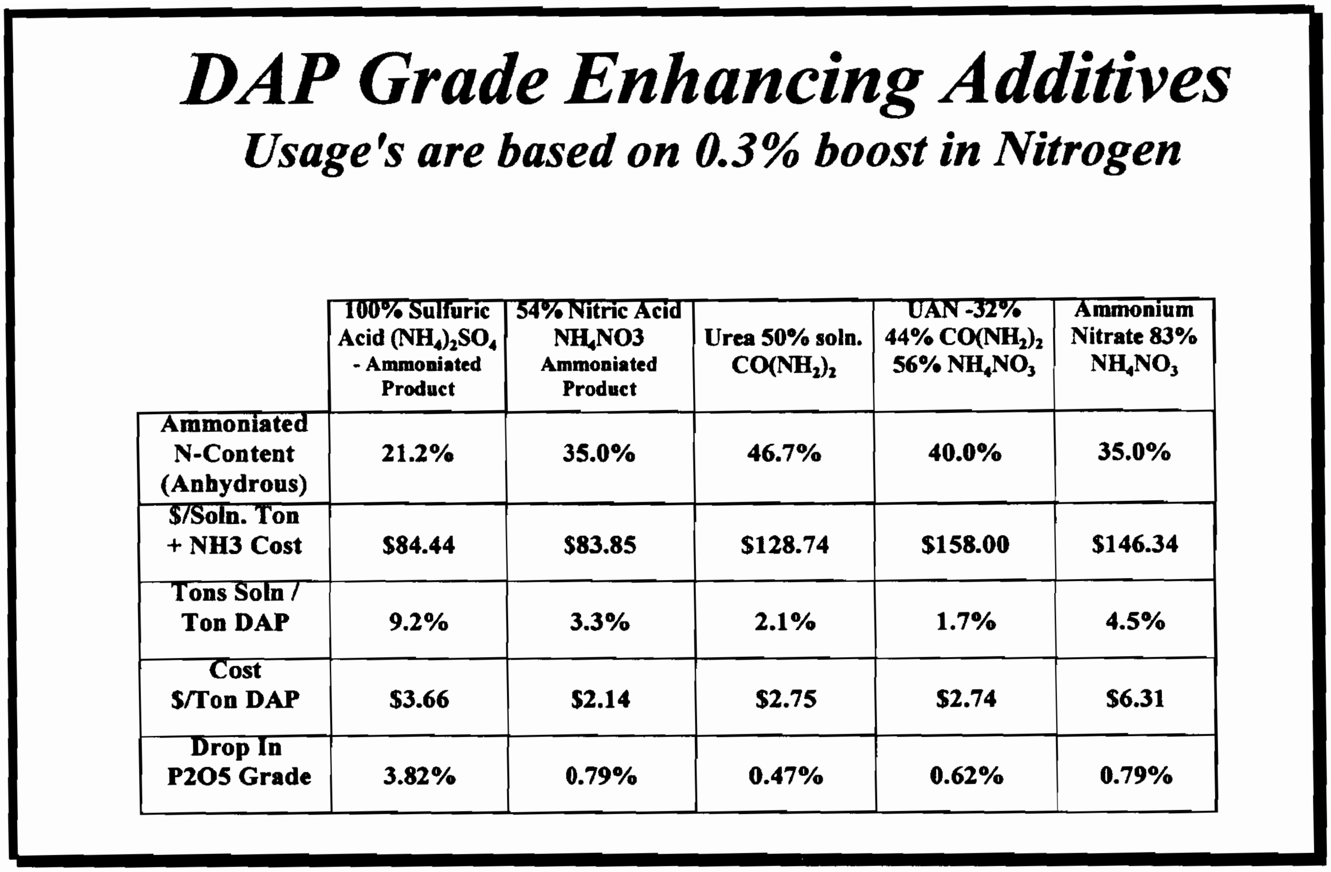


Figure 8. Increases in Production Throughput (1992).



DAP Grade Enhancing Additives

Usage's are based on 0.3% boost in Nitrogen

	100% Sulfuric Acid $(NH_4)_2SO_4$ - Ammoniated Product	54% Nitric Acid NH_4NO_3 Ammoniated Product	Urea 50% soln. $CO(NH_2)_2$	UAN -32% 44% $CO(NH_2)_2$ 56% NH_4NO_3	Ammonium Nitrate 83% NH_4NO_3
Ammoniated N-Content (Anhydrous)	21.2%	35.0%	46.7%	40.0%	35.0%
$/Soln. Ton + NH3 Cost	$84.44	$83.85	$128.74	$158.00	$146.34
Tons Soln / Ton DAP	9.2%	3.3%	2.1%	1.7%	4.5%
Cost $/Ton DAP	$3.66	$2.14	$2.75	$2.74	$6.31
Drop In P2O5 Grade	3.82%	0.79%	0.47%	0.62%	0.79%

Figure 9. DAP Grade Enhancing Additives.

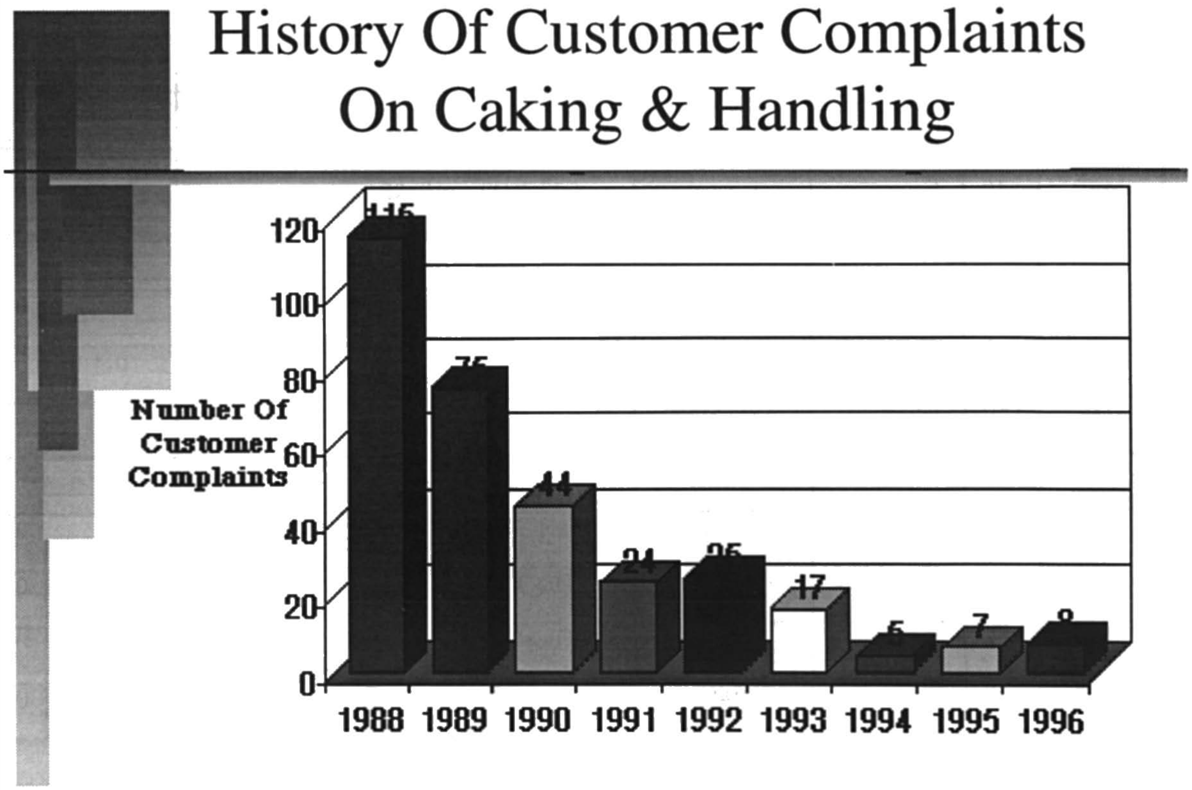


Table 1. History of Customer Complaints on Caking and Handling.

Plant	Product	(F	Class	Coating Agent Supplier	Product I.D.	Point of Application	Usage Gal/Ton	Rate
A	DAP	125	Petroleum oil	ARR-MAZ	Dustrol 3700	Cooler	0.75	0.30%
A	DAP	150	Petroleum oil	ARR-MAZ	Dustrol 3700	Cooler	0.75	0.30%
A	MAP	125	Petroleum oil	ARR-MAZ	Dustrol 3700	Cooler	0.75	0.30%
B	DAP	115	Petroleum oil	ARR-MAZ	Dustrol 367	Cooler & at loading	1	0.40%
B	DAP	160	Petroleum oil	ARR-MAZ	Dustrol 367	Coating drum & at loading	1	0.40%
B	TSP	145	Petroleum oil	ARR-MAZ	Dustrol 367	Coating drum & at loading	2.5	1.00%
B	DAP	140	Petroleum oil	ARR-MAZ	Dustrol 367	Cooler	0.6	0.24%
C	MAP	140	Petroleum oil	ARR-MAZ	Dustrol 367	Cooler	0.6	0.24%
C	TSP	180	Petroleum oil	ARR-MAZ	Dustrol 367	Ladder chute & at loading	1.2	0.48%
C	DAP	160	Petroleum oil	NA	Dustrol 3015N/3064	Plant chute & ribbon blender at shipping	.63/.25	.25%/. 10%
D	MAP	195	Petroleum oil	NA	Dustrol 3015N/3064	Plant chute & ribbon blender at shipping	.63/.25	.25%/. 10%
D	DAP	125	Petroleum oil	ARR-MAZ	Dustrol Product	Plant chute & ribbon blender at shipping	.63/.25	.25%/. 10%
E	MAP	125	Petroleum oil	ARR-MAZ	Dustrol Product	Plant chute & ribbon blender at shipping	.63/.25	.25%/. 10%
E	DAP	120	Petroleum oil	ARR-MAZ	Dustrol 3015W	Ribbon blender at shipping	0.5	0.20%
F	MAP	120	Petroleum oil	ARR-MAZ	Dustrol 3015W	Ribbon blender at shipping	0.5	0.20%
G	DAP	150	Petroleum oil	ARR-MAZ	Dustrol 338	Cooler	0.5	0.20%
G	DAP	150	Petroleum oil	ARR-MAZ	NA	Ribbon blender at loading	0.75	0.30%
H	DAP	150	Petroleum oil	ARR-MAZ	NA	Ribbon blender at loading	0.75	0.30%
H	DAP	120	Footswax	Unacal	Wax unit bottom	Cooler discharge	NA	0.25%
I	MAP	130	Footswax	Unacal	&22% Oil	After FBC on mixing screw	NA	0.60%
J	MAP	120	Petroleum oil	ARR-MAZ	Dustrol 3088	Ribbon blender after cooler	NA	0.30%
K	DAP	NA	Petroleum oil	ARR-MAZ	Dustrol Product	Coating drum	0.5	0.20%
K	DAP	150	Petroleum oil	ARR-MAZ	Dustrol Product	Cooler	0.4	0.16%
L	DAP	150	Petroleum oil	ARR-MAZ	Dustrol Product	Cooler	0.75	0.30%
L	DAP	150	Petroleum oil	ARR-MAZ	Dustrol Product	Cooler	0.45	0.18%
M	MAP	125	Petroleum oil	ARR-MAZ	Dustrol 3115D\	Steam Atomized in cooler	1	0.40%
N	DAP/MAP	122	Petroleum oil	Petrobras	Fuel Oil	Cooler discharge	NA	0.25%
O	MAP	167	Petroleum oil	Ipirango	Fuel Oil	Coating drum after polishing screens	NA	0.25%
P	DAP	149	Petroleum oil	Ipirango	Fuel Oil	Coating drum at screens & cooler	NA	0.25%

Table 2. Anti-Dust Coating Agents Phosphate Fertilizer Industry Survey July 1995.

How Safe is Your Fluid Storage?

Edward Norris
Steve Sutter
The Andersons, Inc.

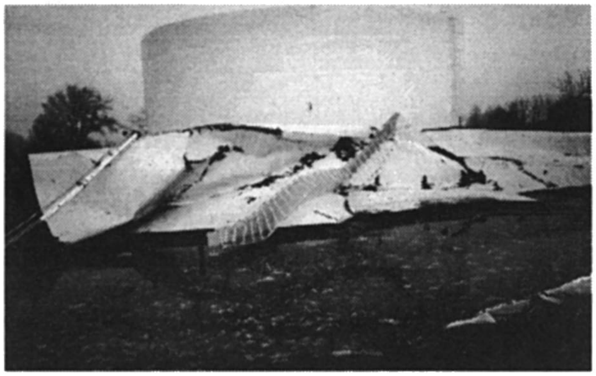
How Safe Is

How safe is your storage?

If someone asked me that question on March 30, 1995 I would have said it was very safe.

The Andersons always employed what we thought were reputable contractors for tank construction, and our tanks were periodically visually inspected by in house technicians. What's more, we prided ourselves on our environmental stewardship programs, and routinely invited State regulators in to inspect the premises. Like many of you, we pumped hundreds of thousands of dollars into diking and other containment, to insure ourselves against an environmental catastrophe. As it turns out, we did some things very well, and other things not so well.

On March 31, 1995 at about 5:20 in the afternoon, a 1/2 million gallon 10-34-0 tank, filled to capacity in preparation for the spring season, experienced a catastrophic failure at The Andersons facility in Poneto, Indiana. What we hope to accomplish today, is to share with you what we did right, and also what we did wrong. Although a catastrophic failure similar to what we experienced in Poneto is an extremely rare occurrence, it could happen to you.

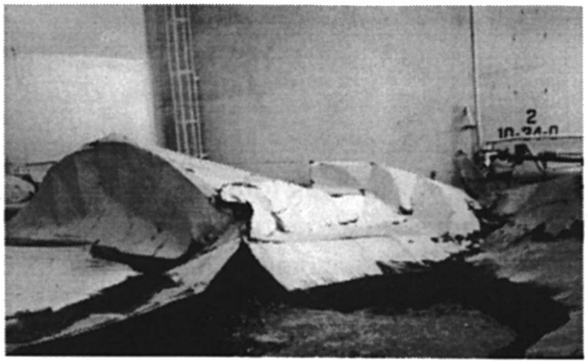


When I received the call informing me of the situation, I was on a winter vacation in Leesburg, Fla., about 900 miles from home, it might has well have been 9000 miles. Fortunately, we have quality folks like Mr. Steve Sutter who can and did jump right in. I will let Steve take over, like he did that day, and tell you how he and many other folks attempted to deal with this near disaster.

