# PROCEEDINGS
# OF THE
# 33rd ANNUAL MEETING
# FERTILIZER INDUSTRY
# ROUND TABLE
# 1983

**October 25, 26, 27, 1983**
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# Tuesday, October 25, 1983

## Morning Session
## Moderators:

**Harold D. Blenkhorn**
**Charles H. Davis**

## Introduction-Keynote Speaker

Gary D. Myers has been president of The Fertilizer Institute (TFI) since February 1983. He joined the Institute's staff as its director of administration in December 1969 and, during the course of his 13 years with the association, he advanced to the position of executive vice president before leaving in August 1982 to become president of the National Council of Farmer Cooperatives. Six months later he returned to the Institute to serve in his current position as the association's chief staff officer.

As Institute president, he serves as spokesman for the nation's fertilizer producers, manufacturers, retailers, brokers/traders and equipment manufacturers. He represents the nation's plant food industry before various governmental agencies and the U.S. Congress.

By voluntary membership, TFI counts more than 320 active member companies among its ranks, and is governed by a 39-member board. Nearly 400 member company representatives serve on the Institute's 12 action committees, which cover key areas of concern to industry and agriculture. Headquartered in Washington, D.C., the Institute's staff (of more than 30 individuals) is responsible for legislative, regulatory and technical matters, as well as information and public relations programs.

Immediately prior to joining the Institute in 1969, Myers had served as director of member services for the National Fertilizer Solutions Association in Peoria, Ill. He has also served as executive vice president for the Illinois Grain and Feed Association.

He is a 1966 graduate of Bradley University, Peoria, Ill. He was born and raised on a large grain farm in central Illinois.

Gary and his wife, Mary, have a son (Brad) and a daughter (Leigh), and make their home in Falls Church, Va.

## Keynote Speaker

*Gary Myers*
President
The Fertilizer Institute

## Outline

I. Mood of Industry
- Conversations indicate good fall, excellent spring
- Idled plants are up or gearing up
- Salespeople, retailers are busy.

II. Mood of Farmers
- Mother Nature & PIK teamed up to dramatically boost farm prices
- Growers are ready to plant to the fenceposts and ditches
- Cash flow is much improved; attitude is very good.

III. Overall Outlook
- Grain & fertilizer markets appear to be on leading edge of a 12 to 15-month rebound
- Companies and economists are predicting an 18 to 20 percent increase in fertilizer consumption—and I've heard nothing to disprove that projection.

IV. Long Term Stability
- Working with members to forge long-term farm policy
- PIK was painful but important lesson for the fertilizer industry
- We must have greater input and impact on U.S. ag policy
- New TFI Committee is setting a policy course:
  - — exports promotion/incentive
  - — reduced government role in price mechanisms
  - — encouraging Common Market to back away from supports, also

## Outlook for Nitrogen

*J. W. Brown*
Managing Director
Canadian Fertilizer Institute

The nitrogen fertilizer industry is currently experiencing one of its deepest cyclical downturns worldwide. Economic weakness, excessive supplies of nutrients, plant closures, record crop production with resulting high grain inventories and low commodity prices, the U.S. PIK program with its greatly reduced crop acreage and the inability of many developing countries to finance purchases and generate exchange earnings and the high value of the U.S. dollar relative to other currencies are all contributing factors to a dismal year.

The last two years have been difficult for world producers and traders in nitrogen fertilizers. World production and consumption for total nitrogen in 1982 actually showed a decline and 1983 will probably be little if any better. As a result, world nitrogen prices have shown a continuous decline, many plants based on high cost feedstock both in the U.S. and abroad have been forced to close.

### *Changing World Supply-Demand Picture*

Western Europe, traditionally a net exporter of nitrogen, became a major net importer of nitrogen fertilizer in 1982. The cost/price squeeze on production of anhydrous ammonia in Western Europe in 1982 led to a reduction in ammonia output of about 12%.

Japan and Korea were likewise caught in the cost/price squeeze on ammonia production. As a result, they reduced exports to less than half of what they had done in 1980. Japan reduced production from 2.1 million nutrient tonnes in 1980 to 1.7 million tonnes in 1982. Exports declined from 700,000 tonnes nitrogen in 1980 to less than 500,000 tonnes in 1982. Korea reduced production from over 1 million tonnes nitrogen in ammonia in 1980 to about 500,000 tonnes in 1982.

India, in 1982 and continuing into 1983, reduced imports of nitrogen by close to half a million nutrient tonnes. India's production, however, showed a remarkable increase during the past three years. In 1982, ammonia production was 62% higher than 1980.

Pakistan and Bangladesh showed the same general trends as India with production from their own plants increasing more rapidly than consumption.

Brazil has reduced its imports significantly in 1982–83. Part of the reduction was due to increased domestic production. However, a significant part of the decline in imports was due to internal economic problems which has resulted in a drop in nitrogen fertilizer consumption of one-third between 1981 and 1982 and probably a further decline this year.

### *Countries with Increased Exports*

Mexican ammonia production has increased dramatically from 1980 to 1982, from 1.5 million nutrient tonnes to over 2 million nutrient tonnes. Consumption has increased but not as the same pace at production.

Eastern Europe and the U.S.S.R. are taking an increasing share of total world traded nitrogen markets. Consumption within this region has grown from 10.8 million tonnes of nitrogen in 1975 to 13.5 million tonnes in 1982. Exports of nitrogen in the same period have increased from 1.7 million tonnes to 4.5 million tonnes. In 1982, the Eastern Bloc countries supplied 25% of the world nitrogen trade.

China's production of fertilizer nitrogen in 1982 of 10.1 million nutrient tonnes was slightly below the previous year. Consumption, however, was down 584 thousand nutrient tonnes with imports down 423 thousand nutrient tonnes.

### *U.S. Situation*

In 1983 fertilizer year, ammonia production of approximately 13.8 million tons was down 22% from the previous year; the lowest level since 1970. This reduced supply came about due to a 15% to 16% reduction in domestic fertilizer consumption (1.8 million tones N) and an 18% reduction in nitrogen exports (460 thousand tons N). In total fertilizer nitrogen demand for domestic consumption and exports declined by 2.2 million tons N or 2.7 million tons ammonia equivalent. Imports, on the other hand, increased by 4% (122.3 thousand tons N) or 160 thousand tons ammonia equivalent.

### *Canada*

Canadian production of anhydrous ammonia increased 3% in fertilizer year 1983 to 2.66 million product tonnes. Domestic consumption increased 5% to slightly more than 1 million tonnes while exports, mainly to the U.S. market, increased 3% to 995 thousand nutrient tonnes.

### *World Outlook 1983/84*

World consumption of fertilizer nitrogen, after two flat years, is forecast to increase by 3.8% in 1984 or 2.36 million nutrient tonnes. A reduction in carryover grain and oilseed inventories with improved prices are the principal reasons for the projected recovery.

### *U.S. Outlook 1983/84*

#### *Demand*

In contrast to the two previous years where fertilizer nitrogen consumption declined by 7% and 16% respectively, prospects for increased nitrogen consumption appear particularly bullish at this time. Agriculture demand for nitrogen will increase in the 18–20% range during the current fertilizer year. Improved commodity prices, created by the drought of the past summer, will lower carryover inventories of corn and soybeans to the lowest levels since the early seventies. Planted corn acreage is expected to rebound from 60 million acres in 1983 to approximately 84 million acres in 1984.

Crop prices across the board have improved dramatically—much faster than nitrogen fertilizer prices. As a result, it takes less bushels of almost any crop to buy a ton of nitrogen fertilizer than at any time since the early seventies.

The corn-nitrogen price ratio is a good example. In the summer of 1982, it took over 100 bushels of corn to buy a ton of ammonia or urea. With changing prices on corn and nitrogen, by August of this year it had changed to 64 bushels. Since August the ratio has improved even further. This ratio now is significantly better than at any time since the early 1970's. The same is true for other crops.

Therefore, the U.S. nitrogen industry can well expect a return on the consumption levels of 1982 or above.

### *Exports*

U.S. exports of nitrogen declined by 18% from 1982 to 1983 or about 460 thousand nutrient tons. The decline was due in most part to greatly reduced shipments of ammonia (−44%) and urea (−25%) while nitrogen exports in D.A.P. and M.A.P. were above the previous year. Increased demand for D.A.P. and M.A.P. will increase the nitrogen moving to international markets during the current fertilizer year whereas ammonia and urea exports are likely to remain at current levels due to low world prices and stepped-up demand domestically.

### *Supply*

In 1983, U.S. ammonia production was the smallest since 1970 (13.8 million tons contrasted with 17.7 million tons in 1982). This sharply reduced output came about due to extended plant turnarounds and permanent and temporary plant shut downs. Natural gas costs going into ammonia production and other down stream products exceeeded the selling price for many producers. The net result was that operating levels as reported by TFI were at the lowest level of the past ten years. We really cannot expect a large increase in this area until ammonia and urea prices climb substantially above current levels.

The question has been asked why some of the plants that are currently closed do not re-open in consideration of the anticipated higher demand this year. It takes only a brief look at the average production costs of ammonia compared to the current average sales price or anticipated price next Spring to provide the answer. The recent TFI ammonia cost survey showed that 38% of the producing plants, producing 31% of the volume, have weighted average gas costs of $3.90 per million BTU, and a weighted average production cost of $173 per ton. Ammonia and urea prices will have to climb well above current levels before these plants will come back on stream. Some plants have renegotiated their gas contracts and are coming back into production but ammonia production will not likely reach the levels of 1981 and 1982.

### *Imports*

Imports of fertilizer nitrogen increased by 4% in 1983 due entirely to a 72% increase in urea imports. Ammonia imports were down slightly (−4%) from the previous year. The current world glut in urea has led to a prolonged period of very depressed prices which may run well into the future. An anticipated pick up in world nitrogen demand in 1984 will tighten the supply and should strengthen prices.

U.S. ammonia imports which have been running at approximately 2.24 million tons in 1980–82 dropped in 1983 to 2.14 million tons with most of the decrease originating in the U.S.S.R. Imports from the U.S.S.R. have dropped from a peak of 1.1 million tons in 1981 to 474 thousand tons in 1983. This is a significant trend. U.S. ammonia imports are increasingly being sourced from Western Hemisphere countries—Canada, Mexico, Trinidad, and Venezuela. We can expect this supply trend to continue.

U.S. imports of nitrogen could reach the 2.8 million nutrient tons level during the present fertilizer year. Some of these increased imports are likely to originate in Canada for both ammonia and urea. Two new world-scale ammonia plants in Canada, with combined annual capacity of over 900 thousand short tons of ammonia and 880 thousand short tons of urea commenced production in the second quarter of 1983. If economics permit, the combined output of these two units could make available an additional 500 thousand tonnes of nitrogen for export markets in 1983/84. With the start-up of a new urea plant in Trinidad later this year, more product will be available to the U.S. market from this source.

### *Summary*

The 1982/83 year was the second consecutive year of declining nitrogen production, consumption, and exports for the U.S. As a result of the Payment in Kind (PIK) program, agricultural consumption in the U.S. plummeted in 1982/83. More than 50 million acres of land was withheld from agricultural production in 1983. Corn acreage planted alone fell from 82 million level in 1982 to 60 million in 1983.

For the first time in two years, the dominant factors affecting nitrogen consumption—acreage, commodity prices, and farm income—are forecast to make a strong recovery in the 1983/84 fertilizer year.

The summer drought significantly reduced yield expectation for corn, soybeans, and other Spring planted crops. Poor yields and the acreage with-drawn from produciton due to PIK, particularly for corn, will reduce the excess grain inventories, excluding wheat, that have plagued agriculture for the past two years. Commodity prices have strengthened this summer in response to reduced supplies, and the stronger prices will put acreage back into production in 1984.

Agricultural demand and prices are forecast to increase throughout the current fertilizer year. The U.S. nitrogenous fertilizer industry is experiencing some relief on gas costs thus reducing the cost of producing ammonia and its derivatives. Urea imports are expected to decline in 1983/84 relative to prior years' levels. It is believed that with the world nitrogen market recovery, world urea stocks will be reduced and world trade will increase in traditional markets.

Total nitrogen demand is expected to outstrip available supplies in the current year. Ending inventories are expected to decline with nitrogen spot prices strengthening especially in the second quarter of 1984. In total, 1983/84 has all the signs for a much improved year.

**WORLD FERTILIZER STATISTICS**
**(Million Metric Tonnes of N)**

| | 1980–81 | 1981–82 | % Change |
|---|---|---|---|
| Production | 62.60 | 62.04 | – 0.9 |
| Imports | 13.16 | 12.46 | – 4.4 |
| Exports | 13.15 | 11.60 | –11.8 |
| Consumption | 60.60 | 60.44 | – 0.3 |

**U.S. EXPORTS AND IMPORTS OF NITROGEN**
**1970 TO 1983 FERTILIZER YEARS**
**(Nitrogen Short Tons)**

| | Imports | Exports |
|---|---|---|
| 1970–71 | 929 | 1,077 |
| 1971–72 | 843 | 1,032 |
| 1972–73 | 882 | 1,508 |
| 1973–74 | 1,068 | 1,269 |
| 1974–75 | 1,198 | 1,115 |
| 1975–76 | 1,218 | 1,239 |
| 1976–77 | 1,842 | 1,251 |
| 1977–78 | 1,857 | 1,798 |
| 1978–79 | 2,240 | 2,467 |
| 1979–80 | 2,565 | 2,642 |
| 1980–81 | 2,454 | 3,088 |
| 1981–82 | 2,531 | 2,498 |
| 1982–83 | 2,654 | 2,037 |

**U.S. NITROGEN—EXPORTS AND IMPORTS—JULY TO JUNE**
**1982 vs 1983**

| | THOUSANDS OF SHORT TONS (N) | | |
|---|---|---|---|
| | 1982 | 1983 | % Change |
| Exports | 2,497.6 | 2,037.3 | –18 |
| Imports | 2,531.2 | 2,653.5 | + 1 |

**U.S. ANHYDROUS AMMONIA EXPORTS & IMPORTS**
**DURING FERTILIZER YEARS 1974–1983**
**(Thousands of Short Tons)**

| | Exports | Imports |
|---|---|---|
| 1974 | 645 | 438 |
| 1975 | 361 | 598 |
| 1976 | 326 | 767 |
| 1977 | 546 | 960 |
| 1978 | 480 | 1,054 |
| 1979 | 554 | 1,735 |
| 1980 | 776 | 2,219 |
| 1981 | 816 | 2,161 |
| 1982 | 760 | 2,244 |
| 1983 | 428 | 2,144 |

**U.S. IMPORTS OF ANHYDROUS AMMONIA BY COUNTRY—JULY TO JUNE**
**1982 vs 1983**

| | THOUSANDS OF SHORT TONS | |
|---|---|---|
| | 1982 | 1983 |
| Canada | 559.5 | 636.6 |
| Mexico | 608.6 | 528.2 |
| Trinadad Tobago | 332.8 | 378.1 |
| Soviet Union | 733.1 | 474.1 |
| Others | 9.5 | 127.2 |
| Total | 2,243.5 | 2,144.2 |

Source: U.S.D.C.

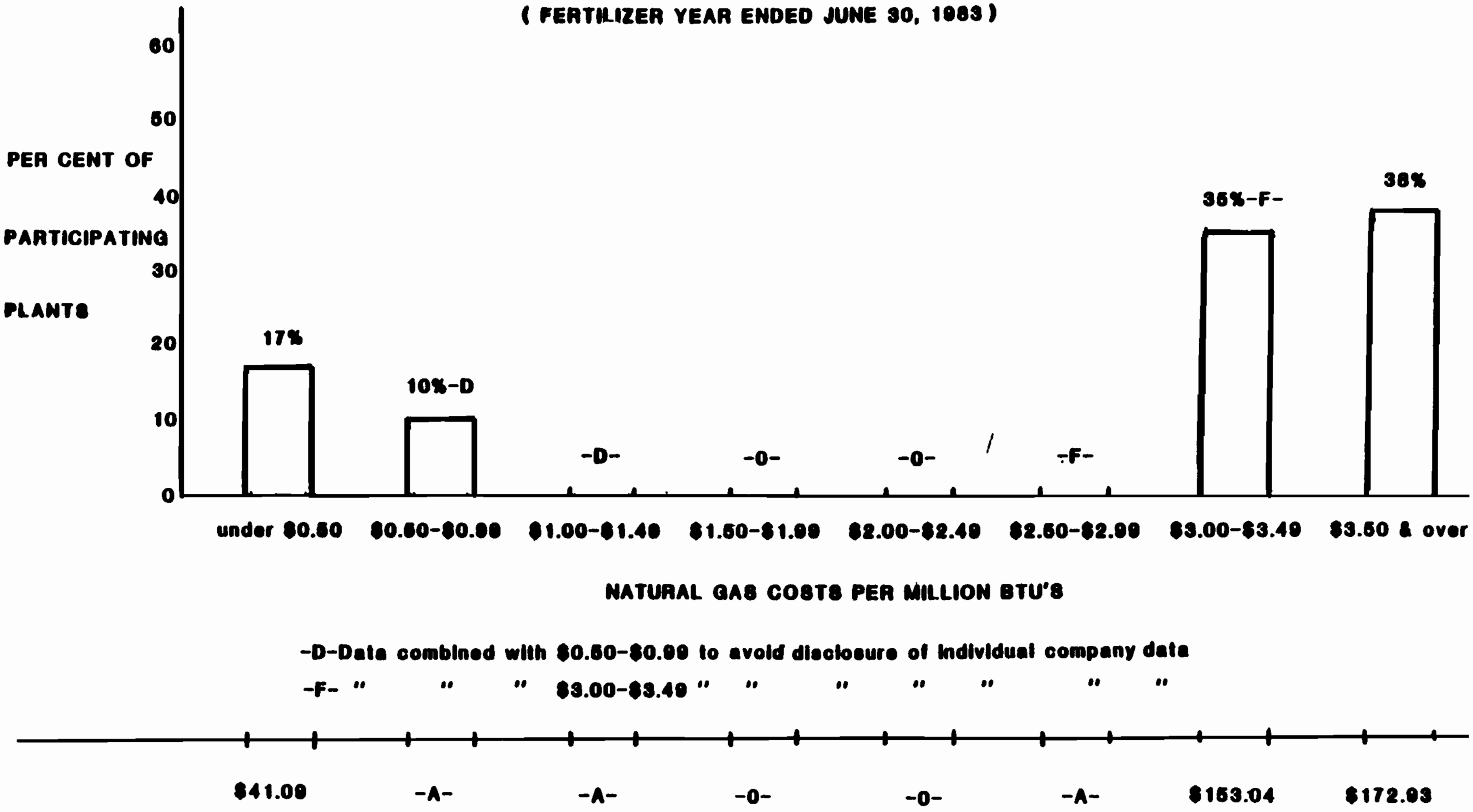
**U.S. IMPORTS UREA—JULY TO JUNE**
**1982 vs 1983**

| | THOUSANDS OF SHORT TONS | |
|---|---|---|
| | 1982 | 1983 |
| Canada | 583.8 | 720.9 |
| Netherlands | 208.8 | 269.0 |
| Venezuela | 12.7 | 122.5 |
| Soviet Union | 35.4 | 261.7 |
| Quator | 42.5 | 69.5 |
| Romania | 0 | 74.9 |
| Others | 30.8 | 107.7 |
| Total | 952.4 | 1,635.9 |

Source: U.S.D.C.

# U.S. ANHYDROUS AMMONIA GAS COST SURVEY

( FERTILIZER YEAR ENDED JUNE 30, 1983 )



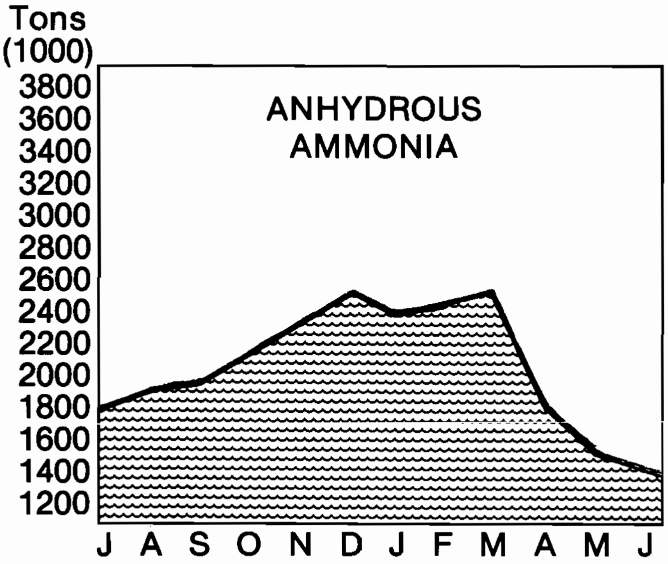
-D-Data combined with $0.50-$0.99 to avoid disclosure of individual company data

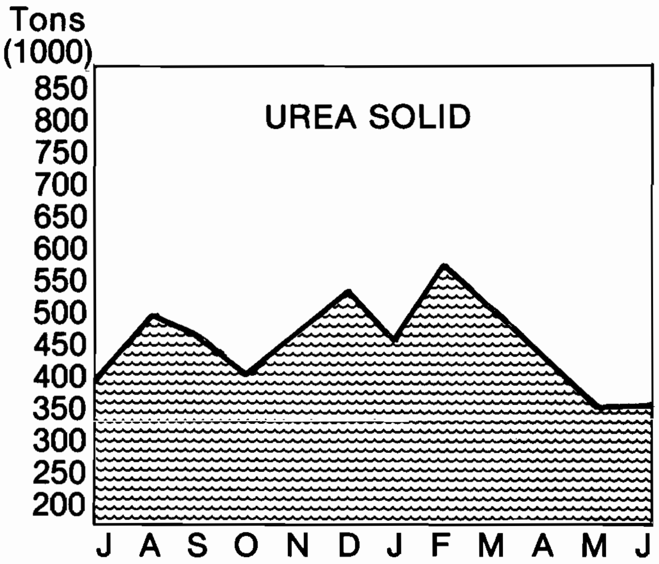
-F- " " " $3.00-$3.49 " " " " " " "

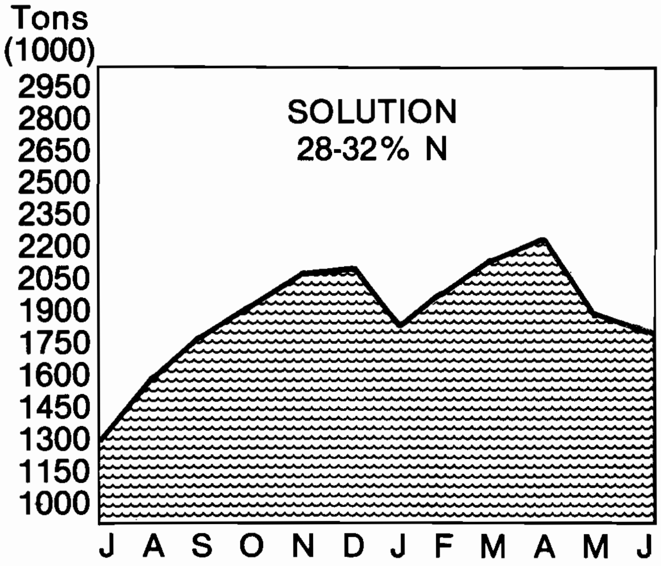
WEIGHTED AVERAGE OF TOTAL PRODUCTION COSTS PER TON (SHORT)

-A-Data not shown to avoid disclosure of individual company data

# U.S. NITROGEN FERTILIZER INVENTORIES





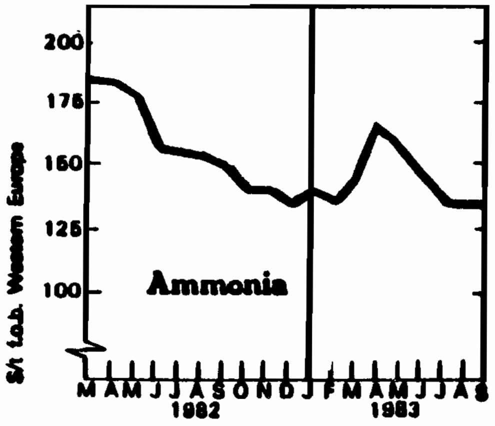


Source: TFI, October 1983

# INTERNATIONAL PRICE TRENDS

# AMMONIA and UREA

**(as at September 20, 1983)**



**Source – FERTILIZER INTERNATIONAL, Number 172, October 1983**

### U.S. NITROGEN SUPPLY-DEMAND BALANCE 1983 AND PROJECTED 1984 (Thousands of Short Tons)

| | 1983 | 1984 |
|---|---|---|
| Domestic Production | 11,401 | 13,499 |
| Producers Beginning Inv. | 2,056 | 1,827 |
| Imports | 2,654 | 2,833 |
| Total Agricultural Cons. | 9,279 | 11,286 |
| Exports | 2,037 | 2,173 |
| Producers Ending Inv. | 1,827 | 1,572 |
| Industrial Use Conversion and Down Stream Losses | 2,968 | 3,128 |

### CANADIAN NITROGEN SUPPLY-DEMAND BALANCE 1983 AND PROJECTED 1984 (Thousands of Short Tons)

| | 1983 | 1984 |
|---|---|---|
| Domestic Production | 2,405 | 3,000 |
| Producers Beginning Inv. | 111 | 182 |
| Imports | 160 | 160 |
| Total Agricultural Cons. | 1,122 | 1,210 |
| Exports | 1,097 | 1,500 |
| Producers Ending Inv. | 182 | 180 |
| Industrial Use Conversion and Down Stream Losses | 456 | 456 |

**U.S. COMMODITY PRICES 1983/84**

| | |
|---|---|
| Corn | +44% |
| Cotton | +22% |
| Soybean | +60% |
| Wheat | +10% |

Source: Chase Econometrics

# Outlook for Phosphates

*Ray W. Rowan*
Vice President
Domestic Phosphate & Potash Sales
Texasgulf Chemicals Company

I have been attending industry meetings and listening to speakers for a long time. There are a few things that became evident to me over the years.

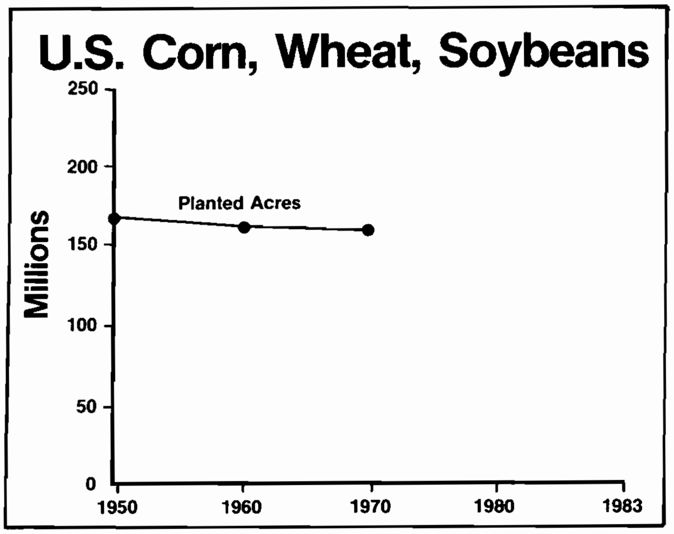
1. The fertilizer business is part of a cyclical industry.
2. Industry forecasts and marketing strategies, regardless of whether they be short term or five years and beyond, are heavily influenced by actual experiences during the previous 12 to 24 months.

The past two fertilizer years have not been outstanding; however, they have been "exceptional." I mean "exceptional" from a negative standpoint. 1981–82 and 1982–83 are exceptional because this is the first time since tonnage records have been kept that U.S. $P_2O_5$ consumption has been down two years in a row.

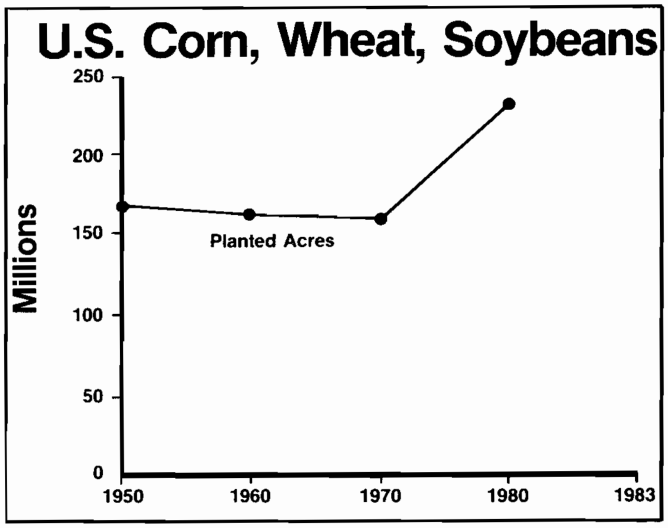
As we study the statistics, I guess we could say there is some "good news" and some "bad news." The "good news" is that the present fertilizer year, 1983–84, is off to a good start on tonnage volume and will easily show an increase over this past year. Obviously, this had to happen sooner or later. The "bad news" is that our preliminary estimate of $P_2O_5$ consumption in the United States for this past fertilizer year was 4.6 million short tons of $P_2O_5$, which is comparable to the U.S. $P_2O_5$ consumption in 1968–69, that's 14 years ago. Yes, we are definitely in a cyclical industry!

At this time, I would like to go through a few slides to help visualize some of the points I will be making as I cover the "Outlook for Phosphates."

Consumption of $P_2O_5$, as well as nitrogen and potash, is closely linked to the total number of acres planted. The PIK Program this past year clearly demonstrates this fact. As we look at the acres planted to wheat, corn and soybeans during the 50's and 60's, we see a flat line. This is because we were growing our crops for basically domestic consumption. The U.S. farmer was able to increase yields through increased fertilizer use, better seed varieties, and generally better farm management practices.

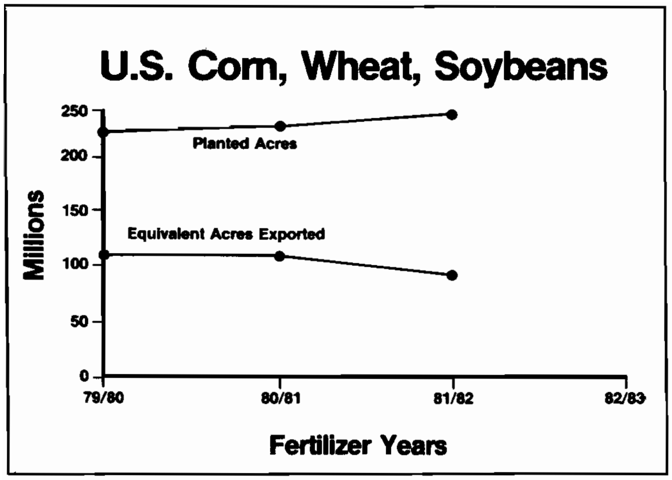


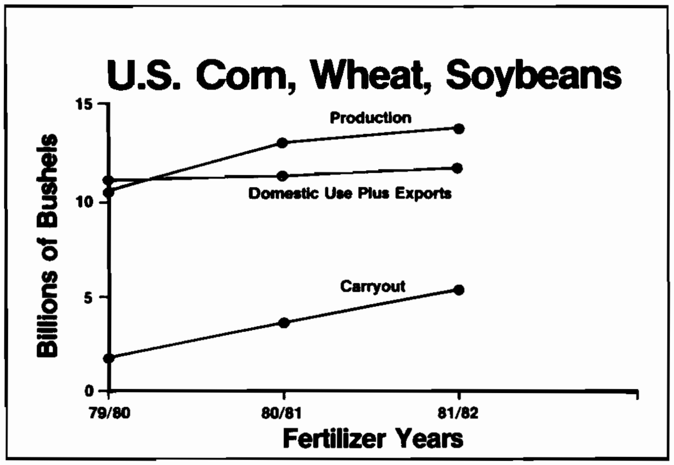
During the 1970's we discovered the export market, or, a truer statement might be, our world neighbors were improving their standard of living to a point where they were needing more feed grains to satisfy their diets. In addition, our relations with Moscow improved through detante and we began shipping grain to Russia. As this slide illustrates, acreage planted to the three major phosphate-consuming crops grew by nearly 50%.



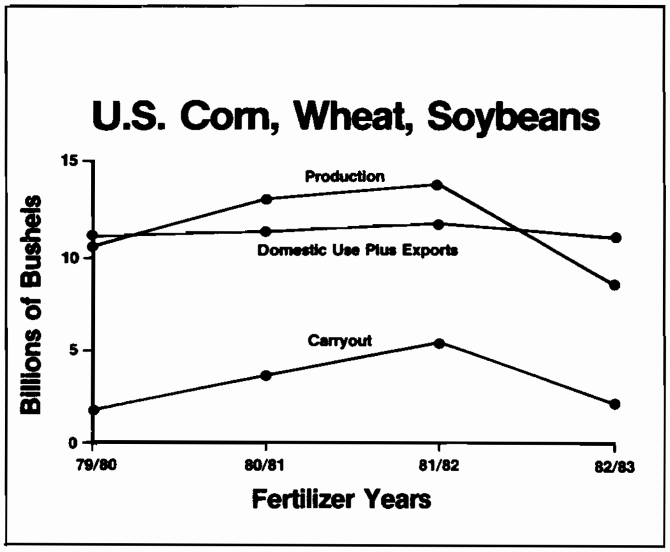
Planted acres continued at fairly high levels in the early 1980's. Our grain exports accounted for 46% of the acres planted in 1979–80. In 1980–81, 45% of the acres planted to corn, soybeans and wheat were exported. In 1981–82, 39% of the acres planted were exported.

The cut back in exports started with the grain embargo to Russia on January 4, 1980. In addition to losing the export sales to Russia, the embargo compromised our dominant role in the world marketplace as a consistent, dependable, long term supplier of wheat and feed grains. Other grain exporting countries were willing to fill the void.



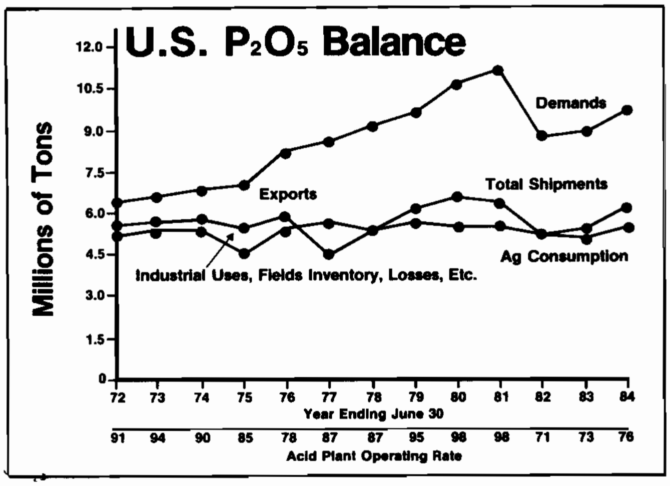


While we were exporting less, our domestic use picked up some, so our total use was staying fairly constant; however, a combination of improved hybrid seeds, fertilizer, excellent weather and good management practices by farmers provided more bushels per acre, which resulted in back-to-back record harvests in 1980–81 and 1981–82. This resulted in increased carryover of grain stocks and set the stage for the PIK Program for the spring of 1983.



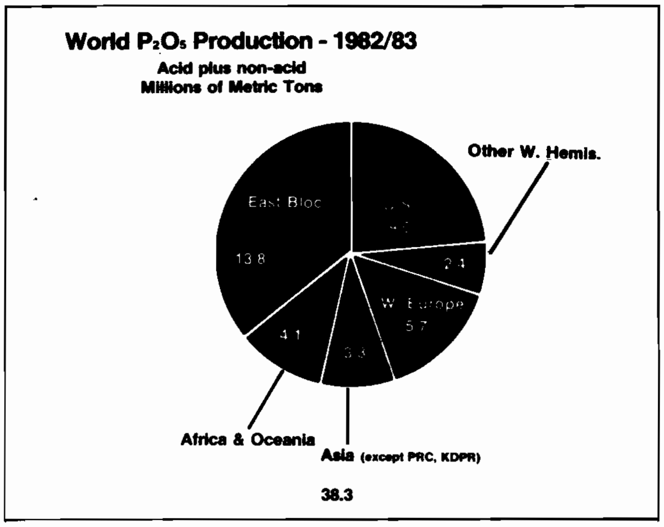
The reduced acres of corn and wheat, due to the PIK Program, coupled with the severe drought, some say the worst drought since the dust bowl years of the mid-1930's, have cut grain production and made a considerable dent in the carryover stocks. Next season we expect planted acres for corn to go from 60 million acres up to 81 million acres, soybeans from 63 million up to 73 million acres, with wheat acres down from 77 to 65 million acres because of the higher carryout stocks of wheat. You will recall that the PIK Program was announced after the winter wheat crop was planted so the impact on acreage reduction was not as great on wheat as it was on corn.