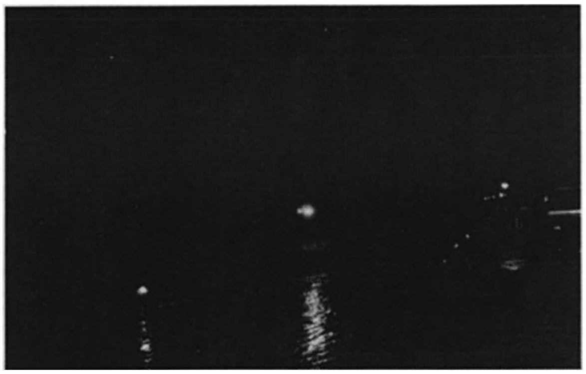
When I received "THE" call I began to make the contacts required by the existing spill procedures. So far, so good. That was the easy part. We quickly ran out of "scripted" material. For the next 48 hrs, virtually everything we did was done by instinct. We had no experience with tank failures of this magnitude, nor had we gone through any formal "what if" planning.

Lesson #1

Think through all of the "What Ifs". Have a plan in place for the unexpected.



When I arrived on site, this is the scene that greeted me.



The tank failure had wiped out all of the power going to the tank farm, and we had power lines down everywhere. Those electrical lines that remained in place had to be shut off for fear of injuring clean-up workers. Since we had not considered this possibility, we had no generators on site to provide emergency power. The only lighting available initially was from the headlights of the trucks we called to help with the clean-up efforts.

Our first priority was to empty the 1 million gallon tank adjacent to the failed tank. When the 1/2 million collapsed, it damaged the flange on the 1 million gallon tank, which was also full. This damaged flange was leaking about a finger sized stream into the dike. In addition, we had no way of knowing whether or not the 1 million gallon tank was structurally sound.

Once this decision was made, it was just a matter of pumping down the 1 million gallon tank and easing the immediate crises right? Right! Except where do we pump it? And how do we pump it?

Lesson #2

Have Generators and Gas Powered Pumps on Hand or Readily Available.

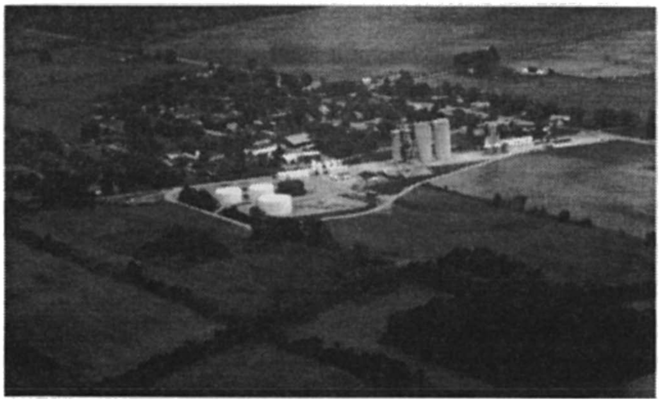
Fortunately we called some of our competitors and found enough space available to ship the 1 million gallons to. Keith Erny, Gen. Manager of the Walton, Indiana Wholesale and Retail facility, found us a pump, more trucks, more man power, and we were in business (sort of). With one pump going and trucks lined up, it was just a matter of time before the immediate threat was over. At about 2:00 AM we decided we needed some more pump power if we were ever to get anything done. Our liquid equipment supplier in Ft. Wayne, Indiana, opened their doors to us that morning and won our undying respect. When our man arrived at about 3:00 AM, he found a note saying "take what you need". Ladies and gentlemen that's customer service! By 4:00 AM we had several pumps going, trucks delivering good 10-34-0 to our competitor's tanks, and dike pumpings to our facility in Clymers, Indiana, where another set of heroes were getting an old soy bean oil tank ready to receive product.

Did I mention heroes? My personal favorites in the hero department that night and the next day, were the members of the Poneto Volunteer Fire Department.

Lesson # 3

(This one we did right)

Take the time to familiarize the local fire department in what you store, where you store it, and how to respond to a situation.



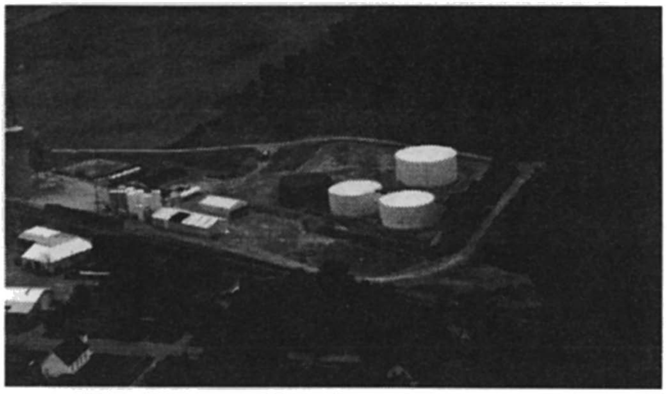
We didn't have anyone running around in Haz Mat suits scaring the local folks and wondering what to do next. We were blessed with a team of professionals that knew what they were handling, and what they needed to do to contain the incident. The time we invested yearly for training with the volunteers was paying off. We also were blessed with what could only be described as just good luck. Unless you're like me and prefer to view it as divine intervention.

One of the first responders from the fire department happened to farm the field directly west of our facility. This 17 acre, tiled field lay between the 10-34-0 that escaped containment, and Elm creek, a local waterway, about 300 yards away. We happened to be building a stone roadway on site at the time of collapse, so a backhoe and bulldozer just happened to be handy. The fireman mounted the dozer, broke the tile prior to discharge into the creek, and dug a collection pit for the 10-34-0 just before it reached the creek. Nitrate checks into Elm Creeke were run for weeks after this incident by our team of Safety and Environmental folks and also the Indiana Department of Environmental Management, the highest finding was 8 PPM, a separate check up stream a 1/2 mile found 9 ppm. We were extremely fortunate.

Lesson #4

(We did this right too)

Think through the layout of your plant, and what direction a catastrophic spill might flow.



Will it run to the sewers? Will it run to the residences down the street? Will it run into the creek at the back of your property? It's important that you think this through so that you can respond quickly and accurately to any threat of this nature. We were lucky by design in this case. Although we were left exposed to the creek on the west side, to the North we had built a collection pond years previous that ordinarily collected the plant's rainwater to be used as process water in the manufacturing of 10-34-0.

On the night of March 31st, our rain water pond collected nearly 800 tons of escaped 10-34-0. The material was reclaimed through the production plant over the next month or so of production.

Lesson #5

No dike will withstand a catastrophic spill of this magnitude. You will have large amounts of product escape containment.

We have always used earthen dikes for large tank containment when the soils in the storage area meet regulations. After this experience, we are more impressed. The force estimate for this occurrence is calculated to have been approximately 14,000,000 pounds or approximately 25M HP of energy. Over the extent of the incident we are estimating over 200,000,000 foot pounds of force.

Lesson #6 And most Important

Prevention

In our opinion, the single most important preventative measure that you can take is to insist that all of your tanks meet the American Petroleum Institute's API 650 and 653 standards. API 650 outlines minimum standards for new tank construction. API 653 outlines minimum standards for rebuilt tanks. "Referencing" the standard and building to the standard are not the same! You will have to specify. We don't have time to discuss all the reasons for building only placarded tanks, it goes without saying we do not want to have a reoccurrence.

The cost of building a 650 tank is approximately 15% - 25% higher than the traditional fertilizer tanks we had constructed. The added cost was less than 5% of the clean up and replacement of the damage done to the system we had in place.

Additional costs we incurred as we assessed our overall storage were:

- Inspection of Company wide liquid storage by a licensed structural engineer
- Repair of <u>100%</u> of our non-650/653 standard storage!!

After weighing just the monetary costs, not to mention the significant emotional and physical stress, "the human toll", we are committed to building to the API standard.

The support we received from the volunteers in the community, the IDEM's Dave Dougherty, the Indiana State Chemists Office, thanks Mr. Mike Hancock, was nothing short of super. I can't go as far as to say that I am appreciative of the experience, but we feel extremely fortunate that personal injury and long term environmental contamination did not exist as an issue.

I'd like to wrap up with a lighter note. True to the support given by all, the President of the Ag group and General Manger of the Wholesale division traveled to Poneto to assist. One of the immediate needs that happened early on in the clean up effort was sump holes to place our pumps in for recovery of product. Graciously accepting any role, these two grabbed a shovel and went to work. As I arrived Saturday on sight, they showed me the wear and tear in the form of blisters on their hands as proof of the depth of their commitment. Later that evening I met with our employees to cover where we were and where we needed to go and little Ed, who is bigger than the average but smaller than me, told me he really would appreciate knowing who was digging the darn holes in the lot. He had traveled out to a lonely place to relieve himself and... well, I will allow you to use your imagination.

How Safe is our Storage?

As industry leaders I would urge all of you to look at your responsibility in the safe storage of our products. We are not an "Island unto ourselves". We will be scrutinized as an Industry as it pertains to our methods and behavior around these extremely important issues. How Safe is Your Storage? We owe it to each other to give this issue the attention and priority it deserves.

The Inland River Barge Industry "It's Back"

Thomas M. Torretti
Peavy Barge Lines

I last addressed the Fertilizer Round Table in November of 1988. I am privileged to be able to address you once again. There have been a lot of changes in our industry since we last talked and I would like to bring you up to date, and talk about the future.

The last 8 years in the barge business has been one of change. That change has been primarily due to the increase in barge freight rates, the building of new barges and retirement of older ones, consolidation within the industry,and the increased demand for barge transportation for all different types of commodities.

From 1989 to 1992 the industry basically maintained its existence. Grain exports were weak to normal, fertilizer consumption was increasing slightly, coal movement both domestic and export was average to a slight increase, ores and alloys for the steel mills steadily increased. Barge rates for bulk commodities remained as cheap (and in some cases cheaper) than they had been the last 11 years. Grain freight rates averaged what they had been in every market from 1981 to 1988 above the break even point.

The year 1993 is a year all of us would just as soon forget. The "Flood of 93" devastated everyone and everything in its path. It was a very trying time for all of us in the agricultural business not to mention those unfortunate people who lost everything they owned. The shutdown of theMississippi River from Cairo, Illinois North, and the Illinois and Missouri Rivers, cost the barge industry and affliated businesses hundreds of millions of dollars. This cost will never be recovered. It was not only disastrous for the barge industry but those shippers of commodities that were stuck for 2 1/2 months. Grain, coal, salt, fertilizer, ores, alloys, meal, etc., all sat and waited. Some commodities deteriorated and became total losses or were rejected when they reached their final destination. This in turn caused a lot of shippers and consumers great hardship.

Going into 1994 we could only go one way and that was up! In late 1993 and 1994 imports of steel slabs, pig iron, ores and alloys hit the U.S. Gulf like a tidal wave. The automobile industry was in high gear and so were the steel mills that feed them. The large steel mills (U.S. Steel, Bethlehem, Wheeling-Pittsburg, Weirton Steel) were facing increasing competition from the new mini-mills. These are niche mills that produce a specialty type steel, like the large mills, at a lesser cost. The imports of the steel slabs, ores, alloys, and pig iron was all new business. Approximately 2.5 to 3 million tons came into the U.S. Gulf.

Along with this influx in the 1st quarter of 1994, fertilizer imports were bigger than they had been in a while. Demand for fertilizer was great due to the lack of harvest in 1993 due to the flood. The ground needed nutrient replenishing because a good deal of the minerals were washed away with the flood. Due to the demand for barges for these bulk commodities, northbound barge transportation increased two times above what it had been. The shipping community had a hard time handling this. The barge industry hadn't seen an increase of any kind for 12 years. Ironically, the grain business (which historically fuels freight rate increases) was not the culprit. When barges moved up river from New Orleans with bulk commodities, it took longer to come back to New Orleans. Why? Because there was no grain to come back with. The 1993 flood ruined a lot of the heartland's plantable ground, so the grain stocks carried over from 1993 to 1994 was at a low level. In fact, northbound freight rates were a premium to southbound grain rates for the first 8 months of 1994. In the 22 years I've been around this business, that had never happened.

Then to add even more fuel to the fire, we produce a 10.5 billion bushel corn crop. Barge freight rates go even higher. Finally, barge companies (after such a long slump) see more black and no red ink. This carries into 1995, and full steam ahead. Barge lines continue to have record earnings. The harvest of 1995 was quite low compared to the boomer we had in 1994. Demand for corn continues to increase. Our stocks of grain are predicted to be at their lowest in 20 years going into the harvest of 1996.

From the beginning of 1996 to present, imports of steel related commodities have drastically been reduced, fertilizer imports were above normal but stung some folks due to a wetter than normal Spring. The Summer months were pretty quiet. Finding grain to move southbound was at a premium. Some grain freight rates were below break even. Our cost of operations has greatly increased. Diesel fuel, towing and switching costs, insurance costs, and barge cleaning costs have all escalated dramatically. This will continue into the foreseeable future.

I want to share with you some statistics on the number of barge operators, the number of covered barges and their age, the number of barges built, shipyards and their yearly capacity, five largest covered hopper carriers, and a history of barge construction over the last 40 years.

Since 1988 the industry fleet has risen from 10,967 to 11,304. This is not a dramatic increase. A lot of covered barges have been relegated to the open top fleet replacing open tops that went to the scrap heap. Barge construction really didn't take off until 1993 with respect to covered barges. Barge prices in 1988, to late 1993, were $200,000 to $220,000. Those same barges today are in the $325,000 to $340,000 range. In the late 80's early 90's covered barges were not replaced. The market would not let us build. As I mentioned earlier, not until late 1993 forward, had the market appreciated enough to be able to build barges. Our industry will only be able to maintain. An over-built society I do not see.

The number of barge operators went from 42 in 1990 to 37 in 1995. These operators are those with as many as 2 barges up to 2,000 barges. There were quite a few mergers and/or acquisitions in the late 80's early 90's. Ingram Barge Line acquired Ohio Barge Line. ACBL purchased SCNO and the Valley Line. Peavey purchased the barge assets of Consolidated Grain and Barge. In 1995, ACBL also purchased ContiCarriers. The big get bigger. I don't foresee any new mergers/acquisitions, but only time will tell.

There is an interesting item to note in Exhibit 5. The average of the industry fleet is approximately 15.4 years old. Of the total number of covered barges, 44% of them were built in 1978 or earlier. This is a pertinent fact. Barges of this vintage may be relegated to loading only grain, salt, coal, etc., and may not be able to load ores, alloys, fertilizer, or any high value commodity. This means the pool of good covered barges is limited. This will also have an impact on the pricing of barge transportation northbound. The reason these older barges won't load exotic or high valued commodities is primarily due to the covers.

The barge industry is back! It took a while, but for those of us who hung in there, the rewards have been worth it. We will continue to become as cost efficient as we can and I envision barge building to continue through the year 2000. The demand for barge transportation will continue to increase. The farmer will plant fence row to fence row. There is no incentive not to. The free market will dictate what he does. This will be good for us and for the folks in the fertilizer business. All other commodities moving by barge will also steadily increase. Aside from our yearly bouts with Mother Nature, EPA issues that are becoming even more critical than before, and rising operating costs, we are healthier and wiser than we have been for a long time. Hopefully, the markets will let us continue in that matter. With the support of the shipping community (such as yourself), we can accomplish this.