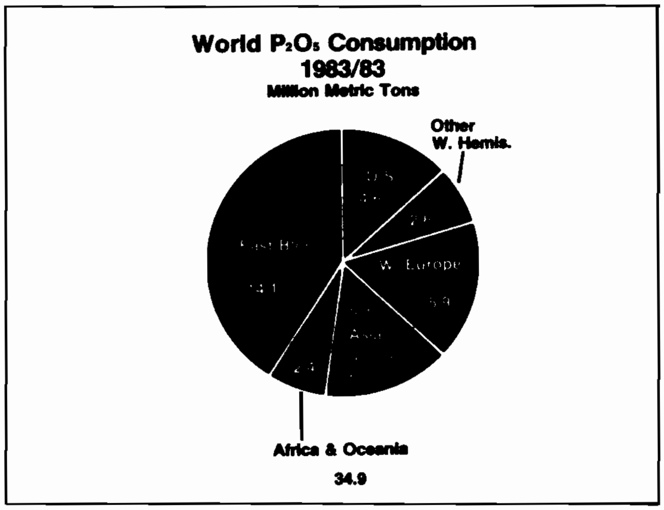
Therefore, these three crops will have expected planting for 1983–84 of 219 million acres versus last year of 200 million acres, or 9½% more acres.



Before I leave the domestic U.S. market and talk about world phosphates, let me review the overall demand for $P_2O_5$ which is logically satisfied by U.S. production, and compare that demand to the rated production capacity of U.S. producers to calculate the operating rates for the various years.

This slide illustrates the cyclical nature of the fertilizer business. The range of operating rates goes from 98% in 79–80 and 80–81 to 71% in 1981–82.





World $P_2O_5$ Consumption 1983/83

Million Metric Tons

Let's spend a minute or two looking at the producers and consumers of $P_2O_5$ in the world marketplace. The United States is the 2nd largest producer of $P_2O_5$ and represents 23% of the world production for 1982–83. The largest $P_2O_5$ production is in the Eastern Block Countries and represents 36% of the world production in 1982–83.

In terms of $P_2O_5$ consumption, the United States is the 3rd largest user at 13%, according to these 1982–83 statistics. The Eastern Block Countries are the largest consumers of $P_2O_5$ at 40%, followed by Western Europe at 18%.

U.S. production in 1982–83 is 23% of the world $P_2O_5$ production.

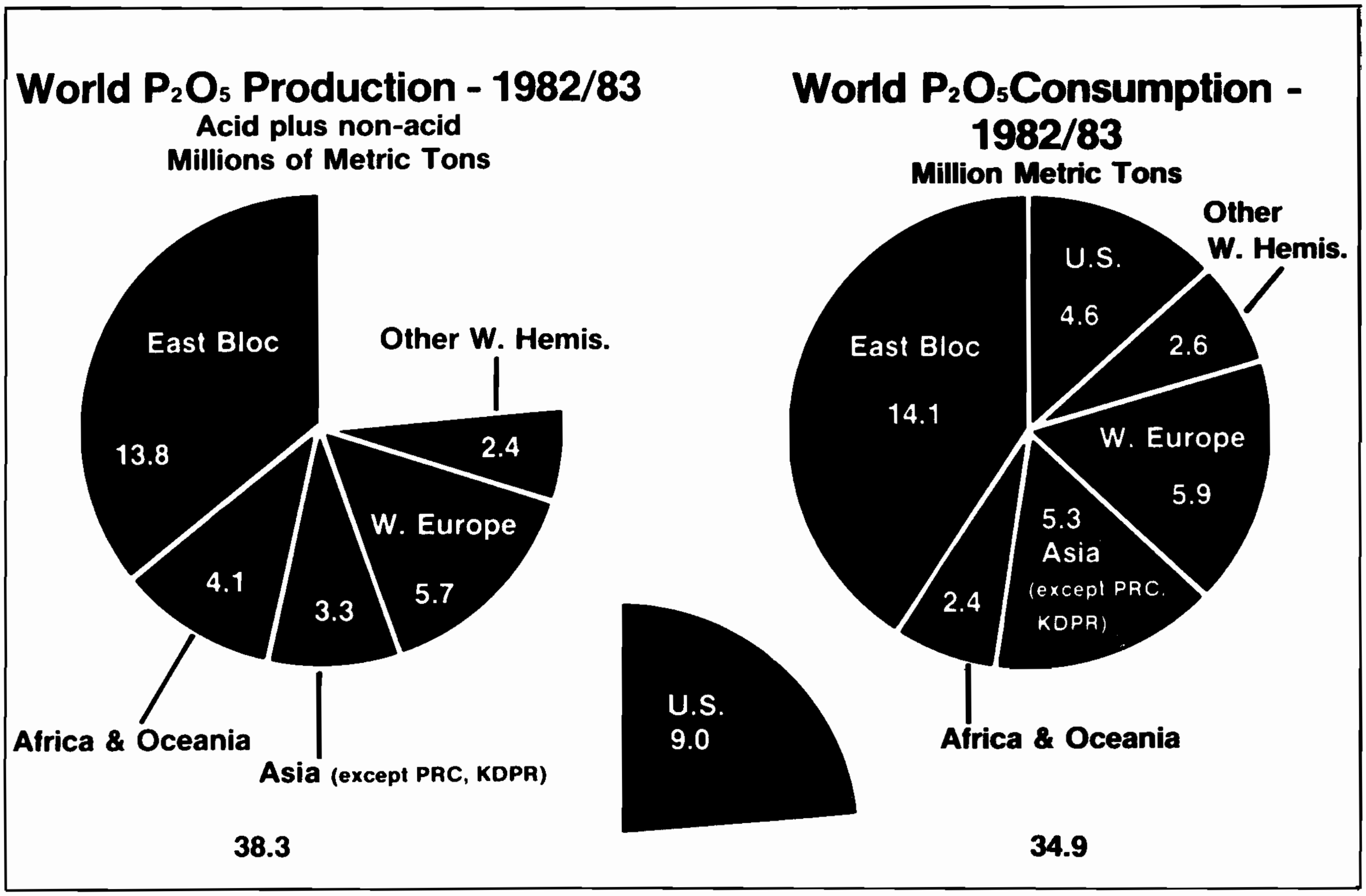
With domestic U.S. $P_2O_5$ production at nine million metric tons and U.S. domestic Ag. consumption at 4.6 million metric tons, it is easy to see how important exports are to the phosphate industry.

In the past 13 years, we have gone from less than one million metric tons of $P_2O_5$ exported to an estimated 3.8 million metric tons this past year. We peaked at 4.4 million metric tons of $P_2O_5$ in 1980–81.

In addition to the $P_2O_5$ we export directly in the various phosphate fertilizer materials, we also export a substantial amount of $P_2O_5$ in the farm commodities we send overseas. In each of the last 9 years we have exported in excess of a million tons of $P_2O_5$ equivalent in the feed grains alone, not to mention the $P_2O_5$ in the cotton, rice and other agricultural products.

That completes the slides. Now let me summarize and give some conclusions on the "Outlook for Phosphates."

1. The PIK Program on corn and the effects of the drought on all crops have lowered our carryover of feed grains, raised commodity prices, and improved the farm income for calendar 1983.
2. Domestic consumption of nitrogen, phosphate and potash will be up in 1983–84 versus last year. A modest increase in the amount



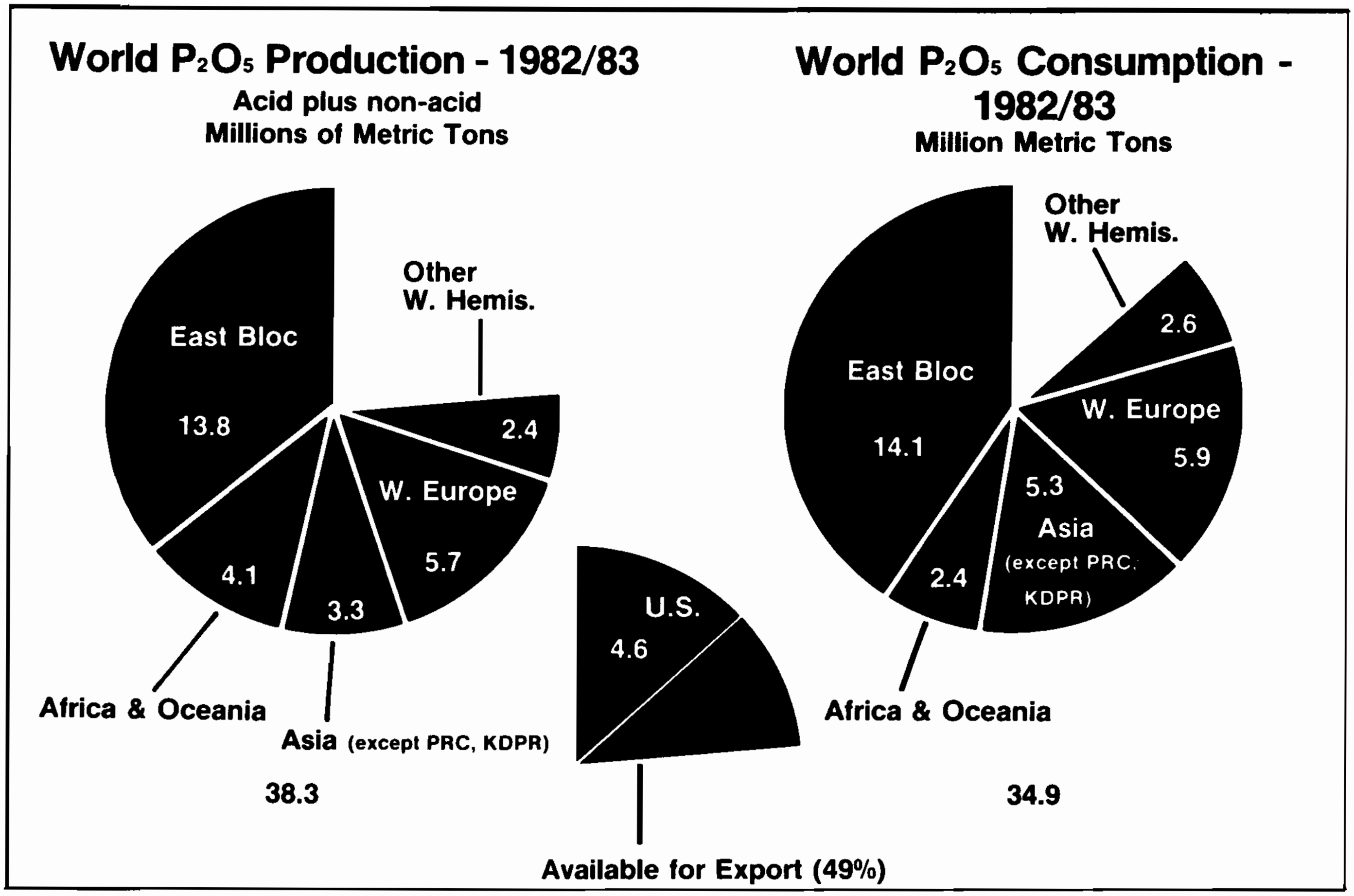
World $P_2O_5$ Production - 1982/83

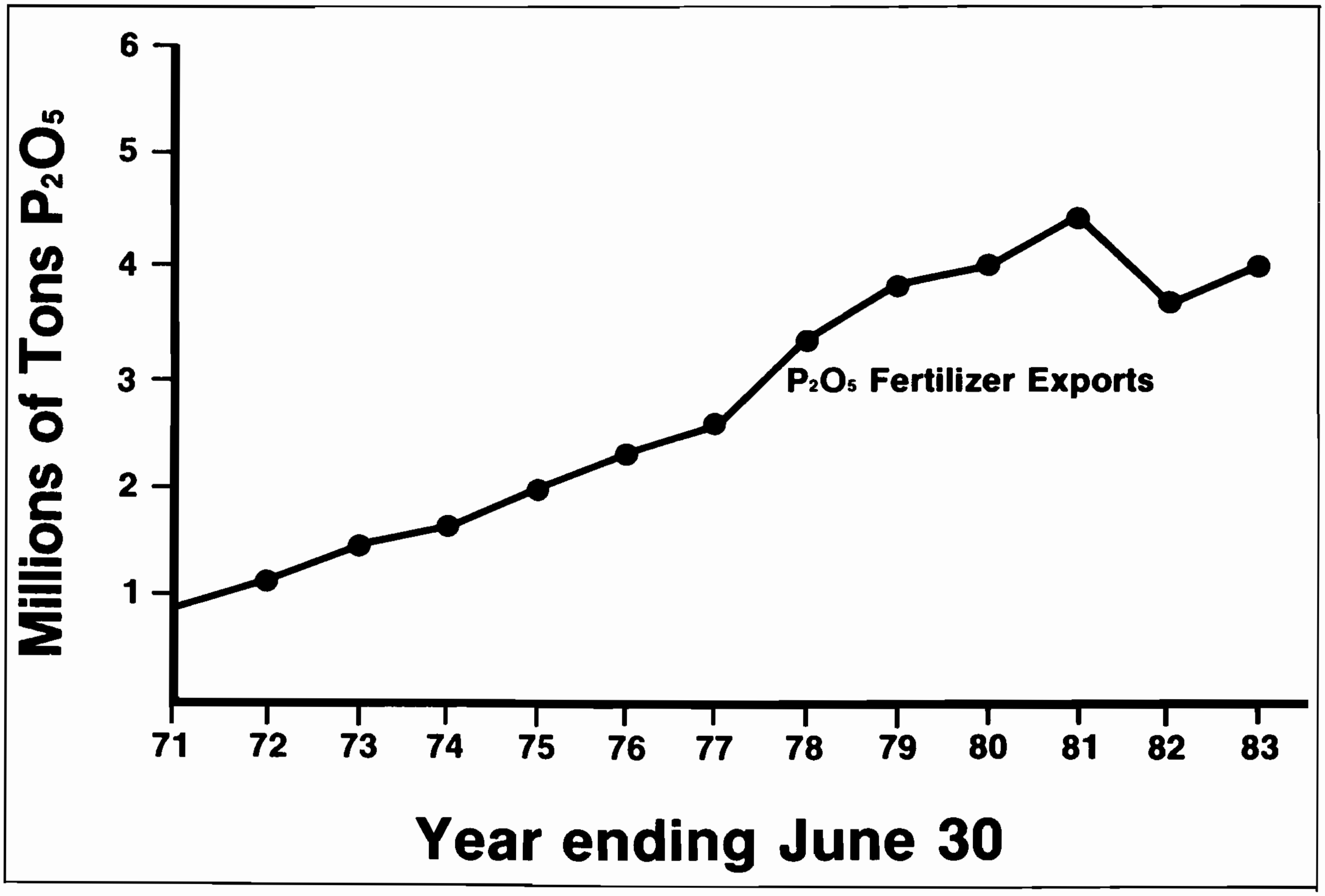
Acid plus non-acid

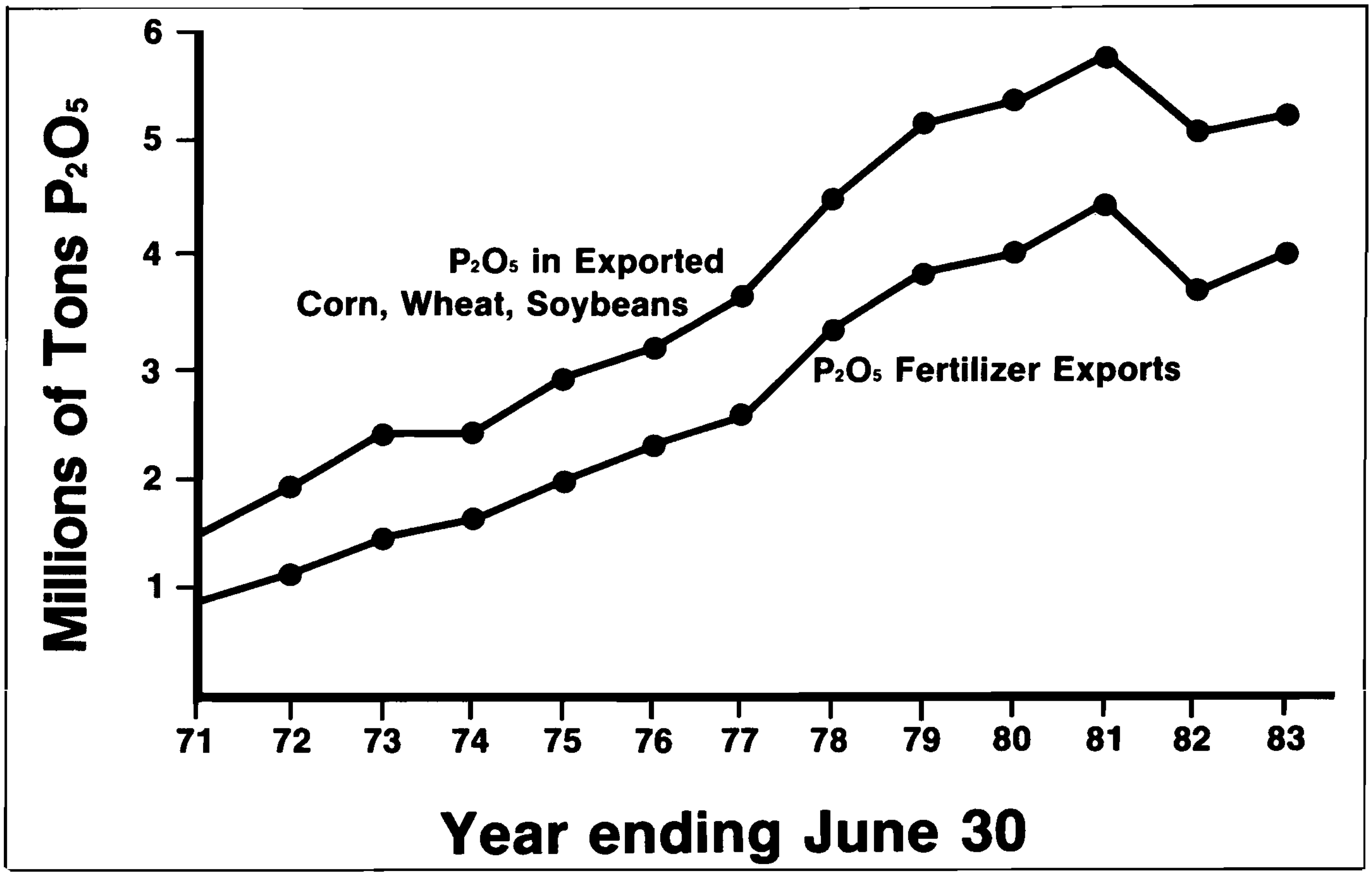
Millions of Metric Tons

World $P_2O_5$Consumption - 1982/83

Million Metric Tons


World $P_2O_5$ Production - 1982/83
Acid plus non-acid
Millions of Metric Tons
East Bloc
13.8
Other
W. Hemis.
2.4
W. Europe
5.7
4.1
3.3
Africa & Oceania
Asia (except PRC, KDPR)
38.3
U.S.
4.6
Available for Export (49%)
World $P_2O_5$ Consumption - 1982/83
Million Metric Tons
Other
W. Hemis.
2.6
East Bloc
14.1
W. Europe
5.9
5.3
Asia
(except PRC, KDPR)
2.4
Africa & Oceania
34.9


Millions of Tons $P_2O_5$
6
5
4
3
2
1
$P_2O_5$ Fertilizer Exports
71
72
73
74
75
76
77
78
79
80
81
82
83
Year ending June 30



of $P_2O_5$ used per acre, plus the increased acres, should result in an approximate increase of 14% in $P_2O_5$ in the United States. 1983–84 should hit 5.3 million short tons versus 4.6 million short tons this past year. Through the balance of the 1980's we expect a growth of 2 to 3% per year.

3. Exports of $P_2O_5$ in 1983–84 will be approximately equal to last year, which we estimate to be 3.8 million short tons. We expect exports of $P_2O_5$ to increase approximately 10% in total from the 1982–83 level through 1986–87. Then we expect proposed production from North African and Middle East countries to put new pressure on U.S. exports of $P_2O_5$.
4. Worldwide consumption of $P_2O_5$ hit approximately 34.9 million short tons last year, up approximately 200,000 tons from 81–82. We expect 1983–84 to be up 12% worldwide and 5% the year after. Then we look for $P_2O_5$ growth to settle down to 3 to 4% per year through the end of the decade.

In conclusion, the phosphate industry is critically dependent on exports for survival; exports of finished phosphates as well as exports of feed grains.

PIK Programs are not the answer to a healthy agricultural economy. Efficient low cost producers are the ultimate survivors in any competitive marketplace. We need to overcome the bureaucratic misconception that reduced acres and inefficient use of our most productive nondepleting natural resource is the way to control a build up of grain stocks. We need to concentrate on *marketing* our ability to produce.

Some thoughts for consideration:

— Extension of foreign aid by using farm commodities rather than dollars

— Guaranteed supply on long term commodity contracts, such as the improvement in the recent Russian grain agreement

— Encourage foreign governments to reevaluate trade barriers that discriminate against U.S. farm goods.

Thank you for your time. I hope I have given you some food for thought on the "Outlook for Phosphates."

## Outlook for Potash 1982 to 1992

*Douglas E. Logsdail*
Executive Vice President
Potash Corp. of Saskatchewan Sales Ltd.

Over this past year I'm sure we've all been asking ourselves if there's any hope for the potash industry. This has been an understandable reaction as we have just experienced the greatest drop in world demand in the past 30 years.

This first overhead shows the trend in world potash production from 1945 to 1965. As you can see, production was increasing at a steady pace over this entire period with no real fluctuations.

In this next overhead, we see the trend in demand and production from 1965 to the present. The mid 1970's saw the beginnings of periods of over and under supply of potash relative to demand. Oversupply periods are crosshatched in red and shortage periods crosshatched in black.

In the early 1980's, rapidly escalating oil prices seriously damaged the ability of developing countries to pay for imported goods. This oil price shock precipitated a world economic recession which saw interest rates increase from less than 10% to greater than 20% over a very brief period.

The net effect of all this on the potash market was a drop in world demand greater than any previous period since 1945. Producers saw inventories reach record levels while prices fell to unprofitable lows. Back-to-back record crops saw U.S. feedgrain inventories reach unprecedented levels, putting downward pressure on grain prices. Low grain prices induced farmers to cut back on fertilizer use, which further increased producer inventories and contributed to periodic shut-downs of production capacity.

Increased production from the USSR and Israel found a home in the North American market, further increasing the competitive pressures on North American suppliers and contributing to very depressed prices. The high exchange value of the U.S. dollar attracted offshore suppliers to the U.S. market while at the same time raising a price barrier to domestic suppliers in offshore market areas. With new production coming on stream from Jordan and New Brunswick, existing producers had a right to be concerned for the future of the potash industry.

Well I'm here to tell you that there is a future for the potash industry. We are going to see a steady improvement in demand and revenues over the next several years. The industry will remain in a position to oversupply the market for the next 3 to 5 years until demand recovers and takes up the slack. But, new production will be required by the early 1990's and possibly as early as 1987–88.

Our forecast of world potash demand for the next 10 years shows a return to the long term trend line growth by 1986–87. Potash demand could reach this trend line even sooner if the Soviets decide to divert an increased share of their total production to domestic consumption as some analysts believe. Should this happen, world supply-demand could reach a balanced position as early as 1987. The forecast also assumes that announced production increases in the Soviet Union and New Brunswick, Canada will be on stream as planned. However, the USSR has had problems getting mines to produce at capacity in the past and New Brunswick is reportedly having some startup difficulties. Should these planned expansions be delayed, world potash supply would drop below this forecast, thus reducing the time frame for world balance in the potash industry.

Turning to a regional look at world supply, this next overhead shows historical supply for the years 1980, 1981, and 1982; and forecast supply for 1985 and 1990. Each region is shown in a different colour, starting with Eastern Europe, which includes the USSR, shown in red. It is apparent that East European production will increase over the decade, reaching 12.9 million tonnes K20 by 1985 and 17.1 by 1990.

North American production will also increase, as shown in green, from 10.5 million tonnes K20 by 1985 to 11.9 million tonnes by 1990.

West European production, shown in blue, will decline slightly by the end of the decade as French production is closed down. Western Europe is forecast to produce 5.1 million tonnes K20 by 1985 and to decline to 4.7 million tonnes by 1990. All other countries in the region are expected to maintain current production capability with no expansions or shutdowns.

Asia, shown in purple, includes Israel and Jordan. Supply is shown to increase as Israel increases production slightly and Jordan comes on stream, reaching 1.8 million tonnes K20 by 1985, increasing to 2.4 million tonnes by 1990. By the end of the decade, Israel will provide about 54% of total regional production, and Jordan will provide about 45%.

Latin America, mainly Brazil, can barely be seen at the bottom of the chart. Latin America will produce 122 thousand tonnes K20 by 1985, as mines in Brazil come on stream, increasing to 292 thousand tonnes by 1990.

World potash production, shown in black, is projected to reach 30.3 million metric tons K20 by 1985 and 36.4 by 1990, a compound annual growth of 3.7% from 1985 to 1990.

Looking at regional potash demand, this next overhead shows historical demand for 1980, 1981, and 1982, with forecasts for 1985 and 1990.

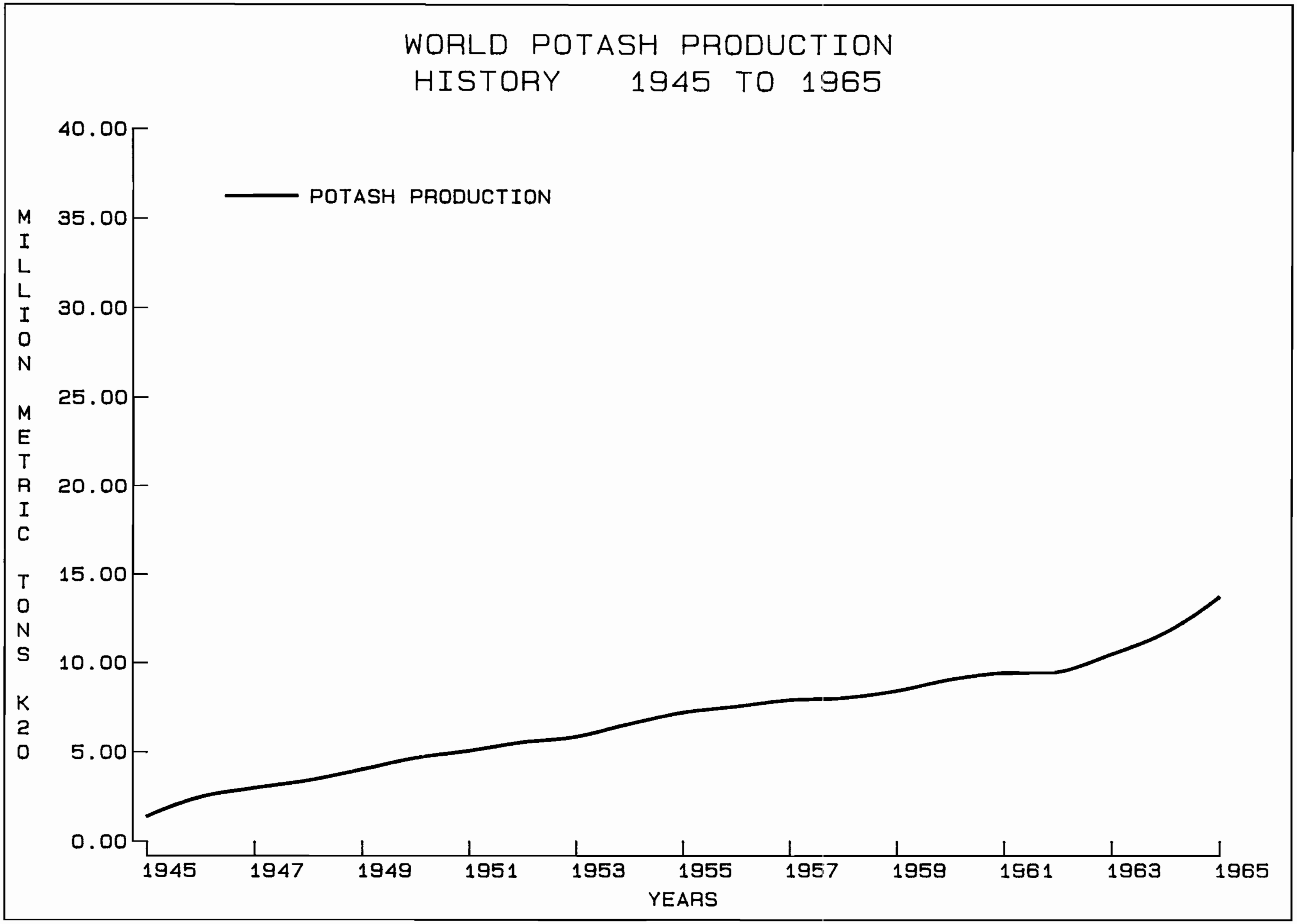
Eastern Europe, including the USSR, again shown in red, is forecast to demand 10 million tonnes K20 by 1985 and 13.1 by 1990.

Western European demand, in blue, is projected to reach 5.9 million tonnes K20 by 1985 and 6.2 million tonnes by 1990.

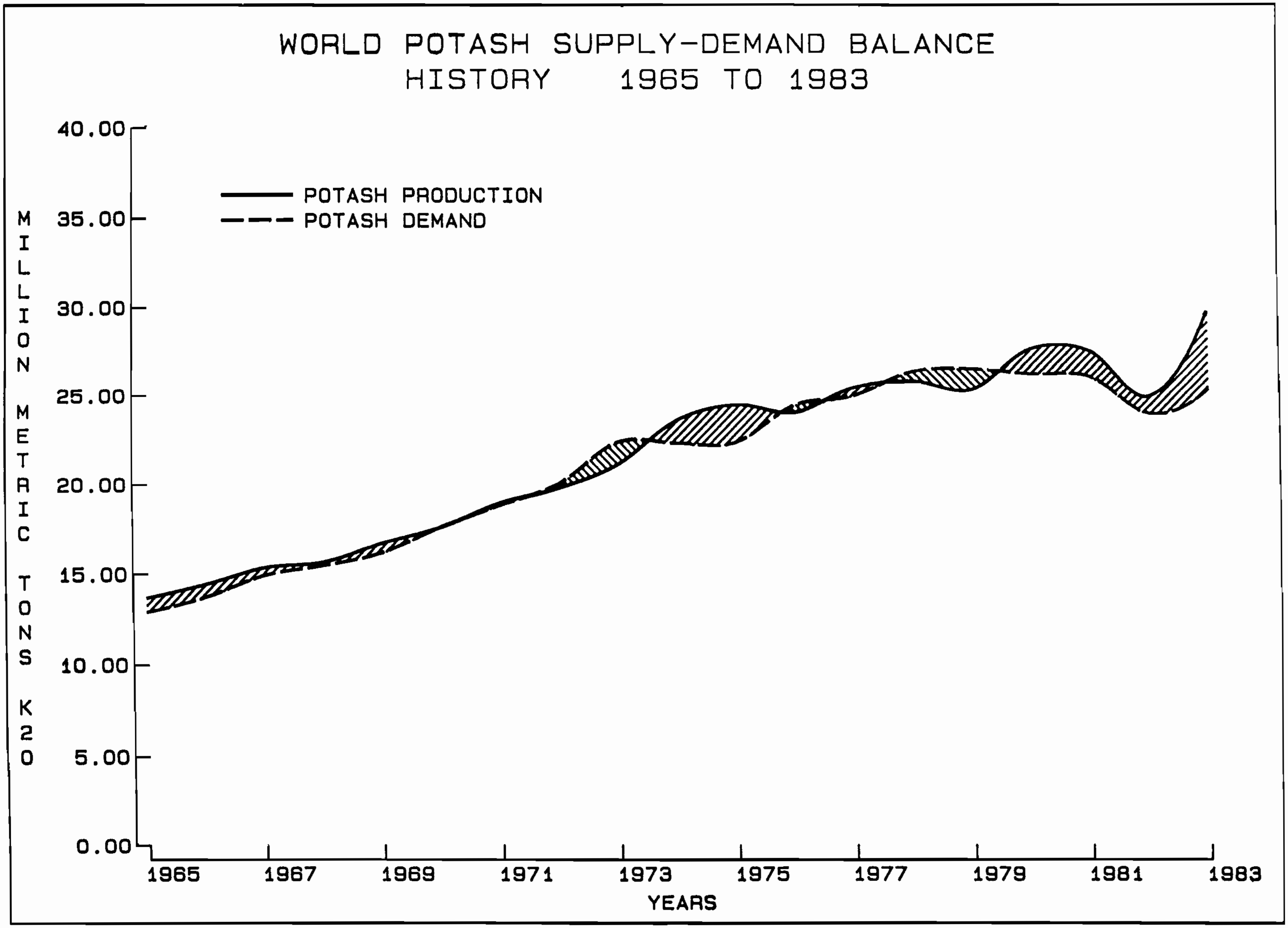
Potash consumption in Asia, shown in purple, will reach 3.4 million tonnes K20 by 1985 and 5.6 million tonnes by 1990. The biggest consumers will remain India, Japan, and China.

North American potash demand, shown in green, is forecast to increase to 7.1 million tonnes K20 by 1985 and 8.7 million tonnes by 1990.

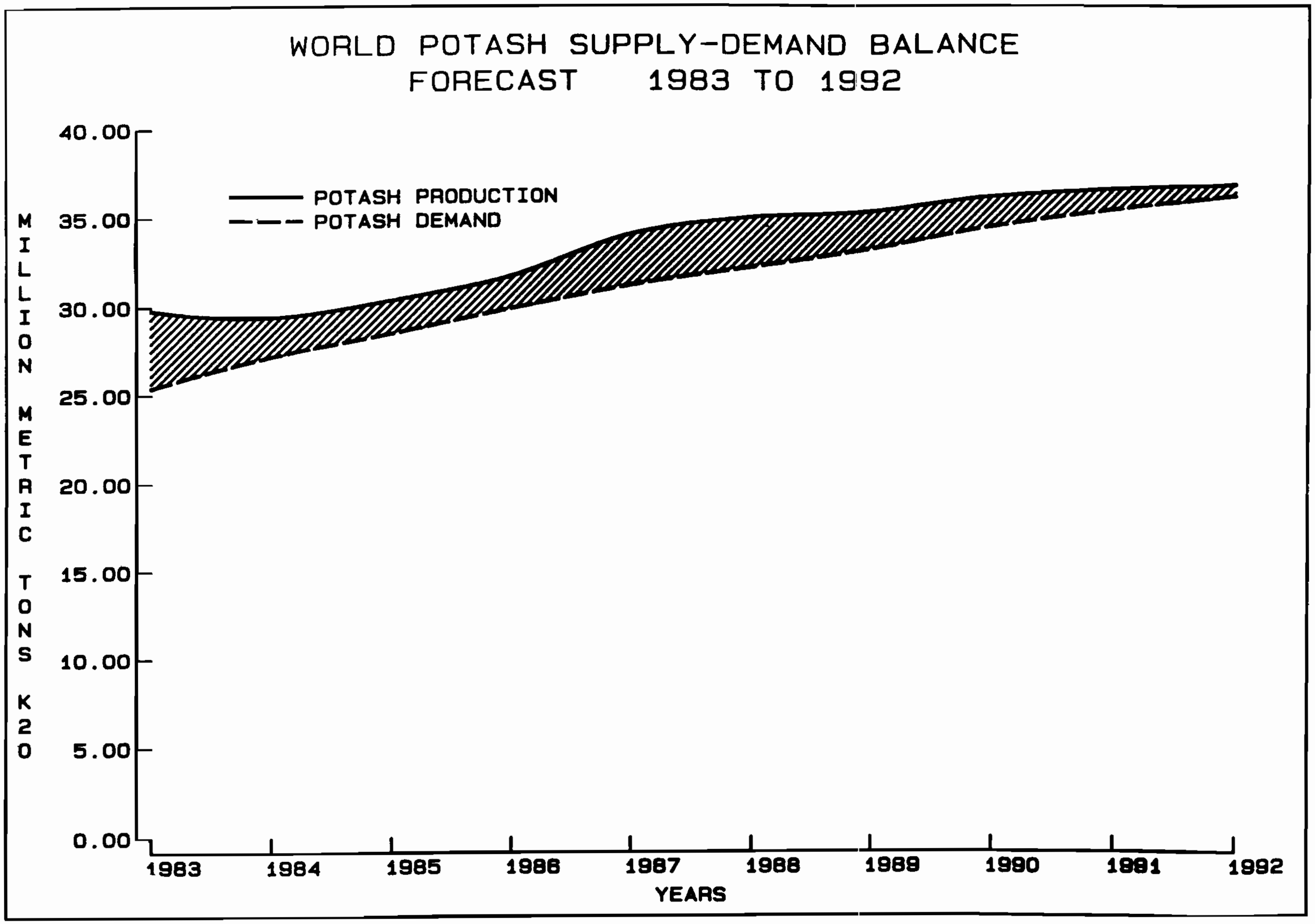
Latin America, shown in brown, will demand 1.4 million tonnes K20 by 1985 and 2.5 million tonnes by 1990.