The 5 largest barge lines control 65% of the available covered barges. That is a staggering fact. As barge lines continue to build, these 5 will increase in size. Of the 5 barge lines, 3 of them are owned by grain companies. This a way to hedge their transportation needs and costs. As long as the barge lines produce good revenues, the grain companies will continue to invest in their success.

The information provided in this speech was taken from the annual Inland River Barge survey compiled by Jack Lambert. Not all tables will equal due to the non-participation of some companies in the survey. It is as close to accurate as can be.

BARGE PROFILE BY YEAR

Year	Covered	Open	Total
1995	11,304	5,897	17,201
1994	10,950	6,113	17,063
1993	10,694	6,237	16,931
1992	10,440	6,188	16,628
1991	10,609	6,305	16,914
1990	10,778	6,011	16,789
1989	10,782	5,749	16,531
1988	10,967	5,556	16,523

Note: Open top barges are 195 ft. or 200 ft. x 35 in. x 12 ft.

Exhibit 1

NUMBER OF BARGE OPEREATORS BY YEAR

Year	Covered
1995	37
1994	37
1993	38
1992	36
1991	36
1990	40
1989	40
1988	42

Exhibit 2

SHIPYARDS PROFILE

Name	Estimated Yearly Production
Avondale	100
Equity-Trinity	300
Galveston	75
Jeffboat	500
Port Allen-Trinity	150
Caruthersville-Trinity	400
Total	**1,525**

Exhibit 3

HOPPER BARGES BUILT BETWEEN 1988 AND 1995

Year	Total	Jumbo Covered	Per Cent of Total Built
1988	207	1	0.48%
1989	420	51	12.14%
1990	461	104	22.56%
1991	526	143	27.19%
1992	732	288	39.34%
1993	456	265	58.11%
1994	424	275	64.86%
1995	503	380	67.00%
Totals	**3,789**	**1,507**	**40% Avg.**

Exhibit 4

DRY CARGO BARGES
(COVERED/OPEN)
Presently Being Operated by Year of Construction

Year	Jumbo Open	Jumbo Covered	Total
1963	49	49	98
1964	21	13	34
1965	7	24	31
1966	148	148	296
1967	72	97	169
1968	67	54	121
1969	84	35	119
1970	89	97	186
1971	218	181	399
1972	214	494	708
1973	163	658	821
1974	275	746	1,021
1975	388	598	986
1976	290	332	622
1977	172	516	688
1978	184	671	855
1979	394	1,170	1,564
1980	244	1,685	1,929
1981	455	1,720	2,175
1982	189	201	390
1983	42	83	125
1984	25	22	47
1985	82	29	111
1986	57	28	85
1987	42	-	42
1988	176	6	182
1989	281	65	346
1990	256	103	359
1991	309	143	452
1992	311	251	562
1993	144	265	409
1994	105	275	380
Totals	**5,553**	**10,759**	**16,312**

Exhibit 5

HISTORY OF HOPPER BARGE CONSTRUCTION 1955-1995

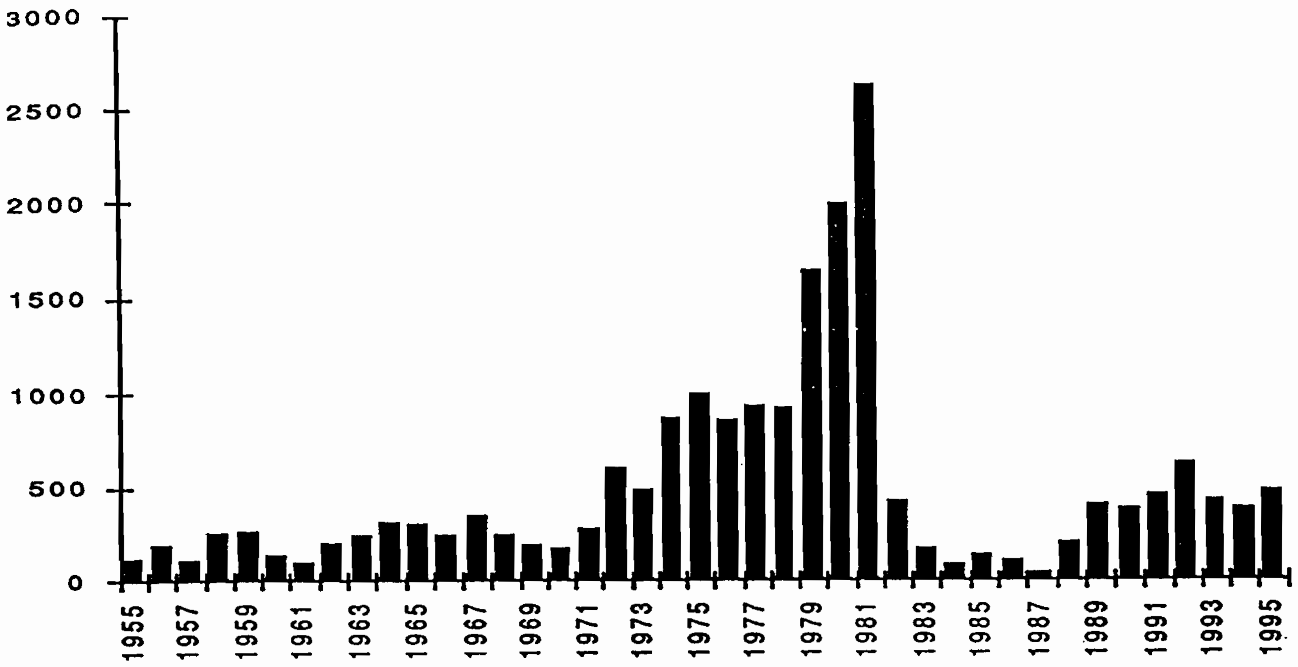


Exhibit 6A

HISTORY OF TANK BARGE CONSTRUCTION 1945-1995

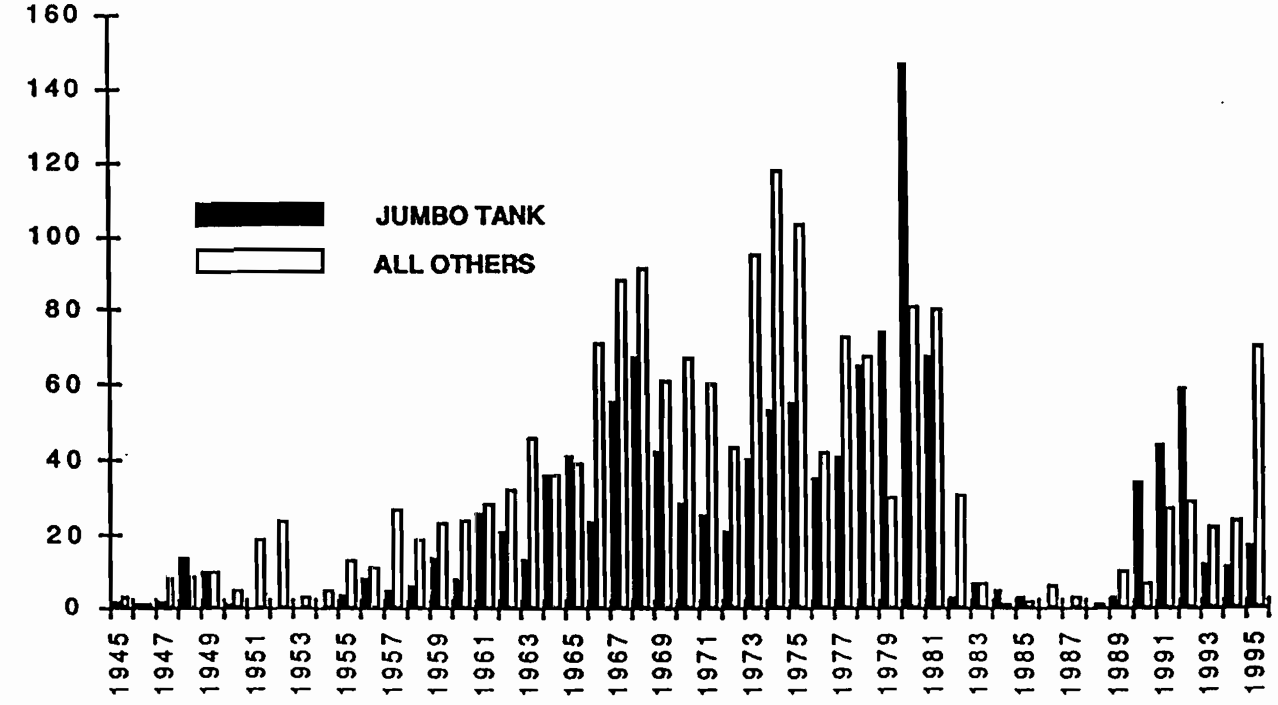


Exhibit 6B

FIVE LARGEST COVERED BARGE LINES

1995		1994		1993		1992	
ACBL	2,540	ACBL	2,086	ACBL	2,144	ACBL	1,998
ARTCO	1,761	ARTCO	1,773	ARTCO	1,849	ARTCO	1,864
PEAVEY	1,405	PEAVEY	1,471	PEAVEY	1,380	PEAVEY	1,240
CCI	907	ORGULF	794	ORGULF	817	ORGULF	822
ORGULF	776	CCI	686	CCI	657	CCI	641
Total	**7,389**	**Total**	**6,810**	**Total**	**6,847**	**Total**	**6,565**
Per Cent	**65%**		**62%**		**64%**		**63%**

* * *

1991		1990		1989		1988	
ARTCO	1,771	ARTCO	1,805	ARTCO	1,814	ARTCO	1,328
ACBL	1,466	ACBL	1,444	ACBL	1,402	ACBL	1,164
PEAVEY	1,075	ORGULF	795	ORGULF	740	ORGULF	663
ORGULF	813	INGRAM	645	VALLEY	584	VALLEY	634
INGRAM	643	VALLEY	577	PEAVEY	548	CGB	565
Total	**5,768**	**Total**	**5,266**	**Total**	**5,088**	**Total**	**4,354**
Per Cent	**54%**		**49%**		**47%**		**40%**

Exhibit 7

Future Fertilizers for Precise Applications and Maximum Economic Yield

Gunnar Kongshaug
Robert M. Millaway
Hydro Agri

Introduction

Modern fertilizers supply up to 18 essential nutrient elements to support the healthy growth and development of growing plants. In the fertilizer industry, the product delivery system can be described as a complex combination of:

- chemical composition,
- physical form and quality,
- packaging,
- transportation and distribution,
- application and agronomic service,
- environmental stewardship and regulatory compliance,
- producer commitment,
- customer service, and payment structure.

During the coming years we will witness development in all components of the product delivery system. The payment structure needs improvement so that farmers in undeveloped countries can obtain fertilizers to increase yield and thus pay for the fertilizer. Transportation cost, which may account for up to 40% of the delivered price at the farm gate, must be minimized. Application technology improvements must permit environmental regulation compliance while increasing energy, time and cost efficiency.

Fertilizer products have been and will continue to be an essential link in the world food production chain. To be successful in the development and implementation of future fertilizers and their delivery systems, the industry must anticipate and respond to changing global, local and social needs.

In this paper, we will focus on the composition and form of future fertilizer products and application systems to maximize economic yield. We will concentrate first on the next 10-30 years, and finally will present a long term perspective, i.e. beyond 2025. While this presentation is limited to "the industrialized agricultural areas", developments in these regions will be good examples for what may follow in developing countries.

It is impossible to predict future fertilizer developments without looking 40 years back and without recognizing today's political signals, social trends and technical possibilities. Therefore, we will try to analyze how agricultural policies, environmental and safety regulations, the farmers' situation, and agronomic and technical developments may influence the future of fertilizer products and their delivery systems.

Agricultural Policy

The agriculture situation we face today is a result of political decisions made some 40 years ago. After the Second World War, most of the industrial countries were far from self-sufficient in food production. Political goals were to achieve self-sufficiency in food production and to improve the agricultural economy. In the post war 40's, approximately 25-40% of the population in the major industrial nations was directly involved in agriculture. Today, in the US, for example, it is only 2%.

The US farm bill, as it has evolved, and the European Union's common agricultural policy (CAP) have governed the direction of fertilizer developments in the western world. Their general principles have been to:

- increase productivity by promoting
- technical innovation and rational agricultural production,
- ensure farmer and community economy, assure food availability at reasonable prices, and
- fix target prices (above world market prices).

These stimuli had a remarkable harmonizing effect on modern agriculture and, in less than 25 years, productivity increased dramatically.

The fertilizer industry contributed strongly to increased agricultural production per capita during the last 20 years. More efficient fertilizers and improved application techniques were developed.

Many farmers moved away from superphosphates to more cost effective fertilizers with higher analysis and higher quality, suitable for refined application systems. During the same period, subsidies became common all over the world, and the world market prices for grain and wheat dropped. In 1986 the wheat market prices were only 40% of the index adjusted prices in the early 1970's [6]. During the period 1986 to 1994 the index adjusted prices were stable at a low price level, far below an unaided break-even price even for large farms.

Agricultural protectionism gave way in 1986 to the GATT agreement. The GATT agreement now limits the export of subsidized products, and will force a change from price subsidies per unit weight produced towards compensatory payment per land area and payment for set-aside land. The world market price for grain and wheat will thus have a significant effect on the evolution of agriculture and the fertilizer industry, and on the products to be developed.

Due to several factors, the world market prices of wheat, corn and other grains have increased during the last year and world stocks are at the lowest level in a long time. Growers have been able to sell their crops at prices above national target prices. If the present high world cereal prices continue, the GATT regulations will have no effect and farmers will try to avoid entering into set-aside contracts.

Future Agricultural Scenarios

The change of agricultural policy from weight to area subsidies is moving the farmer away from thinking volume to focusing on return per unit land area. A grower with high fixed costs either has to improve his operation; drop back to part-time farming and take a salaried job; or sell his land. The farmer will analyze all input costs and look for alternatives. He may, with good intentions, select the cheapest nutrient sources and reduce his input of fertilizers. Growers with a longer perspective have moved towards "The Optimum Economic Yield" concept, which includes the use of precision cropping practices and, perhaps, more specialized fertilizer and application systems. This approach requires that more information and service be readily available to the end user.

All industrialized countries will be forced to further reduce agricultural subsidies. We expect they will be completely removed within 7-15 years for large farms. This will strengthen optimum economics thinking and support a rationalization of agriculture.

There are two contradictory scenarios for the future, with the world cereal market price as the joker in the deck:

Scenario I:

- The market price stays low (like some years ago).
- The industrial countries will have to limit production.
- Likely, this will result in increased set-aside, farm quotas for nitrogen and phosphate input and, perhaps, taxes on marginal nitrogen input.

"Low Price" *	Short Term	Long Term
Fertilizer input	Minimum	Regulated to optimum economic yield
Fertilizer type	Commodity	Specialized products

**: Below break-even price for average farm size.*

Scenario II:

- The market price stays high (like today).
- The industrial countries will remove set-aside and let environmental limitations and export taxes regulate cereal production.

"High Price" *	Short Term	Long Term
Fertilizer input	Optimum	Regulated to optimum economic yield
Fertilizer type	Specialized products	Specialized products

**: Above break-even price*

The initial effect of these two scenarios will be different, but in the long run, both will result in "The Optimum Economic Yield".

For the next 20 years we may experience a fluctuation between the two scenarios. The world market cereal prices will probably slide back to low levels for periods long enough to force farmers to adapt to set-aside, low area subsidies, and quotas for nitrogen. The reason for this is that large grain volumes gradually will become available for export from the Eastern European countries, the Ukraine, Belarus, South America, Canada and USA.

In 30 years it is likely that scenario II will be dominant. The Worldwatch Institute [4] concluded that China will need to import more than 200 mill. tons of grain by the year 2030 (+ 500 mill. people). This is higher than the total cereal production in Western Europe and more than the present global grain trade today. If China starts to eat more meat (similar to the per capita consumption in Japan), they will need to import more than 600 mill. tons of grain simply to meet the animal feed consumption requirements. This will present significant challenges for major fertilizer producers and related agricultural industries in the future.

The Farmers Situation

During the last 40 years, the average farm size in the industrial countries has more than doubled and the number of farmers has substantially decreased. The average farm size varies considerably from the small family farm to the corporate farms. The size of farms will continue to increase and the predicted changes in the US and Germany over the next 10 years could represent the general trends [5, 19, 20]:

2005 versus 1995	U S	Germany	
Average farm size today	490	60	acres
Increase of average farm size	10	120	%
Reduction in no. of farms	7	45	%
Change of average farmer age	53➔55	48➔40	years
% of farmers older than 55 years	45➔30	30➔20	%
% of farm as full time farmers	40➔65	57➔70	%
Professional trained farmers	50➔70	32➔70	%
Reduction in no. of retailers	45	75	%

Today, on large farms in the USA and UK, farmers are professional money managers and well educated agriculturists who pay attention to costs and price trends. The expected increase in full time younger farmers [9] will continue to boost this development in the coming years.

The educated farmer will base his decisions on facts and aim for highly efficient farm operations. He will:

- respond quickly to new products and techniques,
- accept more sophisticated fertilizer concepts,
- focus on product quality,
- market his production directly,
- require more information and advisory service,
- require proof not marketing gimmicks.

The future farmer also will aim for more free time. Many will use consultants, subcontractors and full service dealers offering crop and soil management recommendations, with custom application and spreading included in fertilizer prices.

The grower will also face more professional suppliers and customers. This will place higher demands on education, training and service at all levels, the fertilizer company, the distributor, the retailer, the subcontractor and the grower. We will experience new and innovative alliances between all the players, with the ultimate focus being the consumer. Alliances will be established between the food processing industry and fertilizer companies. Together they will develop fertilizer products and cropping systems which the grower must use to be a preferred supplier. By example, fertilizer companies in co-operation with food processing companies will develop fertilizer concepts to meet specific requirements, like minimizing nitrate content in vegetables destined for baby food.

A reduction in the numbers of players at all levels between the fertilizer producer and the consumer will force the system to place more focus on:

- reduced logistical costs,
- greater market segmentation and product differentiation,
- increased competition,
- environment, safety and health regulatory compliance
- improved communication,
- increased pressure to improve efficiency.

This will strengthen the development towards "The Optimum Economic Yield" via the practical implementation of self policing approaches like "Best Management Practice" (BMP), "Best Used Guidelines" (BUG) and "Best Fertilizer Practice".

Environmental regulations and trends

When developing fertilizer products, the industry must deal with regulations governing production, raw materials handling, waste management, storage, packaging, distribution and application of fertilizer products.

The regulatory impact seems to be most pronounced in Europe and North America. Other OECD countries are expected to move in the same direction, however, it will take several decades before we have similar regulations globally.

"Sustainability" is the new political slogan. Many rich countries aim for an ecologically sound but sustainable agricultural economy characterized by reduced chemical input, ecolabelling, recycling of waste and "organic" farming. Such political trends necessarily will effect the development of fertilizers and the dynamics of the industry.

The main environmental issues which will influence fertilizer product development and use in the next 30 years seem to be:

- Emissions of ammonia and nitrogen oxides,
- Leaching of fixed nitrogen (and phosphate in some areas),
- Heavy metal content (mainly cadmium),
- Organic waste and recycling of nutrients, and
- Life Cycle Analysis (product balance sheet from cradle to grave).

Already, the fertilizer industry has begun to develop new technologies and to invest in new processes and equipment to meet even stricter limitations. Their challenge is to provide fertilizers with higher nutrient efficiencies than today. In concert, the industry must find ways to remove unwanted elements from its fertilizers and develop processes for converting waste materials into useful, or at least, innocuous products.

Emission of ammonia to air, loss of agriculturally important N, demonstrates the need for efficiency improvements. In Europe, it has been estimated [8] that 12 % of total ammonia emissions can be traced to applied fertilizer. Of the remainder, 75 % comes from manure storage and spreading and 0.5 % from fertilizer production. About half of the ammonia emission from fertilizer was derived from surface applied urea, even though urea accounted for only 1/6th of the total fertilizer N-consumption. Ammonia emission from urea typically ranges from 10-25% of applied N, but can increase to 40% on alkaline calcareous soils. Except for ammonium sulfate and UAN, all other nitrogen fertilizers give very low ammonia emissions. With some countries imposing N application quotas, the industry may respond with development of modified urea fertilizer or face reduction in the use of urea .

Emissions of N2O arise during both production of nitric acid and use of fertilizers. Hydro Agri has developed technology for removing N2O from new nitric acid plants (investments are too high for old plants). In the future, we will need to improve our understanding of N2O formation, and develop fertilizers and application techniques to minimize N2O emission from the soil.

Nitrogen leaching to ground water will continue to be discussed in the coming years. Restrictions on the use of nitrogen in nitrate sensitive areas will continue even though scientific research indicates that the "blue baby disease" (methaemoglobinaemia) is caused by bacteria in the drinking water and not by nitrates. This new understanding will however, neither decrease nor increase the NO3- limit of 50 ppm in drinking water.

National goals for the reduction of nitrogen effluents to fresh and sea water have presented new challenges to farmers. Ultimately, we believe the fertilizer industry will encourage the authorities to distinguish between ammonium and nitrate effluents to water. Ammonium in water is mainly derived from sewage; natural decay bacteria in sewage treatment systems need oxygen (4.6 kg O2/kg N) to convert ammonium to nitrate. Nitrate leached from the farm is an "oxygen source" in water.

Hydro Agri now supplies nitrate containing additives to control anaerobic conditions (oxygen deficiency) in sewage and septic systems, drinking water and lakes. Nitrate in water ends up as nutrients for algae or is denitrified to N2 a savings of 2.7 kg O2/kg N.

The leaching of phosphate is now also under debate in some countries. Research has indicated that soluble phosphate is the main contributing factor to excess algae growth both in lakes and the open sea. This will continue to exert pressure on agriculture to reduce P2O5- leaching.

Some elements not necessary for plant nutrition occur in raw materials used for fertilizers. The fertilizer contribution of heavy metals to the top soil is very small compared to the average soil content even after many decades of fertilizer use. The exception is cadmium [13]. The water solubility of cadmium found in ammonium phosphates (DAP, MAP) and compound fertilizers (NPK) is very low compared to the solubility of cadmium found in superphosphates (TSP, SSP and PK). If the concern surrounding cadmium increases, then commercial processes for removal of cadmium from DAP, MAP and NPK will be developed (not possible for superphosphates).

Heavy metals in fertilizer has been addressed as a global problem that should be treated locally. Today authorities allow food production on soils with cadmium levels far above the given tolerance values. In such areas, limitations on cadmium content in fertilizers, from which the average addition of cadmium to top soil is approximately 1.4 ppb per year, will have no noticeable effect on soils with a native cadmium content of 1000-3000 ppb. If the authorities really are worried about heavy metal intake, they must introduce restrictions on the cultivation of specific soils based on maximum heavy metal content and minimum soil pH and will limit the use of sewage sludge, and not impose restrictions on the use of refined fertilizer products.

Safety Regulations and Trends

The well publicized events during the last 5 years, plant explosions, self- sustaining decomposition of fertilizers in transit and storage, and illegal use of ammonium nitrate and urea, will continue to fuel the tightening of safety regulations for fertilizers.

Nitrate containing fertilizers are sensitive to heat, and thus are subject to self-sustaining decomposition and explosion. The International Maritime Organization (IMO), the United Nations and the European Union have established transportation restrictions for fertilizers.

Ammonium nitrate fertilizer additives fall under the classification as dangerous goods (IMO Class 5.1, type A fertilizer) as shown in the table below:

Type	Additive	% AN equal or above	% N above
A1	Inert	70	24.5
A2	Carbonates	80	27.6
A3	Ammonium sulphate	45	26.5
A4	P- and/or K- components	70	24.5

If an additive amended product contains less AN than the given concentration in the table, it is classified as non-dangerous goods (Class 9, type C fertilizer). The maximum organic content allowed for transportation of AN containing products classified as dangerous goods is 0,4% (less than 0,2% if the AN-concentration is above 90%). The text of the regulations is old fashioned and not easy to understand. It seems to be a result of the Oppau explosion in Germany in 1921, and the explosion of a vessel loaded with AN in Texas City in 1948.

For the development of modern fertilizers, these limitations are frustrating as there is no logical link between the rules and the results of detonation tests. For instance, ammonium phosphate mixed with AN reduces sensitivity to explosion by blocking pH reduction during heating. However, potassium chloride mixed with AN seems to increase sensitivity. Nevertheless, both additives are in the same category (type A4). A moderate amount of ammonium sulfate added to AN does not seem to increase its sensitivity to detonation in our tests. But, since AS was involved in the Oppau explosion , it can not be a component in an optimum fertilizer for bulk transportation if the AN content exceeds 45%. This means, to meet the safety rules, the industry must over formulate with about 3 times the necessary amount of sulfur added to AN (ANS 26-0-0-14).

In the future, we expect that the authorities will have to change the regulations to reflect product detonation test results (like for NPK products) and drop limitations based on chemical composition. However, this will take many years since the United Nations first has to change the "Orange Book" recommendations for dangerous goods.

For bulk NK and NPK fertilizers, self-sustaining decomposition is the critical safety issue. Producers are required to characterize the thermal stability of these fertilizers by testing them in a standard trough heated for a given period of time. If the product exhibits self-sustaining decomposition (SSD) after the heat source is removed, the product is assigned to Class 9 (type B) and declared as dangerous goods (type C if decomposition stops). If the decomposition velocity exceeds 25 cm/h, then bulk transport is prohibited.

NPK producers know that the addition of highly water soluble P2O5 or a small amount of magnesium sulfate will decrease the sensitivity to SSD of nitrate containing NPKs, while the use of the lower water soluble superphosphates makes the product more sensitive to SSD. Thus, such products can be formulated to meet regulations based on reliable test data.

It is reasonable that within a few years the same limitations on marine transport will be applied to land transport, storage and handling of fertilizers in both bulk and bags. Several incidents during recent years underline this trend. The bombing incidents in New York's World Trade Center and in Oklahoma City have linked terrorism to fertilizers. It is believed that ammonium nitrate mixed with fuel oil was used in these explosions. In the Republic of Ireland, sales of fertilizers with more than 80% AN are not permitted due to terrorism. As authorities try to use legislation to prevent terrorist acts, we foresee they will limit distribution of A-type fertilizers. This can have a significant effect on straight AN producers and on the use of superphosphates in compound NPK. Additives to AN, such as dolomite, MAP and potassium sulfate are known to reduce its sensitivity to detonation. We expect that more effective desensitizing additives and fertilizer products less sensitive to detonation will be developed during the next 20 years.

Fertilizer Spreading

A recent survey in England showed that 50% of the spreaders in use had never been calibrated and that 60% of the operators had never seen the operation manual for their spreaders [7]. This may seem surprising, since England's agriculture is characterized by large average farm size and a comparatively high degree of sophistication, but it is typical of North America, as well. It is well known that just the physical properties of the fertilizer alone have a significant effect on spreading pattern. To illustrate, spreading tests show that for centrifugal spreaders with a 24 meter working width, prilled fertilizer products with an average particle size (d50) of 2.7 mm give almost the same distribution pattern as a granulated product with d50 equal 3.3 mm.

The quest to maximize yields while meeting environmental regulations, which would limit the input of N, will demand significant improvements in application equipment and techniques. Accordingly, fertilizer products must meet strict nutrient content and quality specifications and also satisfy requirements for accurate spreading. Therefore, to face the challenge, equipment manufacturers and fertilizer producers must cooperate in the development of delivery systems with automatic set-up and simplified calibration procedures [7].

It is well known that fields are not homogeneous in soil type, terrain, drainage and nutrient content. This contributes to variation in yield across the field. Technology is being developed to map the status of the top soil and the variation in yield. Satellite photography already has been adapted to record the productivity of forests. This technology can be refined to map the productivity of agricultural fields [18].

The Global Positioning System (GPS) has now been introduced to agriculture. Initially developed for the US military, GPS enables anyone equipped with a proper antenna and receiver to identify his position anywhere on the earth's surface within 10 m accuracy. A combine harvester equipped with GPS is now able to generate a yield map as it moves across the field. Such equipment is expensive and is used mostly by the larger farmers, service based dealers and sub-contractors. The most obvious advantage of yield mapping is that the farmer can select the most unproductive part of his land for set-aside (and thus reduce the intention of this authority act).

The main problem with yield mapping is that it is not diagnostic. At present, the farmer can not convert the output into a decision system for remedial action, nutritional or otherwise. A low yield in a portion of the field may be caused by limited water availability, poor drainage, variation in organic matter content, disease, insects, weeds or other factors. Yield mapping is, however, excellent for detection of problem areas in the field to be given attention prior to the next season. However, it does not tell the grower what the problem is; only where it is.

In the coming years, "smart" systems taking into account yield influencing factors will be developed. Perhaps in 10-15 years we will see development of cost effective systems capable of:

- instantaneous soil analysis and pest identification,
- on the spot plant sensors, and
- spreaders with variable rate capability linked to a computer mapping system.

These improvements may give advantages to both the farmer and the environment as he can optimize yield and reduce input of pesticide, seed, limestone and fertilizer as dictated by site specific analyses.