MARKET RESEARCH PCS SALES JAB



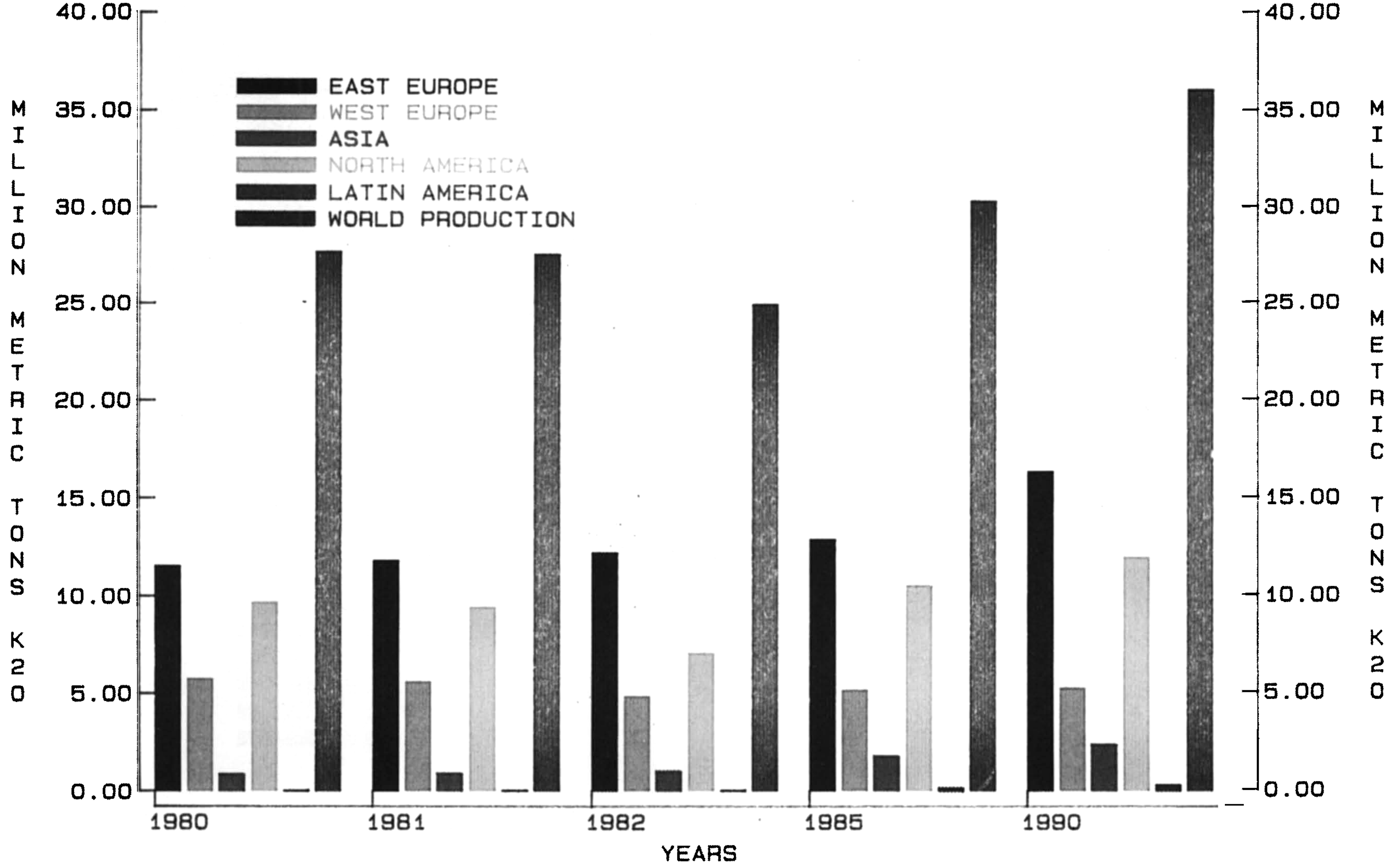
MARKET RESEARCH PCS SALES JAB



WORLD POTASH SUPPLY-DEMAND BALANCE
FORECAST 1983 TO 1992

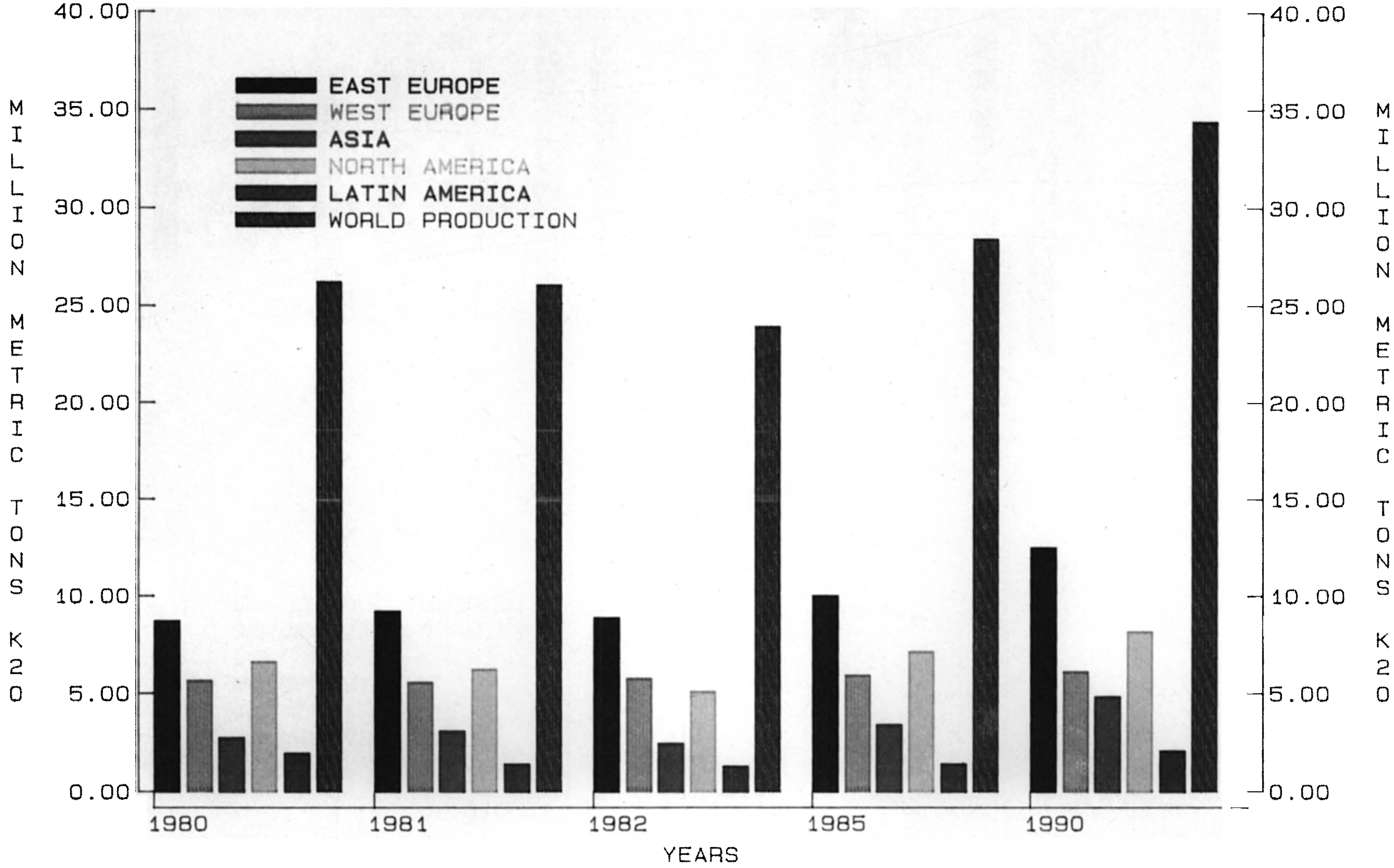
MARKET RESEARCH PCS SALES JAB

REGIONAL POTASH PRODUCTION
HISTORY 1980 1981 1982 FORECAST 1985 1990

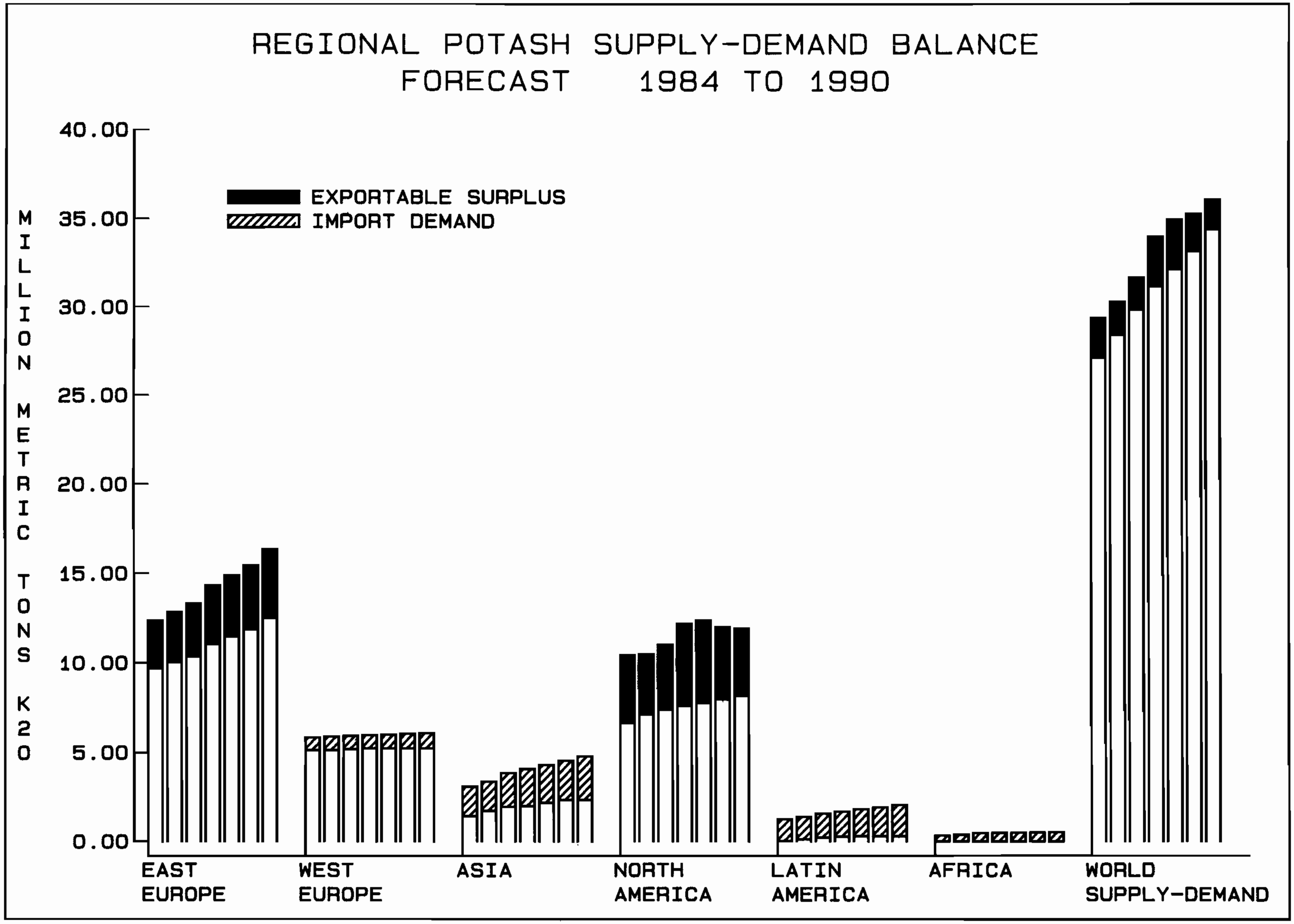


MARKET RESEARCH PCS SALES JAB

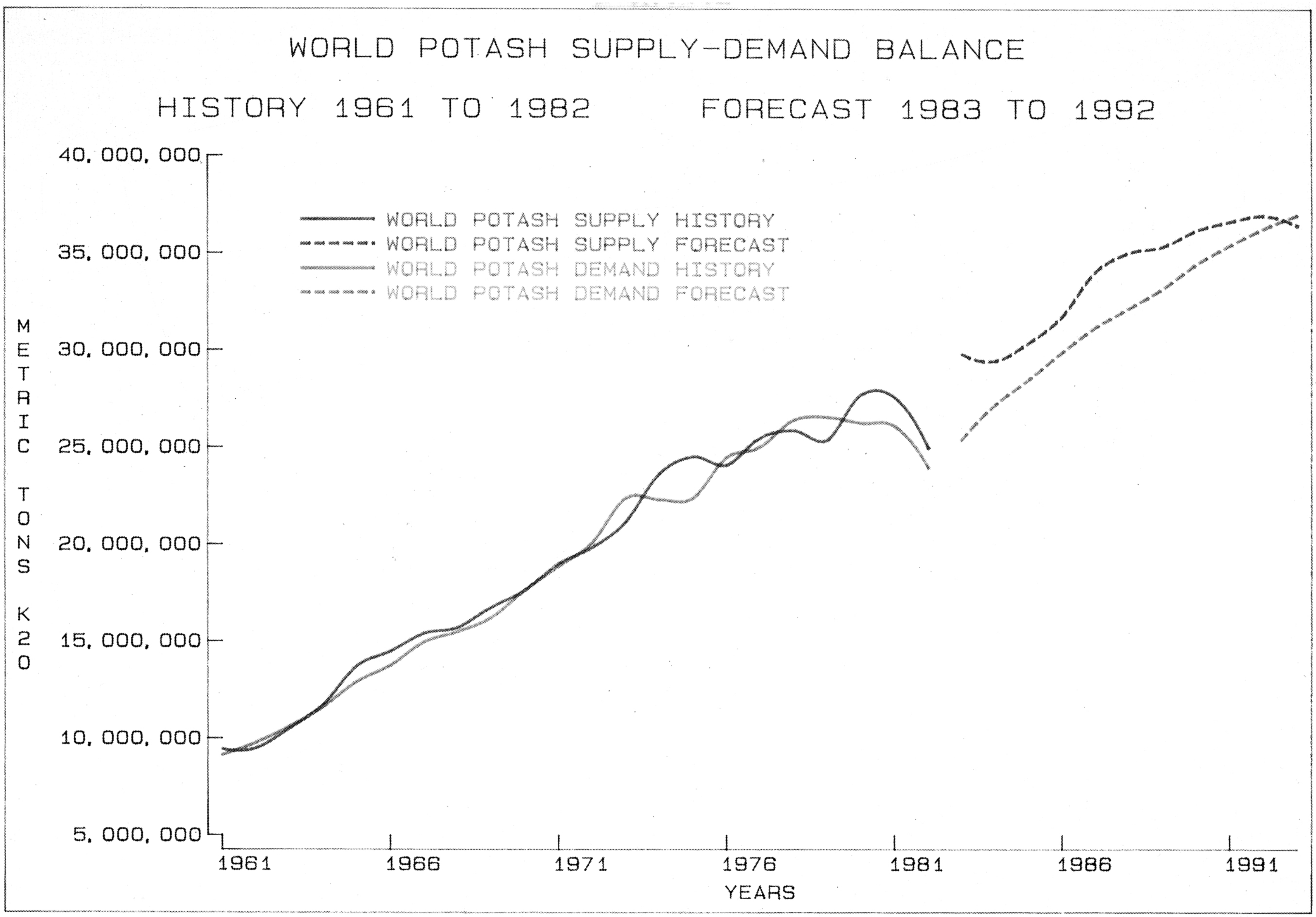
# REGIONAL POTASH DEMAND
## HISTORY 1980 1981 1982 FORECAST 1985 1990



MARKET RESEARCH PCS SALES JAB


REGIONAL POTASH SUPPLY-DEMAND BALANCE
FORECAST 1984 TO 1990

MARKET RESEARCH PCS SALES JAB



WORLD POTASH SUPPLY-DEMAND BALANCE

HISTORY 1961 TO 1982 FORECAST 1983 TO 1992

MARKET RESEARCH PCS SALES JAB

African potash demand, not shown here, is forecast to reach 380 thousand tonnes K20 by 1985 and 570 thousand tonnes by 1990.

Oceania, also not shown, will consume 260 thousand tonnes K20 by 1985, increasing to 280 thousand tonnes by 1990.

World potash demand, shown in black, is forecast to reach 28.4 million metric tons K20 by 1985 and 36.2 by 1990. This represents a compound annual growth of 5% from 1985 to 1990.

Putting it all together on this next overhead, you can see from the solid green areas representing net regional production available for export, that Eastern Europe, primarily .the Soviet Union, and North America, primarily Canada, will be the net exporting regions for the forecast period.

The crosshatched areas which indicate net import demand, show that Asia will remain the largest net importing region followed by Latin America, Western Europe, and finally Africa.

In conclusion let me briefly summarize our outlook for the potash industry. Our forecast of world potash demand for the next 10 years shows a return to the long term trend line growth by 1986–87. Potash demand could reach this trend line even sooner if the Soviets decide to divert an increased share of their total production to domestic consumption as some analysts believe. Should this happen, world supply-demand could reach a balanced position as early as 1987.

We are forecasting world potash demand to reach 28.4 million metric tons K20 by 1985 and 36.2 by 1990. This represents a compound annual growth of 5% from 1985 to 1990.

We are forecasting world potash production capability to reach 30.3 million metric tons K20 by 1985 and 36.4 by 1990, a compound annual growth of 3.7% from 1985 to 1990.

In the shorter term, the outlook for North America is buoyant. Potash consumption in 1984 is expected to increase by about 1 million metric tons K20 over 1983. This increase will result from substantially greater planted acreage, particularily corn, but also aided by increased soybean and cotton plantings. Farmers are coming out of 1983 with relatively high net farm incomes. While a portion of this higher income is going to reduce debt, recent surveys indicate that it will also be spent on inputs. Farm machinery seems to be a third priority after inputs. In general, this implies increased potash useage due to greater acreage and higher application rates than in 1983.

There has been some talk that a bumper crop in 1984 could put the industry back into the doldrums. This just isn't so. It took two or three years of bumper crops in the face of falling demand to create the situation we have just experienced. It cannot be repeated on the basis of one good crop. Certainly a good crop in 1984 will raise grain inventories and cause prices to fall from their current record levels. But prices won't fall to the disastrous levels of 1983. On the other hand, should the 1984 crop be below average for any reason, the world could be facing a grain shortage and todays high prices may not seem so high after all.

# Tuesday, October 25, 1983

## Afternoon Session's Moderator:

## Jean L. Cheval

## Urease Inhibitors—Current Status

*Dr. Roland D. Hauck*
Division of Agricultural Development
National Fertilizer Development Center
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Urea use continues to increase. Solid urea and N solutions that contain urea comprise slightly more than 25% of U.S. agricultural N consumption. The increase in urea production and use stems more from the economies and other advantages of urea manufacture, storage, and handling than from its agronomic characteristics. In fact, under certain conditions of use, urea may be less effective as a supplier of N for crops than other N sources, e.g., ammonium nitrate. Problems associated with the use of urea as a fertilizer mainly are the result of rapid hydrolysis of urea to ammonium carbonate in soil through the action of a urease enzyme complex, causing a rise in pH and evolution of ammonia. Problems include damage to germinating seeds and seedling plants, nitrite toxicity, and gaseous loss of N.

Formerly, agronomists advised farmers not to surface-apply urea without incorporating it into the soil, or to place urea with or near seed. Fertilizer and crop management systems now being adopted by farmers sometimes make such restrictions on urea use impractical or undesirable. In no-till or minimum tillage agriculture, fertilizers containing urea are surface-applied without incorporation and there is risk of losing urea-N through ammonia volatilization. And for some crops, such as small grains, application of urea with seed would be convenient.

Approaches to minimizing problems of urea use include: (1) coating urea to slow its rate of dissolution; (2) adding substances to urea which lower the pH and otherwise alter the chemistry of the urea-soil microsite; and (3) use of urease inhibitors. Successful coatings have been developed, but coated urea products, because of their cost and/or properties are practical only for special situation use. Urea phosphate and urea-urea phosphate formulations, which lower microsite pH, are being developed and widely tested by TVA. These formulations show promise for use with wheat and in minimum tillage cropping systems or other situations where N must be surface-applied without incorporation. However, coating or acidulating urea addresses only a small portion of the total urea used. For the bulk of urea use, either as a solid or in N solutions, addition of an effective urease inhibitor would minimize seedling damage and N loss as ammonia from surface applications.

Many chemicals have been identified which retard the rate of urea hydrolysis by interfering with the action of the enzyme, urease. However, most of these chemicals have been shown to be ineffective in soil. Soil urease activity appears to reside in a very large organic complex (molecular weight, perhaps, >600,000 atomic units). Many soil microorganisms and crop residues also exhibit urease activity; chemicals that may effectively block urea hydrolysis by one enzyme source may be ineffective in blocking the entire soil urease complex. Among the chemicals studied for use with fertilizers are acetohydroxamic acid and its derivatives, various phenols and quinones, and phosphoroamides. Chemicals have been found ineffective because: (1) they are inhibitors of purified urease preparations in solution but not of soil urease; (2) they are chemically or biologically unstable; (3) they contain toxic elements or are potential carcinogens; and (4) they may be too expensive to use at effective concentrations. Phenyl mercuric acetate is an effective inhibitor of soil urease but would be environmentally unacceptable as a fertilizer additive. Quinones found to effectively inhibit soil urease activity include p-benzoquinone and 2,5-dimethyl benzoquinone, but these chemicals have carcinogenic potential. Phenylphosphorodiamidate (PPDA) is the most potent inhibitor of soil urease activity identified to date. It was discovered by an East German research group that screened about 12,000 substances for their potential as urease inhibitors. PPDA has two major limitations. First, it is relatively stable only in a very narrow pH range around neutrality. It decomposes after addition to urea ammonium nitrate solution, but can be incorporated into urea melt. The dry urea-PPDA mixture apparently is stable for several weeks but gradual decomposition of the PPDA probably occurs during prolonged storage. Biological and/or chemical degradation of PPDA in soil appears to be rapid. In many soils, urea hydrolysis in the presence of PPDA is delayed for a few days, after which time hydrolysis is rapid. Greenhouse studies indicate that PPDA has promise for use in flooded rice where urea is added directly into the flood water. Under these conditions urea hydrolysis in the absence of a urease inhibitor can lead to ammonia loss. Ammonia loss from urea amended with PPDA is markedly less. However, the value of PPDA for use in flooded rice systems has not been demonstrated in field experiments.

The second limitation of PPDA is its high cost. Its manufacture probably is through the intermediate compound, POC1, which also is expensive to produce. Phosphorotriamide (PTA) probably can be produced at a lower cost but is considerably less potent than PPDA. Other phosphoroamides also have been tested; none inhibit urease activity in soil as much as does PPDA. Research at TVA and elsewhere is directed toward increasing the stability of PPDA, finding cheaper routes to the manufacture of PPDA and PTA, and identifying related compounds that have potential as urease inhibitors.

In summary, strong arguments can be presented in favor of amending urea and urea-based fertilizers with a chemical that will effectively retard soil urease activity. Although several chemicals show promise as urease inhibitors, none have undergone sufficient development to merit their use with commercial fertilizers at this time. However, progress thus far gives reason for believing that effective urease inhibitors will be developed.

## Fertilizer Quality Control—Can It Be Achieved in Today's Marketing System

*Hilton V. Rogers*
Head, Dept. of Fertilizer Analysis and Inspection
Clemson University

It is an honor for me to have an opportunity to participate in the Fertilizer Industry Round Table. This is a very important meeting to the fertilizer industry and by the trickle-down method, it is also important to the users of commercial fertilizers. In discussing a topic with Joe Reynolds, several subjects came to mind. We felt that "quality control" as it relates to recent changes was something that could be pursued.

In preparing this paper, I solicited some ideas from several of my fellow control officials. The ideas presented are a combination of my own and other control officials. Most of the data came from South Carolina situations but similar conclusions could be drawn from other states.

First of all, we should define "quality control" as it pertains to commercial fertilizer. The marketing of fertilizer is different from that of many other products in that state laws require that fertilizer must be labeled with specific guarantees. Just how close fertilizers must come to actually meeting those guarantees depends on the "investigational allowance" provided in the individual state laws. The Association of American Plant Food Control Officials has a model fertilizer bill called Uniform State Fertilizer Bill. There is a suggested regulation for investigational allowances, however, all states have not adopted these uniform standards. Some states are much more lenient than others in how close companies must come to meeting the labeled guarantees. If a company uses "investigational allowances" as a sole standard for quality control then the quality may vary from state to state.

I like to think of quality control as a standard of excellence that each company has decided it will attain and will present to its customers. This pertains to both physical and chemical characteristics. It can somewhat be compared to how fast a person will drive regardless of the posted speed limit if he knows there are no highway patrolmen on the road.

At best, some states are sampling 12 to 15 percent of the fertilizer tonnage sold and most states are sampling much less than this. Even though some companies complain of penalties, deficiency penalties alone are not enough of a deterrent to force a company to meet guarantees. This is especially true if penalties can be counted as operational expenses. Each company must decide the quality it wants to sell and take the necessary steps to provide that quality.

Now, let us pursue the idea of how important is it that guarantees be fully met? Will crops receiving the fertilizer respond to moderate variations? There is no really good way to determine this since there are various philosophies for applying fertilizer. Some agronomists recommend fertilizer to maintain a medium level of soil reserve for phosphorus and potassium. With this philosophy the fertilizer could vary widely from the guarantee with no immediate effect on the current crop. Yet, a person wants a certain amount of the various plant nutrients or he would not have ordered the particular grade or the particular amount. He should expect to get what he ordered within a practical degree of variation.

What is a practical degree of variation? The medicines we take affect our health. We can get an underdose or an overdose if they do not contain a given amount of active ingredients. I examined a copy of The U.S. Pharmacopeia and found there is a great variation in the deviation allowed from the stated contents listed on the medicine container. As examples, some of the ranges are listed: Warfarin Sodium 97.0–102.0%, Strontium Sr 85, 90–110.0%, Potassium Chloride 99.0–101.5% KCl, Magnesium Sulfate 99.0–100.5% $MgSO_4$, Morphine Sulfate 93.0–107.0% and Streptomycin Sulfate not less than 65.0%. Is it as important to meet the exact labeled amounts of plant nutrients in fertilizer as it is to meet the exact stated ingredients in medicine? I don't think so but this will be discussed later.

Now to get back to the assigned topic "Fertilizer Quality Control—Can It Be Achieved in Today's Marketing System". Some plants in South Carolina are doing exactly that and I am going to discuss some steps they are taking to achieve it. South Carolina has used the AAPFCO investigational allowance for N, $P_2O_5$ and $K_2O$ since 1978. Three of the plants we will discuss are dry blenders, one is a granulating plant and the other a clear liquid plant. Generally, the deficiency percentages are based on those samples which had guarantees for two or more of the primary nutrients.

The slides will illustrate how the plant is achieving this record. Size of materials are carefully examined and are matched as closely as possible. The equipment is kept operational making sure gates are not leaking so as to allow accurate weighing of ingredients. The same person does most of the mixing.

Hopper and scales are kept clean. An electronic type load cell system is used which clears each batch. The same conscientious man has operated the front-end loader for years. This place is kept immaculate and contamination is avoided. A limited number of grades are made and there is little error in formulation.

This is a new dry blending plant but there is an old liquid plant at the same location. An electronic type load cell system is used and scales and hoppers are always clean. All excess material is pushed aside so as to not contaminate material bins. A computer is used to formulate grades and the complete formula and guarantee is given to each customer. A copy of the printout is sent to our office and is attached to the registration form for customer mixes. The printout provides all required information including grade and the guaranteed analysis, list of materials, weight and manufacturer.

**TABLE 1**
**S & S Farm Supply, Ridge Spring, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1978 | 35 | dry blend | bulk | 17.1 | 22.7 |
| 1979 | 46 | dry blend | bulk | 6.5 | 24.0 |
| 1980 | 79 | dry blend | bulk | 11.3 | 20.4 |
| 1981 | 67 | dry blend | bulk | 13.4 | 18.6 |
| 1982 | 68 | dry blend | bulk | 7.4 | 19.0 |
| 1983 | 37 | dry blend | bulk | 2.7 | 19.6 |
| 6 yr. average | | | | 10.1 | 20.7 |

**State average for all types and all containers.

**TABLE 2**
**Farmers Warehouse, Manning, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1978 | 29 | dry blend | bulk | 3.4 | 22.7 |
| 1979 | 53 | dry blend | bulk | 32.1 | 24.0 |
| 1980 | 28 | dry blend | bulk | 3.5 | 20.4 |
| 1981 | 55 | dry blend | bulk | 18.2 | 18.6 |
| 1982 | 32 | dry blend | bulk | 9.4 | 19.0 |
| 1983 | 45 | dry blend | bulk | 0 | 19.6 |
| 6 yr. average | | | | 13.2 | 20.7 |

**State average for all types and all containers.

**TABLE 3**
**J. W. Williamson, Norway, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1983 | 41 | dry blend | bulk | 0 | |
| | 2 | fluid | bulk | 0 | 19.6 |

**State average for all types and all containers.

**TABLE 4**
**J. R. Battle, & Company, Nichols, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1978 | 21 | dry blend | * | 14.2 | 22.7 |
| 1979 | 47 | dry blend | * | 4.3 | 24.0 |
| 1980 | 49 | dry blend | * | 24.1 | 20.4 |
| 1981 | 45 | dry blend | * | 8.9 | 18.6 |
| 1982 | 73 | dry blend | * | 1.4 | 19.0 |
| 1983 | 31 | dry blend | bag | 6.5 | 19.6 |
| | 23 | dry blend | bulk | 0 | |
| 6 yr. average | | | | 8.3 | 20.7 |

*Exact number not known. Mostly bulk but some bag.
**State average for all types and all containers.

This plant was built in 1977 and sells both bagged and bulk goods. The place is kept very clean and one person does most of the mixing.

A commitment was made several years ago to improve quality control. The percentage of deficiencies has decreased dramatically. Everything is kept as clean as a large plant can be kept. Micronutrient materials are individually weighed at intervals. An electronic scale system is used to weigh materials. The same person has been weighing for a number of years. Each step from weighing to drying is carefully monitored. The sulfuric acid and rock phosphate are weighed for accurate formulation of normal superphosphate.

This small liquid plant has had an excellent record for most years even though a relatively small number of samples were taken. The operator checks his formula for each batch. The entire operation is simple but the equipment is kept in excellent condition as those ingredients can be carefully weighed.

The plants discussed are doing an excellent job with a 6 year average deficiency record well below the state average. If these plants can do it in today's marketing system, why can't others? They can, with the same kind of commitment.

Dry blending has been getting the blame for the increase in deficiency percentage. It is without question that the dry blended fertilizer percent of total tonnage has shifted dramatically in South Carolina in the past 10 years. In 1969 about 80 percent of the tonnage was granulated and 11 percent was dry blends. In 1983 about 30 percent was granulated fertilizer and dry blends have increased to about 60 percent. Some other states have similar situations. In the same period statewide deficiency percentages also increased starting in 1969 at 11.9 percent reaching a peak of 28.2 percent in 1979 and decreasing or leveling off with 21.6 percent of all samples being deficient in one or more elements in 1983. Many dry blend plants have had a decrease in deficiency percentages while a few older granulating plants shipping fertilizer into the state have had increased deficiency percentages in the past four years. Some plants of each of the fertilizer types are not doing a good job and this situation must change.

I submit that reasonable quality control can be achieved but it is going to take all of us especially many of those in this audience. It is going to take maximum effort of fertilizer material manufacturers to supply materials that meet specifications of both chemical and physical characteristics. Uniform particle size is of utmost importance in keeping dry blends in a stable mixture. It is necessary that machinery and equipment manufacturers supply equipment that

**TABLE 5**
**International Minerals & Chemical Corp., Spartanburg, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1978 | 250 | granular | * | 12.4 | 22.7 |
| 1979 | 271 | granular | * | 10.3 | 24.0 |
| 1980 | 296 | granular | * | 12.1 | 20.4 |
| 1981 | 409 | granular | * | 6.4 | 18.6 |
| 1982 | 257 | granular | * | 5.1 | 19.0 |
| 1983 | 138 | granular | bag | 8.0 | 19.6 |
|  | 109 | granular | bulk | 10.1 |  |
| 6 yr. average |  |  |  | 9.1 | 20.7 |

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*Exact number not known. Both bag and bulk.
**State average for all types and all containers.

**TABLE 6**
**Ridge Farmers Mutual, Ridge Spring, SC**

| Year | No. of Samples | Type of Fertilizer | Type of Container | Percent Deficient | State % Deficient** |
|---|---|---|---|---|---|
| 1978 | 16 | clear liquid | bulk | 12.2 | 22.7 |
| 1979 | 12 | clear liquid | bulk | 0 | 24.0 |
| 1980 | 12 | clear liquid | bulk | 0 | 20.4 |
| 1981 | 7 | clear liquid | bulk | 0 | 18.6 |
| 1982 | 12 | clear liquid | bulk | 20.0 | 19.0 |
| 1983 | 9 | clear liquid | bulk | 0 | 19.6 |
| 6 yr. average |  |  |  | 4.4 | 20.7 |

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**State average for all types and all containers.

is capable of mixing materials then handling the fertilizer in a manner that a uniform mixture is maintained. It will take the local fertilizer manufacturer with the commitment to buy top quality materials, hire top quality employees, and buy and maintain top quality equipment. It will take the researchers and educators to determine factors of quality and educate fertilizer users as to the value of quality products. Users must be able to recognize and willing to pay for quality.

The Fertilizer Institute has a slide set and script which illustrates helpful hints for better quality products. It is no doubt that if these hints are followed, top quality can be attained. The script lists the reasons for a quality control program. They are:

1. Assure that your customer receives what he paid for—no more or less.
2. Improve analysis of blends through less contamination and more accurate weighing.
3. Reduce segregation to avoid numerous problems.
4. Improve spread patterns in the field.
5. Assure chemical compatibility.
6. Minimize penalties, unhappy customers.
7. Improve inventory control in your plant.
8. Maintain your business reputation as a quality producer.

It may be that with the present state-of-the-art of fertilizer handling, quality standards may need to be adjusted from a practical standpoint. Studies are being implemented which may or may not affect the "investigational allowance" of the AAPFCO model bill and regulation. In addition to "investigational allowances," there may be a need to have a small tolerance to allow for conditions for which manufacturers have little control.

Industry certainly has the pledge of most control officials to assist in education and to have an open mind to changes in laws and regulations when changes seem warranted. However, allowances should never be so great as to allow poor quality products to be sold. Plants which consistently distribute sub-par quality fertilizer should not be granted registration or license.

All of us are in the same business of assuring fertilizer users of high quality products which are so essential in the production of food and fiber.

Thank you for allowing me to be on your program.

# What is Happening to Quality Control in Blending? (Control Official)

*Dr. David L. Terry*
Assistant Director and Coordinator Fertilizer Program
Division of Regulatory Services
University of Kentucky

## Introduction

The quality of blended fertilizer has been of concern since the beginning of the practice of blending in the late 1930's and 1940's (Hignett 1965). Segregation was identified early as the main problem in producing blended fertilizers that were "on grade" and that would stay "on grade" during handling (Hignett 1965). The earliest discussion on bulk blend quality problems that I could find in the Proceedings of the Fertilizer Industry Round Table was in 1959 in which Mr. W. L. Hill of the USDA discussed the problem of segregation in fertilizers (Hill 1959).

The objective of my presentation, however, is not to discuss what causes off-grade blends, but to evaluate the quality of blends produced today in the United States and then to make some suggestions from a control official's viewpoint on bulk blend quality control.

### QUALITY OF BLENDS PRODUCED IN THE U.S.

#### *Background*

Fertilizers have been sampled and analyzed by control officials since the late 1800's when some of the state fertilizer laws were first enacted. There has also been a real question since the first sample analyzed fell below the guarantee as to whether the fertilizer was deficient. How do you determine when a sample is deficient? By definition, a manufacturer's guarantee means that the fertilizer will contain not less than the guaranteed concentration (AAPFCO 1983). For example, if a fertilizer has a guarantee of 20% total nitrogen, then if the fertilizer actually contains only 19.9% N then it is deficient and a violation of the law. The manufacturer has the right to ask how confident are you that during sampling, sample reduction and preparation and analysis that you, the control official, did not cause the result to be below 20% when in fact the true concentration of nitrogen in the fertilizer is 20%.

The real answer to the question as to how confident you are in calling a sample deficient can be obtained from use of statistics. Up until 1968 there was no agreement among control officials as to how much an analytical result can be below the guarantee before one can "confidently" say it is deficient. The Association of American Plant Food Control Officials (AAPFCO) adopted a set of "Investigational Allowances" in 1968 based on some pioneer work by Miles and Quackenbush that enable a control official to call a sample deficient and make an error no more than one time in 100 (Rund 1974). By definition these "Investigational Allowances" take into consideration the inherent variations in sampling, sample preparation and chemical analysis (AAPFCO 1983). It is important to note that the investigational allowances do *not* allow for the inherent variations in fertilizer manufacture. This is the responsibility of the manufacturer.

Now, with that brief background, let us try to evaluate the quality of blended fertilizers in the U.S.

#### *Criterion of Quality*

The quality of blends can be evaluated in several ways; however, I have chosen to use the sample deficiency rate of official state regulatory samples as the criterion. The deficiency rate is defined as the percentage of samples with one or more deficiencies in the NPK analyses.

It would be easy if every state (1) used the AAPFCO investigational allowances, (2) identified each sample as to whether it was a blend or not and (3) reported the results of the analyses of official samples such that one could determine the deficiency rate of the blend samples. Unfortunately, I found ony two states, South Carolina and Iowa that accomplish all of the above in their publication. We collect this information in Kentucky but do not publish it.

I immediately consulted the "Fertilizer Quality Control Survey" recently conducted by the AAPFCO and The Fertilizer Institute (TFI); however, the results from that survey do not allow one to evaluate the quality of blends under the standard AAPFCO investigational allowances. It became painfully obvious that *we do not know* what the quality of blended fertilizer is in the U.S.!

#### *Quality of Blends—An Estimate*

In order to get an estimate of the quality of blends in the U.S., I wrote to 12 states, requested the needed information, and received useable information from 9 states. I was able to identify the blends by either a code in the data sent by the state or by knowing the types of fertilizers manufactured by a particular company. This required a sample by sample evaluation. I manually applied the AAPFCO investigational allowances to the data from those states not using them. Very briefly I found that the quality of blends in the 9 states surveyed for the past four fertilizer years ranged from a low of about 25% to a high of about 75%.

The deficiency rates of the blends had no relationship to overall deficiency rates for 1981–82 reported in the Quality Control Survey of AAPFCO/

TFI. For example, one state reported an overall deficiency rate of about 10%, but their blend deficiency rate was over 50%; another whose reported overall deficiency rate was about 17% had a blend deficiency rate of about 40%.

The comparison of the deficiency rates of blends from two states who use different investigational allowances is not valid. For example, in the above mentioned survey Kentucky and Missouri reported blend deficiency rates of 34 and 18%, respectively for 1981–82. However, when compared using the AAPFCO investigational allowances, the deficiency rates were 43 and 44% for Kentucky and Missouri, respectively. What appeared at first to be a significant difference in blend quality between the two states turned out to not be significant.

It is my estimate that the blend deficient rate nationwide is in the range of 40–50% when the AAPFCO investigational allowances are applied. As a point of information, a joint sampling study among AAPFCO, TFI, and the Association of Official Analytical Chemists is now underway to re-evaluate the AAPFCO investigational allowances. The results of this study should be available in about one year.

## *SUGGESTIONS ON BLEND QUALITY CONTROL*

My suggestions relative to bulk blend quality control follow:

(1) Each blend plant should establish and enforce a rigid set of manufacturing practices designed to produce quality blends.

(2) Each plant should sample and have analyzed sometime before the busy season at least 10 samples of each of their most popular mixes. From these analyses they should compute the average analysis, the standard deviation and coefficient of variation. This would provide information on the quality and expected deficiency rate of their production and a basis for making improvements in their process.

(3) Control officials should make a point of providing assistance as well as regulatory control to the industry.

(4) In making comparisons of deficiency rates among states, you should know what investigational allowances are being used by each state so that only valid comparisons are made.

## *SUMMARY*

The quality of blends in the U.S. must be evaluated using a common set of investigational allowances. The estimated quality of U.S. blends using the official sample deficiency rate as the criterion and the AAPFCO investigational allowances is 40–50% deficiencies. Suggestions to blenders on quality control emphasized adherence to a set of good manufacturing practices. Control officials were encouraged to provide assistance as well as control to the industry.

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# What is Happening To Quality Control in Blending? (Blender)

*Henry T. McCarley*
President, Burley Belt Chemical Co.

Burley Belt Chemical Company is an operating company of Top Yield Industries, Inc., operating in the State of Kentucky. Top Yield operates in Kentucky and Indiana doing business with wholesale and retail clientele. The corporate headquarters are located in Lexington.

Burley Belt has thirteen operating facilities in Kentucky. Four of these units operate as wholesale and retail. Nine are retail only.

The eastern Kentucky terrain and the tobacco market dictate that we continue to supply bagged fertilizer to our customers. Our product mix consists of 98% dry products and 2% liquid nitrogen. We therefore dry blend all products for the market place. Our four large plants were converted from ammoniation units to dry blenders. Extra care had to be given to planning, developing and building dry blenders. Each of our blenders are unique. The equipment's performance is very important in quality control.

Our plant at London handles bulk fertilizer by use of an overhead crain. A special blender had to be built to compensate for this piece of equipment. A series of hoppers was placed in line and, beneath the hoppers, we built a 45 foot holding hopper on scales with an 18" stainless steel drag chain in its bottom. The chain pulls the product to the 2 ton blender located at one end. After blending, the product is then carried by elevator to the bagging hopper.

For our bagging operation at the Somerset location, we have a 90 ton capacity, six unit cluster system. Fertilizer product is weighed by gravity into a 2 ton hopper and dropped into a 2 ton blender. From the blender the product goes into the bagging hopper.

Impregnation of chemicals has caught on fast in the Somerset area. Because careful consideration must be given to the control of chemicals used for tobacco versus corn, it was necessary to have two blenders available for the impregnation of chemicals for the respective crops. The two blenders are served by a common weigh hopper and a common load out conveyor.

Egg crate compartments have been constructed in two of our bagging hoppers. This has helped to prevent segregation.

The other locations are unique also, but because of time limitation, I chose London and Somerset to prove my point.

There are some things that we feel we do that helps us in our quality control efforts in blending the dry products. Some of these examples are as follows:

1) When we receive a product to put in our bins, we feel the bins should be completely clean and uncontaminated from use during the prior season. It is important that the bin walls and floor be clean.
2) When scales are replaced, we use digital readouts to afford more accuracy when weighing a product.
3) In our bagging operation, we have installed grates beneath the bags so the product can go immediately back to the bagging hopper.
4) We encourage our payloader operators to keep all bins and aisles cleaned.
5) We use belts and drag chains. We have eliminated augers and, where practical, try to bypass as many elevators as possible. This eliminates grinding and tearing down of granular particles.

There is a good relationship between fertilizer manufacturers/blenders in the State of Kentucky and our Kentucky regulatory service. We work very closely in an effort to insure the farmer that he does get fertilizer products that he has purchased both in quantity and quality. Our regulatory service has given aid in developing and testing new equipment and product mix. We do feel, however, that companies who bag products get more than their share of samples because bagging operations begin much earlier in the spring than do the bulk operations. I am pleased to note that the regulatory service, in conjunction with T.F.I. and A.O.A.C., have a study underway in trying to determine the best way for sampling bagged products. Results of a test sampling of every fourth bag that was conducted at our London and Somerset plants is shown in Table I.

It is the speaker's personal opinion that, when probing a bag of fertilizer, the smaller and heavier particles will fall into the probe first. This test data shows consistently higher potash percentage with low nitrogen and phosphorus.

We, at the operational level, can be the best housekeepers, build the most sophisticated equipment and give extra care for all products we blend;

**TABLE I**
**Test Sampling of Bagged Product**

| | **N** | **$P_2O_5$** | **$K_2O$** | |
|---|---|---|---|---|
| **Product** | **10** | **10** | **10** | **RV** |
| Bag No. 4 | 9.75 | 9.95 | 11.08 | 101 |
| 8 | 9.99 | 9.99 | 9.20* | 98 |
| 12 | 10.27 | 10.41 | 9.20* | 100 |
| 16 | 10.47 | 10.57 | 9.50 | 103 |
| 20 | 11.20 | 10.35 | 9.20* | 105 |
| 24 | 9.18* | 9.69 | 11.50 | 99 |
| 28 | 9.28* | 9.93 | 11.18 | 99 |
| 32 | 8.17* | 9.77 | 12.03 | 96* |
| 36 | 8.79* | 9.96 | 12.50 | 100 |
| 40 | 7.72* | 9.26* | 14.28 | 97* |
| 44 | 9.11* | 9.71 | 12.30 | 100 |
| 48 | 8.11* | 9.94 | 13.45 | 100 |
| 52 | 7.46* | 9.08* | 15.00 | 97* |
| 56 | 8.42* | 9.40 | 14.70 | 102 |
| 60 | 7.53* | 9.20* | 14.67 | 97* |
| 64 | 8.22* | 9.61 | 12.92 | 98 |
| 68 | 8.51* | 9.93 | 14.55 | 103 |
| 72 | 6.48* | 8.23* | 15.95 | 92* |
| 76 | 7.37* | 9.07* | 16.10 | 99 |
| 80 | 8.65* | 10.39 | 15.20 | 107 |
| Average | 8.73 | 9.72 | 12.72 | 100 |
| **Product** | **5** | **10** | **15** | |
| Bag No. 4 | 5.45 | 10.41 | 12.49* | 93* |
| 8 | 5.13 | 10.13 | 12.78* | 92* |
| 12 | 6.00 | 9.78 | 14.48 | 100 |
| 16 | 4.99 | 9.92 | 13.18* | 93* |
| 20 | 4.96 | 9.78 | 14.07* | 96* |
| 24 | 4.50 | 9.14* | 16.48 | 102 |
| 28 | 4.68 | 9.73 | 15.32 | 100 |
| 32 | 4.64 | 9.67 | 16.15 | 102 |
| 36 | 4.62 | 9.56 | 16.58 | 104 |
| 40 | 4.44* | 9.09* | 16.62 | 102 |
| 44 | 4.44* | 9.15* | 17.90 | 107 |
| 48 | 4.52 | 9.07* | 18.20 | 108 |
| 52 | 4.40* | 8.97* | 18.00 | 107 |
| 56 | 4.20* | 8.69* | 18.50 | 107 |
| 60 | 4.29* | 8.82* | 17.27 | 103 |
| 64 | 4.51 | 9.42 | 18.40 | 110 |
| 68 | 4.21* | 8.85* | 18.45 | 107 |
| 72 | 4.93 | 9.92 | 18.50 | 113 |
| 76 | 4.93 | 9.81 | 18.50 | 112 |
| Average | 4.73 | 9.45 | 16.41 | 103 |

*Deficient

however, our ability to blend on analysis is only as good as products that are shipped to us by major producers. Quite frankly, during the past two years of unprofitable conditions from the basic producers, product quality and analysis have suffered drastically.

Two terminals on the Ohio River furnish the following information concerning shipments of 18–46–0:

6 Suppliers 6 Shipping Points

Average N — 17.78
Average $P_2O_5$ — 45.945

At one location, twenty barges of product were received with an average analysis of 17.78N & 45.945 $P_2O_5$* slides 2–3 & 2–4. The highest analysis of these twenty barges tested 18.05 and 46.05. The lowest analysis was 17.08 and 46.10.

The second of the two locations received fourteen barges. Analyses were sent on ten barges of product. The companies were called again this last week to see if they had in their records an analysis of the barges shipped. It was confirmed that they do not have records pertaining to the analyses. It is rather strange also that four barges, where analysis was given, showed an analysis of 18–46–0.

| | |
|---|---|
| SUPPLIER #1 | |
| 18.02 | 46.0 |
| 18.01 | 45.04 |
| 18.01 | 45.09 |
| 18.02 | 46.04 |
| 17.08 | 46.0 |
| 18.01 | 46.02 |
| 18.01 | 46.02 |
| 18.02 | 46.02 |
| 17.91 | 45.80 |
| SUPPLIER #2 | |
| 17.62 | 46.06 |
| 17.68 | 46.12 |
| SUPPLIER #3 | |
| 17.67 | 46.06 |
| 17.52 | 46.02 |
| 18.07 | 45.06 |
| 18.05 | 46.05 |
| 18.0 | 46.02 |
| SUPPLIER #4 | |
| 17.62 | 46.0 |
| SUPPLIER #5 | |
| 18.01 | 46.02 |
| 17.77 | 46.20 |
| SUPPLIER #6 | |
| 17.83 | 45.56 |
| 17.7 | 46.09 |

TERMINAL #2 ANALYSIS

18 - 46 - 0
18.5 - 47.0 - 0
17.76 - 46.10 - 0
18 - 46 - 0
17.68 - 46.05
18 - 46.02 - 0
18 - 46 - 0
18 - 46 - 0
17.6 - 46.5 - 0
17.4 - 46.3 - 0
3 Suppliers—5 Shipping Points

In conjunction with our regulatory service, random sampling was conducted at various Burley Belt locations to find out the various particle size of product in inventory. The raw materials varied in average particle size from 1.47mm to 2.13mm. It is most difficult to hold product in a blend when particle size varies more than .10mm.

Average is only part of the story. These products were screened using sieve numbers 6, 8, 10, 12, and 20. This overhead shows the percentage of materials held on these various screens for various products sampled. During the past 12 months, it appeared that our greatest problem involved coarse potash being more nearly the size of standard. It has been almost impossible to find two DAPs with the consistency of particle size. Mixing these two products with either a granular urea or a prilled urea further complicated our efforts in blending. We haven't helped ourselves either at the field mixing level by using various size lime filler.

It is a fact that the State of Kentucky does not regulate products of major producers coming into the state. The regulation occurs when products are sold to the consumer. If we, as blenders, continue to accept products that are being offered in the market place without regard to specification of size and weight, we will continue to have conflicts between our various regulatory agencies and our retail blenders. The State of Kentucky sampled 1,256 fertilizer products during 1981–82. 39% of the samples taken showed deficiencies in one or more elements; however, the cumulative total proved a 101% relative value for all tests made. One could conclude that our retail blenders are doing an excellent job in putting the product in the mix. Our uncontrolled factor that we are held accountable for is our inability to control particle size and analysis.

In conclusion, three main factors are emphasized at Burley Belt Chemical Company for better quality

| % Retained on Sieve Size No. | | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|---|
| Urea | BBMG | 1% | 58% | 22% | 13% | 6% | 0% |
| Urea | BBMP | 0% | 1% | 7% | 20% | 67% | 5% |
| Urea | BBLG | 1% | 52% | 22% | 16% | 9% | 0% |
| Urea | BBCM | 0% | 29% | 23% | 23% | 24% | 1% |
| Urea | CT | 2% | 62% | 22% | 10% | 3% | 3% |
| Urea | BBFG | 1% | 57% | 20% | 13% | 9% | 0% |
| Urea | BBPM | 0% | 28% | 29% | 20% | 19% | 4% |
| Urea | BBFP | 0% | 20% | 27% | 19% | 20% | 14% |

| % Retained on Sieve Size No. | | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|---|
| DAP | BBM | 1% | 15% | 19% | 26% | 36% | 3% |
| DAP | BBL | 1% | 21% | 19% | 22% | 36% | 1% |
| DAP | L | 0% | 3% | 15% | 35% | 47% | 0% |
| DAP | D | 0% | 10% | 22% | 32% | 35% | 1% |
| DAP | CT | 0% | 14% | 18% | 21% | 43% | 3% |
| DAP | BBF | 1% | 27% | 26% | 23% | 23% | 0% |
| DAP | BBF | 2% | 25% | 23% | 24% | 26% | 0% |
| DAP | BBF | 1% | 23% | 25% | 24% | 26% | 1% |

| % Retained on Sieve Size No. | | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|---|
| MP | BBM | 1% | 21% | 17% | 16% | 45% | 10% |
| MP | BBL | 0% | 1% | 7% | 19% | 68% | 5% |
| MP | BBF | 0% | 1% | 6% | 17% | 69% | 7% |
| MP | BBF | 0% | 20% | 22% | 24% | 31% | 3% |

| % Retained on Sieve Size No. | | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|---|
| SP | BBM | 0% | 6% | 10% | 18% | 59% | 7% |
| SP | BBF | 1% | 19% | 14% | 14% | 41% | 11% |

| % Retained on Sieve Size No. | | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|---|
| Filler | BBF | 5% | 57% | 12% | 8% | 17% | 1% |
| Filler | BBL | 1% | 34% | 28% | 20% | 15% | 2% |
| Filler | CN | 0% | 20% | 17% | 17% | 39% | 7% |
| Filler | F | 8% | 57% | 10% | 8% | 14% | 3% |
| Filler | F | 4% | 39% | 15% | 16% | 24% | 2% |

PROBLEM

| % Retained on Sieve Size No. | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|
| Filler | 0% | 20% | 17% | 17% | 39% | 7% |
| MP | 0% | 1% | 7% | 19% | 68% | 5% |
| DAP | 0% | 10% | 22% | 32% | 35% | 1% |
| Urea | 1% | 52% | 22% | 16% | 9% | 0% |

PROBLEM

| % Retained on Sieve Size No. | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|
| Urea | 1% | 58% | 22% | 13% | 6% | 0% |
| Filler | 5% | 57% | 12% | 8% | 17% | 1% |
| DAP | 0% | 3% | 15% | 35% | 47% | 0% |
| MP | 0% | 1% | 6% | 17% | 69% | 7% |
| or SP | 0% | 6% | 10% | 18% | 59% | 7% |

BEST POSSIBLE

| % Retained on Sieve Size No. | 6 | 8 | 10 | 12 | 20 | Thru 20 |
|---|---|---|---|---|---|---|
| Filler | 0% | 20% | 17% | 17% | 39% | 7% |
| MP | 1% | 21% | 17% | 16% | 45% | 10% |
| Urea | 0% | 29% | 23% | 23% | 24% | 1% |
| DAP | 2% | 25% | 23% | 24% | 26% | 0% |

control. One, we stress the use of proper equipment. Two, a program of good housekeeping. And, three, the use of raw materials that are sized properly and meet analysis.

## What Is Happening To Quality Control in Blending? (Blender)

*Michael R. Hancock*
Quality Assurance Manager
Ag Products Group
The Andersons

In 1978 Wayne LeCureux, of The Andersons, spoke at the Fertilizer Round Table on the topic, STATUS OF PARTICLE SIZE OF FERTILIZER MATERIALS. A review of that presentation indicates that what was of priority and/or concern then continues to be of concern now. The sizing of fertilizer material continues to be a critical element in achieving a quality bulk blended product. The consistent sampling of all inbound material provides information relevant to chemical analysis, screen profile, density and moisture, and others as necessary, all of which are considerations in bulk blending.

The Andersons functions as a regional warehousing and distribution center. Whereas five years ago a larger percentage of fertilizer went out as dry mixed bulk and bagged fertilizer, currently dry straight material represents the larger percentage of product movement. We have fertilizer storage capacity in our Maumee location in excess of 225,000 tons, and regional warehouses which can provide an additional 100,000 ton storage capability. Our material comes to us by rail, in unit train loads, or by water via the Great Lakes, St. Lawrence Seaway or river systems (Mississippi, Ohio, Illinois, etc.).

The topic, *WHAT IS HAPPENING TO QUALITY CONTROL IN BULK BLENDING,* would give the impression that a change, either positive or negative, had occurred or perhaps was occurring. If change is, in fact, occurring, it is focusing on the area of product awareness or specifically getting the product for which was paid.

As an organization which not only warehouses but blends over 200,000 tons of fertilizer material, we are acutely concerned with the product received and, as indicated earlier, closely monitor this material. Prior to the receipt of product into our facility, it was necessary to go through some basic planning stages and ultimate establishment of criteria for material to be received. My discussion will hereon focus on some of those functions we perform prior to and in actually handling product.

*Product Selection*—This is based on individual requirements and marketability of the product and/or resultant blends. Our basic raw materials are DAP, TSP, UREA, POTASH (Coarse & Granular) and MAP. Product mixes will vary from region to region and, as stated above, reflect specific needs or likes. While product mix may vary from company to company, some considerations will be consistent:

— Producers will most always be able to provide product data relevant to analysis, sizing and moisture. This data information provides a range where the analysis, sizing or moisture may fall and then will provide what is typical, or the norm, for the product.

— The identification of specific needs based on an individual situation can sometimes be met utilizing the data sheets. It may be necessary, however, to outline personal requirements and select your material according to a producer who can meet your needs.

— Particle sizing is most often the critical consideration for blend operations when selecting their raw material. The standard today is that there is NO STANDARD. As Wayne LeCureux stated five years ago, "It seems like each basic producer feels he should be the standard." This is not to say some work has not been done to offer some guidelines. Canada, with its Size Guide Number (SGN), tendered an offer to at least bring a method of selecting raw material. The accuracy and feasibility of the SGN is still undergoing extensive review. It still rests with the blender to identify their needs.

— Handling characteristics and product compatibility are also factors which need to be identified. Material which comes into your plant in good condition but breaks down easily in handling will create problems just as if it arrived in poor condition.

— Once the product mix and material specifications have been identified, the second step and continuous responsibility begins—COMMUNICATION. Relaying your needs to prospective suppliers is important to you and to the suppliers. How often have you heard someone say, "We could have changed that but never knew a need existed." This communication must also take place with your personnel so they know what they should be looking for.

— The on-going portion of this function can be identified as Documentation and involves developing product history (Sampling, Screening & Analysis).

*Sampling*—Implement a systematic program where material received is sampled. We sample most of our product out of rail cars and use a nine probe (three probes per pocket for three gated cars) method. While this is not an AOAC approved method, it has provided a consistent method of evaluating the material.

*Screening*—All sampled material should be screened using either the U.S. or Tyler screens. As we have been using the Tyler screens, I am more familiar with their specifications. The screen sizes used are +6, −6+8, −8+10, −10+14, −14+20, −20+28 and −28. These sizes have provided us with consistent profile information, but in no way limits you from selecting any other screens as you see fit.

*Analysis*—Your samples should be randomly sent to a laboratory for analysis to ensure the guarantee nutrient value is present. Most producers will supply you with their analysis if you request it, and this can usually be received prior to product receipt.

I realize what is being said here is probably common knowledge, but I wonder if it is common practice. It would certainly be nice to be able to give your supplier a rail car number and indicate you would like all your product like that. The predictability of product is the case we are dealing with and is the reason documentation and on-going communication is recommended. In the time period July, 1982 to June, 1983 we obtained over 400 samples of raw materials. It is based on these annual and even semi-annual figures that make it possible to discuss specifics and not generalities.

The importance of this planning, communication and historical documentation goes hand in hand with achieving Quality in Bulk Blending. More importantly it is through this interaction and, hopefully, cooperative effort that it will be possible to produce more compatible, uniform products. As was stated in the 1978 presentation, and is still applicable, additional governmental regulations are not desired. The fertilizer industry must attune itself to the users of their products and we need to be certain industry receives the information to stimulate this action.

## What is Happening to Quality in Blending? (Producer)

### Trends in Diammonium Phosphate Particle Size

*Mabry M. Handley*
Technical Services Manager
IMC Corporation

Segregation of bulk blends is a continuing problem in the fertilizer industry. By definition here, we shall consider segregation as a deficiency caused by the incomplete mixing or unmixing of plant food materials where, as a result, a sample taken does not contain the guaranteed chemical analysis. This, of course, presupposes that all of the proper amounts of plant food were introduced into the formula and none were lost during the mixing process.

It is important to recognize that many recorded deficiencies are a direct result of improper formulations; consisting of failure to add the correct quantities of constituents or the loss of any of the given plant food values during the mixing step. It is equally important to recognize that sampling techniques can lead to apparent segregation or deficiencies in the analysis. How and where a sample is taken, and the way the sample is prepared, has a definite bearing on the analysis. Many deficiencies are believed to reflect problems with uniformity rather than actual deficiencies in average composition.

Now that we have, more or less, defined segregation, let's consider one more basic fact. Segregation is virtually impossible to avoid in manufacturing mixed fertilizer. To completely avoid it, our method of manufacturing mixed fertilizers would require homogeneous materials rather than the heterogeneous ones we must use. Any heterogeneous product will show tendencies toward segregation. All we can do is to work to reduce this tendency to acceptable tolerances.

It's generallly known, from studies at TVA and by others, that differences in particle size have a greater effect on segregation than any other parameter, including density and particle shape. Closely size-matched materials produce a blend having a low tendency to segregate. This problem of size-matching is a primary one for the producer. A blender cannot improve the uniformity of blends if the materials supplied by producers vary from load to load or varies from producer to producer. In studying the problem, we find ourselves confronted with a wide range of physical conditions under which fertilizer materials are made, handled, stored, and transported. Each has effects on the particle size received by the blender. This study was restricted to a single portion of this, what material from producers look like sizewise and has the size changed with time?

This study is of DAP. This material is used by approximately 95% of all blend plants and is generally considered the base material to which the size of other materials are compared. If DAP is not consistent, the blender has no way of selecting the other materials to match it. In addition, DAP production has been changing. The trend has been to large capacity units. Also, the existing units tend to run hotter and with higher specific gravities in the preneutralizer. All of these could have an effect on particle size.

We have made two studies. The first was in the spring of 1976, the second in the March-April period of 1983. For the surveys, several producers of DAP were contacted and asked to determine the average screens for their plant shipments for a one month period. The information was to be made public but the identities of the producers were to be kept confidential. Eight companies were in the first survey. They represented about 35% of the DAP capacity in this country. Eleven companies assisted in the second survey; here the survey represents over one-half this country's DAP capacity. Most companies weight averaged the screens for their one month of shipments; however, at least two producers made up a monthly composite sample. Two producers reported results from two locations or from two plants at the same location. These are identified by adding A and B after the number of that producer. There were some differences in which screens were reported. Each manufacturer has his own convention, but most did report on the 6, 8, 10, 14, and 20 Tyler Mesh screens. These are the ones shown. The odd size screens were left out of the table since their inclusion might identify a particular company to some people.

Looking at the 1976 data, one can see uniformity at both extremes, particularly on the small size, but there are large differences between producers on both the 8 and 10 mesh. The greater variations are on the 8 mesh. The control at the extremes is not surprising since almost everyone screens on approximately 6 mesh and slightly above 14. The percentage of fines removal is very high for production screens. Size of material between the extremes depend on equipment configuration and operating techniques.

Next we took a look at this data from a statistical point of view. It was decided to drop one bit of data. Company number 4 is the smallest on the list. The large amount of +8 reported without any information on the +10 was suspect. This one bit of data unbalances the entire information for +8; therefore, it was left out of the analysis.

Next we've taken the average of each screen size for the data. Although there is quite a difference between the size of some of the producers within this study, we had no way of knowing how much tonnage was involved in the shipment screens that were reported, so the mean, or average, is not weighted. Standard deviations were also calculated. For those who don't know statistics, this is a way in which to characterize the spread or variation in the data. Its significance is that you would expect about two-thirds of the data to fall within plus or minus one standard deviation from the mean.

A plot of the mean indicated a size guide number (SGN) of about 201 for all reporting companies.

The plot of the standard deviations shows the large variation between producers on the 8 mesh.

The data for the 1983 study shows much less variation between companies than the 1976 study. There have been movements by producers that were in both studies. Those that were a little large have moved down, those that were on the small size have increased the size of their profile. I should warn you that the number representing companies in the 1976 survey is not necessarily the same number in the 1983 study.

Means and standard deviations were also calculated for this set of data.

A plot of the mean very closely resembles that of the earlier study. Here the SGN is 203. However, a plot of the standard deviations shows how much more closely product from the producers is together sizewise now. If the averages were looked at together one would miss how much more uniform the material is now from producer to producer. It's only when the standard deviations are looked at that one can see the improvement made in the last seven years. During this period of time, DAP has become a more standard size material. Producers have brought their units in much closer to the industry average.

I realize many of you, as users, still see large differences in size from producer to producer and sometimes from shipment to shipment. Looking at averages does not solve that problem. Individual shipments may vary dramatically from these averages depending on how well a plant is handling its reclaiming from warehouses and what has happened to the material after it leaves the producer. We are currently tracking material through rail shipments, through warehouses, and through barge shipments. We do not have enough data yet to quantify what happens but there is no doubt that degradation does occur (as you would expect) and that warehouses often do a poor job of reclaiming material sizewise. In one case we've looked at the majority of the smaller fraction of four very good rail cars ended up in only two trucks going to one blender.

I believe the information I've presented today is good news. The producers are aware of the blenders' problems with segregation and have been responsive. Improvements in reclaiming, handling, and additional screening are being put in place and I believe the producer, today, is more quality conscious than at any time in the past.

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3. Smith, G.E., Proceedings of the Fertilizer Industry Round Table, Washington, D.C., 1961, pp 90–96.
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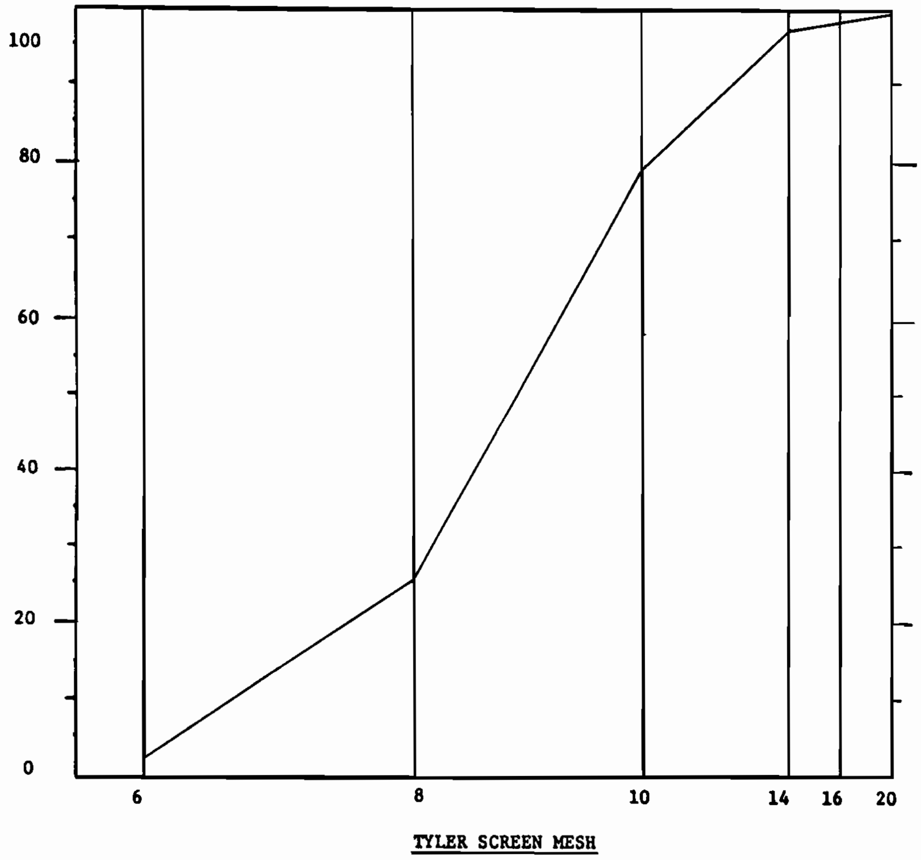
## 1976 - PARTICLE SIZE DISTRIBUTION OF DAP PRODUCT

| Tyler Mesh | Company | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 6 | 2 | 1 | 3 | 3 | 0.3 | 0 | 0.2 | 1 |
| 8 | 20 | -- | 45 | 67 | 22 | 9 | 13.5 | 37 |
| 10 | 80 | 71 | 80 | -- | 79 | 72 | 72.4 | 77 |
| 14 | 94 | 96 | 96 | 99 | 98 | 96 | 96 | 98 |
| 20 | -- | 99 | -- | 100 | 99.5 | 99.8 | 99.5 | -- |

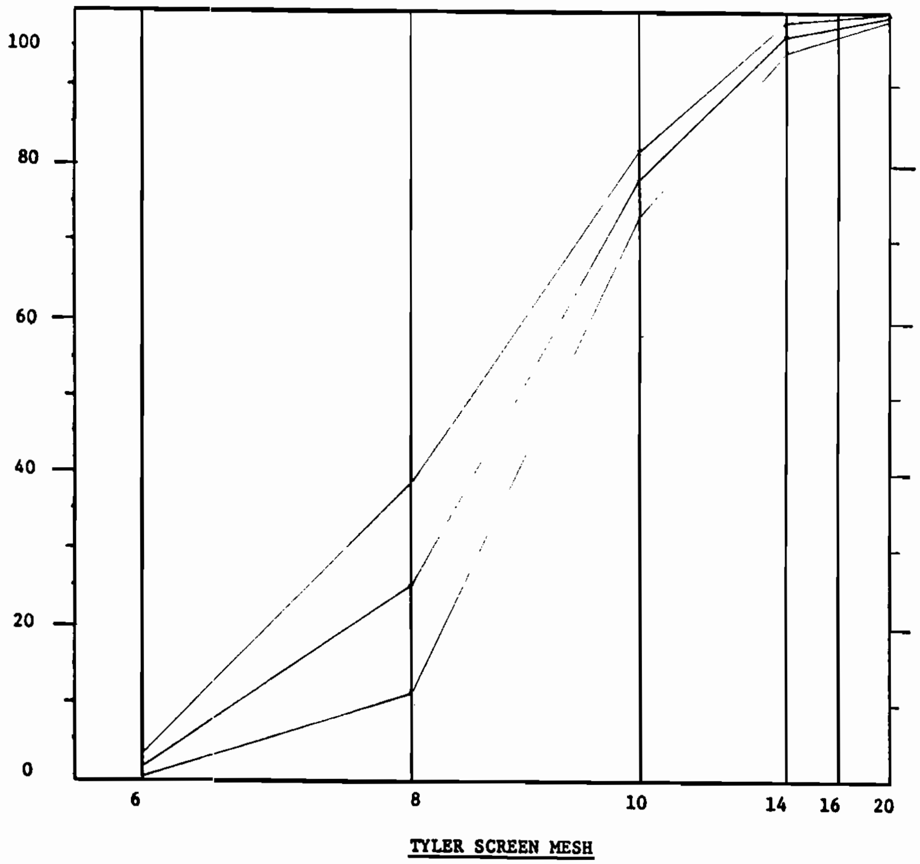
1976 STUDY - NON-WEIGHTED AVERAGE

**PARTICLE SIZE DISTRIBUTION**



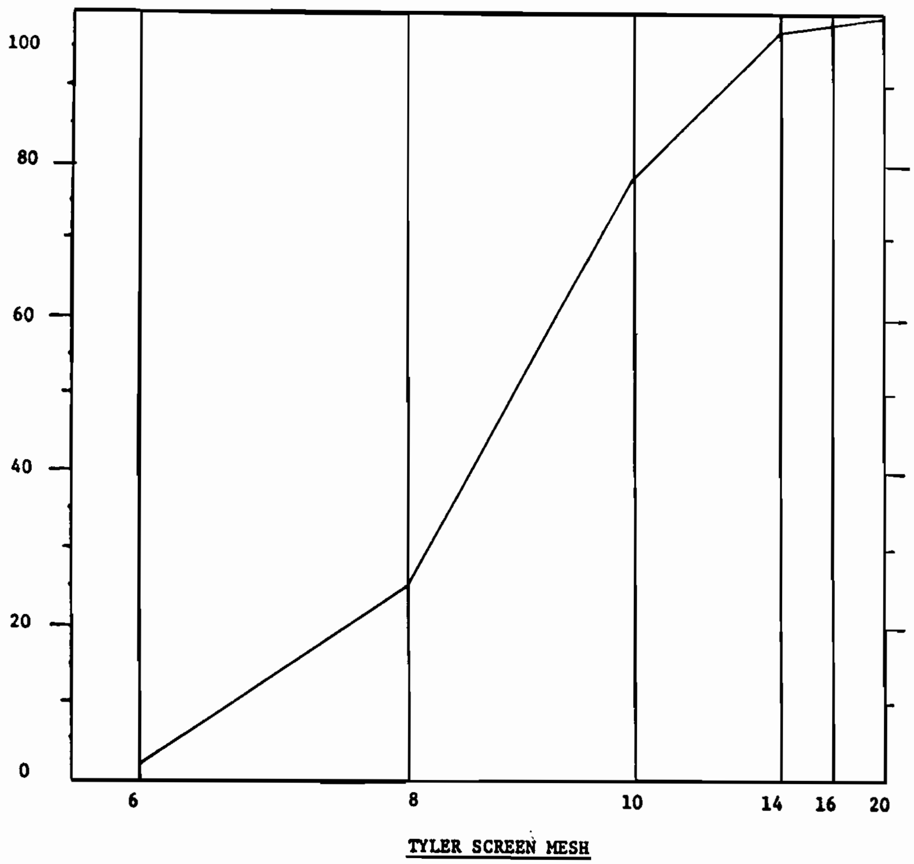
1976 STUDY - 1 STANDARD DEVIATION

**PARTICLE SIZE DISTRIBUTION**



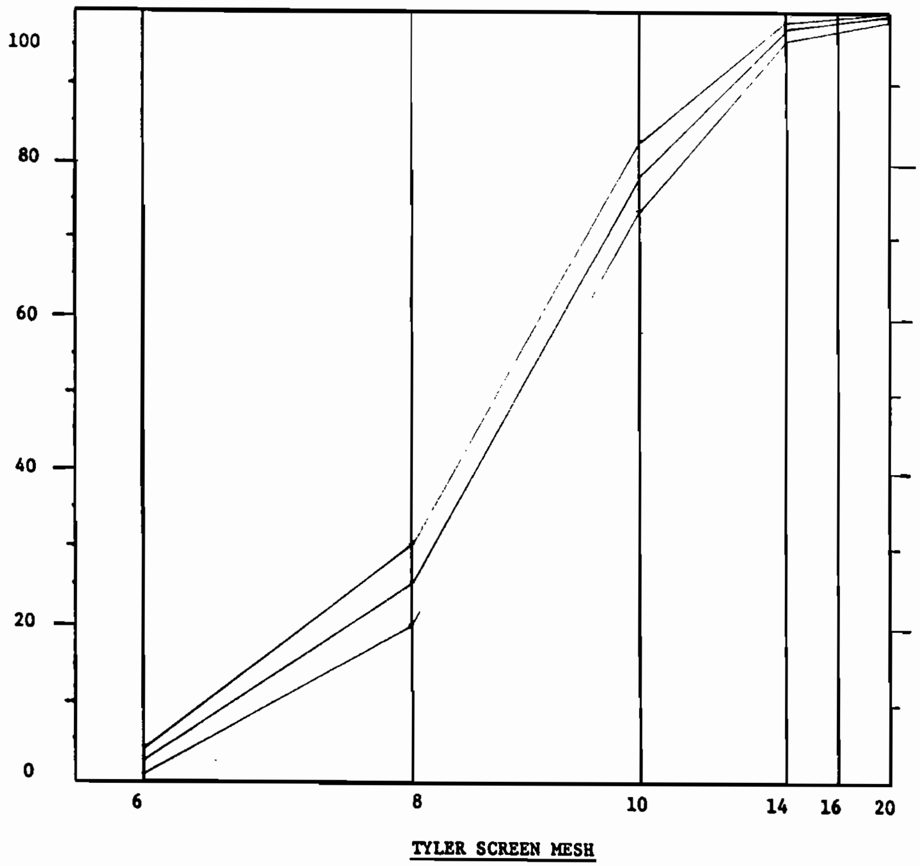
1983 STUDY - NON-WEIGHTED AVERAGE

**PARTICLE SIZE DISTRIBUTION**



1983 STUDY - 1 STANDARD DEVIATION

**PARTICLE SIZE DISTRIBUTION**



# 1983 - PARTICLE SIZE DISTRIBUTION OF DAP PRODUCT

| TYLER MESH | COMPANY | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3A | 3B | 4 | 5A | 5B | 6 | 7 | 8 | 9 | 10 | 11 |
| 6 | 1.5 | 2.0 | 1.4 | 1.5 | 0.4 | 2.3 | 0.4 | -- | 4.0 | 0.0 | 1.0 | 3.4 | 2.0 |
| 8 | 22.5 | 24.5 | 27.5 | 24.1 | 18.0 | 29.0 | 29.2 | 22.9 | -- | -- | 19.2 | 34.7 | 28.0 |
| 10 | 71.8 | 68.6 | 84.2 | 81.4 | 73.9 | 79.0 | 76.5 | 82.7 | 80.0 | 70.0 | 81.0 | 85.7 | 79.0 |
| 14 | 96.5 | 95.5 | 98.5 | 97.9 | 98.1 | 97.1 | 95.5 | 97.6 | 99.7 | 96.0 | 98.0 | 97.7 | 98.0 |
| 20 | 99.7 | 99.2 | 99.9 | 99.6 | 99.9 | 99.9 | 99.4 | 100.0 | -- | 98.0 | -- | 99.9 | 100.0 |

# What is Happening to Quality in Blending? (Producer)

## Quality Control in The Potash Industry

*Joe A. Gosselin* Research Chemist
Kalium Chemicals

Thank you Mr. Chairman, members and guests of the Round Table. I appreciate having the opportunity to talk on the subject of quality control in blending; more specifically, quality control of particle size as it relates to the potash industry. In my remarks today, I will first attempt to address the changes in particle size which have occurred in the potash industry in the last 10 years, followed by some of the technical details affecting particle size control in the potash industry.