Use of GPS coupled with variable spreading will result in better use of fertilizer systems. Three directions can be foreseen:

- split application employing NPK starter and precise top dressing,
- dry bulk blending on the spreader, and
- liquid mixing on the applicator.

Nitrogen Fertilizers

Manufactured fertilizer products supply part of the nitrogen need to achieve optimum crop growth and yield. Other nitrogen sources are aerial deposition, biological fixation and mineralization of nitrogen from organic matter in the top soil. Aerial nitrogen deposits are derived mainly from combustion and from ammonia emitted from animals and plants. These deposits, which can account for 10-30 % of the fertilizer supply, will slowly decrease in the future as a result of pollution control measures.

The main forms of nitrogen supplied in fertilizers are amide (NH2+), ammonium (NH4+), and nitrate (NO3-). Amide (urea) is hydrolyzed by soil bacteria to ammonium after a few days. Ammonium is reversibly adsorbed on soil colloids where it remains available for crops and soil bacteria. In the soil, ammonium is converted by native bacteria to nitrate, or it can be taken up by plants directly. Nitrate is a nutrient for both plants and micro-organisms. As nitrate is weakly bonded to soil particles, it is very mobile in soil and may be lost by leaching. Another avenue of loss of nitrate is denitrification, the ultimate natural biological process for the return of fixed nitrogen to the atmosphere. Soil-borne denitrifying bacteria use nitrate as an oxygen source during the degradation of organic matter. This anaerobic conversion occurs mostly in waterlogged situations. Such nitrogen processes in soil may release ammonia (NH3), nitrous oxide (N2O), nitrogen oxide (NO) and elemental nitrogen (N2) to the atmosphere.

The fate of fertilizer nitrogen varies considerably and is difficult to measure as it is affected by crop species, soil type, climatic conditions, type of fertilizer and application system. Typically, 40-60 % of the fertilizer nitrogen is taken up by the plants, and moved above ground level; 20-50 %, is incorporated into the soil's organic matter [3].

Optimum plant growth is achieved by sustaining a dissolved nitrate content in the soil solution which is far below the peak value after fertilizer spreading [15]. This can result in high potential losses to air, water and soil organic matter.

The objective for the N fertilizer product of the future is to maximize nitrogen use efficiency and to minimize losses.

The main N fertilizers are:

		Formula	% N
Urea	UREA	$(NH_2)_2CO$	46
Ammonia Anhyd.	NH3	NH_3	82
Ammonium Sulphate	AS	$(NH_4)_2SO_4$	21
Ammonium Nitrate	AN	NH_4NO_3	33-35
Calcium Nitrate	CN	$Ca(NO_3)_2$	15.5
Potassium Nitrate	KN	KNO_3	13

Other N products are available also such as ammonium chloride (26% N), calcium cyanamid (20% N), ammonium bicarbonate (17% N), and sodium nitrate (16% N). These products are not cost effective N in commodity cropping systems and are mainly produced as forced by-products. None of them has a position in the future fertilizer concept.

The main N fertilizers can be mixed with other compounds, as appropriate, to give new N fertilizers.

			% N
Urea Ammonium Nitrate	UAN	AN + UREA	28-32
Calcium Ammonium Nitrate	CAN	AN + Carbonates	22-27
Ammonium Sulphate Nitrate	ASN	AN + AS	20-26

These can be used alone or mixed with other nutrients to produce more specialized fertilizers.

The use of anhydrous ammonia and aqua ammonia has decreased in many countries due to the high risk of ammonia loss and the cost of the specialized equipment required to handle it safely. The limited use of straight urea and AS in Europe is related to high N losses from ammonia volatilization and soil acidification (and reduced yield). In general, the use of ammonia, straight urea and ammonium sulfate will not increase in the industrial countries. Limitations also may be introduced for use of these fertilizers, especially on alkaline calcareous soils, in order to reduce ammonia emissions. However, in tropical areas with more acid, sandy soils and in paddy soils, urea and ammonium sulfate will be the leading N fertilizers in the future. For the more temperate zones, AN will be the main N source, but with the addition of carbonates or other desensitizing agents to meet tightening safety regulations.

Calcium nitrate and potassium nitrate are very efficient fertilizers for precision horticulture and other high cash crops. Today they are sold as specialty fertilizers, and the market volumes will increase as we foresee more specialized cash crop production.

Due to the nitrate leaching problem, split application on demand will be used for the future N fertilizers. New developments in controlled release technology may provide cost effective products for use in commodity crops.

To obtain slow release of soluble nitrogen, four techniques have been employed:

- large particles (urea supergranules, forestry grade AN),
- nitrification inhibitors (dicyandiamid, nitrapyrin, terrazole, etc.),
- slowly soluble urea derivatives (methylene urea polymers, isobutylidene diurea, crotylidene diurea, melamine, triazone), and
- coatings (sulfur coated urea, and plastic and resin coated products).

Large particles are a solution only for paddy rice and forestry. Hydro Agri developed urea supergranules around 1980. Yield increase of 15% in rice was achieved, but logistical and application costs were prohibitive.

During the 1980's Hydro Agri carried out extensive testing of nitrification inhibitors. However, on productive soils, consistent economic or environmental benefits were not forthcoming. Small benefits, however, could be observed when inhibitors were used with fertilizers on marginal to poor soils and occasionally when applied with manure in the autumn. We do not expect that nitrification inhibitors will be a part of the future fertilizer system.

The slow release urea derivatives are expensive to produce. Unless there is a breakthrough in cost and nitrogen release predictability, they will be used only as N fertilizers in high cash, long season annual crops and in perennial crop niche markets.

The use of coatings to control the release of nitrogen from fertilizer particles may have an interesting future. Today, these products are relatively expensive and used only for long season annual crops, newly established orchards, turfgrass and container grown ornamentals. Recent developments, however, have shown that it may be possible to establish cheaper and better coating systems to improve control of nitrogen release and pattern.

Phosphorus Fertilizers

Soils contain large amounts of phosphorus, mainly associated with organic matter and combined as minerals with low water solubility. Crops remove around 110 kg P2O5/ha per growing season, but the amount varies greatly. Phosphorus in chemical fertilizers is in the form of (ortho) phosphates (PO4) which must be dissolved in the soil solution to be utilized by plant roots.

The objectives of phosphate fertilization are:

- to supply the crop with available phosphate during the early plant development phase,
- to minimize loss to organic matter,
- to minimize loss to metal phosphates with very low water solubility, and
- to minimize leaching of P2O5 (sheet leaching, run off).

The most important phosphate fertilizers are:

		% P_2O_5
Mono Ammonium Phosphate	MAP	50-56
Di Ammonium Phosphate	DAP	46-53
Single Superphosphate	SSP	18-20
Triple Superphosphate	TSP	46
Mono Potassium Phosphosphate	MKP	52
Ammonium Poly Phosphate	APP	34-40

Typical concentrations of two main compound phosphate fertilizers based on phosphoric acid as intermediate product:

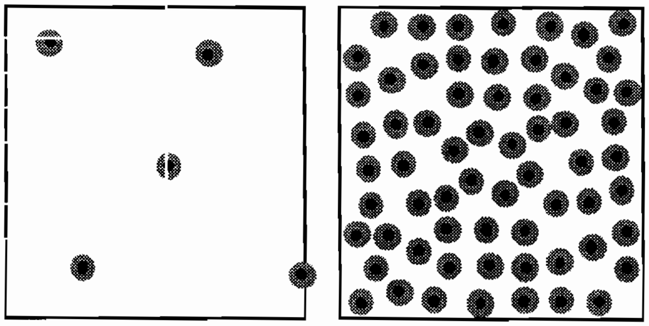
		% P_2O_5	% w.s.
Sulfur-route NPK	NPK	3-17	60-95
Nitro -route NPK	NPK	3-16	70-75

For the supply of phosphate, two different schools of thought seem to exist:

- maintenance of plant available P2O5 content in the soil (P2O5-maintenance), and
- supply P2O5 as a starter to support seedling establishment and early plant development (P2O5-starter).

During the last decades, the phosphate content in soils has been built up in many areas. Today, most of these soils still in intensive agricultural use are rich in phosphate and advisors have started to recommend reduction of P2O5 input to maintenance levels. As phosphate diffuses only about 3 mm laterally from the original particle per season, the granule size of the P2O5 fertilizer is extremely important. With coarse particles of TSP and DAP, one can achieve distribution of 4-5 particles per 100 cm^2 (=16.5 in^2) soil area. Thus, only a small amount of the P2O5 can be utilized the first year (P2O5-maintenance). Tests with finely divided P2O5 distributed around the seed as a starter have shown significant yield effects in the first year, even in soil rich in P2O5 .

The figure below demonstrates the different supply patterns of DAP with 48% P2O5 and 3.0 mm particles versus NPK with 5% P2O5 and 2.7 mm particles.



Horizontal P2O5 distribution pattern from broadcast phosphate fertilizers on 100 cm2 soil surface after 3 mm diffusion during one season (DAP to the left; NPK with 5 % P2O5 to the right).

Phosphate fertilizers with 2.6 mm particle size covers almost twice the soil surface compared to 3.3 mm particles during one season. This indicates that the future phosphate fertilizer should have smaller particles.

The water solubility of P2O5 was a major topic some 10-20 years ago. Research has shown that if at least 50-60% of the citrate soluble P2O5 is water soluble, crop response to phosphate is maximized. This is logical as the citrate soluble phosphate gives sufficient phosphate ions in the soil solution and therefore acts in effect, as a slow release P2O5 fertilizer.

The use of Single Superphosphate (18% P2O5) has been reduced during the last 20 years due to its low nutrient content. Triple Superphosphate and PK are used mostly for autumn application. Tests indicate that precise application of P2 O5 as a starter at planting is better for most crops.

As we focused for many years on building up the soil phosphate content, P2O5 seems to have become a forgotten nutrient for yield optimization. Future phosphate products must provide sufficient release of the P2O5 nutrient as the young plant develops. While this may reduce both autumn application of superphosphates and broadcasting of coarse particles with high P2O5 content (TSP, PK, DAP, etc.), it will strengthen the use of multinutrient fertilizers with low or moderate P2O5 content. Liquid P2O5 fertilizers are becoming an interesting new alternative in Europe as they have been for 25-30 years in the USA.

Potassium, Magnesium and Sulfur Fertilizers

Potassium, magnesium and sulfur fertilizers have not been implicated in significant environmental problems, except for localized potassium intrusion to ground water where high rates of manure had been used on sandy soils. The objectives of these fertilizers are to maximize yield, and to minimize immobilization and loss to the environment. The main fertilizers for supplying these elements are (see chart in the next column):

Typically, these products are added to compound fertilizers (NPK, NP), but they are used alone, as well.

Potassium chloride, dolomite, ammonium sulfate and gypsum are the least expensive raw materials. However, no process seems to be available in the coming years for low cost production of the other potassium, magnesium and sulfur products. SOP, KN, MgS and ATS are used in specialty fertility programs both as straight fertilizers and in combination with urea, AN and NPK. KN, MKP, MgN and ATS will be used mainly in liquid fertilizer formulations. Elemental sulfur can not be added safely to a melt of ammonium nitrate, and likely will be used only as an additive to urea, ammonium phosphates and potash.

		Main Formula	% K_2O	% MgO	% S
Potassium Chloride	MOP	KCl	60	-	-
Potassium Sulphate	SOP	K_2SO_4	50	-	18
Potassium Nitrate	KN	KNO3	44	-	-
Mono PotassiumPhosphate	MKP	K_2HPO4	35	-	-
Dolomite		$CaCO_3MgCO_3$	-	15	-
Kiserite	MgS	$MgSO_4*H_2O$	-	27-29	22-23
Magnesium Nitrate	MgN	$Mg(NO_3)_2$	-	26	-
Ammonium Sulphate	AS	$(NH_4)_2SO_4$	-	-	24
Ammonium Thio Sulphate	ATS	$(NH_4)_2S_2O_3$	-	-	26-43
Gypsum	Gyp	$CaSO_4*xH_2O$			15-18

In the coming years, we do not foresee new developments in sources of Mg, S and K, only an increased use of current sulfur and magnesium sources in fertilizer products. Sulfur is at the starting phase of a "boom time" and agronomic experts have indicated that magnesium may be next nutrient that will claim major attention.

Due to the aggressive SO2 cleaning programs, the agricultural need for sulfur in fertilizers has increased in most of the European countries. During the 1980's, aerial deposition of S dropped below the supply needed for oilseed rape, and in the 1990's, lower than that needed for cereals [16,17]. Sulfur should be applied in the spring and, for some crops, again with the first top dressing. An N/S ratio of 6 to 1 is needed for oilseed rape and 12 to 1 for cereals (one application per year).

In NPK fertilizers, often sulfur is added as ammonium sulfate in the place of fillers to maximize total nutrient content. Ammonium sulfate is used also in combination with urea. But, current safety regulations limit the development of cost effective sulfate-containing AN products that can be classified as C-type (non-dangerous goods). By using AS, we have in principle only two product options left:

- The current product, ANS 26-14 % S (44% AN and more than 3 times the required S-content; N/S =2/1).

As we are hopeful that in the future the authorities will use detonation tests for classification, the "new" ANS product will be:

- ANS 27-4.5% S (66% AN, 18% AS and 16% dolomite with N/S=6/1).

This product seems to be as safe as the present C-type fertilizers and could substitute for a significant amount of the existing CAN and AN market.

In the meantime, gypsum will remain the main sulfur source for a cost effective homogeneous NS product:

- NS 24-5% S (69% AN and N/S=5/1).

Agronomic tests have shown that gypsum mixed homogeneously with AN or urea gives the same sulfur response as do water soluble sulfates.

Micronutrient Fertilizers

Micronutrients are those nutrient elements required in small amounts by plants. Such nutrients are iron, manganese, zinc, copper, boron, molybdenum, chlorine, cobalt and selenium. Deficiency of a micronutrient results in crop yield reduction just as does a deficiency of any of the other nutrient elements. It is well known that deficiencies in micronutrients occur naturally in certain soils in definable areas. Such soils can become agriculturally productive with application of fertilizer containing the limiting micronutrients. However, during the last 10 to 20 years there have been more frequent reports of micronutrient deficiency causing yield reduction in crops grown on soils where such effects had not been noticed before. As removal of micronutrients from the soil continues with increasing crop size, the soluble reserves of a given element in some soils is reduced to a level where replacement becomes necessary.

Micronutrient fertilizer materials are manufactured mainly as water soluble chelates or sulfate salts and may be formulated to produce combination products containing several of these important nutrient elements. Such products can be added to liquid or dry fertilizers for soil and foliar application. Micronutrient materials can easily be mixed homogeneously into urea and complex NPK fertilizers. Some elements, like manganese and copper, can not be added to straight AN as they increase its sensitivity to detonation.