First I would like to review the particle size distribution study of major dry fertilizers which was conducted in 1973 by The Fertilizer Institute. In this study, 24 fertilizer companies, including 9 potash companies, submitted shipping screen analyses of actual shipments to the Tennessee Valley Authority for statistical analysis. I would like to point out at this time that the potash industry submitted far more comprehensive data than either the nitrogen or phosphate producers. I feel that this is an early indication of the potash industry's interest in and commitment to quality control.

**TFI 1973 PARTICLE SIZE SURVEY OF MAJOR DRY BLENDING MATERIALS**

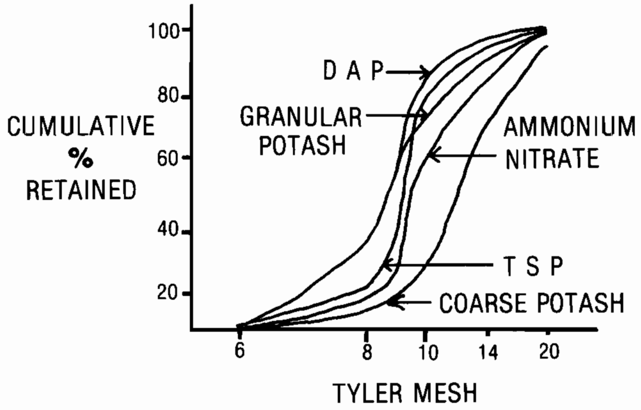
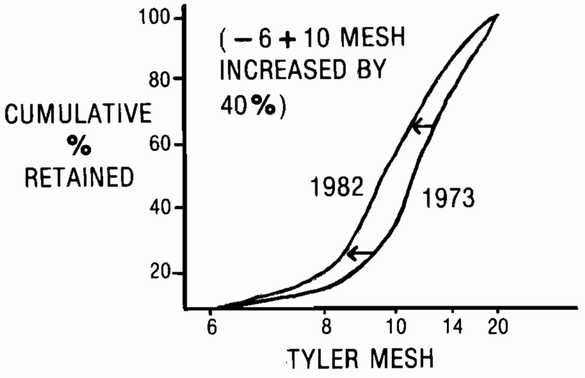


Figure 1 gives a graphical representation of the typical particle size distribution of the major dry fertilizer materials analyzed. From this survey, it was concluded that granular potash was compatible in size with TSP, DAP and, to a lesser degree, ammonium nitrate. Coarse potash was found to be incompatible in size with TSP, DAP and most ammonium nitrates. Urea, which was also part of the survey, was not included in the previous figure due to inadequate data. The limited data reported for urea did compare favorably with coarse potash.

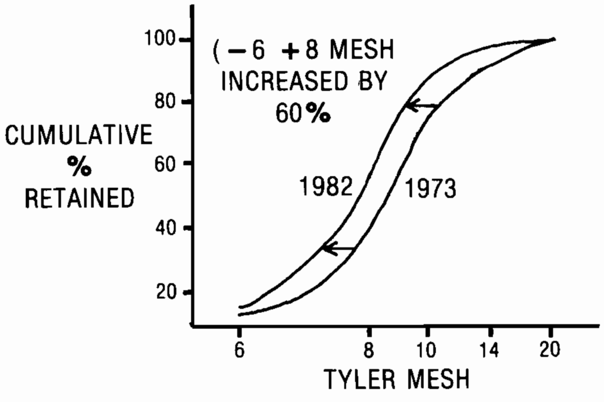
Since 1973, there have been changes in the particle size distribution of both granular and coarse potash. A comprehensive survey of the Saskatchewan potash industry, which was conducted by CANPOTEX in 1982, gives us the opportunity to determine what changes have occurred. Although this study did not include American producers, I feel that it is quite representative of the potash industry as a whole.

**COMPARISON OF COARSE POTASH FROM 1973 TFI AND 1982 CANPOTEX SURVEY**



Typical coarse potash, as shown in Figure 2, has increased in size since 1973 due to an increase of approximately 40% in the −6 +10 Tyler mesh fraction. This increase in coarse potash is mostly due to market pressures to make coarse potash more compatible with other major dry fertilizers. Coarse potash is preferred by the blender due to its lower price when compared to granular potash.

**COMPARISON OF GRANULAR POTASH 1973 TFI AND 1982 CANPOTEX SURVEY**



Tyical granular produce, as shown in Figure 3, has increased in size since 1973 due to an increase of approximately 60% in the −6 +8 Tyler mesh fraction. Although it is difficult to assign a specific reason for this change, a combination of market pressure for a granular product which would more closely match granulated urea and ammonium nitrate, the increase in size of coarse potash and more efficient production are probably the main reasons for this change.

Now let us turn to the technical aspects of quality control in the potash industry. First the production of particles for blending grade potash varies slightly from producer to producer but consist of three major processes.

—Flotation
—Compaction
—Crystallization

The variables which directly affect the particle size of the blending grades generated from these processes are too numerous to allow me to cover them in any detail. However, I think it is important to point out that there have been significant improvements in these processes and that these improvements, along with improved quality control, have helped in producing higher quality products.

The production of potash particles of adequate size and strength is followed by the screening process. During the screening process, potash particles are sized to produce coarse and granular blending grades. The particle size distribution of these is controlled by:

1) the economics of the process
2) the type of process used
3) the particle size distribution of other blending materials

The most severe problem to overcome once a blending grade material has been produced is segregation. Some potash mines use special equipment to prevent segregation from happening at the plant, such as distribution chutes which are used to spread product in Kalium warehouses.

With today's changing modes of transportation, which involve unit trains, large capacity vessels, and large field warehouses, segregation and breakage have become even more of a problem. Several potash companies are presently looking at ways of reducing the amount of segregation and breakage which occurs at their offsite locations.

The importance of continued interaction between producers and blenders cannot be emphasized enough. This interaction occurs through such organizations as the TFI, CFI, state associations, and meetings such as the Round Table, and by direct contact between the blender and the producer's sales or technical representative.

Some potash producers have participated in the initiation and development of several programs to improve both the production of potash blending grades and the practices used by blenders.

One of the most recent examples of cooperation between the producers and blenders is the development by the Canadian Fertilizer Institute of the SGN system of materials identification. SGN stands for size guide number and is a single number which represents the average particle size of a material. This size guide number is intended to help the blenders more easily choose size compatible materials.

This program was introduced in Canada in 1982 and is totally voluntary. It is supported by most Canadian potash producers, along with most nitrogen and phosphate producers. Although it is too early to accurately determine what effect the size guide number has had on the quality of blended material, some of the Canadian blenders which are using this system have reported a reduction in the nutrient deficiencies found in official samples.

Additional examples of cooperation between fertilizer producers, fertilizer control officials and the bulk blenders are the TFI Bulk Blenders Manual and the various bulk blend workshops.

Further improvement in the quality control of potash blending grades can be expected as processes and economics improve. However, blenders must also accept a share of the responsibility for seeing that products are properly handled in order to minimize problems.

The potash industry's or any raw material producer's attempt to provide a satisfactory blending grade material can easily be destroyed through improper handling in the blending plant, which can cause segregation and/or breakage. Improper mixing of dry fertilizers due to either improper sizing of materials or inadequate mixing equipment can also cause problems.

There is no question that improvements in bulk blends have been made in the last ten years. Continued work and cooperation between raw material producers, bulk blenders, fertilizer associations and fertilizer control officials will ensure that problems are solved and improvements are made.

Thank you.

# Wednesday, October 26, 1983

## Morning Session's Moderator:

## Joseph E. Reynolds, Jr.

## Computer Simulation of Fertiliser Granulation Plants

*I. K. Watson*
UKF Fertilisers Limited/Stamicarbon b.v.

### 1. *INTRODUCTION*

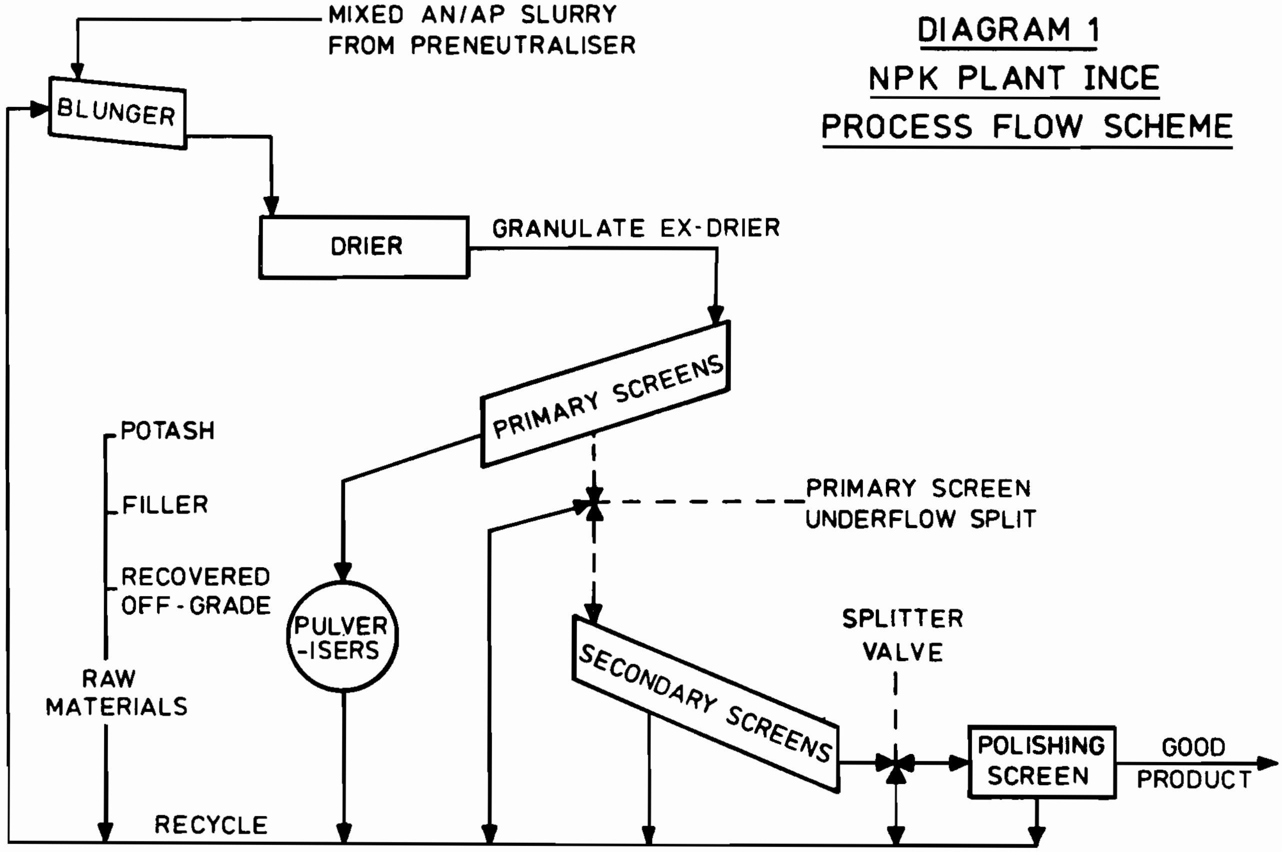
This presentation is an abridged version of the paper written by Mutsers, Slangen, Rutten and Watson, presented to the Fertiliser Society in London in April 1983. Those wishing for fuller details should refer to that paper (Proceedings No 215).

The computer model described is based on two similar models made for two of UKF's fertiliser plants: the CAN plant at Geleen, Holland and the NPK plant at Ince, England. A flow diagram of one of these plants is shown in diagram 1.

### 2. *WHY USE A COMPUTER?*

In fertiliser granulation plants (from which prilling plants are excluded), generally a considerable part of the material leaving the granulator is eventually fed back to the granulator. This recycled material usually consists of screened-off fines, crushed over-size, and fine dust from the cyclones. In some cases, also on-size product, as such, or after being crushed, is recycled. The fraction of the flow from the granulator that is recycled can vary considerably; in most processes it exceeds 50% and in some case it may even reach up to 90%. When the plant is in equilibrium, the amount of on-size product leaving the plant equals the total amount of liquids and solids fed to the plant. Further, the sieve analyses of all the flows remain constant in time.

The recycling of material, nearly always an indispensable element in the granulation process, makes



the behaviour of granulation plants much harder to understand. The characteristics of the recycle, which are themselves the result of what has happened previously in the granulator, influence in their turn what will happen later on in the granulator. As a result of this, a certain interference in the process can have an effect upon the equilibrium state which is markedly different from its effect after one pass. Further, in some cases an unstable, i.e., time-dependent behaviour of the granulation loop is caused. The large periodical oscillations which may result in this case, are unfavourable for plant capacity as well as product quality. It is evident that, both in optimising the static equilibrium state, as well as in finding causes of instabilities, the effects of the solids recycling have to be taken into account. The concepts of equilibrium and granulation stability are important to the understanding of the granulation process.

The mechanism through which the solids recycle works has been discussed by van der Leek (Ref. 1). By means of his equilibrium theory of the so-called V/G and L/G Lines it is possible to explain most of the observed phenomena.

Fortunately, the modern computing techniques that have arisen since then offer new opportunities. In principle, an exact computational elaboration of the van der Leek theory is now possible. The technique to be used consists essentially of making mathematical characterisations of the size enlarging action of the granulator, the separating action of the screens and of the size reducing action of the crushers, followed by computing the equilibrium state of the solids loop. When the granulation occurs through agglomeration, the amount of liquid phase has to be calculated, and, in order to do this, a heat and water balance over the granulator has to be set up. The models only give information above the magnitude and the size distribution of the various flows. The quality of the granules (roundness, mechanical strength, etc.) is not considered.

## 3. *THE COMPUTER MODEL*

### 3.1 Basis

The model concerns itself with the flow of solids throughout the plant, and how the characteristics of solid flows change.

The characteristics of the solid flows are quantified in terms of the following parameters:

a. Mass flow rate, tonne $hr^{-1}$
b. Sieve analysis* for a specified set of sieves†

In a fertiliser plant (and thus in a model) four changes can occur to a solid flow stream:

a. A separation process, where larger particles are separated from smaller ones (screening)
b. A size reduction process where particles are made smaller (crushing)
c. A size enlargement process where particles are made larger (granulation)
d. A combination process where two different streams are added together (mixing)

In terms of the two parameters given above (mass flow, sieve analysis) changes of both occur in granulation, screening and mixing. In the case of crushing a change only occurs in sieve analysis.

In a computer model there are three basic building blocks:

— the screens

— the crushers

— the granulator

The process of mixing is one of simple arithmetic, and will thus not be considered further.

### 3.2 Screens

The basic concept is that of the probability P, of a particle, size d, passing through a sieve mat, size $d_s$.

For a particular sieve installation the following sort of curve can be made.

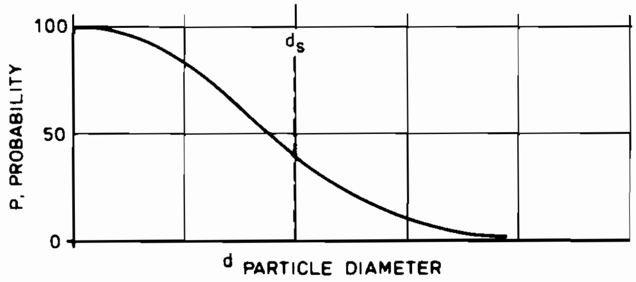


FIGURE 2: PROBABILITY CURVE FOR A PARTICLE PASSING THROUGH A SCREEN

With an ideal screen of course, the picture would look like this:

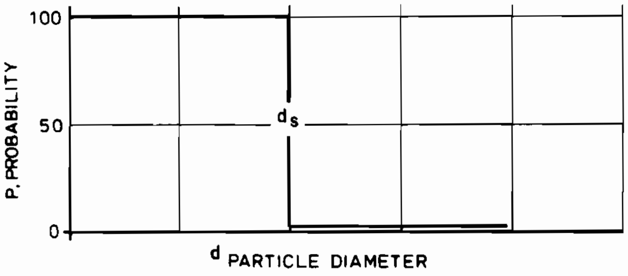


FIGURE 3: IDEALIZED PROBABILITY CURVE FOR A PARTICLE PASSING THROUGH A SCREEN.

This picture is never realised.

Also, where the curve actually crosses the $d_s$-line (either below or above the theoretical 50%) is

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*Sieve analysis can be either fractional (as in Ince model) or cumulative (as in Geleen).

†These can be in regular intervals, e.g. every 0.05 mm, or each ISO sieve fraction sub divided into a number of equal fractions. These values are used as a standard throughout the whole programme.

dependent on the working of the screen. Blinding will give a figure lower than 50%, whereas worn sieves, or the combination of slotted screens with unround product may give figures above 50%.

In a computer model the probability curve can either be defined as a data array of, say, 10 probability values at certain d-values, or alternatively, three probability points can be defined at e.g. $d_s$, $d_s + 0.5$, $d_s - 0.5$ mm. On the basis of these, the probability curve can be built up from two "straight lines" on a log-probability plot.

### 3.3 Models of Crushers

Three types of crushers were modelled:

- chain mill
- roll crushers
- cage mill

For the sake of brevity only the roll crusher model is described here.

### *Roll Crusher*

After analysing a lot of plant data for different values of $d_{rolls}$ (= distance between the rolls) it appeared that the particle size distribution of the roll crusher outlet was approximately proportional to $d_{rolls}$, i.e. all our measurements could be described by the same function of $d/d_{rolls}$.

In figure 4 this function is shown:

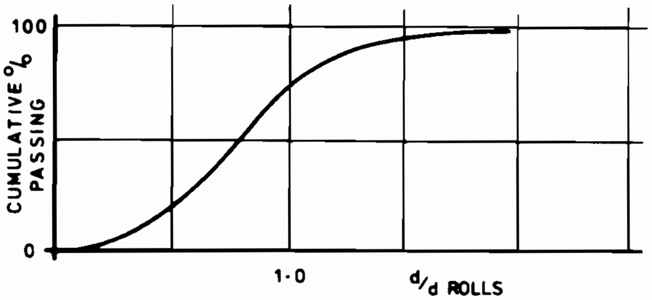


FIGURE 4: EFFECT OF RATIO PARTICLE DIAMETER TO ROLL CRUSH GAP WIDTH IN SIEVE ANALYSIS OF CRUSHED MATERIAL.

This same function has been used throughout all our calculations, independently of the mass flow to the crusher and the size of the particles in it.

### 3.4 Model of the Granulator

### 3.4.1 β-Curve

For the sake of clarity the derivation of a normalised β-curve is illustrated graphically. The bases are the cumulative sieve curves of the blunger feed and the granulate ex-drier. We use the convention of a cumulative undersize (passing) analysis. (Thus $d_{10}$ is a smaller diameter than $d_{90}$).

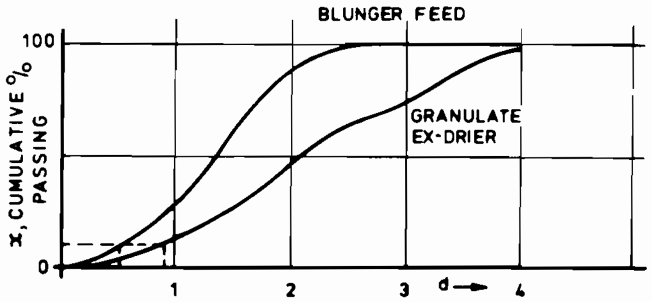


FIGURE 5: CUMULATIVE SIEVE ANALYSIS GRANULATOR FEED AND GRANULATE

$$\beta_{10} = \frac{d_{10} \text{ blunger feed}}{d_{10} \text{ granulate}}, \text{ etc}$$

from the cumulative curves above, a β-curve is derived.

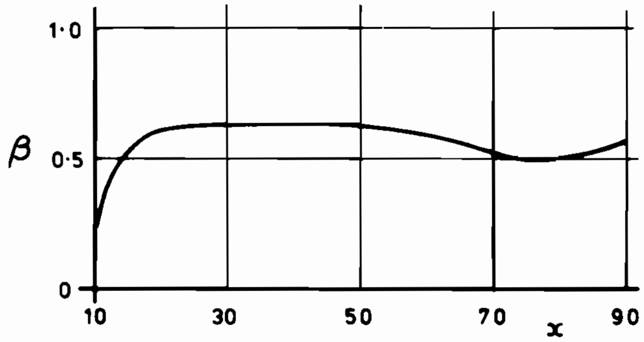


FIGURE 6: UN-NORMALISED β CURVE

In practice a β-curve can be defined either in terms of deciles, or a particle diameter (granulate or feed). The form of the β-curve differs little whichever method is used, and for practical computing reasons, the decile method was chosen.

A normalised β, $\bar{\beta}$ is derived as follows:-

$$\bar{\beta}_x = \frac{\beta_x}{\beta_{50}}$$

It follows thus that $\bar{\beta}_{50}$ is unity.

It has been found in practice that for a particular fertiliser grade, a normalised β-curve retains its shape independently of $\beta_{50}$.

In the computer model the normalised β-curve is treated as if it were a property of the blunger. Whether this is in fact so, is considered later.

### 3.4.2 The Sherrington Equation

In our computer models we assume that the Sherrington agglomeration model holds. The Sherrington equation (Ref. 2) is

$$y = k(1 - 3\beta t)$$

where k = voidage fraction
t = contraction ratio
y = volume ratio of liquid to solid phases

From this the following relationship is derived

$$\beta = \frac{k - y}{3kt}$$

In our model we assume that $\beta$ is in fact $\beta_{50}$, and that k and t are constants. Thus if y, the fluid phase ratio is known, $\beta_{50}$ can be calculated.

Thus knowing $\beta_{50}$, and having a normalised $\beta$-curve (stored in a data-array), the values $\beta_{10}$,$\beta_{20}$, etc. can be calculated. From the cumulative sieve analysis of the blunger feed, the cumulative sieve analysis of the granulate (ex-drier) can be calculated.

### 3.4.3 "y", the fluid phase ratio

Hunter & Hawksley (Ref. 3) show that y can be calculated from the granulator water content and the solubility of the formulation.

$$y = \frac{w(1 + s)\rho_s}{(1 - ws)\rho_l}$$

where $w = \dfrac{\text{weight of water}}{\text{unit weight of dry solids}}$

$s = \dfrac{\text{weight of solids dissolved}}{\text{unit weight of water}}$

$\rho_s$ = density of solid phase

$\rho_l$ = density of liquid phase

### 3.4.4 Water Content

In our models we suppose that the liquid phase, which is present in the solid particles fed to the blunger, does not contribute to the capillary forces causing agglomeration. The water content of these solid particles is, therefore, counted as solid phase.

A complication arises in the calculation of effective granulation water content, and this is the moisture loss through evaporation. We can consider granulation to be largely complete before evaporation begins, or the opposite. Either case is a simplification since we are treating dynamic processes in the model as if taking place instantaneously.

The Ince model considers that water evaporation takes place after granulation, and the Geleen model vice versa. In practice the difference is compensated for by the use of different k and t values. In the case of the Ince model, two granulator water contents are thus calculated by the computer:

— granulation water content; exclusive of water from the recycle-also no evaporation loss.

— ex blunger water content; inclusive of water from the recycle and also corrected for evaporation loss.

The first is used for calculating $\beta$, and the second for comparison with plant measurements.

### 3.4.5 Solubility

For the CAN Model, the data for pure ammonium nitrate are used. Measurements have shown that the $Ca(NO_3)_2$ content has no significant influence on the amount of liquid phase which is present under granulation conditions, and can therefore be ignored. In the case of NPK's, the solubility is measured experimentally using a hydraulic press.

The solubility data are stored in the computer as a quadratic function of temperature. (In the case of NPK's the equation constants can be changed).

Thus, in order to calculate solubility, we need to know granulation temperature.

### 3.4.6 Granulation Temperature

A heat balance over the blunger has to be made, the main processes are:

— Mixing of slurry and recycle; the recycle warms up and the slurry cools down until a combined mixed temperature is reached.

— Cooling through evaporation of water and passage of air through the blunger.

Further, in both models the effect of heat losses from the blunger and energy dissipation are taken into account.

## 4. *COMPUTER MODEL: COMPUTER/MATHEMATICAL ASPECTS*

### 4.1 Basic Principles of Calculation Procedure

The calculation procedure is iterative, each iteration for example being one residence time period round the recycle loop.

Before the calculation begins, all the various process conditions must be known, together with details of the equipment performance. These are read in from an input list or data array in the programme.

The calculation begins with the recycle: in order to start, two assumptions have to be made:

— the recycle screen analysis

— the recycle quantity

Thereafter the calculation proceeds through the following steps:

- addition of solid raw materials to recycle and calculation of granulator feed sieve analysis.
- heat and mass balance over the granulator; calculation of granulation temperature and water content; calculation of solution phase ratio.
- calculation of granulation over granulator plus drier.
- calculations over screens and crushers-

thus

— end product quantity and sieve analysis

— recycle quantity and sieve analysis.

In the Ince model, the quantity of end product is compared to the quantity of raw materials, and the calculated recycle sieve analysis and quantity is compared to the assumed start values. If all three of these values are the same, then the equilibrium situation exists.

### 4.2 Types of Model, and Methods of Determining Equilibrium

Basic Model Types:

The two principal model types are:

- a static model
- a dynamic model

### 4.2.1 Static Model

The static model concerns itself exclusively with the determination of the equilibrium situation for a particular set of operating conditions. The manner in which the equilibrium is reached is ignored: in other words, the granulation stability is not considered at all.

The model only seeks the granulation equilibrium, whatever it is, and does not consider whether in real life such an equilibrium is attainable and/or usable. In the static model, at the beginning of each new iteration, new assumed recycle conditions are made. The value of these assumptions is derived from the old value and the difference between calculated and assumed value.

### 4.2.2 Dynamic Model

In contrast to the static model, the dynamic model considers how the plant behaves. Not only what the equilibrium is, but how it is reached, and how quickly.

The Ince model is dynamic, and for Geleen both a static and a dynamic model have been made.

In the Ince dynamic model, the end recycle quantity and recycle sieve analysis from one time-step become the start situation for the next time-step.

In the dynamic model of the Geleen-plant, the residence-time distribution in the rotary-drier is taken into account. Here no start-assumption has to be made. The equilibrium calculated by the static model is the start point for the dynamic model. For a given disturbance (in the AN-temperature, for instance) the computer programme calculates the effect of this disturbance as a function of time.

The advantage of a dynamic model is that it can see the effects of disturbance to the process. If an incorrect start assumption is made, then sometimes no equilibrium conditions can be reached. This is purely a reflection of real life—if, for instance, the recycle loop is burdened up with dust, then by setting normal feed rates it is indeed unlikely that a granulation equilibrium would be reached—or certainly one which has any practical significance.

An example of a calculation with the Ince model is given in Appendix 1 where the effect of a change in plant throughput is demonstrated.

## 5. *COMPARISON OF COMPUTER PREDICTIONS WITH PLANT OBSERVATIONS*

Generating data from a computer model is not very difficult. However, collecting reliable data from the plant is. We all know the problems of obtaining representative samples coming from the discharge of a bucket elevator.

Similarly, collecting reliable heat and water data over the blunger so that good k and t values can be found is not simple.

Even allowing for these difficulties, the model and plant situation appears to be in fair harmony. Table 1 presents the average value of six measurements on six different days, compared with the results obtained via the model.

**TABLE 1**

| | **Difference Between Measurement and Calculation** |
|---|---|
| Granulation Temperature (° C) | +0.3% |
| Size enlargement $\beta_{50}$ | +4.4% |
| $d_{50}$ of Granulated Product | +1.3% |
| Amount of Recycle | −1.5% |

## 6. *THE USE OF THE MODEL TO PREDICT PLANT CONDITIONS*

### 6.1 Effect of AN melt water content

Appendix 2 shows the effect of changing AN melt water content on medium particle size of the granulate ($d_{50}$), the granulation temperature ($T_6$), and the relative amount of product size material in the granulate ($\Delta\eta$: relative to normal plant operation).

There are no surprises in this graph: as more water is added, $d_{50}$ increases, whilst the other two decrease.

### 6.2 Effect of recycle temperature

See Appendix 3.

The kink in the lines is caused by the AN crystal phase (II/III) latent heat. If the recycle is colder than 84°, then the melt in warming up the recycle also has to provide latent heat.

### 6.3 The Effect of Cage Mill Speed

See Appendix 4.

As one would expect, speeding up the mill decreases granulate $d_{50}$. However, not so obvious, is the fact that it has minimal effect on the amount of product size material in the granulate.

## 7. *CONCLUSIONS*

1. Computer models work, and give, within limits, good agreement with plant conditions.
2. They can be used to investigate process conditions, and so

— define bottlenecks
— predict effects of changes
— optimise plant operation. (At UKF Ince the production rate of one major production was considerably enhanced as a result of studying with the computer.

3. Computer models are a useful training aid.
4. The weak point is the model of the granulator

— use of β curves
— granulation is often not only by agglomeration

## 3. REFERENCES

1. J.van der Leek; Proc. ISMA Technical Conference, The Hague, 1976 p.p. 94–114; "Agglomerate Granulation as an Equilibrium Process".

2. P.J.Sherrington; Chem Engr. (London). July/Aug. 1968, p.p. CE 201–CE 215: "The granulation of sand as an aid to understanding fertilizer granulation".

3. G.Hunter and J.L. Hawksley; Proc.ISMA Spec.Dev.Conference, New Delhi, December 1975: "Some developments aimed at reducing recycle ratios of high-analysis NPK process".

This shows an iterative calculation to determine granulation equilibrium in a dynamic manner. At the start equilibrium exists with feed rates at 35 tph. The feed rates are instantaneously dropped to 25 tph. After 22 passes of the recycle loop a new equilibrium is reached.

The column headings have the following meaning:

GWS - effective granulation water content at start of iteration;
GWE - ditto, end
GTEMP - effective granulation temperature
SOLN - "y" = solution phase ratio
BETA - $\beta$50
PROD - production rate - amount of on-size product leaving the plant in tph
GRAN - reycle ratio
D50 - d50 of granulate mm

The step change disturbance results in an oscillation of plant conditions - granulate d50, production rate and so on.
(N.B. : Sometimes the oscillations increase rather than diminish, and no stable situation is reached).