It is our position that the best way to supply micronutrients is to include them in precision placed compound NPK fertilizers and liquid starters as this gives an optimum application pattern and maximizes plant accessibility. With blends containing coarse granules of single micronutrients, we can realize less than one particle per growing plant, particularly when applied broadcast.

Today many companies produce tailor made NP and NPK mixes with micronutrients, but not all are for the direct benefit of the crop. By example, in Finland selenium is added to NPK products used for bread wheat production to increase the human daily intake of this element. And, in Norway, cobalt is added to grassland fertilizer to increase the intake by grazing sheep. In the future, as the intensity of agricultural production increases to meet the expanding demands for food and fiber, the addition of micronutrients to fertilizers will increase.

Organic Fertilizer and Alternative Farming

The huge amount of animal manure produced annually is a resource that ideally should be utilized on the farm. Manure is both an organic amendment to improve soil structure and a crop nutrient source. The nutrient value depends on the species of animal, type of feed and method of storage [3]. Part of the nutrients in manure are water soluble, while the rest are water insoluble salts or organic complexes ("unavoidable " losses). Agronomic tests confirm that manure cannot replace mineral fertilizers. But, manure will always be part of a future fertilizer program for farms with livestock production on site or in close proximity thereto.

Some years ago, Hydro Agri developed a dewatering process which could concentrate manure in a mobile unit at the farm site into a dry product free of odor, clean enough for recycling. However, costs were prohibitive. To date, there seems to be no economically sound way to produce a dry product from manure that can be sold as a fertilizer.

Without a breakthrough, the longterm solution to the manure problem seems to be relocation of livestock production to areas where the manure can be used locally on cultivated land.

Sewage sludge is another huge waste problem with low nutrient content. Field research shows that except at exceedingly high rates, sludge gives poor nitrogen response. Further, a large fraction of the phosphate is too strongly bonded to the organic fraction to be readily available. Moreover, many sewage plants use iron or aluminum salts as flocculants in the treatment process. Sludge from such sewage plants tends to give a negative phosphate effect due to the excess iron or aluminum salts, which immobilize water soluble phosphate in the soil.

The public sector considers farm disposal of sewage as nutrient recycling and environmentally friendly. It is not. The content of nutrients in composted domestic organic waste is very low and the nutrients are strongly bonded to the organic matter. While this waste may be used on some farms, it is not a future fertilizer product. Rather, its only real value is as a soil amendment and perhaps an addition to the phosphate pool of poor soils. Incineration of sewage seems to be a better alternative than farm spreading. This route yields energy and the ash can be used as land fill, after extraction of the phosphate salts contained in it.

Alternative farming (biological, ecological, biodynamic, organic, etc.) rejects the use of fertilizers produced in chemical plants. During recent years, non-traditional agricultural systems have gained popularity and official political recognition . In the wealthier industrialized countries, alternative farming has received sudsidies. The Swedish government, intends to designate 10% of the arable land for alternative agricultural production. These systems, however, produce less yield at a higher cost per hectare than conventional agriculture. The benefits to farmers, consumers and the environment are questionable [3].

Advocates of alternative agriculture regard chemically produced fertilizers as detrimental to soil life, crop development and food quality, but scientific data does not support this. Organic farmers believe that the nutrient ions (ammonium, nitrate, phosphate, etc.) produced by the industry are different from those released by living organisms and natural geological processes. Organic agriculture will continue to be a niche market for untreated minerals like phosphate rock, feldspar meal, etc., but these products will not be a significant part of the future fertilizer system.

Alternative agriculture has been an interesting experiment which could have contributed valuable knowledge to intensive agriculture. What began as a movement to revolutionize agriculture has however, changed from idealism to commercialism, signaling the beginning of the end. Alternative farming requires more land at the expense of efficiency. It cannot be a solution to feeding the growing population of the world.

Physical Form of Fertilizers

Fertilizers are delivered to the farm in dry, liquid and suspension form. Dry products can be granulated, compacted or prilled.

Compacted fertilizers typically have poor spreading properties and tend to be dusty. Production volumes show a falling trend. During the last 20 years, the industry has significantly improved the quality of granulated and prilled products. Particle size distribution and flowability now can be closely controlled with the development of modern coatings and conditioning agents, which resist caking, suppress dust and reduce moisture pick up. In the future, we will realize further improvements in coating systems. As an example, in 1992 Hydro Agri introduced Tropi-Cote®, a specialized coating and conditioning formulation for dry fertilizers used in areas with high temperature and humidity. With this new formulation, moisture pickup has been reduced by 90 %, resulting in major improvements in handling properties of hygroscopic fertilizer products.

Future dry fertilizer products will be granulated or prilled with particle size distribution according to customer requirements. Accordingly, for precision agriculture, the trend toward increasing the average particle size far above 3 mm should stop, as the future fertilizer concept aims for increased number of particles per growing plant. By example, the new line of NPK miniprill products Hydro Agri recently has launched for the home garden, landscape and golf course markets give 8-10 times more particles per unit area of ground cover than standard sized products. Hydro Agri has also developed large fertilizer particles for paddy rice and forest fertilization, markets where standard products were clearly inappropriate. These examples show that the physical form of future fertilizer products will be tailored to fit the end use and thus will be an important parameter in the development of the "Total Economic Yield" concept.

Bulk blending of fertilizer products is well established in many markets. The ultimate spreading quality and crop use efficiency of physical blends is highly dependent on the particle size and shape of the raw materials. Segregation of nutrients due to differences in particle shape and size of the blend components, and the high nutrient content in each particle contributes to uneven application and few particles per growing plant. Hence, blended products can show large deviations in nutrient content from batch to batch, from field to field and row to row. Clearly, this is counter to the future fertilizer concept. On the bright side, there are some large bulk blending companies which operate with tight raw material specifications and employ on-line nutrient analysis and particle size monitoring. Such plants operate at higher cost but should prosper in the future.

In the US, the application of fluid fertilizers increased from almost zero in 1955 to around 40% of the total nitrogen fertilizer consumed today. More recently, fluid fertilizers have become common in parts of the UK and France. Anhydrous ammonia became popular in North America in the 1960's and was the leading fluid fertilizer for many years. But, its use has dropped significantly due to high equipment cost, unpredictable ammonia losses, and strict safety regulations.

Today, urea ammonium nitrate solution (UAN) with 28-32 % N is the leading non-pressure fluid nitrogen fertilizer, but straight solutions of urea and ammonium nitrate also are common. In North America, ammonium polyphosphate solutions (APP) are the most widely used, most cost effective liquid phosphate starters and sidedressers. These solutions, with analysis 10-34-0 to 11-37-0 are readily produced in mobile cross-pipe reactors and moved directly to the dealer's storage. If high quality superphosphoric acid with low MgO content is used, the resulting APP liquids will remain stable in storage through the season. Homogenous NPK solutions can not be produced with high nutrient content as potassium readily crystallizes out. The maximum stable N+P2O5 +K2O concentration is 27-30% [10]. For greenhouse horticulture and open field full bed mulch drip irrigation systems in high cash crops, the more expensive water soluble fertilizers are used, like potassium nitrate, calcium nitrate, mono potassium phosphate, technical grade MAP and ammonium nitrate.

The main advantages of liquid fertilizers are that they are easy and efficient to transport and handle, and can be applied more uniformly and accurately than solids. Equipment is simple and relatively inexpensive. Depending on the area and crop, the total cost of applying nutrients to the soil can be cheaper with liquids; in other cases, solid fertilizers will give the lowest cost. Solutions make excellent carriers for additives. Secondary nutrients, micronutrients and pesticides easily can be combined with liquid fertilizers. Ammonium thiosulfate can be mixed with UAN solution to add sulfur. Ammonium polyphosphate liquids are compatible with zinc salts and soil pesticides. Liquids are well adapted for irrigation systems, however, a major drawback is the low nutrient content of multinutrient formulations [1]. Thus, farmers often preplant with high analysis dry fertilizers and use the liquids for starters and supplemental fertilization during the growing season.

It is certain that the use of liquid fertilizers will increase in Europe as they have in the U. S. Liquids afford precise calibration and placement, which are critical to efficient use of phosphate and micronutrients. Since surface applied UAN and urea solutions can lose ammonia at almost the same rate as top dressed dry urea, current techniques for soil injection and irrigation induction will have to be refined. Similarly, more cost effective additives to suppress ammonia loss will have a place. Nevertheless, development in Europe will not follow the same rapid course as in the US, since in much of Europe, farms are smaller and are located on more ridged and hilly landscapes, so investments in transportation, storage and application systems can be quite high at the individual farm level.

Suspension fertilizers contain solid microcrystals in a liquid carrier. The advantages over clear liquids are higher nutrient content and lower production cost. The disadvantages are limited storage life, precipitation of solids, and the need for agitators and specialized application systems. For these reasons, suspensions have scarcely become established in Europe, despite efforts to introduce them. In the US, the large scale and high intensity of farming together with a well developed distribution and service sector have allowed the successful introduction of suspensions [10]. But, they seem to have leveled off. Suspensions likely will not be developed on a large scale in Europe.

The Future Fertilizer System

The future fertilizer concept must re-supply the soil with what the crop has removed and compensate for the other unavoidable losses. All essential nutrients, primary-, secondary- and micro- must be involved in the balances. Hence, there will be increasing attention given to precise quantification of nutrient losses from crop removal and other factors to design fertilizer application programs which replace these nutrients. The unavoidable loss of nutrients to water, the atmosphere, and to non-labile soil complexes will be minimized by optimizing fertilizer product composition and form, refining application systems and improving application timing.

To increase nitrogen efficiency, split application on demand will be a part of the future system. The use of current slow or controlled release technology seems to be neither a solution to the leaching problem nor to efficient crop nutrition. Fertilizer spreading needs to be improved by development of application systems capable of more accurate distribution, perhaps in combination with on-line soil and yield mapping.

Crop Specific Multinutrient Fertilizers.

As the intensely cultivated "industrial" soils approach "saturation" in the labile nutrient pool of mineral and organic complexes, the trend will move towards multinutrient prescription fertilizers [14]. It will start in intensely cultivated high cash crop areas adjacent to population centers. Ammonia losses, concern for nitrate leaching, safety regulations and the increasing need for precise phosphate distribution, will cause the standard volume grades (commodities) to lose position in favor of differentiated products and specialty fertilizers. We foresee that direct dry application of straight AN, urea and DAP will gradually decrease and will be replaced by prescription formulated, high quality blends and homogeneous multinutrient fertilizers (fluid and solid).

In split application systems, we expect the trend will move toward full season programs including:

- NPK "starter" with low N-high P2O5-products combined with K2O, S, MgO and the necessary micronutrients applied at planting.
- NS fertilizer (AN + AS or CaSO4) at first top dressing/side dressing, and
- straight nitrate or AN based fertilizer thereafter as necessary.

To meet the many challenges, we should anticipate an increased demand for new fertilizer grades. Fertilizer producers can respond only by extending production flexibility. The demand for specialty fertilizers will increase in the greenhouse industry, the vegetable and fruit industry, the professional turf sector, the home and garden sector and in industrial crops. As most of these segments operate with a high net value compared to fertilizer input cost, growers will adopt more expensive fertilizer concepts, if and when they are demonstrated to be reliable and profitable. This will further drive development towards crop specific multinutrient fertilizer systems ("Designer Fertilizers").

Low volume precision sprinkler and drip irrigation systems dominate in much of the high value cropping areas. Hence, we may experience increased investment in the development of both water soluble crystalline products and more complex liquid fertilizers. Use of standard volume liquids will continue to increase in the open field, commodity crop sector, especially on irrigated large farms on flat terrain.

The Ion Exchange N Fertilizer

The ultimate goal for development of a nitrogen fertilizer product is to increase nutrient use efficiency and avoid loss. In theory, this can be done with a fertilizer system with two properties:

- controlled release of nitrate to the root solution in proportion to the need of the growing plant, and
- a "buffered" system with the ability to absorb and store surplus nitrogen derived from excess fertilizer and mineralization of organic residue in the soil, especially after harvesting.

We are looking for a chemical product which can "buffer" the nitrate concentration in the soil:

$XNO3 \leftrightarrow X+ + NO3-$

The problems facing us are several:

- inorganic nitrate salts have high water solubility,
- nitrate does not form insoluble precipitates,
- available organic complexing agents are biodegradable,
- inorganic anion exchange systems have very low affinity for nitrate, and
- organic anion exchange resins are inefficient and expensive.

Another alternative is to use cation exchange materials such as clay or zeolites to regulate ammonium. Zeolite is being evaluated for its ability to increase the cation exchange capacity and water retention capacity of coarse textured soils. While this may reduce total N-leaching through retention of ammonium, it will have no direct effect on nitrate absorption and retention.

It will be quite difficult to incorporate all the required mechanisms into one type of fertilizer but research will continue. If an effective and inexpensive ion exchange fertilizer can be developed, it will strongly influence both the fertilizer and agricultural industry of the future.

Marine Cultivation

Marine plant biomass is almost equal to that from terrestrial primary production, but only 5-10% of the world 's protein production is harvested from the sea [12]. Scientists have suggested that marine production can be increased significantly by the use of fertilizers. In the marine food chain, fish consume zooplankton which in turn eat algae. And, algae depend on light and dissolved nutrients for photosynthesis. Marine algae, at the base of the food chain, need a supply of nitrogen, phosphate and water soluble silica to thrive. Nitrogen probably could be supplied by ammonium nitrate or a straight nitrate fertilizer products. Phosphate need only be water soluble, and the water soluble silica can be derived from a sodium silicate product.

Under the auspices of the EU R&D program, Maricult, of which Hydro is a 20% sponsor, 16 mill US$ will be employed to support a 5 year study to identify and define the potential for and environmental limitations to increased effective production from the sea. Some of the goals of Maricult are to determine how to stimulate the right species by use of fertilizers; to define the system's maximum nutrient carrying capacity; and to understand the relationship between CO2 absorption and nutrient supply.

FAO estimates the global harvesting of fish and other marine food organisms to be 100 mill. t/yr. Scientists indicate that it may be possible to increase this by another 50 mill. t/yr. within only 0.1% of the ocean surface by the use of 12 mill. t . N, 4 mill. t. P2O5 and 10 mill. t. Si [11]. The cost of fertilizers would be very low compared to the value of the final marine products. Aside from the food value, the increased algae growth will absorb considerable amounts of CO2 from the atmosphere. In fact, scientists have suggested that these "oceanic" fertilizers may be the only realistic way of controlling the atmospheric CO2 content.

Marine cultivation offers some very interesting possibilities in the quest to feed the growing world population and combat environmental degradation. If it becomes a commercial reality, ocean farming could re-vitalize the fertilizer industry as a whole. However, the extensive research required and the associated global analysis of the moral, ethical, social and legal issues have only barely begun. Therefore, it will take several decades before marine cultivation is established on a large scale.

Concluding Remark

During the last decades, we have a witnessed tremendous strides in the development of new manufacturing processes and new fertilizer products to meet new demands. This trend must continue if the fertilizer industry of the future is to meet new requirements from its customers, its colleagues and from society.

References:

1. Achorn, F.P. [1982] Fluid Fertilizers. The Fertilizer Handbook, The Fertilizer Institute, Washington DC. Chapter 4, page 71-89.
2. Agra Europe (1995). EIU gives stark warning on 1995 grain crops. Oct.6.
3. Bøckman, O.Chr., Kaarstad O., Lie O.H., Richards We. (1990), Agriculture and Fertilizers. Fertilizers in Perspective. Agricultural Group, Norsk Hydro a.s., Oslo, Norway.
4. Brown, Lester R.(1995), State of the World. Worldwatch Institute, Washington.
5. Buhlmann, Vølke (1995). Forcast based on "Statistisches Jahrbuch über Ernährung Landwirtschaft und Forsten". Private communisation.
6. Christodoulou, Maria and et.al. (1994 and 1995). Agriculture in EU and the CAP reforms. Reports to Norsk Hydro.
7. Dawson, C.J. (1994). Report from Workshop 2. Fertilizer spreading and application. The Fertilizer Society International Conference. Proceedings no. 354.
8. ECETOC (1994). Ammonia Emissions to Air in Western Europe. Technical Report no. 62 , July 1994.
9. FAR LETTER, (1994) Vol. 10, No. 2 June, Norcross, GA.
10. Hauffe, W. (1987) Fluid Fertilizers. Ullmann's Encyclopaedia of Industrial Chemistry. Vol A10, chapter 2.2, page 346-356.
11. Hoell, E (1995). Private communisation. Norsk Hydro Research Centre, Porsgrunn, Norway.
12. Hoell, E. and Olsen, Y.(1995) Is there a sustainable blue revolution? (Marine Cultivation - A New Area for Fertilizer). The Fertilizer Round Table, 45th annual meeting, Oct. 23-25.
13. Kongshaug, G. (1992). Trace Elements in Phosphate Rocks, Problems with build up in soil. Fact or fiction? Fertilizer Industry Round Table, Oct. 26-27.
14. Kongshaug, G. (1995). Fertiliser for the Future. The Fertilizer Society International Conference, Dec.6-8.
Proceedings no. 374.
15. Kuhlmann, H. (1992). Fertilizer for today and a vision for the future. Internal Hydro Agri report.
16. RIVM (1993), Rijksinstituut voor Volksgezondheid en Milieuhygiene, The Netherlands.
17. Schnug, E., Hanelelaus, S. Murphy, D. (1993). Impact of Sulphur Fertilization on Fertilizer Nitrogen Efficiency. Agriculture. Volume 17, page 9.
18. Tveitdal, S. (1995), Private communication. United Nation Environment Program, GRID Arendal, Norway.
19. U.S. Dept. Commerce. (1994) Census of Agric. 1992 Georgraphic area series, Part 51, U.S. summary and state data. AC92-A-51, Washington, D. C.
20. USDA. (1982, 1987, 1992) Crop production summary. Nat'l Agric State Ser., Washington, D. C.

Application of Technology to Natural Disasters in Fertilizer Plant Design

Robert E. Robinson
Robert E. Robinson and Associates

Introduction:

We tend to think of our Earth as a very stable, unchanging home. Actually, many kinds of geological events on Earth are constantly occurring. Energy is the driving force of most such changes. Movement of the wind and water, electric storms, fires, volcanic eruptions, earthquakes and landslides all involve energy. When such an event causes damage or loss of life, we call it a natural disaster.

Disasters caused by the actions or neglect of man are not properly attributed to nature, and could be called industrial disasters. Some consequential events such as fires, explosions, and water damage can result from either natural or industrial causes.

When we choose sites or locations and build plants we should attempt to apply mathematical, scientific and technological principles to our work to minimize the probability of losses due to these natural disasters.

Choice of Plant Sites:

In the case of new construction, we usually have some degree of choice in the selection of sites. While economic factors such as cost of materials transportation, availability of raw materials and power, ecological considerations and construction costs are usually overriding, consideration should always be given to the possibility and probable frequency and severity of the occurrence of natural disasters.

Construction costs are directly related to site suitability, including grading and or fill requirements and the need for pile foundations. The necessity to provide roads, docks, and other utilities can be a major factor in construction costs. Even for small to medium sized facilities, weather, earthquake, flooding, and soil mechanics studies including test borings, compaction analyses, and soil samples are wise investments.

Flooding:

Exposure to the risk of floods is usually indicated by past history and subject to evaluation by the use of probability and statistics, hence the degree of risk over time is somewhat predictable.

Damage to footings and foundations is much more rapid and severe when inflicted by rapidly moving water as from raging rivers or streams, while well constructed foundations often suffer little damage when flooded by still or slow moving waters.

The creation of systems of dams, dykes and reservoirs has been quite successful but also quite expensive. In some locations, systems of storm drains, sumps, and sewers or aqueducts are advisable and effective against both flash floods and flooding from extended storms. Oversized gutters and downspouts and large floor troughs for rapid drainage of roofs and floors are good design practices.

Obviously, the risk of flooding must be a serious factor in site selection and plant design.

Earthquakes:

The movements and collisions of the earth's tectonic plates cause earthquakes to occur because stresses build up and then are suddenly released when the contacting plates slip or are crushed in local areas. Earthquakes are sometimes associated with volcanic activity and rarely with the impact of a large meteorite.

It has been estimated that there are over 100,000 earthquakes worldwide each year. Most are relatively minor, but the range of intensity is enormous. Remember that the Richter Scale is exponential. Each increase of 1.0 on the Richter Scale represents 10 times greater intensity, so that an increase of 2 from Richter 5 to 7 represents an increase of 10 times 10 or 100 in intensity, which is mathematically expressed as 10 squared or 10 raised to exponent 2. For an increase from 5 to 8 the increase is 10 to the power 3 or 1000 times more intense.

The time duration of earth shocks and quakes ranges from less than one second to a maximum of about 30 seconds. A major shock is rarely a single shock, however, and usually there are a number of after shocks of varying intensity. For design purposes earthquake forces are regarded as reversible. Design against vertical forces must be against both upward and downward forces and design against horizontal forces must be against any direction.

Displacement, or local movement of the ground may range from a fraction of an inch up to tens of feet. Some of you may remember an aerial photograph taken after the San Andreas quake showing a highway in California which crossed the fault line at about 90 degrees. On one side of the fault the roadway was completely shifted about 20 feet relative to the road on the other side of the fault. Other photographs showed similar displacements.

It is the combination of displacement and time which determines the intensity of an earthquake. The average rate of displacement expressed as feet per second is a velocity, technically a vector having magnitude and direction. The rate of change in the velocity expressed in feet per second per second is an acceleration also having magnitude and direction, and therefore also a vector. It is this acceleration, usually in a horizontal but possibly also with an upward or downward component which, coupled with a property of mass which we call inertia, causes the forces and stresses which bring structures down. Consider the basic formula from physics, using algebraic symbols:

$$F = M \times A$$

This is simply saying that force equals mass times acceleration. The units used must be consistent, of course.

In the Systeme International (SI) system, the physical units are:

$$\text{Kilograms force} = \text{Kilograms mass} \times (\text{Meters/Seconds})\text{squared}$$

In the English system the formula and physical units used in this equation are:

$$F = \frac{W}{g} \times A$$

$$\text{Pounds force} = \frac{\text{Pounds force}}{(\text{Feet/Seconds})\text{squared}} \times (\text{Feet/seconds})\text{squared}$$

Just after the Kobe quake I saw on TV a clip from a security camera in a grocery store in which the bottom of a food storage shelf unit and the floor seemed to move very quickly to the right relative to the camera while the loaded upper shelves resisted this motion because of their inertia, appearing to remain nearly stationary relative to the camera. The shelf unit tipped and then fell.

Figure 1 shows graphically the idea of an overturning moment. If the displacement was about 1.25 feet and occurred in about 1/2 second, the horizontal acceleration would have been just over 1/4 that of gravity, 0.28 x g, or from zero to about 9 feet per second in one second. The inertia of the mass of the shelf unit resists this acceleration and a resisting force acts in a direction opposite to that of the acceleration.

At rest, the weight is evenly divided between the front and back feet of the shelf unit, but during the horizontal acceleration, the resisting horizontal reactive force creates an overturning moment as a result of which the left vertical support reaction increases and the right support reaction decreases beyond zero and becomes an uplifting force. When the center of gravity moves beyond the left reaction overturning will result.

This is only a simple example employing some crude approximations, of course, but it simulates in simplified fashion a tall structure and is indicative of the order of magnitude of possible values of horizontal accelerations during severe earthquakes.

Consider the basic equation from mechanics, using algebraic symbols:

$$S = Vo \times T + 0.5 \times A \times T^2$$

This is simply saying that distance of displacement occurring in the time interval T equals initial velocity Vo times time T plus one-half times the uniform acceleration rate A times the time interval T squared. If at time T = 0 the unit is at rest, the velocity Vo = 0 and Vo x T = 0, so that the first term on the right side of the equation drops out, having a value of 0 so that:

S = 0.5 x A x T^2

Again all units used must be consistent.

In Kobe, Japan most of the newest earthquake resistant buildings survived with little or no damage, while most of the older structures were completely leveled.

Historically, estimates of quake intensity have been very much too low for high intensity zones. In the past we have underestimated the possible accelerations and consequently the forces and stresses to be resisted. Many older buildings are seriously deficient. Efforts have been going forward to strengthen many buildings in the San Francisco and Los Angeles areas.

Earthquake loadings are somewhat different from wind loads in that they result from accelerations of structures at their foundations. Estimated horizontal and vertical seismic zone accelerations are used to calculate a shear force which is multiplied by a series of correction factors to estimate a maximum design base horizontal shear force. This force is distributed through the structure by code rules and the resulting loads are added to conventional loads in the structure according to code specified rules.

At present building codes recognize a number of seismic design classifications which define seismic design procedures for piping systems, piping support design, various building and equipment support structures, and architectural components. Maximum probable horizontal and vertical seismic accelerations are defined based on geographic site zone seismicity and the nature of the structure. An importance factor based on performance level and degree of survivability required and a factor for type of structure and structure ductility are determined. A factor for the natural period of structure vibration and a site structure interaction factor based on the nature of the soil or ground are chosen. In the case of tall structures located close together a structure interference factor may be required. The maximum probable horizontal acceleration is multiplied successively by each of these factors and then by the total structure dead and live load to obtain the Design Total Base Shear Force.

This base shear force is then distributed to the various floors in accordance with the code.

Horizontal and vertical acceleration values range from about 0.05 up to about 0.30 times g, the acceleration of gravity, which is usually taken as 32.17 feet per second per second.

Concrete structures have suffered earthquake damage disproportionately relative to steel structures. Concrete is an essentially rigid material having very low ductility. It is strong in compression, particularly in blocks and large masses, but we have seen repeated failures of elevated highway piers even when well reinforced with steel. Such concrete members don't seem to be able to flex or bend enough to absorb enough energy from the sudden shock of a big quake without rupturing.

Steel, in contrast to concrete, is quite ductile and will stretch or flex and absorb significant shocks. But any structures must be well designed and well built, and located on suitable soil or rock. The ductility of steel structures enables them to flex and absorb some of the energy from an earthquake, reducing the stresses and strains.

Foundations built on soft alluvial soil and on fills are subject to soil liquefaction with sudden settlement and instability during a quake. Under certain conditions water and steam may be forced into these soils and they may essentially suddenly liquefy or fluidize, losing almost all physical strength almost instantly.

Connections are of utmost importance in any structure. Steel welds cracked in 120 supposedly earthquake resistant buildings in the Northridge, California quake. Improved welded connection designs are being developed.

High strength bolts and high strength steels are very good, but some ductility is necessary to withstand the very sharp initial shock loadings. Very high strength bolts cannot be overtightened beyond specifications without risk of failure. Shock absorbing moment resisting beam to column and column to footing connection designs have been and are being developed and tested. Vibration frequency analyses are being used in designing tall structures.

For piping systems, better designs with clearances and flexing joints on long runs can allow displacement and flexure without failure to reduce the loss of fuels and water supplies, also reducing the feeding of natural gas fed fires and maintaining water supply integrity for disaster fighting capability.

Earthquake loadings are not required by statute in many areas of the world, but are increasingly being added to design specifications. As research and design development progress, techniques and standards are being continuously improved and changed.

Tornados:

Tornados are very intense cyclonic windstorms capable of major local damage. They may occur aloft as well as at surface level, and vary in diameter from as little as 30 feet to as much as 3000 feet. Wind velocities as high as 300 miles per hour have now been reported. Much of the continental U.S. is susceptible to potential tornado damage. There does not appear to be much hope in attaining any real accuracy in predicting frequency or locality of occurrence. Fortunately, the duration of tornados is usually short, the land area impacted by a single tornado is usually quite small, and the probability of a hit in any particular area is very slight.

Building practices and codes do not generally provide for forces generated by intense tornadic winds, but since most wind storms are not "killer storms" the use of good sound construction practices and avoidance of building obviously vulnerable structures are sound practices. There is little justification in over building simple isolated farm structures which are usually unoccupied. Keeping such constructions low to the ground, securely anchoring roof structures, and using good connections will help minimize wind damage at the most frequently encountered wind velocities. Public structures with high occupancies should be designed with higher "importance factors" to better safeguard continuing function during emergencies and to better protect human life.

Electrical Storm Damage:

Damage from lightning strikes is not unusual, with fire being a frequent result. Fortunately, systems of lightning rods or arrestors and grounding rods are quite efficient and are advised for wooden structures or those considered vulnerable to lightning or fire. Fuel storage tanks are vulnerable and fires in such tanks resulting from lightning strikes are not unusual. Information on lightning rod and ground systems can be found in the National Electrical Code Manual.

Hurricanes:

Hurricane risks are well known. These are large tropical maritime wind storms which can cause major damage to coastal areas from high velocity winds, wind driven water, waves and surf action, and high water flooding. In contrast to tornados hurricanes are large storms with greater repetition in susceptible areas, more lengthy durations, and much greater land area coverage by an individual storm. Wind and storm surges of rising water usually cause the most damage.

Consideration of hurricane risk should certainly be taken in plant location studies, and exposed sites in hurricane flood plain areas are to be avoided where possible. Sturdy construction, often of open wall, well anchored shed roof type has been fairly successful.

Codes and Standards:

The American Society of Civil Engineers publishes an ANSI/ASCE Standard entitled MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES, which is revised and reissued from time to time as new technical knowledge warrants. It contains recommendations on minimum wind, snow, rain, and earthquake loads, giving maps which set forth various geographic zones and zone factors. Care should be taken that the latest available revision is obtained and used.