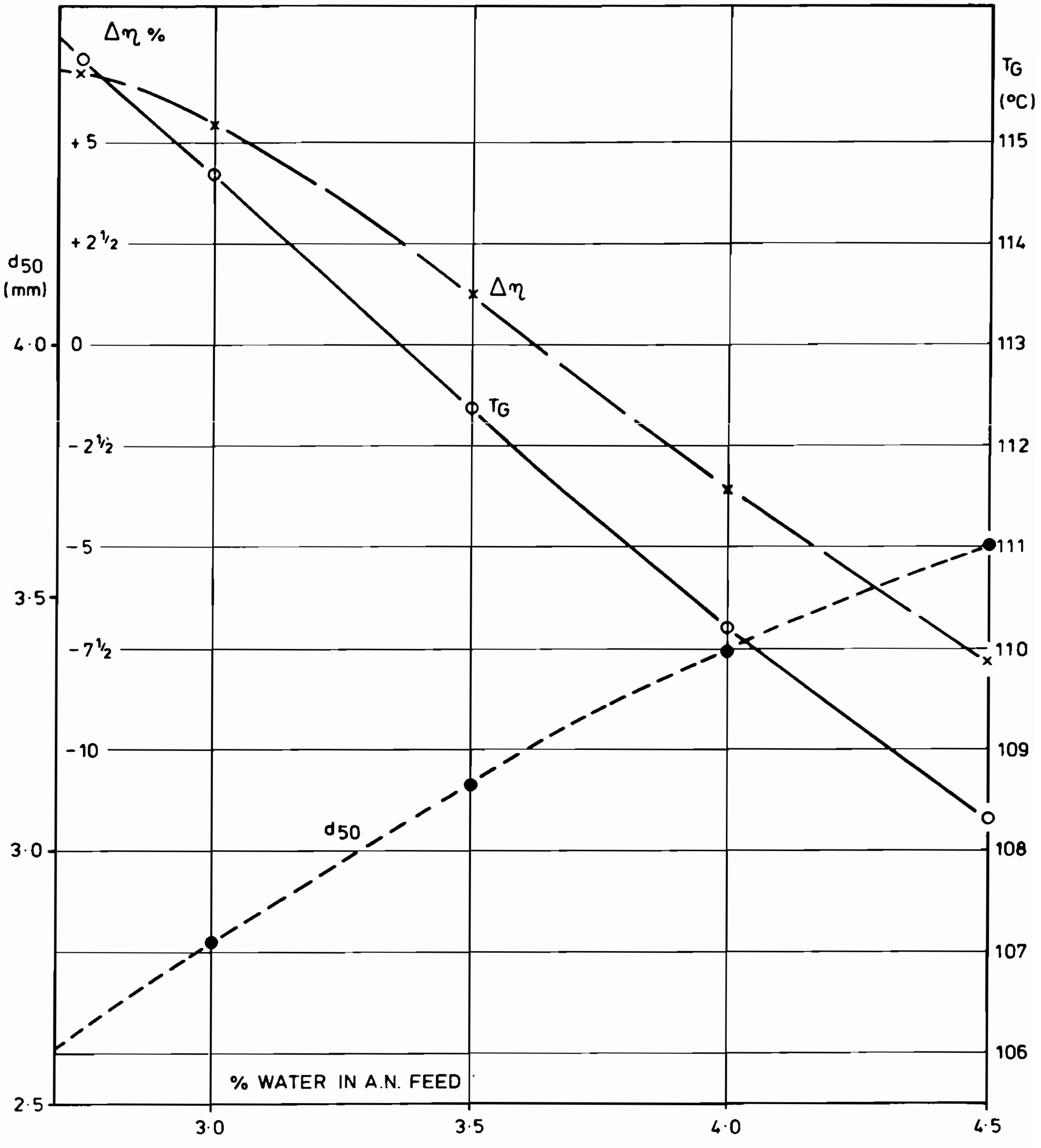
The equilibrium appears in practice to have been reached after 16 passes of the loop. In the last six passes (17 to 22) little change occurs. These last cycles are dependent on the convergence test limits used for testing for equilibrium. In this example one of the equilibrium test criteria is the difference between production rate and feed rate must not be greater than 0.1 tph.

```
 GIVE PROD-N RATE BASED ON RAW MATERIALS FEEDS (T/H)
 ( 35.0000)
‡25


I LN    GWS    GWE   GTEMP   SOLN   BETA  PROD   GRAN    RR   D50
1  2  1.806  1.394   95.5   .136   .695  28.6  136.3   3.8  3.37
1  3  1.394  1.393   95.1   .135   .696  33.6  132.7   3.0  3.09
1  4  1.393  1.427   96.4   .141   .684  34.9  124.1   2.6  2.94
1  5  1.427  1.522   98.2   .154   .655  18.9  114.2   5.1  2.89
1  6  1.522  1.657   97.1   .168   .625  28.2  120.3   3.3  3.07
1  7  1.657  1.571   97.6   .159   .644  21.8  117.1   4.4  3.04
1  8  1.571  1.616   97.1   .163   .635  27.7  120.2   3.3  3.10
1  9  1.616  1.572   97.6   .159   .644  22.7  117.5   4.2  3.07
1 10  1.572  1.610   97.2   .162   .636  26.7  119.8   3.5  3.11
1 11  1.610  1.578   97.5   .159   .643  23.6  118.2   4.0  3.08
1 12  1.578  1.601   97.2   .161   .638  26.1  119.5   3.6  3.10
1 13  1.601  1.582   97.4   .160   .642  24.2  118.5   3.9  3.09
1 14  1.582  1.597   97.3   .161   .639  25.6  119.3   3.7  3.10
1 15  1.597  1.585   97.4   .160   .642  24.5  118.7   3.8  3.09
1 16  1.585  1.594   97.3   .161   .640  25.4  119.2   3.7  3.09
1 17  1.594  1.587   97.3   .160   .641  24.7  118.8   3.8  3.09
1 18  1.587  1.593   97.3   .161   .640  25.2  119.1   3.7  3.09
1 19  1.593  1.588   97.3   .160   .641  24.8  118.8   3.8  3.09
1 20  1.588  1.592   97.3   .160   .640  25.1  119.0   3.7  3.09
1 21  1.592  1.589   97.3   .160   .641  24.9  118.9   3.8  3.09
1 22  1.589  1.591   97.3   .160   .640  25.1  119.0   3.7  3.09
```

APPENDIX 2

# THE EFFECT OF A.N. MELT WATER CONTENT



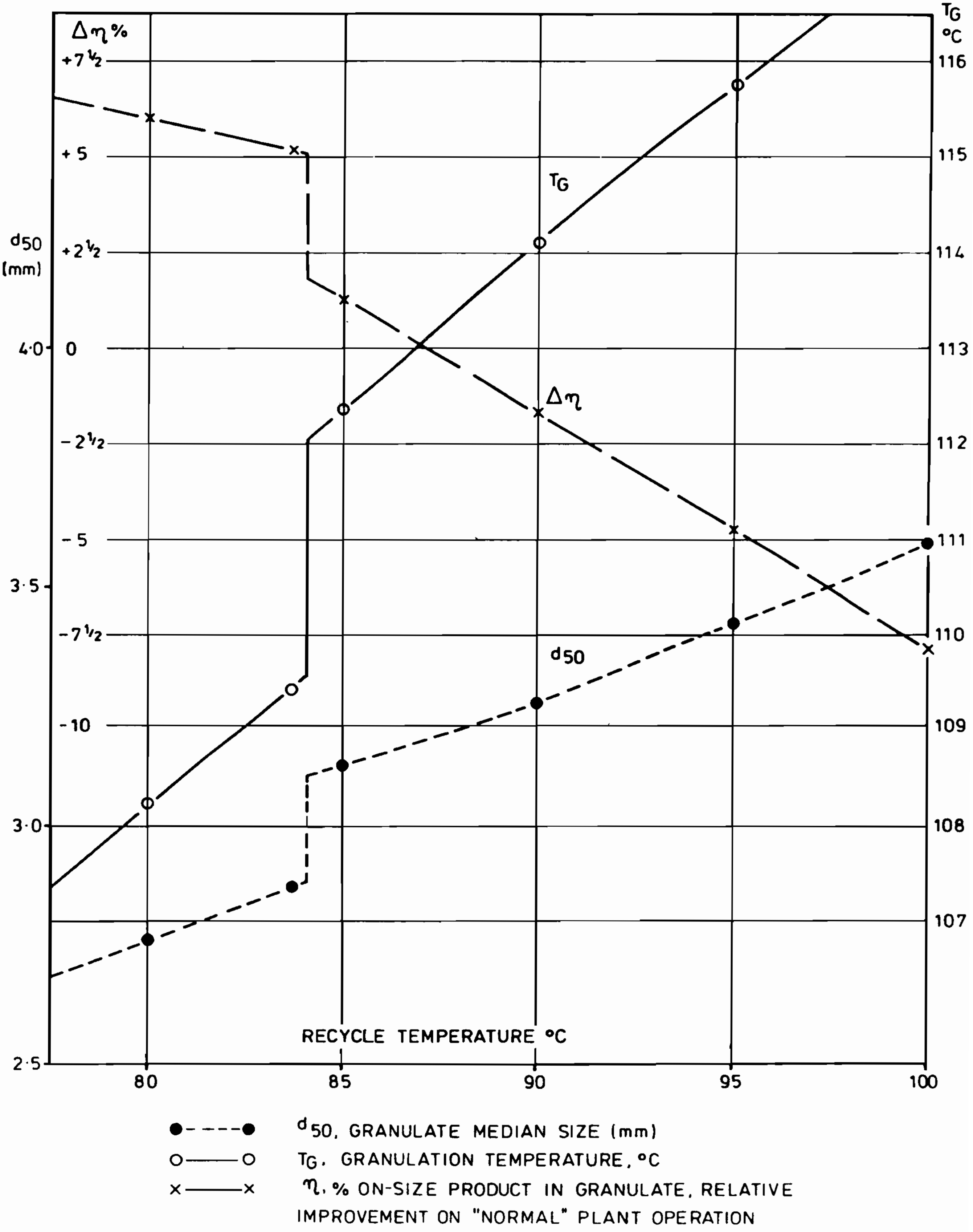
●- - - -● d50, GRANULATE MEDIAN SIZE (mm)

○——○ TG, GRANULATION TEMPERATURE, °C

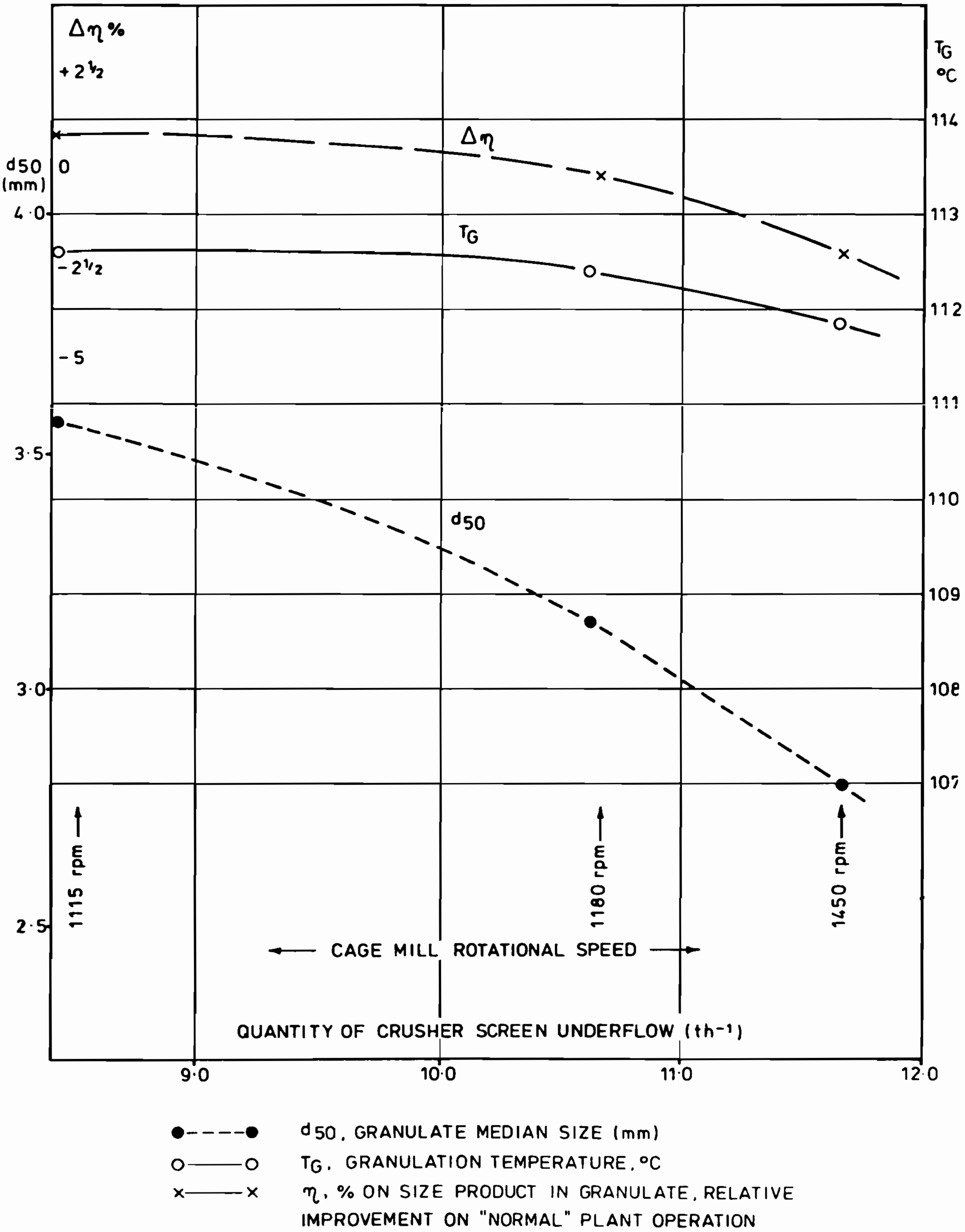
×——× η, % ON-SIZE PRODUCT IN GRANULATE, RELATIVE IMPROVEMENT ON "NORMAL" PLANT OPERATION.

APPENDIX 3

# THE EFFECT OF RECYCLE TEMPERATURE



## THE EFFECT OF ROTATIONAL SPEED OF PRIMARY CRUSHER (CAGE MILL)



# Selecting Screens for Granulation Plants

*S. J. Janovac*
Product Manager
W. S. Tyler, Inc.

Generally, there are four types of vibrating screen actions. These are inclined, circle throw units wherein the screen body, in it's motion, describes a circle, usually adjustable to suit the separation. The next is a straight line or linear motion at a 45° angle to the screen body and are classified as horizontal screens. The next is a sifter type that has an oscillating motion in the horizontal plane.

All of these require the entire screen mechanism to be set in motion to effect a separation.

The fourth type is linear and perpendicular to the screen surface and is the only type where only the screen cloth is actuated to effect the separation.

For simplicity, we will classify the first three types as mechanical screens remembering that the entire screen body is vibrated as opposed to the linear and perpendicular type which we'll classify as electro-mechanical.

The reason for the differentiation is to point out there is no one type of screen best suited to all screening applications. Typically, most all mechanical screens will operate within a range of two to five times gravity before the integrity of the screen body is adversely affected.

Conversely, the electro-mechanical type with a stationary body and only the wire cloth actuated or vibrated, "G" forces, or the amount of energy imparted to the wire cloth, is twelve to fifteen times the force of gravity. The Hummer with electro-magnetic vibration is even higher.

Consider, also, the fact that it is the wire cloth that actually separates material according to size and it is the vibrating screen that stratifies the feed bed, and through the action carries the material from feed to discharge where the granules are continually subjected to the screen cloth for either acceptance or rejection.

If all granular fertilizers were bone dry and contained no near-size material, then the one screen best suited for the application would be an inclined, circle-throw mechanical screen which combines both capacity and efficiency but, because of the relatively low "G" force restrictions, does not have the ability to handle the adverse factors of screening, such as dampness, the affinity of attracting moisture, plasticity, dust and particularly near size granules which obviously is that portion of the feed that is very nearly the same size as the aperture it must pass through. Almost without exception, the near size which causes pegging or plug blinding of the wire cloth is the finer of the two separations that are normally accomplished in all granular screening operations.

Screen cloth blinding is cumulative; it doesn't generally happen all at once, but all at once it's happened.

The product is out of specifications and the product recovery rate is higher with more fines in evidence in the product.

And therein lies the difference between mechanical screens and electro-mechanical screens with their much higher force input to the wire cloth and their ability to either preclude blinding almost entirely or to lengthen the cumulative affects over a much greater period of operation.

However, since the screen motion is perpendicular and all energy is concentrated initially on stratification and aerating the feed bed, there is no practical forward motion imparted to the granules. Vibration sets the material in motion and gravity conveys and is the reason for installation angles of 33° to 36°, which is pretty much the same as the angle of repose of the material itself.

Fertilizer materials, even at the "present state of the art," are still one of the more difficult classes of material to screen. Tonnage rates are modest, but separations are medium coarse to medium fine, depending upon one's definition; there is dust, temperature, moisture, corrosion and near-size material.

The advantage is the granular nature which lends itself ideally to using Ty-Rod type weaves. Ty-Rod does not exercise as close control over particle size limitations as does square mesh, but it is freer screening and has a good aperture to wire diameter relationship that provides good open area, yet is very serviceable.

Again, the initial purpose of the screen is to stratify the feed material, forcing the coarser granules to the top, allowing finer particles to pass down through the pulsating bed to be subjected to the screen cloth for passage or rejection. Of course, if the tonnage rate is too high, stratification becomes more difficult and separations will be incomplete.

Theoretically, the depth of bed should be no more than six times the opening of the separation. For example, at an initial separation at 6 mesh with an aperture of .131", the depth of bed should not exceed ¾" to perhaps 1" and is one of the reasons for multiple, parallel screens for higher tonnages.

Capacity is relative to width just as screen length is relative to efficiency or completeness of separation. The true undersize, or fines, can generally be divided into two groups. The first is the half size, which is that portion that is less than half the size of the screen opening. The half size passes through within a quarter to a third of the screen length. The remaining length of screen travel is used to work on the near size so that product recovery is achieved without an inordinate amount of product being lost with the fines.

The majority of granular plants employ two surface screens. The first surface exercises control over the top size of the product, and, obviously, the second surface controls the bottom size. The coarser, top size separation is easier not only because the separation is coarser but also the amount of oversize is less. It is always easier to remove a small amount of oversize from an undersize product than it is to remove undersize from an oversize product which the second surface is trying to do. Not as bad as finding the proverbial needle in the haystack, but difficult nonetheless and is compounded by a concentration of near-size material.

However, successful screening of fertilizer is being accomplished by high speed, high energy input into Ty-Rod type screen cloth and effectively combats the adverse factors affecting screening normally associated with fertilizer.

## Production and Use of High-Nitrogen Mixtures

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Since 1960, there has been a shift in the ratio of the major plant nutrients used in the U.S. as indicated by the following tabulation:

| Year | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| 1960 | 1.2 | 1.2 | 1.0 |
| 1965 | 1.6 | 1.2 | 1.0 |
| 1970 | 1.8 | 1.1 | 1.0 |
| 1975 | 1.9 | 1.0 | 1.0 |
| 1980 | 2.1 | 1.0 | 1.2 |
| 1982 | 2.3 | 1.0 | 1.2 |

These data show that the $N:P_2O_5$ ratio has increased and that there has also been a slight increase in the $K_2O:P_2O_5$ ratio. This is one reason many companies with ammoniation-granulation plants have expressed considerable interest in producing high-nitrogen grades. They report that recent popularity of minimum tillage programs has also created considerable interest in granular high-nitrogen mixtures. They are particularly interested in this development because their mixture does not segregate during application while some blends do. Segregation problems have been reported when dry bulk blends of prilled urea, diammonium phosphate (DAP), and potash are applied through minimum tillage equipment.

In a typical minimum tillage program, the field is not plowed and fertilizer is applied at the same time the seed is planted. This application is usually made in stubble from the previous crop. A sketch of a typical fertilizer hopper used in minimum tillage equipment is shown in figure 1. Table 1 shows the degree of segregation that occurs when the blend is added to this hopper. Usually the smaller materials collect in the center of the hopper and larger materials collect toward the outside edges. Static tests were made in which a blend of urea, DAP, and potash

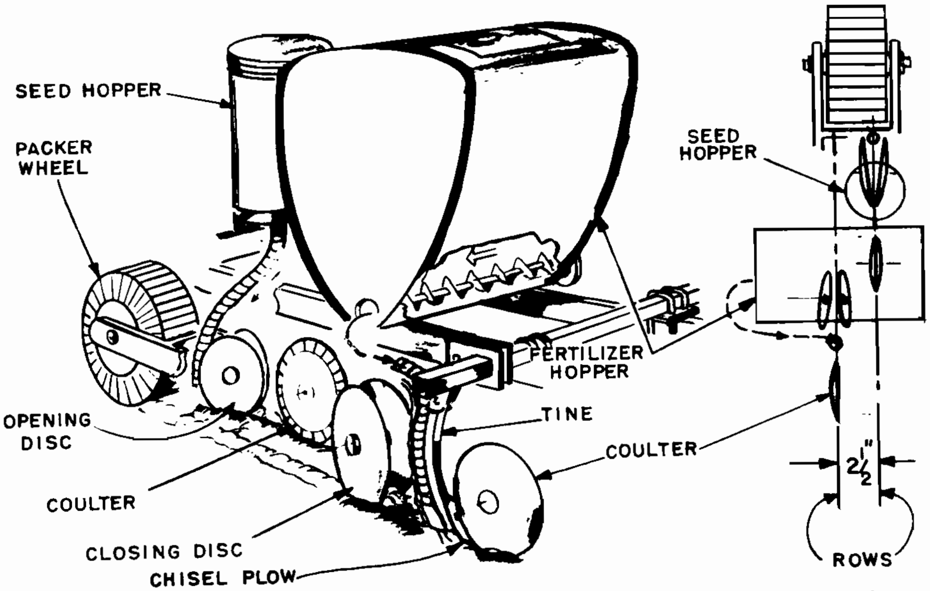


FIGURE I
MINIMUM TILLAGE EQUIPMENT FOR SOLID FERTILIZER

**TABLE 1**
**Application Tests Using Minimum Till Planter and High-Nitrogen Mixtures of Nominal 19–12–12 Grade**

| Sample No. | Bulk Blends | | | Homogeneous Granules | | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| 1 | 18.9 | 12.3 | 9.2 | 19.0 | 12.0 | 11.4 |
| 2 | 19.0 | 10.8 | 11.1 | 19.1 | 12.2 | 11.2 |
| 3 | 19.0 | 11.3 | 10.4 | 19.2 | 12.1 | 11.2 |
| 4 | 18.9 | 12.4 | 9.9 | 19.0 | 12.2 | 11.1 |
| 5 | 18.8 | 11.6 | 10.8 | 19.1 | 12.2 | 11.2 |
| 6 | 19.2 | 11.6 | 10.8 | 19.3 | 12.2 | 11.1 |
| 7 | 19.0 | 13.7 | 8.8 | 18.9 | 12.1 | 11.3 |
| Average analysis | 19.0 | 12.0 | 10.1 | 19.1 | 12.1 | 11.2 |
| Maximum deviation, % (from average) | 2 | 14 | 14 | 2 | 2 | 2 |
| Maximum deviation, units | 0.4 | 2.9 | 1.9 | 0.4 | 0.2 | 0.3 |

was sampled as the material discharged from a planter attachment of the type shown in figure 1 for solid fertilizers. Seven samples were taken as the hopper was emptied; the analyses of these samples are shown in table 1. A similar test was made in which a nominal 19-12-12 grade homogeneous mixture was added to and discharged from the hopper. The analyses of these samples are also shown in table 1. These data show that as the dry bulk blend was applied the phosphate and potassium application varied as much as 14 percent and variation in application of the homogeneous product was only 2 percent. Nonuniform application may cause some germination damage and it will cause uneven growth. The particular applicator used in the test had a uniform weight of fertilizer during the tests. Its coefficient of variation was calculated to have a weight variance of only 3.9 percent. The uniform application of the homogeneous product is an excellent advantage. Its potential for growth in minimum tillage programs is good. The most popular ratios for programs of this type are a 2:1:1, 1.5:1:1, and a 2:1:0.

Most companies with granulation plants of this type report that the most economical source of supplemental nitrogen (nitrogen other than ammonia) is prilled urea. Companies near urea plants can buy concentrated urea solution at a lower price than prilled urea. However, plant tests show that it is much more difficult to produce high-nitrogen grades from urea than from ammonium sulfate or ammonium nitrate. The highest production rate and lowest number of plant operating problems were encountered when ammonium sulfate (either as crystals or as $H_2SO_4$ + $NH_3$) was used as the supplemental source of nitrogen. When ammonium sulfate was used, because it had a relatively low nitrogen content, the resulting grade also had a low total plant nutrient content. When urea was used, the plant nutrient concentration was relatively high. For example, the 2:1:1 ratio using ammonium sulfate was a 16-8-8 grade and when urea was used this grade was a 22-11-11. Formerly, most ammoniation-granulation plants used low-pressure ammoniating solutions as a source of supplemental nitrogen. However, most of the newer nitrogen complexes do not have facilities for producing this nitrogen solution (free $NH_3$ pressure) and a large percentage of the plants that formerly produced it have stopped production. Therefore, the main source of nitrogen in addition to anhydrous ammonia in ammoniation-granulation plants is ammonium sulfate. Ammonium sulfate has a relatively high delivered cost and for this reason many granulation plants are interested in using urea as a source of supplemental nitrogen for producing their products. Some use a combination of a small quantity of ammoniating solutions and large quantities of ammonium sulfate. In most instances urea is the lowest cost delivered supplemental nitrogen source to the ammoniation-granulation plants.

### *Urea-Based Products*

In producing high-nitrogen grades, some of the main problems encountered in use of large quantities of urea are the lower melting point, lower critical humidity of the product, and decreased product hardness. However, the economic advantages and excellent physical appearance (well rounded granules) justify extra efforts in using urea as a source of supplemental nitrogen for production of homogeneous NPK mixtures. Table 2 shows the melting point and hardness of fertilizer mixtures. These data show that in products with relatively high urea contents the melting points are significantly lower than those that have ammonium sulfate as the source of supplemental nitrogen. These data also show that the moisture content of the high-nitrogen grade (19-12-12) has a significant effect on the melting point. The 19-12-12 grade, containing about 0.30 percent mois-

### TABLE 2
### Physical Characteristics of High-Nitrogen Homogeneous Fertilizer Mixtures

| Nominal Grade[1] | Supplemental N-Source | % of Formulation Weight | Product Moisture % of Total | Melting Point ° F | Hardness Pounds | Critical Humidity[5] |
|---|---|---|---|---|---|---|
| 19-12-12[1] | Urea | 27 | 1.4 | 164 | — | — |
| 19-12-12[1] | Urea | 27 | 1.8 | 159 | 3.1 | 35–40 |
| 19-12-12[1] | Urea | 27 | 0.3 | 208 | 3.1 | — |
| 32-16-0 | Urea | 55 | 0.6 | 220 | 4.0 | 50–55 |
| 13-13-13[2] | Ammonium sulfate | 50 | 1.3 | 358 | 6.4 | — |
| 13-13-13[3] | Ammonium sulfate | 28 | — | — | — | — |
| | Ammonium nitrate | 11 | — | 388 | 5.4 | 65–70 |
| 15-10-10[2] | Ammonium sulfate | 62 | 1.1 | 400 | 3.8 | 65–70 |
| 6-24-24[2] | Ammonium sulflate | 4 | 3.0 | 305 | 3.9 | 70–75 |
| 19-9-0[2] | Ammonium sulfate | 82 | — | 403 | 7.1 | 70–75 |
| 16-8-8[3] | Ammonium sulfate | 57 | — | 314 | 6.5 | 55–60 |
| | Ammonium nitrate | 7 | — | — | — | — |
| 18-46-0 | — | — | — | 371 | 11.56 | 80–90 |
| TRA 35-17-0[4] | Urea | 69 | 1.3 | 212 | 4.2 | 50–55 |
| 28-28-0[4] | Urea | 49 | 1.0 | 235 | 3.9 | 50–55 |

1. Formulated for a 22-11-11 grade
2. All supplemental nitrogen from ammonium sulfate
3. Part of supplemental nitrogen from ammonium sulfate and remainder from ammonium nitrate
4. TVA granular urea-ammonium ployphosphate products
5. At 86° F

ture, had a melting point of 208° F. The product with about the same grade and a moisture content of 1.8 percent had a melting point of 159° F. Melting points of these products are emphasized because of procedures that must be taken in drying and granulating the product. For products with low melting points, it is essential that the product be dried in a dryer with a long retention time, reasonable air velocity, and a low drying temperature. The 35-17-0 and 28-28-0 grades are TVA granular urea-ammonium polyphosphate products containing between 20 percent and 30 percent of their $P_2O_5$ in the nonorthophosphate form (polyphosphate). Note how polyphosphate helps to increase the melting point and hardness of the product. These and other data show that the presence of polyphosphate in granular products improves the storage characteristics of the products. Both 35-17-0 and 28-28-0 grades have stored satisfactorily in bulk and in bags at locations throughout the U.S. The 35-17-0 is coated with about 1 percent by weight kaolin type clay that has been treated with an amine. The 28-28-0 is not coated.

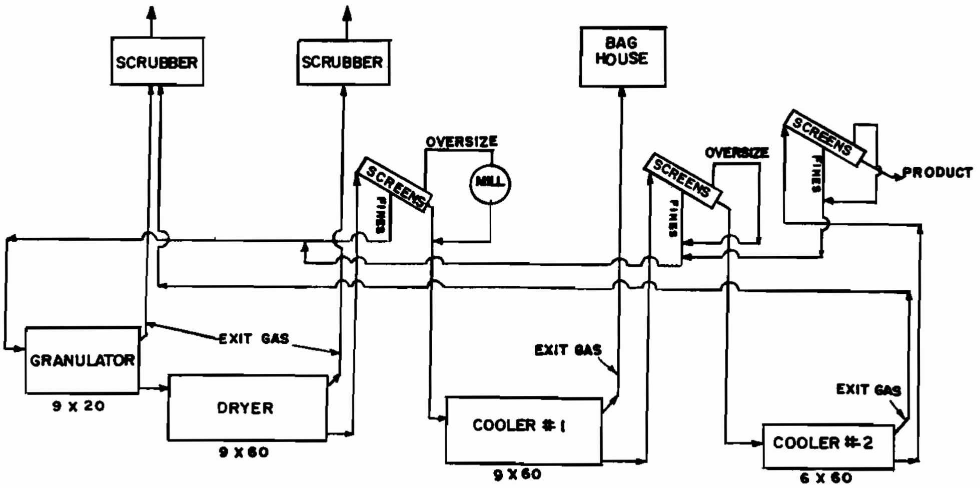


FIGURE 2

FLOW DIAGRAM FOR GRANULATION PLANT

In a commercial plant test in which an attempt was made to produce a 22-11-11 grade (no polyphosphate) using the formulation shown in table 2, concentrated urea solution (70–80% urea) was used and there were problems in metering this solution to the ammoniator-granulator. Therefore, the resulting grade was a nominal 19-12-12. Operating results from the tests are also shown in table 3. The flow diagram of the plant is shown in figure 2. This plant has a 9- x 20-foot ammoniator-granulator which discharges into a 9- x 60-foot cocurrent dryer. Product from this dryer is screened on 5- x 15-foot vibrating screens. Fines from these screeens can be either recycled to the granulator or to the cooler. Crushed oversize from the screening operation is also cooled. Provisions are available to recycle some of the product sized material to the ammoniator-granulator. The plant has two coolers; one cools the product and crushed oversize and the other cools only product sized material.

Calculations showed that retention time of material in the dryer was only 4 minutes. However, there was good air flow through the dryer. Inspection of the dryer showed that many of the flights within it were missing and that there was poor flight design. With this low retention time, it was difficult to sufficiently dry the product without causing it to melt within the dryer. However, it was possible to operate the plant for as long as 4 hours. The resulting product was a nominal 19-12-12 grade. Best results were obtained when all of the ammonia, phosphoric acid, sulfuric acid, and scrubber liquor were added to the pipe-cross reactor (PCR). Concentrated urea solution was added through an open-end pipe so that it discharged into the stream of melt from the circular discharge of the PCR. Product was stored in bulk piles and these piles were covered with plastic sheets. After about 1 month of storage, product in the bulk piles was still freeflowing and individual granules appeared to be of excellent shape. However, hardness of the granules was substantially lower than that of DAP (2 lbs versus 11.5 lbs for DAP). The product did not appear dusty and probably would not dust during application from conventional spinner applicators if the recommended spinner speed (600 rpm) was used. The critical humidity (% relative humidity at which product starts to absorb moisture) is 35–40 percent, which is somewhat lower than that of the 16-8-8 grade using primarily ammonium sulfate as the supplemental source of nitrogen. Therefore, N:P:K products containing this amount of urea should be covered during bulk storage to avoid moisture absorption. This precaution is not necessary in the production of the lower-analysis 16-8-8 grade.

In another plant test, a nominal 32-16-0 grade was produced using phosphoric acid, sulfuric acid, and ammonia in the PCR; the supplemental source of nitrogen was prilled urea. The formulation and operating results from this test are shown in table 3. The plant has a 10- x 20-foot ammoniator-granulator, a 10- x 60-foot rotary dryer, and material from the dryer is screened on two Tyler screens. Oversize is crushed in the large hammermill. This crushed oversize is returned to the granulator. The product sized material is cooled in a 5- x 50-foot rotary cooler.

**TABLE 3**
**Plant Tests of the Granulation of High-Nitrogen Grades**

| **Grade of Formula** | **22-11-11** | **32-16-0-3.6S** |
|---|---|---|
| Production rate, ton/hr | 12 | 20 |
| Test duration, hrs | 4 | 4 |
| Formulation, lbs/ton | | |
| *PCR* | | |
| Anhydrous ammonia | 230 | 172 |
| Phosphoric acid (53.4% $P_2O_5$) | 412 | 225 |
| Sulfuric acid (93% $H_2SO_4$) | 518 | 598 |
| Scrubber water | 112 | 65 |
| Fresh water | 47 | |
| *Granulator* | | |
| Urea solution (34.5% N) | 730 | — |
| Prilled urea | — | 1097 |
| Operating Results | | |
| *PCR* | | |
| $NH_3$:$H_3PO_4$ mole ratios | 1.2:1 | 1.2:1 |
| Highest skin temperature, ° F | 360 | 270 |
| *Granulator* | | |
| Product temperature, ° F | 160 | 185 |
| Product pH | 6.8 | 6.0 |
| Recycle tons/ton product | +5.0 | 4.5 |
| *Dryer* | | |
| Furnace temperature, ° F | 240 | — |
| Exit gas, temperature, ° F | 160 | 178 |
| Product temperature, ° F | 166 | 170 |
| Retention time, minute | 4 | 10 |
| Product temperature, ° F | 100 | 100 |
| *Product Chemical Analysis* | | |
| N | 19.4 | 31.1 |
| $P_2O_5$ | 12.5 | 16.4 |
| $K_2O$ | 12.1 | — |
| $H_2O$ | 2.3 | 0.6 |

Data in table 1 indicate that the melting point of the product is 220° F. Because of this relatively low melting point, precaution should be taken to avoid melting the product during drying. Fortunately, solid urea was used in this formulation and the product temperature from the dryer was kept at about 170° F. Only the pilot burner was used to heat the air to the dryer. These was no good system for feeding urea to the plant. Urea was added by dumping a predetermined amount of urea from a front-end shovel into the recycle elevator. This caused wide fluctuations in plant operations. However, it was possible to operate for a period of 4 hours. It was the opinion of the authors that, if the plant had had a good urea feed system, it would be practical to produce the 32-16-0 grade.

Melting point data show that this product melts at 220° F, which is slightly higher than the melting point of product during the test for production of 19-12-12 (159 to 208° F). Its melting point was even higher than the dry sample of 19-12-12 (0.3% moisture). Probably one of the reasons the 32-16-0 product could be dried to lower moisture is that retention time in the dryer was higher in the test for this grade than in the test for the 19-11-11 grade. Perhaps the presence of potash in the 19-12-12 helps to depress the melting point. Both the 32-16-0 and the dry 19-12-12 had a hardness of about 3.9 pounds.

**TABLE 4**
**Cost Comparisons[a] for Granulation Suspension and Bulk Blending Mixtures of 2:1:1 Ratio[b]**

| | Average Total Cost For Four Locations $/Ton of Nutrients |
|---|---|
| Granulation[c] | 387.64 |
| Suspensions[d] | 382.68 |
| Bulk Blends = | |
| Blend to Grade | 395.66 |
| Custom Blend | 357.17 |

a. Based on June 1983 prices used least cost for materials
b. 22-11-11 grade except for custom blending grade was 27.3-13.6-13.6
c. Capital investment $10,000,000, return on investment 10%, total annual production 200,000 tons
d. Capital investment $500,000, return on investment 10%, total annual production 10,000 tons

*Cost Comparison*

Cost comparisons between granular homogeneous mixtures, suspension mixtures and bulk-blend mistures were made. Results of this study are shown in table 4. Material costs used in the study were based on June 1983, prices as reported by *Green Markets*. It was assumed that a 2:1:1 ratio would be produced. Two types of blends were considered; one in which a grade was blended and the other in which a custom mixture (fractional grade) was produced. The grade considered was a 22-11-11 for granulation, suspensions and bulk blending to grade. The grade produced for the custom blend assumption was a 27.3-13.6-13.6. Four locations (Sheffield, Alabama; Joplin, Missouri; Norfolk, Virginia; and Russellville, Kentucky) were considered. It was assumed that the capital costs for bulk blending and suspension plants were $500,000 and capital investment of the granulation plant was $10 million. It was also assumed that there would be a 10 percent return on investment, that total production for the granulation plant was 200,000 tons per year and that total production for the bulk-blending and suspension plants was 10,000 tons per year. Data in table 4 show that the average total costs of producing a grade by granulation, suspensions, and bulk blends are about the same since these costs vary only about 3 percent and degree of accuracy of this estimate is greater than 3 percent. However, all costs of producing grades are about 10 percent greater than those of custom blending to fractional grades. The reason for the difference is the requirement for filler to produce exact grades such as 22-11-11 as opposed to 27.3-13.6-13.6. Also materials used in bulk blending have the same or slightly lower costs than the comparable cost of granulation plants. Although the cost of suspensions and granulated mixtures appear to be somewhat higher than bulk blends, perhaps their advantage in uniform application justifies the extra expense.

*Summary*

By 1983 the total amount of mixtures produced in the U.S. has decreased to an estimated 18 million tons. About 55 percent of these mixtures were bulk blends, 23 percent were granular homogeneous mixtures, and 22 percent were fluid mixtures. The shift toward blends has increased mostly at the expense of granular mixtures. Most of the remaining 81 granulation plants, hwoever, are highly efficient operations with fairly large annual production (greater than 50,000 tons). Annual production of these plants is expected to increase because of their improved efficiency and because their products fit well into new fertilizer application systems such as minimum tillage, uniform application of fertilizer pesticide mixtures, and use of solid starters. Plant operating data show that although it is economically attractive to use urea for producing high-nitrogen products, it is difficult to do so and that the storage qualities of the products are inferior to ammonium sulfate-based products. It is important that the products have a low moisture content. The urea used in bulk blends should be of larger-than-usual size to minimize surface area and have satisfactory hardness.

# MAP—A Market Update and Effect of Temperature on Crystal Growth

*Roy D. Space*
Agrico Chemical Company

In today's talk, I will cover two topics in relation to MAP. The first is an update on the trend of fertilizer consumption in the United States. It will give a comparison of fluids, anhydrous ammonia and dry to the total overall consumption. H. C. MacKinnon presented part of the original comparison to this group at the November 1981 meeting. I believe you will find it of interest in light of industry conditions the last couple of years. The second part will be more technical and will present one explanation for the growth of crystals in a suspension fertilizer such as 10-30-0 made from MAP.

## *FERTILIZER TRENDS*

The fact that fertilizer consumption in the United States was down for the last fertilizer year is, of course, not news. Using USDA data, Figure 1 shows the trend of U.S. consumption in millions of NPK tons since 1965. The overall total doubled between 1965 and 1978 and then had two more good years before starting the down trend. You will note that all three types, dry, anhydrous ammonia and fluids, follow the same general pattern as characterized by the total.

**Figure 1**
**U.S. Fertilizer Market**

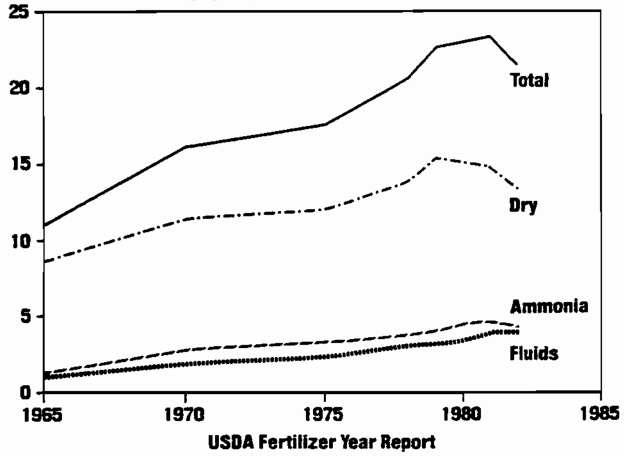
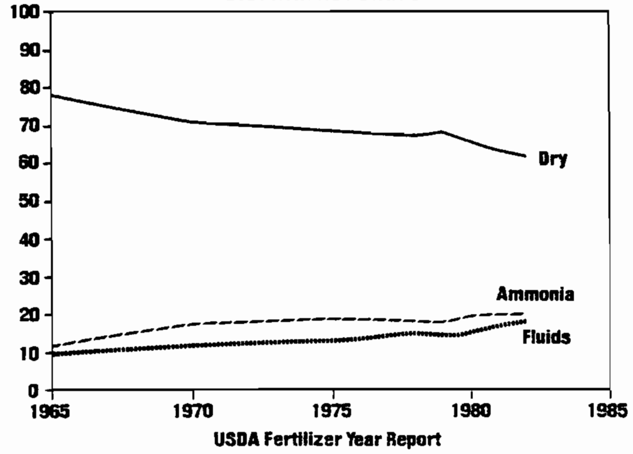
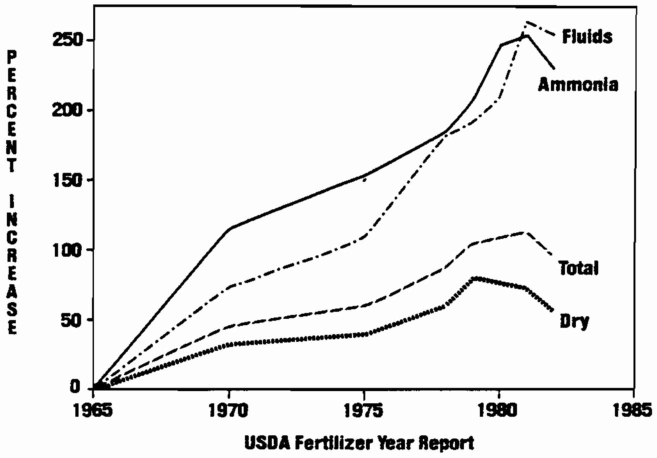


**Figure 2**
**U.S. Market Share**



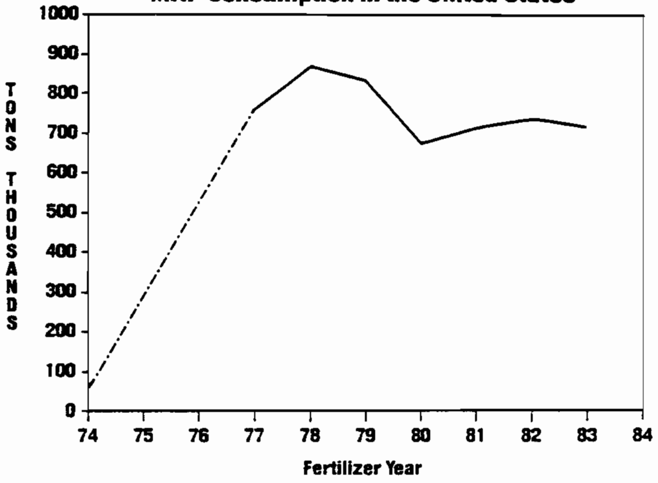
However, if we relate the tons sold to percent of market share, a different pattern is observed as illustrated in Figure 2. Now it is apparent that the liquids have been gaining on dry products steadily since 1965. The trend cannot continue indefinitely but it is a stable graph and continued in the down years shown in the previous Figure 1.

**Figure 3**
**Trend in U.S. Fertilizer Consumption**



We have now seen how the market has grown and how the product mix has been shifting. How has the rate of growth for individual products been doing? In Figure 3, the percent of increase for each type is compared to its self since 1965. By about 1978 the total tonnage had doubled, that's 13 years. During the same period, both ammonia and fluids had doubled and even tripled over 1965. I will not attempt to cover all the reasons for the change since they range from foreign economic policies to industrial changes. However, it is of interest to mention three major points, 1) new UAN production, 2) introduction of Fluid Blend technology and 3) energy costs.

**Figure 4**
**MAP Consumption in the United States**



Since this presentation is on MAP suspensions, we should also look at that specific product. MAP was of only minor concern as late as 1975. One producer made a MAP of sorts; TVA had some interest.

However, when Agrico needed MAP for testing in Fluid Blends, an acceptable material was not available and had to be imported. After testing and development of Agrico's patented Fluid Blend process, production began in 1976. In Figure 4 we have the U.S. consumption of MAP since FY 1977. Prior to 1977, data is not available from our records or TVA's and is shown as a broken line. Its consumption has been generally following the overall recent industry trend with little growth. Due to agronomic advantages it would increase if not for the MAP-DAP price differential.

*CRYSTAL GROWTH*

Crystallography is the scientific treatment of the description and arrangement of the atomic structure of crystals. Even at its best, with a single pure compound, the study is complex. A MAP base suspension is anything but a pure compound and its crystal growth is beyond description by a firm set of rules. In the time allowed, I will limit my discussion to one factor that has an effect on crystal growth—temperature. Even temperature is so interrelated to other factors that exceptions are often the rule.

**TABLE 1**
**Fluid Blend Reaction Temperature**

| Source | In/Out |
|---|---|
| Heat of Solution MAP | Out |
| Heat of Solution $NH_3$ | In |
| Heat of Neutralization | In |
| Mechanical Action | In |
| Radiation & Evaporation | Out |

Before we look at the effect of temperature, let's consider the energy of the system. The temperature of a batch of Fluid Blend product is controlled by the five (5) factors or sources of heat given in Table 1. MAP itself has a negative heat of solution, removes heat and is more soluble at higher temperatures. However, overall, its effect is small. Ammonia is just the opposite and generates a large amount of heat as it dissolves. Enough heat is produced from the ammonia to raise the final suspension temperature by 15°F to 17°F. The heat of neutralization between the MAP and ammonia is also quite large, resulting in an observed temperature rise of as much as 90°F. Mechanical action is from the pump and the turbine, both of which add heat. A major and very large loss of heat is through radiation and evaporation. To illustrate, if a bath of 10-30-0 is prepared under insulated or near adiabatic conditions, the final temperature may exeed 170°F starting with a 60°F raw material temperature. The 110°F temperature rise is a result of 15°F from the ammonia and about 90°F from neutralization and perhaps 5°F mechanical. However, most Fluid Blend units see only an 80°F temperature rise, losing 30°F through radiation and evaporation. In terms of heat energy, 220,000 btu are produced and 60,0900 btu are lost.

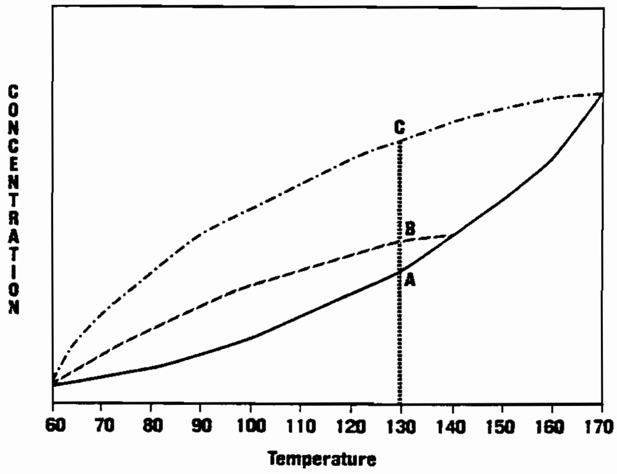
**TABLE 2**
**Ammonia Heat of Solution**

| MAP | lbs. Ammonia | Temp. Rise |
|---|---|---|
| 11-52-0 | 89 | 15.6° F. |
| 11-53-0 | 92 | 16.1° F. |
| 11-55-0 | 97 | 17.0° F. |
| 10-50-0 | 97 | 17.0° F. |

One variation in batch temperature can be the MAP itself. In Table 2 are given the calculated temperature increases as a result of dissolving ammonia for different MAP sources to make a ton of 10-30-0. The reaction is very violent and liberates approximately 350 btu per pound of ammonia added. A difference of one unit of $P_2O_5$ is a little less than 2%. Therefore, 11-52-0 will produce a 2° lower temperature (2% of 90°) than 11-53-0. In general, the total 3°F or 4°F difference is not significant compared to all other factors such as ambient temperature of the raw materials.

Temperature has a two sided effect on making a good suspension. Initially, a high temperature is a benefit in the breaking down of solid MAP. At higher temperatures MAP is more soluble and has a faster reaction rate with ammonia. As the reaction proceeds, the pH increases and the last MAP dissolves and reacts very slowly unless aided by elevated temperature.

**Figure 5**
**Crystal Driving Force**



Once the reaction is completed, temperature becomes the Blender's worst enemy. The higher the final temperature, the slower the cooling to ambient temperature and the greater the chance for excessive crystal growth due to supersaturation. Supersaturation is the driving force for both nucleation (crystal formation) and crystal growth. In Figure 5, supersaturation is illustrated. The lower curve is the equilibrium solubility of MAP. The upper curve is the observed concentration of a supersaturated solution with an initial temperature of 170°F. A solution with an initial temperature of 140°F produces the middle supersolubility curve. No scale is shown on the left because too many factors alter the curves in a Fluid Blend to be reproducable. On or between the solubility and supersolubility curves is where all suspension fertilizers are found. The greater the distance above the solubility curve, the more potential for crystal growth or formation. As the product cools, crystals form, grow or the degree of supersaturation increases. If we consider the points A, B and C, Figure 6 gives a mathematical expression for supersaturation. For the two points, B and C, point C has a greater potential for crystal growth than point B. This explains why a final product temperature of 140°F is preferred to a final temperature of 170°F. The higher final temperature will always have a supersaturation greater than or equal to one with a lower temperature.

**FIGURE 6**
**Supersaturation**

$$S_B = \frac{B}{A} \geqslant 1$$

$$S_C = \frac{C}{A} \geqslant 1$$

$$S_C \geqslant S_B$$

Although both nucleation and growth can occur in a supersaturated solution, slow cooling favors growth and quick cooling favors nucleation. This is especially true in suspensions that are not lacking nucleation sites provided by clay and other impurities. In addition, a hot static tank will form temperature gradients across the tank. Figures 7 through 10 illustrate how a tank temperature's profile might change with time. Imagine the temperature being measured across the diameter of a full tank at the middle. Phosphate is a poor conductor of heat and cools slowly. No values are given in the figures for temperature due to effects such as mass, tank size and radiation values and the curves are for visual effect.

How does the temperature gradient relate to crystal growth other than slow cooling effect? Consider a point on curve $T_3$ at P. Referring back to our solubility curves, it can be easily seen that the solubility and the supersolubility are greater at P than

**Figure 7**
**Storage Tank Temperature Profile**

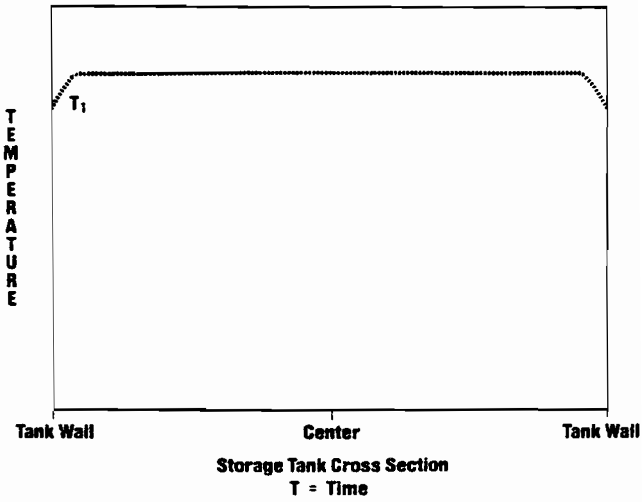


**Figure 8**
**Storage Tank Temperature Profile**

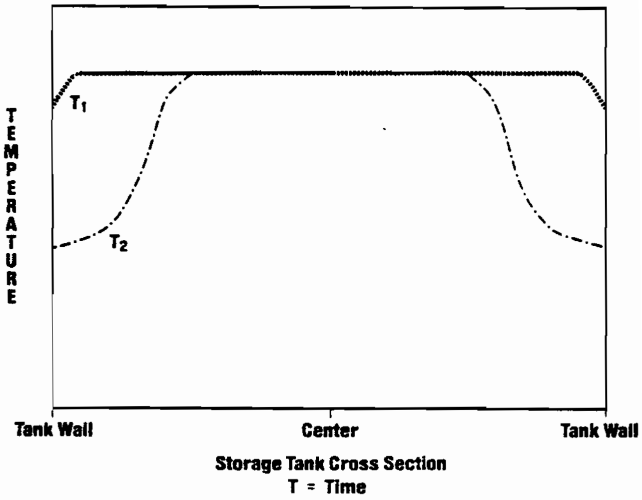


**Figure 9**
**Storage Tank Temperature Profile**

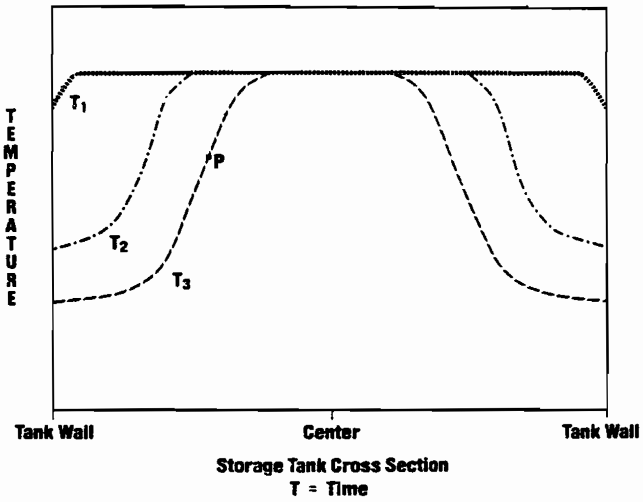
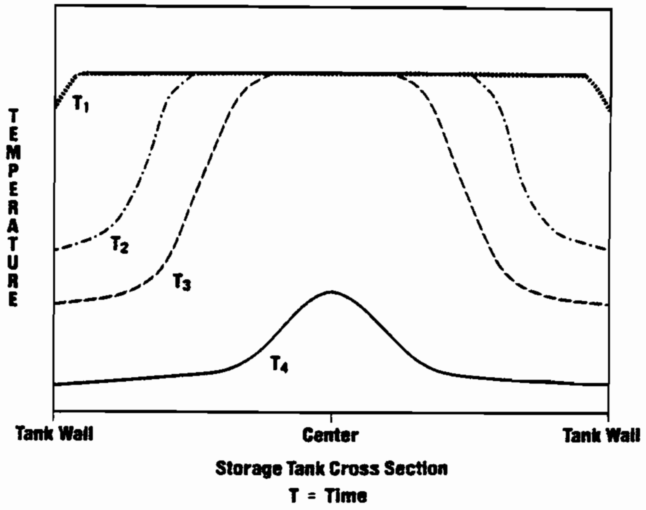


**Figure 10**
**Storage Tank Temperature Profile**



at the tank wall. We then have the condition described in Figure 11, Crystal Growth by Ion Migration. That is, as material is removed from solution by crystal growth at the tank wall, it is replaced by migration from the hot inner part of the tank. The greater the temperature difference the greater the concentration difference and migration. This results in a high degree of supersaturation being maintained and crystals grow. This is not unlike the more familiar osmosis that is also concentration driven.

**FIGURE 11**
**Crystal Growth by Ion Migration**

**Temperature**
$T_2 \geqslant T_1$

**Phosphate** $[DAP]_2 > [DAP]_1$

What can be done to reduce the temperature or its effect? The product temperature can be reduced by using a product cooler or by adding hot product to a cold heel. This favors nucleation over growth. Circulation is also important to prevent formation of temperature gradients and aid in cooling. Pump circulation does a better job of reducing temperature gradients than air sparging. Most Fluid Blend dealers already know that temperature control is important. I hope this has helped to explain why.

# Conversion of Commercial Dihydrate to Hemihydrate Phosphoric Acid Plants

*Barry Crozier,*
Licensing and Consultancy Services,
Norsk Hydro Fertilizers

## Summary

Changes in the cost of raw materials and utilities for phosphoric acid production over the last ten years have increased the importance of energy conservation and $P_2O_5$ recovery efficiency. As a result, attention has turned to hemihydrate technology for phosphoric acid manufacture.

Commercial operation of hemihydrate and hemidihydrate plants is now well established, and operating cost savings of over 10% can be demonstrated. With the current drive for profitability in today's competitive market, such a saving can have a major influence on the economic survival of a phosphoric acid plant.

Because of the current state of the international economy, capital investment in new manufacturing capacity is limited and so restricts the opportunity for phosphoric acid producers to build new hemihydrate plants. Therefore, Norsk Hydro Fertilizers has developed technology to allow existing dihydrate phosphoric acid plants to be converted to the hemihydrate processes.

Recently,·a number of detailed studies have been performed which examine in detail the process and engineering factors involved in the conversion of existing plants. Two of these are described here.

In addition, a section of this paper has been devoted to highlight the first completed conversion of a commercial plant, which took place at Windmill Holland in mid 1983.

### *MOTIVATION*

There have been two developments over the past ten years which have led phosphoric acid producers to consider converting their existing plants to hemihydrate (HH) and hemidihydrate (HDH) technology. These are:

(1) Changes in the phosphoric acid production cost structure which have put much greater emphasis on the importance of high $P_2O_5$ recovery efficiency and enhanced energy savings, (1, 2).
(2) Commercial production of phosphoric acid utilizing the hemihydrate technology has been firmly established in practice, (3, 4, 5, 6).

### *Costs*

In addition to the reduced energy consumption by production of strong acid directly from the filter, (7), the hemidihydrate (HDH) process can achieve improved $P_2O_5$ recovery efficiency which results in higher raw material savings.

1983 cost comparisons between a HDH plant and a conventional dihydrate unit are shown in tables 1 and 2 for the case of a typical U.S.A. mine site operation. The energy reduction of the HDH route amounts to over US $7 per tonne $P_2O_5$ at today's costs and the raw material cost saving is almost US $9 per tonne $P_5O_5$. Therefore the use of the HDH process instead of the dihydrate route can cut production costs by approximately 10%, at a mine site location.

Energy is saved by avoiding the use of steam in phosphoric acid concentration. If a phosphoric acid producer has steam available from a sulphuric acid plant, the use of a HDH plant will release this steam for maximum electricity cogeneration, (7).

**TABLE 1**
**PHOSPHORIC ACID PRODUCTION COSTS—DIHYDRATE PLANT 1983 COSTS FROM A USA MINE SITE LOCATION**
**Phosphate: 68% BPL Florida (31.6% $P_2O_5$; 45.8% CaO)**
**Product acid concentration = 42% $P_2O_5$**

| Item | Unit | Consumption, unit per ton $P_2O_5$ produced | Cost, US$ per ton $P_2O_5$ produced |
|---|---|---|---|
| Phosphate rock | ton | 3.349 | 66.98 |
| $H_2SO_4$ (100%) | ton | 2.8 | 84 |
| Steam 1.p. | ton | 1.75 | 7 |
| Electricity | kWh | 125* | 6.25 |
| Process Water | 1,000 US gall | 1.77 | 0.39 |
| Cooling Water | 1,000 US gall | 15.9 | 3.4 |
| Labour | man-hours | 0.42 | — |
| Chemicals | US$ | — | 0.6 |
| Total | | | 168.62 |

*assumes rock requires grinding to specification given in table 4.
*NB*. Rock is at typical mine site production cost.
Other costs are typical of USA phosphoric acid producers.

**TABLE 2**
**PHOSPHORIC ACID PRODUCTION COSTS—HDH PLANT 1983 COSTS FROM A USA MINE SITE LOCATION**
**Phosphate: 68% BPL Florida (31.6% $P_2O_5$; 45.8% CaO)**
**Product acid concentration = 42% $P_2O_5$**

| Item | Unit | Consumption, unit per ton $P_2O_5$ produced | Cost, US$ per ton $P_2O_5$ produced |
|---|---|---|---|
| Phosphate rock | ton | 3.242 | 64.84 |
| $H_2SO_4$ (100%) | ton | 2.579 | 77.37 |
| Steam 1.p. | ton | 0.18 | 0.72 |
| Electricity | kWh | 100* | 5.0 |
| Process Water | 1,000 US gall | 1.56 | 0.34 |
| Cooling Water | 1,000 US gall | 7.2 | 1.53 |
| Labour | man-hours | 0.42 | — |
| Chemicals | US$ | — | 1.05 |
| Total | | | 150.85 |

*assumes rock is provided at size analysis given in table 4.
*NB*. Rock is at typical mine site production cost.
Other costs are typical of USA phosphoric acid producers.

### *Commercial Operation*

Since the start up of the hemihydrate plant at Windmill Holland in 1970, successful commercial operation of hemihydrate technology has been established by a number of phosphoric acid producers (3, 4, 5, 6). A list of HH and HDH plants employing technology developed by Fisons Fertilizers and licensed by Norsk Hydro Fertilizers is given in Table 3.

**TABLE 3**
**Operators of Commercial Scale HH and HDH Plants**

| Company | Process | Start-up Date |
|---|---|---|
| Windmill, Holland | HH | 1970 |
| Trepca, Yugoslavia | HDH | 1974 |
| A & W, UK | HDH | 1980 |
| CSBP, Australia | HDH | 1981 |
| Pivot, Australia | HDH | 1981 |
| HCl, Cyprus | HH | 1982 |
| Windmill, Holland | Conversion to HH | 1983 |

Since 1970, Norsk Hydro Fertilizers (previously known as Fisons Fertilizers) has developed its hemihydrate processes together with the operators of licensed plants. Because of the know-how obtained and the expertise which has been achieved, technology is now available, which has been proven in practice, to convert an existing dihydrate plant to a hemihydrate process. Detailed studies for a variety of operating companies and the successful conversion and operation of the plant at Windmill Holland BV demonstrate that the operators of existing phosphoric acid plants can now obtain the savings of hemihydrate technology.

Thus, the combination of proven economic benefits and established commercial operation opens the door to the technology being adopted by more progressive companies than ever before.

## *PLANT CONVERSION IN PRINCIPLE*

Any conversion of an existing dihydrate plant to a hemihydrate process starts with a review of the process design and operating parameters of the hemihydrate technology with respect to the dihydrate equipment available. The objective is to achieve compatibility between the two. The main unit operations to be considered are as follows:-

### *Phosphate Rock Feed*

The hemihydrate process can normally accept a coarser particle size analysis of phosphate rock than the dihydrate process. Details are given in Table 4. Consequently, a plant converted to hemihydrate technology can utilise the existing rock feed and preparation system with minimal modifications.

Furthermore, comparing the rock size specification required for a hemihydrate plant with the particle size distribution of common phosphates such as 72% BPL Khouribga Morocco and 72% BPL Florida concentrate (given in Table 5), shows that these phosphates may be used in the hemihydrate process without further grinding.

**TABLE 4**
**Typical Phosphate Rock Size Specification Required by Hemihydrate and Dihydrate Processes**

| Tyler Sieve Size (Mesh) | Aperture (microns) | % Through | |
|---|---|---|---|
| | | Hemihydrate Process | Dihydrate Process |
| 10 | 1,700 | 100 | — |
| 32 | 500 | 75 | 100 |
| 60 | 250 | 25 | 95 |
| 100 | 150 | — | 60 |
| 200 | 75 | — | 30 |

The heat of reaction when producing calcium sulphate hemihydrate is approximately 20% lower than when producing the dihydrate form. Furthermore, the hemihydrate reaction slurry is cooled to 100°C whereas the dihydrate slurry is cooled to 80°C, requiring extra cooling capacity. As a result the reaction cooling load in the hemihydrate process is lower than in the dihydrate process. The acceptable temperature differential across a flash cooler in a hemihydrate system is larger than in a dihydrate plant; therefore, the cooling capacity of an existing flash cooler can be increased.

### *Gas Scrubbing*

Because the operation of a hemihydrate process is at a higher temperature than a dihydrate plant, it results in increased fluorine evolution mainly as $SiF_4$, in the exhaust system. The degree of fluorine evolution is dependent on the level of impurities (for example, silica, aluminum) in the phosphate rock being processed. It is therefore necessary to examine an existing gas scrubber system to assess whether it can cope with the increased fluorine levels in the reaction exhaust gases.

### *Filtration*

The filtration rate of hemihydrate slurry can be lower than that of dihydrate slurry, because of hemihydrate permeability and acid viscosity. In order to maintain or increase the existing capacity it may be necessary to extend or add to the existing filter.

Commercial hemihydrate plants have used belt, table and tilting pan filters, each of which has been satisfactory. Therefore the use of an existing filter of these types is not expected to present a problem.

### *Transformation*

The rate of transformation of hemihydrate to dihydrate can vary with different phosphate rocks. Normally it is sufficient to provide a residence time of 2–3 hours and a small flow of sulphuric acid.

However the transformation rate can be increased if necessary, by chemical additives.

Agitation in the transformation stage though important is not critical and a simple mixing system will suffice.

## CONVERSION TO THE HEMIHYDRATE PROCESS

Following the principles outlined above, a number of detailed feasibility studies to convert commercial dihydrate plants to the HDH process have been completed and two of these are outlined below:

### *CASE 1*

The existing reaction system of a conventional dihydrate plant is shown in Figure 2.

The proposed reactor configuration of the hemihydrate stage of the converted plant is shown in Figure 3. The proposed converted plant is described below.

#### *Hemihydrate Reaction*

Phosphate rock is fed to compartment 1 by the existing equipment. The rock is digested in a controlled flow of recycle slurry from the flash cooler seal compartment 9. The compartments 1, 2, 3, 4 and 5 constitute the hemihydrate stage reactor 1.

Reaction slurry overflows to compartment 6, through a new weir, where it reacts with sulphuric acid and precipitates the bulk of the hemihydrate. Return acid from the filter also flows to this compartment, where it controls the solids content of the slurry, as in dihydrate operation.

The slurry continues through the attack tank to compartment 7, from where it is pumped through the flash cooler to compartment 9. Slurry under flow control is pumped from compartment 9 to 1. The remainder flows through compartments 8 to 6 to 7. Thus compartments 6, 7, 8, 9 constitute the hemihydrate stage reactor 2.

#### *Cooling*

Only one flash cooler is required; therefore, one pump and cooler become spares. The existing pumps are used as they draw less than full load HP with slurry of approximately 1.8 specific gravity. The suppliers have indicated that the existing neoprene pumps can be operated up to 120° C and are used elsewhere in other hemihydrate plants.

The operating temperature of the digestion system is 98°C to 100°C, with an 8°C temperature drop across the flash cooler. Experience in other hemihydrate plants indicates that flash cooler scaling is significantly less than for conventional dihydrate plants, and so this increased temperature drop does not lead to excessive washing and maintenance.

#### *Hemihydrate Filtration*

Cooled reaction slurry is pumped from compartment 8 to the existing digester, which acts as a filter feed tank. The slurry is fed to existing belt filters, where the strong acid is separated from the hemihydrate crystals.

It is proposed to replace the hemihydrate filter feed pumps, which provide a higher discharge head, with alloy pumps, and to use the existing rubber lined pumps for the gypsum service.

The fibrecast slurry lines for the hemihydrate filter feed will be replaced by rubber lined mild steel pipework.

Steam injection will be installed at the vacuum box on the belt filters to reduce scaling. The hemihydrate filter cake is washed with filtrate from the gypsum filter. The first filtrate (after the cloudy port) is the product acid; the second filtrate provides the return acid.

Checks on the filtrate pumps have shown that the change in specific gravity from 1.35 for No. 1 filtrate to 1.50 can be accepted without an increase in motor size. The return acid on the hemihydrate filter will have a specific gravity between 1.35 and 1.40.

The hemihydrate cake is slurried with filtrate from the gypsum filter and is pumped to the transformation tank.

#### *Gas Scrubbing*

A higher quantity of F is liberated in the hemihydrate mode. Between 25% and 50% of the F in the rock can be liberated in the reaction system when producing 42% $P_2O_5$ acid. Most of this passes to the flash cooler. Fluroine to the gas scrubbing system will be between 100 and 200 kg/h. The vent gas flow to existing scrubbers is expected to be adequate. However, changes to scrubber internals may be necessary to increase the number of transfer units to accommodate the increased fluorine evolution.

#### *Transformation and Dihydrate Filtration*

Because strong acid is produced directly from the filter, the weak acid storage tanks become redundant and it is proposed that one of these be used as the transformation tank. It will be necessary to install an agitator and baffles in this tank to ensure adequate mixing.

There is a small flow of sulphuric acid to this tank.

The dihydrate slurry is pumped to an existing unused tilting pan filter. The first filtrate is pumped to the hemihydrate cloth wash and the second filtrate is pumped to hemihydrate cake wash.

The gypsum cake is slurried with pond water, and discharged to the gypsum stack.

### *CASE 2*

The reaction system of the existing dihydrate plant is shown in Figure 4. The production capacity is 325 tpd $P_2O_5$ as 28% ex filter concentrated to 42% $P_2O_5$ in conventional vacuum exaporators. The phosphate rocks is 72 BPL Florida. Reactor details are given below:-

Reaction volume, total = 29,300 $ft^3$
operating = 22,000 $ft^3$

Vessel type : single annular vessel with central compartment.
Material of Construction : concrete lined with rubber and carbon brick.

Agitation:

No agitators in annulus = 6
Absorbed power = 5 × 75 HP + 1 × 150 HP at rock feed point
No. of agitators in central compartment = 1
Absorbed power = 50 HP
Material of construction = AISI 317

The proposed reactor configuration of the hemihydrate stage of the converted plant is shown in Figure 5. The proposed converted plant is described below.

### *Hemihydrate Reaction*

The dihydrate plant reaction vessel provides sufficient slurry volume for the hemihydrate stage compartments 1 and 2. It is proposed to build dividing walls in the vessel (as shown in figure 5) such that the two resulting compartments will have the volumetric ratio of 2:1.

Studies have shown that the existing agitation is satisfactory for the hemihydrate duty.

The filter feed tank in the dihydrate plant is suitable for the same duty in the hemihydrate stage.

Phosphate rock is fed to compartment 1 by the existing equipment. Slurry is pumped from compartment 2 to a flash cooler and is recycled under flow control to compartment 1. Slurry from compartment 1 overflows to the second compartment where it reacts with sulphuric acid to complete the hemihydrate precipitation. Return acid from the filter also flows into this compartment.

### *Cooling*

The existing flash cooler has the following dimensions:

diameter = 14.0 ft.
straight height = 15.5 ft.

It operates in the dihydrate mode under the following conditions:

temperature drop = 7°F
pressure = 6 in. Hg absolute
slurry circulation = 10,000 gall/min.

In the hemihydrate mode the temperature in the reaction system is 98–100°C and the flash cooler can operate at a temperature drop of 8°C without an increase in scale deposition. As a result, the flash cooler system is satisfactory for a hemihydrate plant capacity up to 600 tpd $P_2O_5$.

### *Hemihydrate Filtration*

The existing filter is a horizontal tilting pan type with an effective area of 618 sq. ft. The material of construction of the pans is AISI 316. The hemihydrate slurry is fed to this filter.

Steam injection will be installed in the filter central valve to reduce scaling.

Two existing slurry filter feed pumps of capacity 750 gall/min are to be used for the hemihydrate duty, one is an installed spare.

The filter ancilliary pumps are satisfactory at the following capacities:

return acid pump : 590 gall/min
1st wash pump : 390 gall/min
2nd wash pump : 390 gall/min
3rd wash pump : 390 gall/min

### *Gas Scrubbing*

As in the previous case, there is a higher quantity of fluorine liberated in the hemihydrate system when producing 42% $P_2O_5$ acid. Most of this passes to the flash cooler. The existing fume scrubber with a gas flow of 121,000 acfm needs to achieve an efficiency of 99% to remove the increased fluorine evolved.

### *Transformation and Dihydrate Filtration*

Having produced strong acid directly from the filter and thus avoided the need to concentrate the acid further, the weak acid storage tanks are no longer required. It is proposed to use one of these as the transformation tank. It is necessary to install an agitator and baffles to ensure adequate mixing.

There is a small flow of sulphuric acid to this tank.

Filtration of the dihydrate slurry will take place on a belt filter of 430 sq. ft. This is a new item of equipment.

## *FROM DH TO HH IN PRACTICE*

In June 1983, Windmill Holland BV completed the conversion of its dihydrate plant to the hemihydrate process. Process engineering was carried out by Norsk Hydro Fertilizers (formerly Fisons Fertilizers); the detailed engineering was performed by Windmill Holland. Details of the conversion are given elsewhere (8).

The converted plant was started up using Togo phosphate during the week commencing 4th July 1983. Although only limited data is available so far, the following important observations have been made.

During the first week the plant throughput was up to 35 t/h rock, which was the design rate. In the second week throughput was between 38–42 t/h rock. These rates were achieved without the use of dilution cooling.

The acid concentration has been in the range 41–45% $P_2O_5$.

Filterability of the Togo hemihydrate crystals has been excellent, and the rates achieved have been above design.

The Togo hemihydrate crystal properties from the original HH plant and the converted HH plant are compared in Table 6 below.

**TABLE 6**

| Item | Togo Hemihydrate from Original HH plant | Togo Hemihydrate from Converted HH plant |
|---|---|---|
| Specific Surface Area cm²/g | 1400 | 1520 |
| Porosity | 0.67 | 0.65 |
| Permeability cm × $10^{-9}$ | 36 | 25 |

Since September 1983 the converted plant has been operating with 72 BPL Florida phosphate. Again the above design production rate of 40 tph rock feed has been achieved and the filtration rate is higher than expected. The Florida hemihydrate crystal properties from the original HH plant and the converted plant are compared below in Table 7.

**TABLE 7**

| Item | Florida Hemihydrate from Original HH plant | Florida Hemihydrate from Converted HH plant |
|---|---|---|
| Specific Surface Area cm²/g | 1,850 | 1,750 |
| Porosity | 0.68 | 0.68 |
| Permeability cm × $10^{-9}$ | 24.3 | 25 |

## *CONCLUSIONS*

No matter what differing trends develop in the world fertilizer industry, the importance of raw material efficiency and energy conservation will remain paramount. Now that hemihydrate processes have been firmly established in commercial operation, substantial savings are reliable.

The full scale HH and HDH plants operating according to Norsk Hydro Fertilizers technology can demonstrate production cost savings of around 10% compared to the dihydrate route.

Studies of a number of commercial dihydrate plants plus the successful conversion and operation of the phosphoric acid plant at Windmill Holland have shown that the benefits of the HDH and HH processes are now available to companies which currently employ conventional dihydrate technology by converting their existing plants.