The Uniform Building Code is a model code published by the International Conference of Building Officials which is revised every two years. Many local codes have adopted provisions from this code, but the latest edition of the appropriate local code should always be consulted.

The codes are not teaching tutorials, and they expect that users will be properly qualified and that they will keep themselves up to date and currently informed as to theory and methods.

The European Convention for Constructional Steelwork (ECCS) in Brussels offers similar materials.

Design:

It is beyond the scope of this paper to discuss design in depth, but a few remarks may be useful. In conventional design, using established procedures and data from the applicable codes, various static and dynamic loads are determined and applied to the structure and transmitted to the foundations through members of the structure.

The structure as a whole and each member and connection are then analyzed and checked to assure compliance with various design requirements. Loads include dead loads caused by the weight of the structure itself and all installed fixtures and equipment, and live loads caused by occupancy, weight of material being processed, wind and snow. These loads are all applied to the building structure as appropriate in accordance with the standards.

Earthquake loads differ in that they originate from movement of underlying soil and foundations and occur throughout the structure as a result of various accelerations in the structure. Because of safety factors already present in a properly designed conventional structure, increases in allowable stresses against added vertical earthquake loads may be allowed but certain checks must be made. Bracing against horizontal lateral forces in a conventionally designed structure may be found to be quite inadequate for earthquakes. Many existing space frames have insufficient horizontal bracing to withstand lateral side forces. A typical possible failure mode in a horizontal plane in such a frame is shown in Figure 2. Excessive side forces may cause buckling in the unbraced top flanges of beams, possibly weakening the beams and overstressing beam to column connections.

A number of specific requirements are detailed in the codes. A proper analysis is lengthy and tedious but most important.

Figure 3 shows several ideas for lateral restraint of heavy rotating shell equipment such as dryers, coolers, and granulators. Foundation piers should be well anchored and proportioned to resist tendencies to turn over under lateral displacements. Anchor bolts should be made substantially stronger than they otherwise might be and should be fitted with long pipe sleeves to allow for lateral displacement and some vertical stretching without failure. Baseplates should be keyed to foundations with shear keys placed in slots in the concrete piers. Thrust roll assemblies provide natural restraints against lengthwise lateral movement, but trunnion bases and thrust roll assemblies should be designed for possible earthquake loads. A possible design for a lateral and vertical restraint placed over a shell tire consisting of a rolled steel plate band bolted to the ends of a trunnion base is shown.

Figure 4 shows a design of a possible earthquake shock and energy absorbing moment resisting beam to column flange heavy welded connection intended to reduce the possibility of weld cracking under severe earthquake loading. Connection designs for this purpose are being developed. Much research is being done currently on earthquake design and codes and standards are being revised continually. Probabilistic design is being used, and for the worst earthquake and tornado loadings design is focussed on survival of structures as a whole to protect human life, but may allow permanent yield deformations to occur under extreme conditions.

Current structural steel design information is contained in the 9th Edition of the "Manual of Steel Construction - Allowable Stress Design" published by the American Institute of Steel Construction, Inc. In addition to design information this manual contains specifications, codes, and commentaries. The basic standards are contained in the "Specification for Structural Steel Buildings," called the

AISC Specification. Various specifications, codes, commentaries, design information, and extensive data on properties of structural steel shapes are included. This ASD manual is the fundamental working reference employing traditional elastic design principles and some coverage of the newer plastic design techniques.

An alternate design method has been available for about ten years, covered in the AISC "Manual of Steel Construction - Load and Resistance Factor Design, 1st Edition." This technique is considered to provide more uniform structural reliability and better economy, but either is currently accepted.

Conclusions

Throughout the world, building codes are being progressively updated and improved, and the engineering schools and universities will certainly train their students in the best available technologies for safer designs. In many places legislation will probably place added restrictions on the building of facilities on poor sites.

Managers and owners need to ask the right questions when planning facilities or reviewing operations to assure that all participants are informed and committed to dealing with the potential effects of natural disaster events.

REFERENCES

1. International Conference of Building Officials: "Uniform Building Code," Most recent edition (supplement issued every year), 5360 Workman Mill Road, Whittier, CA 90601-2298

2 Building Officials & Code Administrators International, Inc. (BOCA): "BOCA Basic/ National Building Code," Most recent edition

3 American Institute for Steel Construction (AISC): "Manual of Steel Construction ASD," containing AISC Specification for Structural Steel Buildings - Allowable Stress and Plastic Design, Most recent edition (revised as warranted)

4 American Institute for Steel Construction (AISC): "Manual of Steel Construction LRFD," based on the AISC Load and Resistance Factor Design Specification for Structural Steel Buildings, Most recent Edition (revised as warranted)

5 The American Society of Civil Engineers "ANSI/ASCE Standard: "Minimum Design Loads for Buildings and Other Structures," Most recent revision (revised as warranted)

6 Brockenbrough and Merritt: "Structural Steel Designers' Handbook," 2nd. Ed., McGraw Hill Book Co., 1994. A very good current structural reference

7 Tall, Beedle, and Galambos, Editors: "Structural Steel Design," The Ronald Press Company, 1964. A very good older text

8 Merritt and Ricketts: "Building Design & Construction Handbook," McGraw Hill Book Company, 1994. A good current building handbook

9 Henry J. Lazarro: "Earthquakes," John Wiley & Sons, Inc., 1996. Much current data, well presented

10 Hanson, Robert D. and Henry J. Degenkolb: "The Venezuela Earthquake, July 29, 1967," American Iron and Steel Institute, New York, 1969. Very good and thorough treatment of a major earthquake at Caracas

11 Gore, Rick: "Living With California's Faults" and "The Earth's Fractured Surface" and "Living On The Edge" (Maps), National Geographic Magazine, April 1995, p. 2-35

12 Reid, T.R: "Kobe Wakes To A Nightmare" National Geographic Magazine, July 1995, p. 112-136

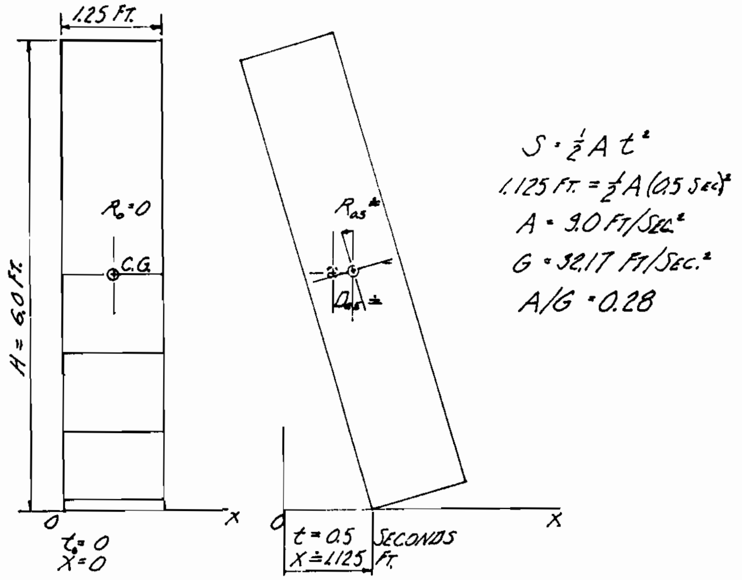
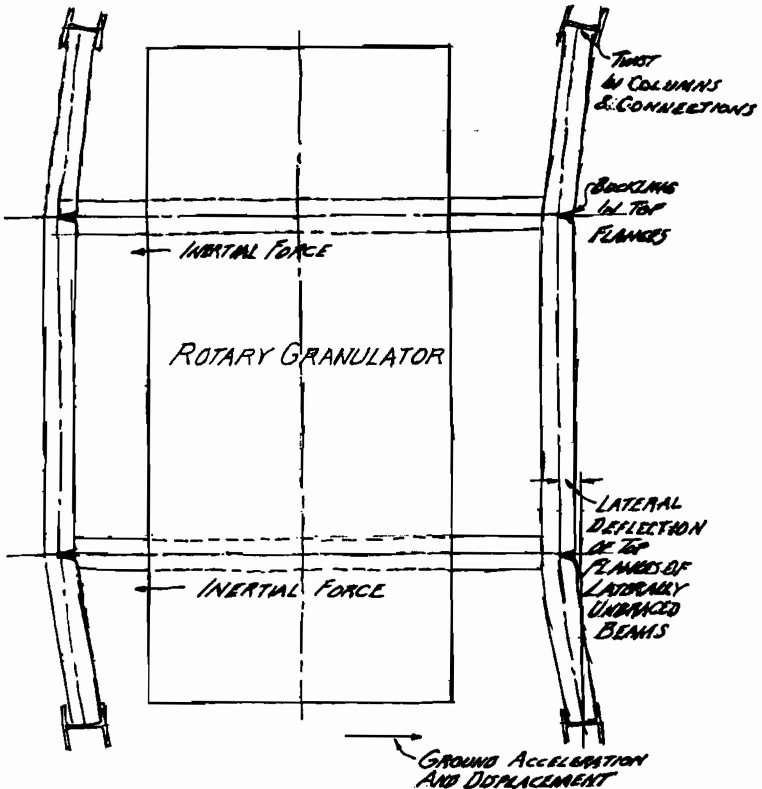


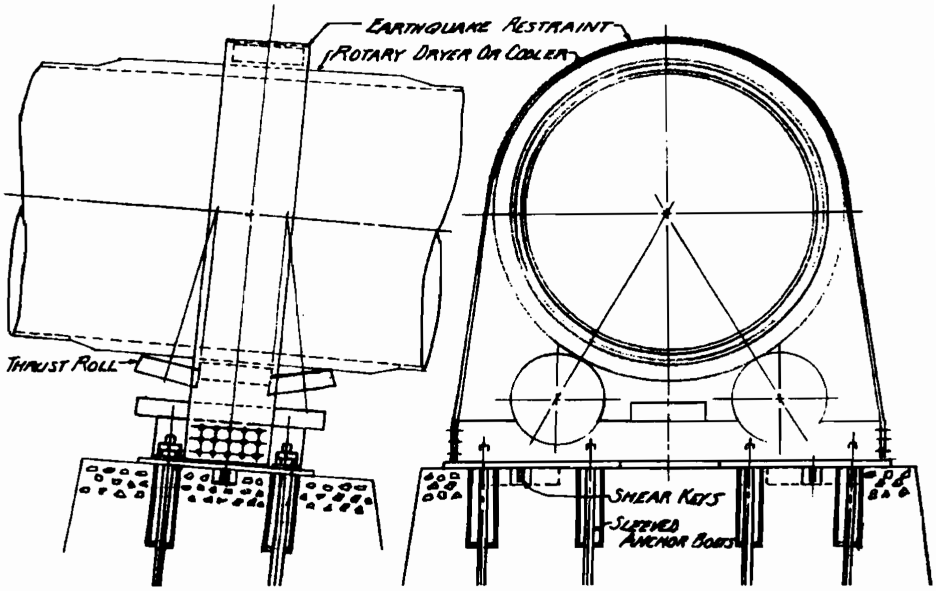
FIGURE 1

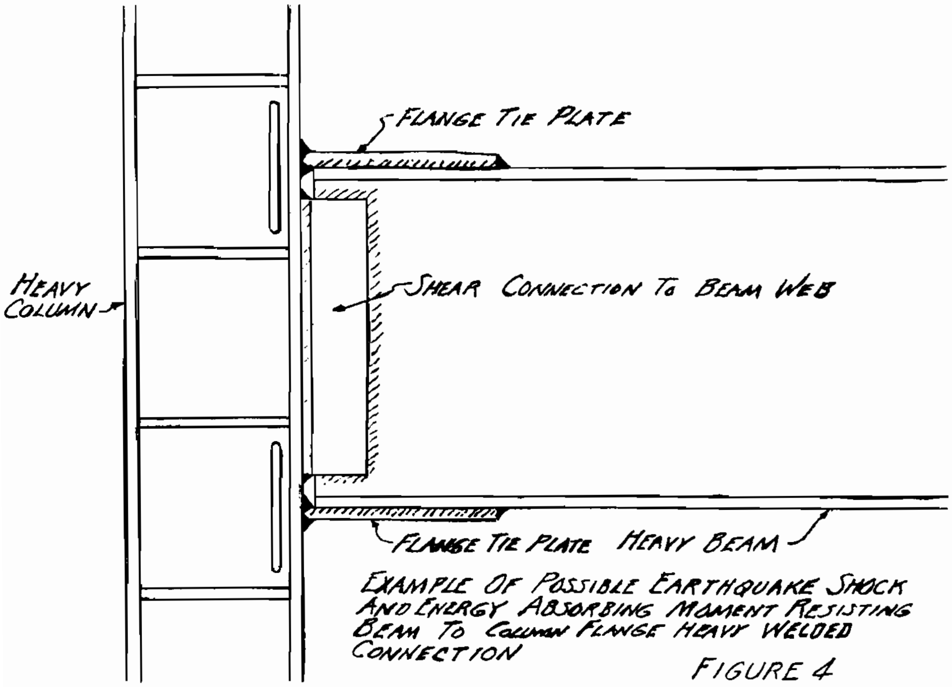
FIGURE 2



PLAN VIEW - FAILURE IN HORIZONTAL PLANE OF FRAME UNDER LATERAL SIDE FORCES FROM MAJOR EARTHQUAKE

FIGURE 3





EXAMPLE OF POSSIBLE EARTHQUAKE SHOCK AND ENERGY ABSORBING MOMENT RESISTING BEAM TO COLUMN FLANGE HEAVY WELDED CONNECTION

FIGURE 4

FINANCIAL STATEMENT

OCTOBER 23, 1995 TO OCTOBER 28, 1996

Cash Balance October 23, 1995		$ 38,273.40
Income October 23, 1995 to October 28, 1996		
Registration Fees - 1995 Meeting & Cocktail Party & Coffee Break Receipts	$ 8,635.49	
Sale of Proceedings	701.78	
Registration Fees - 1996 Meeting & Cocktail Party & Coffee Break Receipts	25,160.00	
Total Receipts October 23, 1995 to October 28, 1996		34,497.27
Total Funds Available October 23, 1995 to October 28, 1996		$ 72,770.67
Disbursements October 23, 1995 to October 28, 1996		
1995 Meeting Expenses (Incl. Cocktail Party)	$ 13,085.17	
Misc. Expenses Incl. Postage, Stationery, etc.	460.27	
1995 Proceedings	7,082.50	
1996 Meeting Preliminary Expense	3,519.00	
Directors' Meetings	1,415.15	
Total Disbursements October 23, 1995 to October 28, 1996		25,562.09
Cash Balance October 28, 1996		$ 47,208.58

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary\Treasurer

Meeting Attendance 143