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Figure 1

Hemidihydrate Process

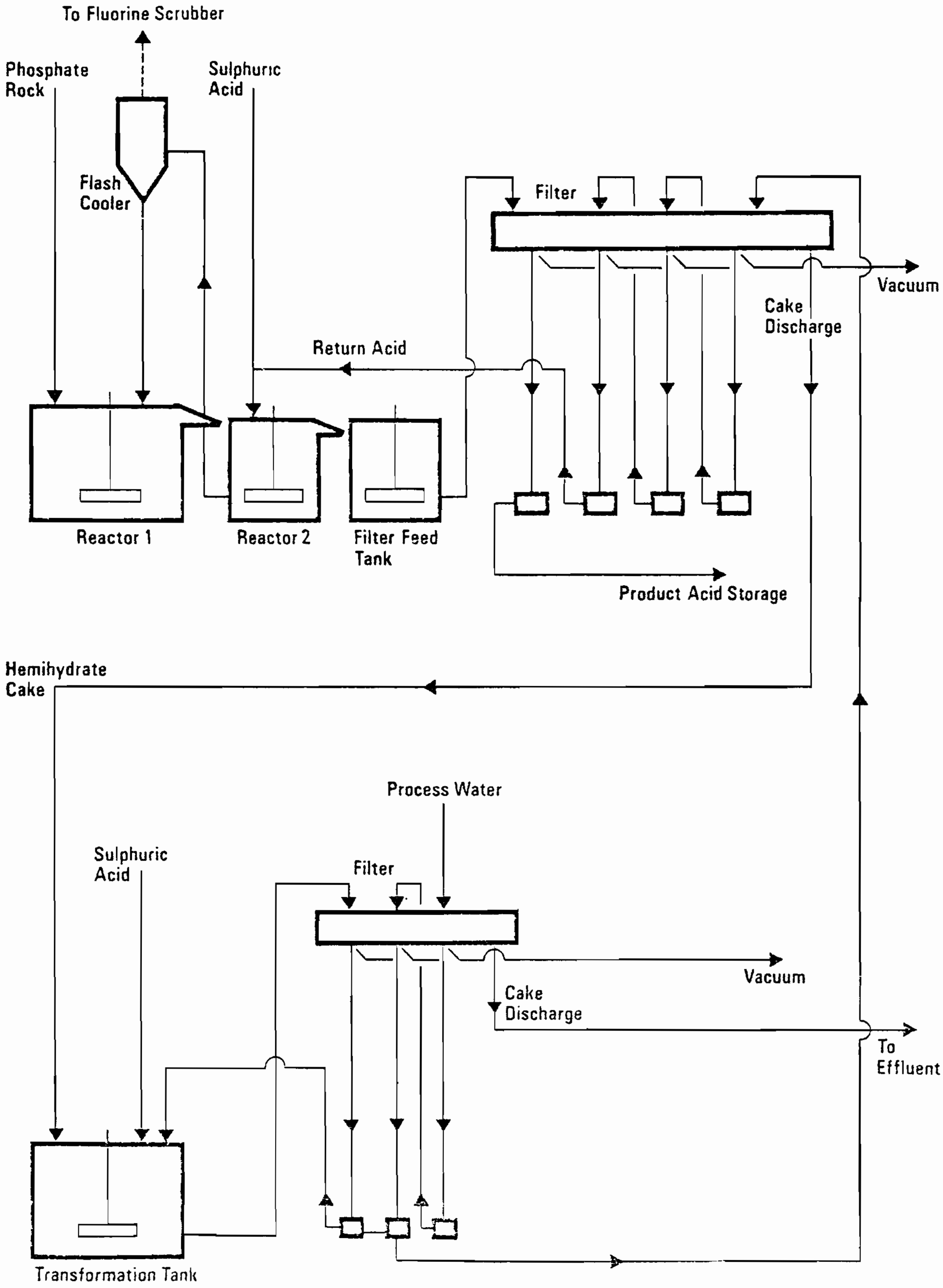
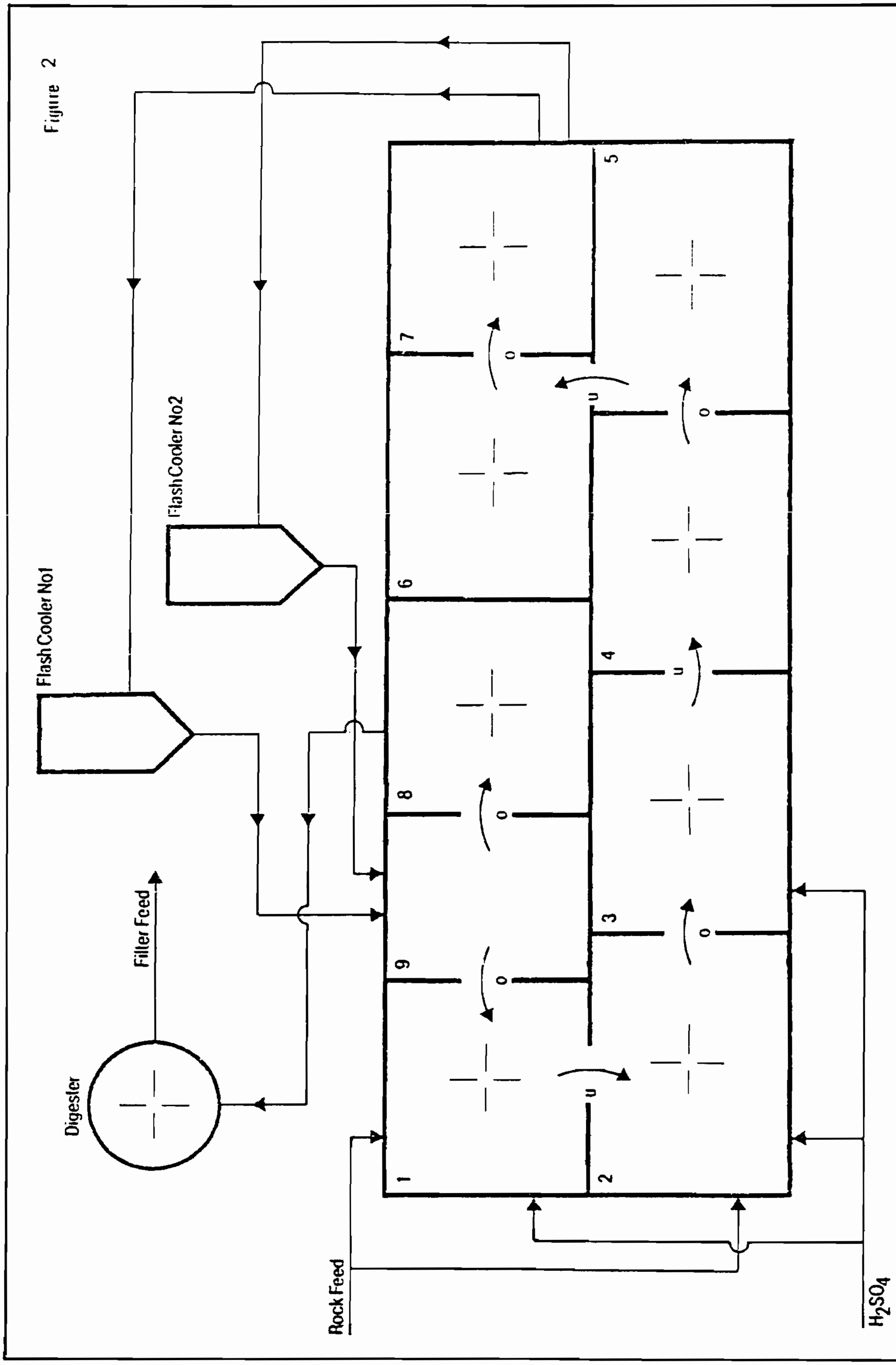
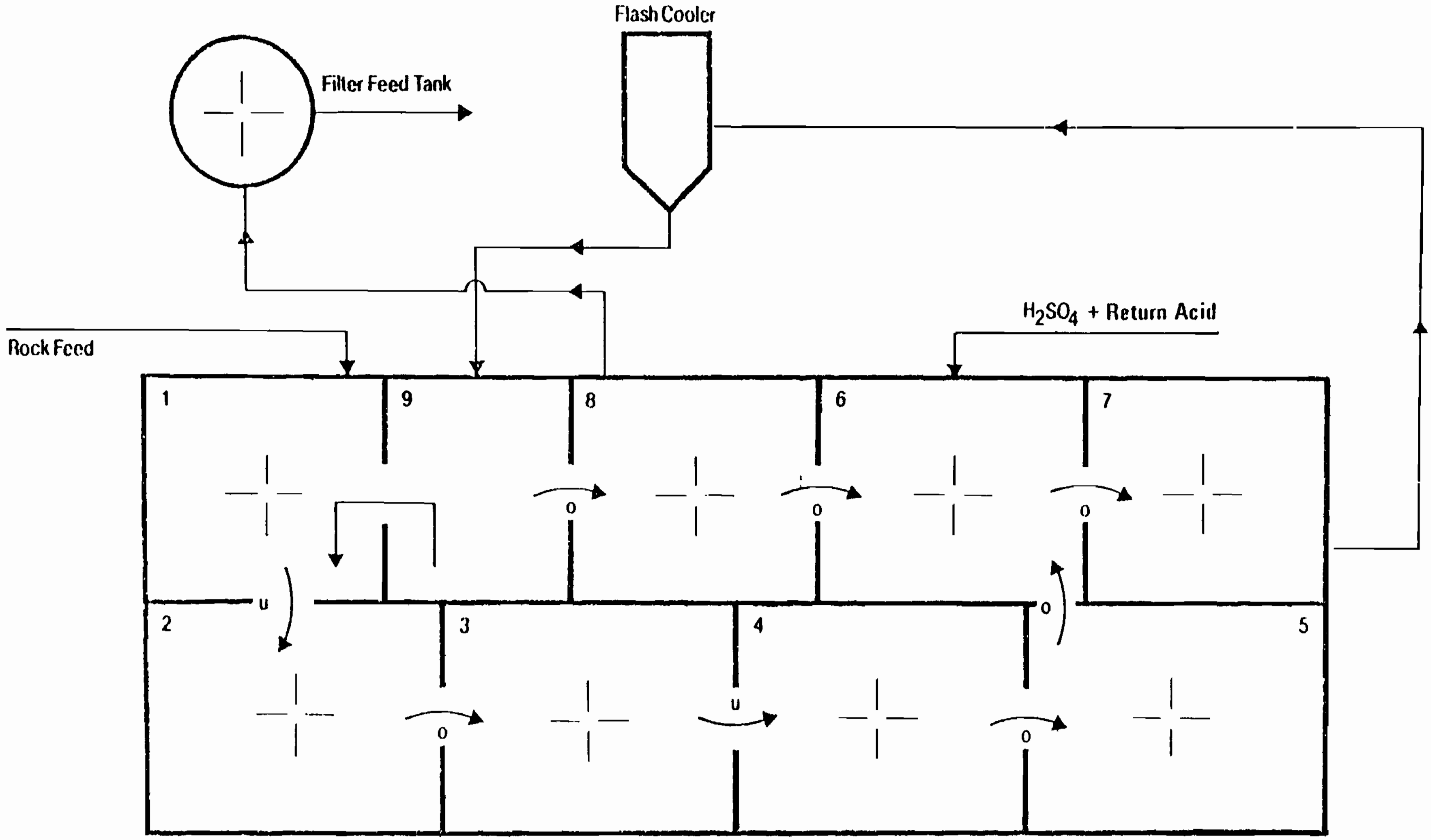


Figure 2



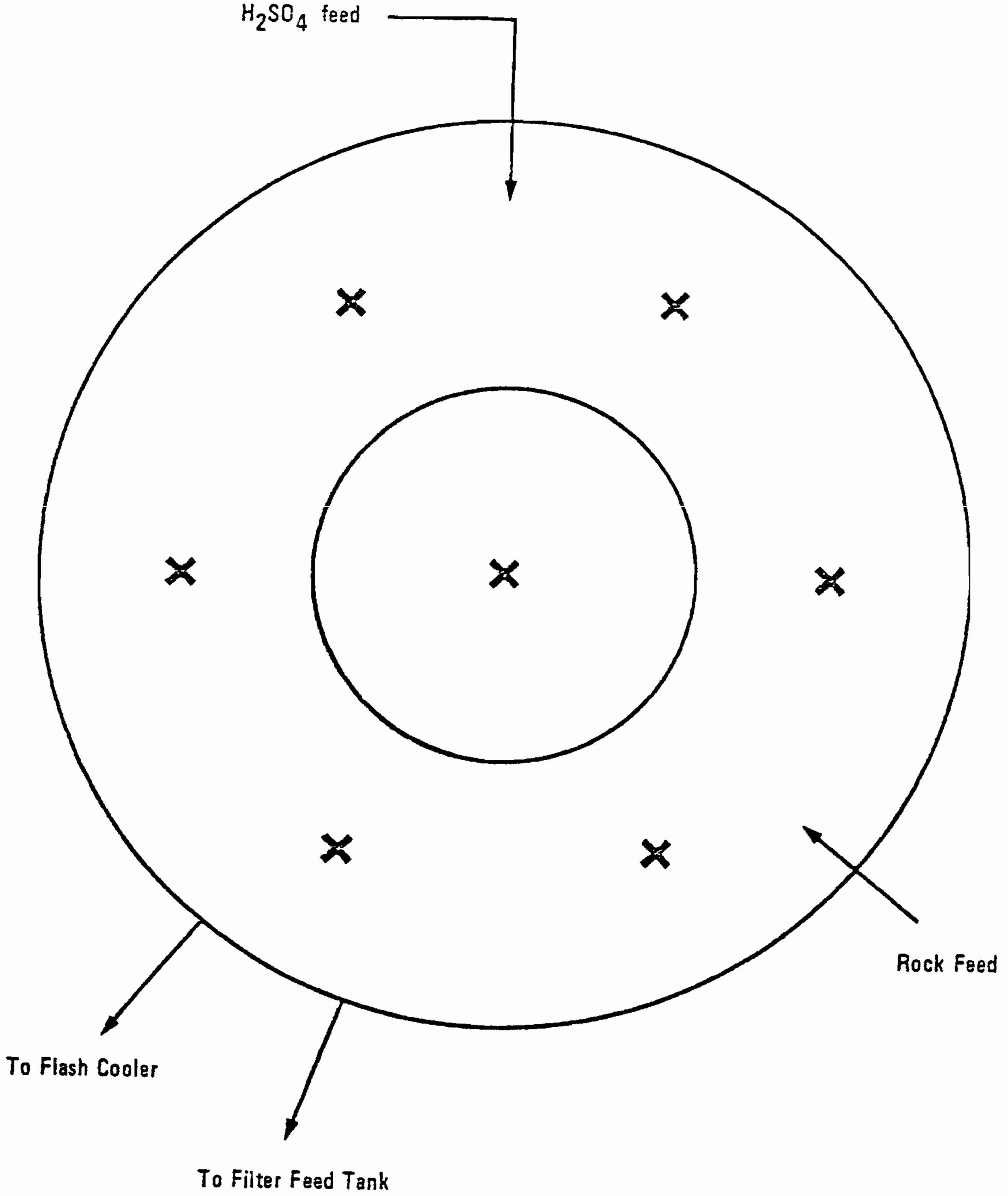
Existing Dihydrate Plant

Figure 3



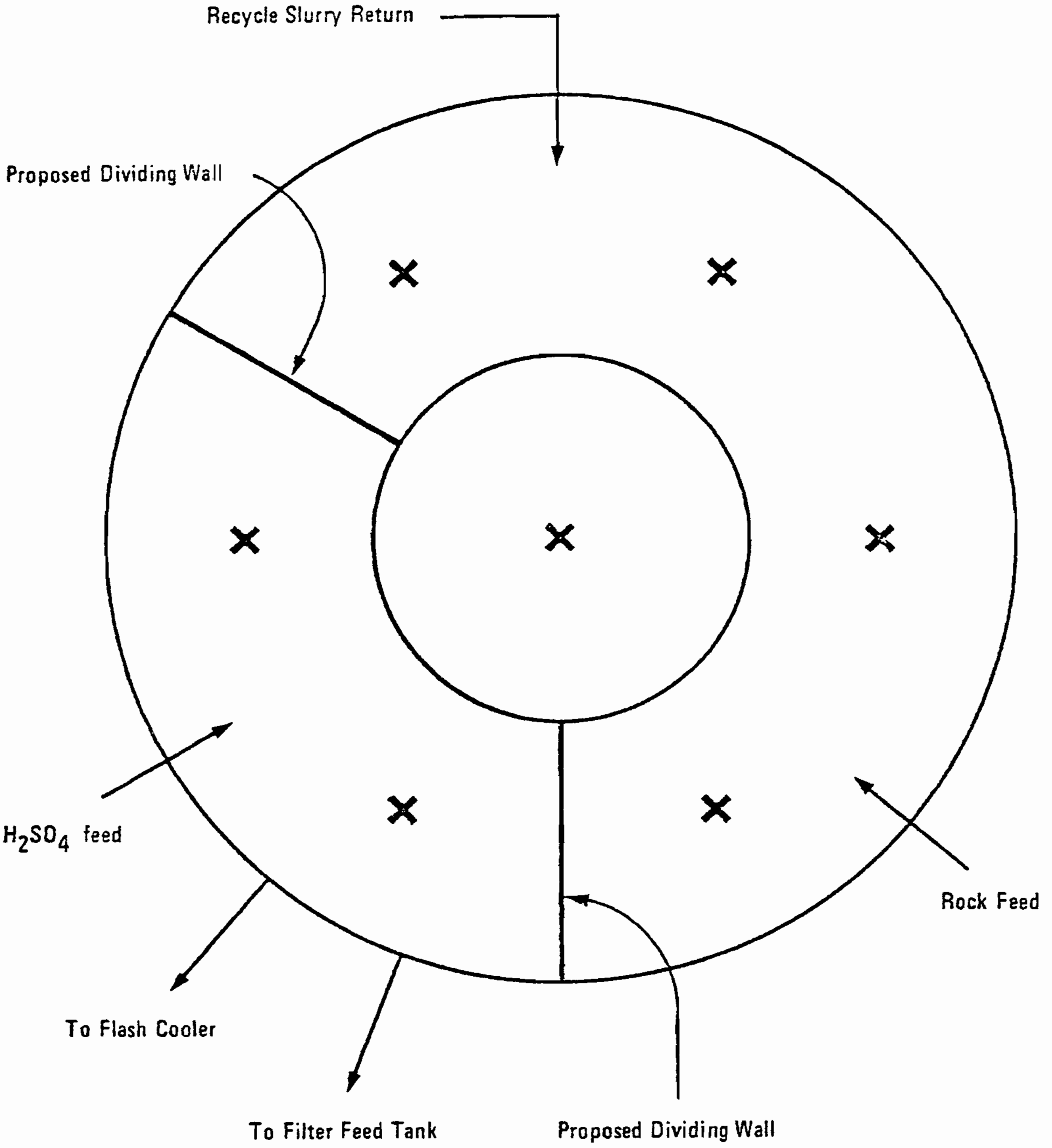
Converted Hemihydrate Stage Reaction System

Figure 4



## Case 2
## Existing dihydrate reaction system

Figure 5



Case 2 Proposed conversion to hemihydrate reaction system

# Wednesday, October 26, 1983

## Afternoon Session's Moderator:

## Herman G. Powers

## Fertilizer Plant Safety

### A. *Driver Training*

*Glenn A. Feagin*
International Minerals & Chemical Corporation

Unless you represent a company with a total employment of less than 10 people, you are required by law to provide driver training for anyone assigned by you to operate Powered Industrial Trucks. Both OSHA (The Occupational Safety & Health Administration), who supervises general industry, and MSHA (The Mine Safety & Health Administration), who supervises both surface and underground mining, have regulations requiring driver training.

In addition, the Department of Transportation and the Interstate Commerce Commission have rules regulating training for over-the-road equipment drivers.

I would like to focus mainly on OSHA requirements. However, most of my remarks will also apply to MSHA-supervised locations.

OSHA Safety & Health Standard 29 CFR 1910.178 covers the operation of Powered Industrial Trucks. There are about 10 pages of general operating rules and safety regulations listed in the June 1981 printing of the OSHA Handbook #2206, "General Industry Safety & Health Standards". One of these rules outlines the requirements for Driver Training and I quote:

> "OPERATOR TRAINING. Only trained and authorized operators shall be permitted to operate a powered industrial truck. Methods shall be devised to train operators in the safe operation of powered industrial trucks."

A real catch-all statement if I ever read one. It gives you plenty of rope! Better make sure that you do not hang yourself with it. But, really, it's no problem. All you have to do is devise a program that will adequately train your employees and that will stand up under critical examination by a compliance officer.

OSHA does not completely abandon us with only this short statement as a guide! The National Institute for Occupational Safety & Health (NIOSH) in their booklet, "Outline For Training of Powered Industrial Truck Operators", gives some help. By the way, this booklet is available from the Superintendent of Documents, Washington, D.C. The order number is DHEW (NIOSH) Publication No. 78-199. I recommend that a copy be obtained.

In this booklet, some of the points made are:

1) It is the employer's responsibility to provide training.
2) Training can either be done by the employer or an outside firm can be engaged to conduct the program.
3) The employer can devise his own training course. There are no special requirements as long as it works.
4) The only requirement for course instructors is that they must have sufficient knowledge and experience to teach effectively.
5) Training should be updated at least every two years, more often for operators who have poor driving records.
6) Even occasional drivers must be trained, and drivers must be trained to safely operate each type vehicle assigned to them.
7) A log of all training activities must be kept.
8) OSHA Compliance Officers may question employees both to check log information and to determine if employees are adequately trained.
9) Training should be performed on company time and at least 10 hours practice time is recommended for new drivers.
10) A closely supervised 1 to 2 weeks probationary period for new drivers is recommended.
11) Equipment covered under the training requirement includes:
    ***Fork Trucks
    ***Industrial Tractors
    ***Platform Lift Trucks
    ***Motorized Hand Trucks
    ***Specialized Industrial Trucks

That original short paragraph certainly got long in a hurry; and, I left out a lot of things covered in the booklet.

One might be tempted to say: "That's a lot of work and trouble. I haven't got time for all of that. I'll just let it go. It doesn't matter." DANGEROUS THINKING!! If a serious vehicle accident or a general

OSHA inspection never occurs, you may get away with it. However, if an accident does happen, you could be in real trouble.

For the first accident, you could be cited for a serious violation. Then, if another accident occurred, you might be cited for a willful violation. Serious violations carry fines; willful violations can carry jail terms. Actually, a good training program can save money by increasing production and reducing repair costs.

While the NIOSH booklet gave a lot of information, it still left the question as to what is a satisfactory training course unanswered. As additional information, I would like to describe the program used in our plants. I must state that IMC makes no claims that it would cover all conditions which might exist at your particular location.

Before any IMC employee can operate any vehicle, he or she must be trained and licensed to operate that particular type tractor. For example, an operator with only a license for a forklift truck would not be allowed to operate a front end loader, or vice-versa.

Training consists of:

1) Lecture course on general rules.
2) Written examination on general rules.
3) Specific training and practice on each type vehicle.
4) An actual operating test conducted by a qualified examiner.

The results of these tests are put into the employee's personnel file and become a permanent record. Also, his name is added to the list of qualified drivers which is kept posted at the plant.

A review course is conducted once each year for all drivers. Again, a written account of the training update is placed in the employee's personnel file.

Each qualified driver is given an IMC Equipment Operation Certificate listing the types of equipment he or she is qualified to operate, and also a pocket-sized copy of a set of Powered Industrial Vehicle Safety Rules.

Special attention is given to the training of new operators. In addition to the general training course, they are given hands-on training and allowed to practice until their instructor feels that they are capable of handling the equipment under plant conditions.

If drivers operate company vehicles off the plant property, we make sure that they have the correct State Driver's License and that the vehicle meets any required safety standards.

OSHA regulations state that farm vehicles are not classified as powered industrial motor trucks. However, I do not know whether or not they have ever ruled that farm-type vehicles used by commercial operators are actually exempt. Therefore, we include them in our training course. Also included are operators of any special equipment such as floater-type spreaders. Even if it is not required by law, it is just good business to do so.

A pre-employment physical examination is required by IMC to insure that the potential operator is physically able to safely operate a vehicle.

Driver training is not a one shot deal. Vehicle safety is regularly covered at our plant safety meetings. Films and slide programs are very popular.

One last and very important point . . . "If it is not in writing, you did not do it." KEEP RECORDS!! It may be a lot of trouble, but I know from personal experience that it is a real comfort to have them when they are needed. Set up a system and see that it is kept up-to-date. This applies not only to driver training, but to all other types of safety training conducted.

# Fertilizer Plant Safety
## B. *Machinery Guarding and Lockout*

*F. C. McNeil*
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The topics of machine guarding and equipment lockout are two that all of us have heard and read a lot about.

Some may view these subjects as separate or independent, yet their goals are similar. One is designed to protect the worker while the equipment is in operation, while the other provides a safe condition while it's inoperative.

By now your company has surely instituted a program for machine guarding . . . and the warnings about hazardous nip and pinch points, danger zones, etc., may be an old story, but believe me the safety message cannot be repeated enough. Each year, far too many workers are injured because of inadequate machine guarding or poor guarding practices.

Guarding means preventing workers from contacting moving mechanical parts which could cause physical harm. Guarding may be by means of fencing or a rail enclosure to prevent access to danger points, or it may also be achieved by locating the mechanical hazard to a normally inaccessible place. But fencing and location are limited in effectiveness and acceptability.

The third, and probably the most effective, is guarding by enclosure, meaning a fixed barrier mounted on equipment to prevent access to dangerous moving parts.

I am sure that all of you are aware of operations with a good equipment guarding program and you may possibly know of some with a guarding system that is less effective. I would suggest that if a guard of this type exists, it be upgraded to meet standards and a thorough review of safety guarding be performed throughout that plant.

When reviewing existing machine protection or designing new guards, we must first identify the:

- Point of operation
- Power transmission

After this has been established, then we must insure that guards conform with the following criteria:

- It meets the minimum OSHA/MSHA requirements
- Protects workers' hands, arms, and other body parts from contact with the dangerous moving parts
- Is firmly secured and not readily removable
- Ensure that objects cannot fall into moving parts
- Permits safe, comfortable, and relatively easy operation
- Will allow machinery lubrication without guard removal
- That a system exists for machine shut-down before guard removal
- And finally, determine if the existing guard can be improved.

Metal is usually the best material for guard construction. Usually the enclosure is a metal frame of pipe, angle or bar stock with a filler of expanded, perforated or solid-sheet metal. Where visibility is required, plastic or safety glass may be practical.

Wooden guards generally are not recommended because of flammability or lack of durability and strength. However, in highly corrosive atmospheres, wood might be considered.

A problem many plants encounter is the failure to replace guards once they have been removed. But before we lay complete blame on the worker, let's consider a few possibilities as to why this condition may exist.

### *DOES MANAGEMENT ENFORCE SAFETY RULES?*

Does management really enforce guard replacement? Is this safety rule only followed when it is convenient to do so? In other words, does safety become secondary when time becomes a factor in production or shipping schedules?

### *WHAT IS DESIGN OF GUARD?*

What is the design of the guard? . . . Is it difficult to replace. . . . too big, too heavy, or poorly fitting? These conditions can make it easy for people to leave if off at start-up.

### *WHAT IS THE PHYSICAL CONDITION OF GUARD?*

What is the physical condition of the guard? . . . Is it badly bent out of shape, or broken, making it a major task to remove or replace? We must remember that guards have to be maintained to be effective . . . they should be considered an essential part of the equipment.

Yes, management must shoulder the blame. Should any of these situations exist, then the responsibility rests with management to take the necessary steps to see that these conditions are properly corrected.

When machine safeguarding requires expertise not readily available at a plant, then there are several avenues where assistance can be sought. Some of these sources are:

### *EQUIPMENT MANUFACTURER*

Equipment manufacturers . . . they can often supply the necessary literature, advice, and possible personal assistance to help solve the problem.

### *INSURANCE CARRIER*

Your insurance carrier will often provide the assistance of their safety specialist.

### *GOVERNMENT AGENCIES*

Some government agencies offer consultation services for on-site evaluations of workplaces and hazard control. OSHA funds one such program that is offered free-of-charge to employers in every state. This consultation program is completely separate from the standard OSHA inspection—there are no citations issued or penalties proposed.

### *CONCEPTS AND TECHNIQUES OF MACHINE SAFEGUARDING BOOKLET*

Another good source of information is the booklet, "Concepts and Techniques of Machine Safeguarding", published by the U.S. Department of Labor Occupational Safety and Health Administration.

Now let's look at the other side of the coin . . . what precautions can be taken to protect employees while working in the danger zone of machinery in its off position.

The standards which require use of lockout/tagout systems are currently being reviewed for possible revisions. Revisions are being considered because of the alarming number of incidents which tend to demonstrate the seriousness of worker exposure to hazardous situations during maintenance operations. Accidental start-up of equipment during maintenance and inspection has too often resulted in loss of limbs, electrocutions, severe trauma, chemical or thermal burns, and acute respiratory problems.

In general, anyone working on and around machinery runs a serious risk unless equipment is locked-out, and cannot be accidently started. The best method to prevent accidental injury to employees while performing inspections or maintenance on equipment/machinery is to use a system of lockout devices, coupled with a documented lockout procedure.

Typical conditions which require lockout precautions are:

- Any time repairs must be performed on electrical circuits.
- Whenever moving parts of machinery or equipment are being cleaned or lubricated.
- When it becomes necessary to remove jammed parts or to clear blocked mechanisms.
- To prevent operation by unauthorized persons and/or equipment use during off hours.
- When maintaining lines carrying hazardous liquids under high pressure, such lines should be clearly marked. Valves in the system should be capable of being locked out. In the case of high-pressure lines, there should be a means of safely relieving pressure in the blocked sections. There should also be a means available for lines to be capped or blanked.

The first phase of a lockout/tagout program is to establish a realistic written procedure that is applicable to all machinery and equipment. This procedure will be developed through a thorough study of your particular operation.

After a procedure has been written, an employee training program should be conducted that clearly explains the procedure, emphasizing its importance and includes a full explanation of what disciplinary actions will be taken against violators. A 1979 BLS statistic revealed that of the 554 workers injured while servicing equipment, 61% had received no instructions on lockout procedures.

A normal lockout procedure will usually consist of 6 basic steps:

1. *The notification of all concerned personnel:*—Operators, Supervisor, etc., should be advised that the equipment/machinery will be locked out.
2. *Review the entire lockout procedure*—before any work begins, think through every required step and double check everything.
   For example: Review shutdown and work authorization to insure the correct system is being locked out and worked on.
   - Check to see that all switches are properly marked so that the right ones are locked out.
   - Determine if there are any related systems that also need to be shutdown.
   - Are the workers wearing the required protective equipment?
3. *Identify all energy sources*—-associated with equipment/machinery.
4. *Neutralize all energy sources* by:
   - Turning off electrical power.
   - Lowering all suspended parts that might be affected by gravity or other forces.
   - Venting pressure from pneumatic lines.
   - Draining or bleeding hydraulic lines.
   - Release or blocking spring energy.

   It is important to never rely on secondary protection:
   Example: Do not lockout the 120 volt auxiliary service on a 440 volt system; always kill the main power source to a piece of equipment.
5. *Lockout the power source*—against accidental start-up of machinery and prevent equipment motion resulting from stored energy. After attaching lock to electrical controls, valves, etc., place a warning tag to alert others to the locked-out status of the machinery/equipment.
   No employee should be authorized to remove the lock and tag unless he/she is the one who originally placed it.
6. *Test Machinery/Equipment*—Never enter a danger zone until the equipment has been tested to insure it is secure and no dangerous movement is possible. Means of testing can be:
   - Pushing start buttons to verify that the power is off.
   - Inspect moving parts to insure that they are at complete rest and properly secured.
   - Operate valves to be sure no machine parts will be activated by pressure.
   - Test electrical circuits to insure that they are dead.
   - Double check for other workers who may be located in the danger zone.
   - And, perform any other test that may be specifically outlined in the written lockout/tagout procedure.

In the event there may be some source of energy that cannot be locked out, take special precautions such as:

- Using tags.
- Constructing barricades.
- De-energizing the power source at the circuit breaker.
- Remove fuses.
- Posting a co-worker to stand guard if necessary.
- Post signs on doors and gates to hazardous areas. If possible, lock these areas off.

Before restarting machine/equipment, check to insure that:

- Equipment is in operating condition, properly lubricated, adjusted, set up, and ready for service.
- All guards are in place.
- No tools have been left behind.
- All blocks, braces, pins, and chains have been removed.
- All pressure tubes, pipes, or hoses have been reconnected.
- Work areas are clear for normal operation.
- All workers are clear of the danger zone.
- And, employees are wearing the personal protective equipment required for normal operation.

The supervisor should be notified of any damaged or missing parts or of any potential hazard before the equipment is set into motion.

There are four hard and fast rules that all employees should be trained to understand and respect relating to the lockout procedure:

1. DO NOT remove covers or alter warning tags.
2. DO NOT BYPASS or remove locks placed by another person.
3. DO NOT enter the danger zone without authorization.
4. DO NOT try to start locked out equipment.

The heart of any lockout program is the lock itself. Decisions will have to be made on such things as the type of lock to use—key or combination; who will be issued a lock; who will have possession of the keys or combination; and how will the lock be identified.

The answers to these questions will vary, but here are some guidelines that you may wish to follow:

- Key-operated padlocks are used more often than combination locks because supervisors usually have much better control over keys than combinations.
  Locks should be issued to every employee who works on equipment during a shutdown stage.
  No key or combination should fit more than one lock.
  A lost lock or key should be immediately reported to the supervisor.

Another important lockout device often referred to as a redbird is a useful piece of equipment that should be part of every lockout/tagout program. . . . We have found that the metal redbird is a lot more durable than the aluminum type because it was discovered that the aluminum could be twisted and broken off rather easily.

In closing, I would like to leave you with a couple of good sources of lockout information:

ANSI Z244.1-1982 American National Standard for Personal Protection—Lockout/Tagout of Energy sources, and

OSHA's study of Selected Occupational Fatalities Related to Lockout/Tagout Problems.

In this brief presentation, we have only touched on the high points of machine guarding and lockouts which in turn is only a portion of your overall safety program. It is important to remember that to be effective, safety must have a sincere commitment from every plateau of management—only when safety is encouraged, monitored, and enforced on the same level as the rest of the activities within an organization will its full value be realized. When safety is truly considered a necessary and valuable tool, then not only will it reduce injuries, but it will become a major contributor to the improvement of employee morale, product quality and operation efficiency, while at the same time help to reduce overhead.

## Fertilizer—Pesticides Impregnation Operations

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## Introduction

The production and use of fertilizer-pesticide combinations is not new. My first experience with this practice happened about 30 years ago in Iowa. In a continuous mixing-packaging operation, we impregnated Dieldrin and Aldrin on granular N-P-K grades to make cornstarter fertilizer-corn root worm treatment combos. Various insecticides and herbicides have been impregnated on home and garden type fertilizer for many years.

In the mid 1960s, there was a flurry of activity in the manufacture of fertilizer-herbicide mixtures in our North Eastern territory, which subsided rapidly without generating any notable volume. In the later years of the 1970s, interest was revived in these types of products because of promotion by some pesticides manufacturers. At this time we began a studied and planned expansion of our activity in this area.

I will talk to you about our experience and our recommendations in the business of making and distributing fertilizer-pesticides combinations for agricultural uses.

To establish a platform, let me tell you that the product efficacy of these combos has been demonstrated to be excellent and in some cases superior to separate herbicide and fertilizer applications *when* the products have been properly made and applied. Close control from the point of order-taking until the material is on the soil is essential for satisfactory performance. If you are not prepared or willing to give extra special attention to these products *don't get* into the business. Therefore, most of our comments will be directed toward recommended procedures. From the outset, be aware that considerably more prep and mixing time is required to properly prepare these products as compared to ordinary blending. There are many variables, but generally assume a production rate/unit that is 50% of a fertilizer blending operation. I will not present any definitive cost analyses for these type of operations because of variations in conditions from plant to plant and different methods and opinions as to the assessment of costs. Certainly, there are some additional management and administrative costs above that of ordinary blending.

### *Products and Formulations*

Our program has been restricted to herbicide-fertilizer combos. Many of the popular insecticides have high toxicity to personnel and the ordinary blending plant facility is not equipped to safely handle such materials. Moreover, much of the insecticidal requirements do not fit well with fertilization-use-optimization.

We've applied generic terms to identify herbicides that have been used in farm mixtures. Both fluid and powder type formulations of some of these chemicals have been used. Fluid formulations are recommended because the chemicals can be absorbed by the fertilizer or better coated on the fertilizer to produce uniform mixes.

All of the formulations are custom mixed and there is an almost unlimited range of combinations that can be concocted on paper. However, there is a major limiting factor and that is fluid phase. The absorptive capacities of fertilizer materials varies and the quantities of pesticides and fertilizer to be mixed varies, so fluid phase concentrations of the combos must be calculated before attempting mixing.

**FLUID PHASE CALCULATIONS**

Chemicals Bulk Density (Lbs./Gal.) LESS
Lbs. Active Ingredient/Gal. EQUALS
Fluid Phase (Lbs./Gal. Chemical)

$$\frac{(100)(\text{Gals. Chem./Ton})\ (\text{Fluid Phase, Lbs./Gal.})}{(2{,}000 + \text{Lbs. Chem.})} = \text{\% Fluid Phase}$$

We calculate fluid phase rather simply by assuming that the active ingredient concentration of the chemical product is solid phase and that the solvents, adjuvants and remainder of the chemicals formulations is fluid phase. In view of significant differences in fluid phase characteristics of emulsifiable and flowable chemical formulations and the chemicals themselves, this system may seem overly simplified, but it has proven adequate in practice.

We conducted laboratory studies to establish guidelines for acceptable fluid phase levels. This work also established the need for addition of absorbents such as "Microcel-E" to avoid adverse physical condition of mixes that can result from high fluid phase. The table here shows the effects of fluid phase in relation to fertilizer application rates and maximum label recommendations of a popular herbicides duo combined with a 1-1-1 ratio fertilizer blend. It's obvious that the best control for high fluid phase is the use of higher fertilizer rates. "Microcel-E" or similar absorbents are effective in reducing the undesirable effects of effective fluid phase but their use should be minimized because of cost, dustiness and disproportionate absorption rates compared to fertilizer.

**FERTILIZER AND CHEMICAL RATES VS MICROCEL-E NEEDS**

| Fertilizer Rate Per Acre (Lbs.) | Sutan + 6.7E Rate Qt./Ton Fertilizer | Atrazine Rate Gal. 4-F/Ton Fertilizer | Water Added To 4-F (Lbs.) | Microcel-E Needed Lbs./Ton Fertilizer |
|---|---|---|---|---|
| 300 | 24.4 | 2.7 | 10.8 | 26 |
| 350 | 21.0 | 2.3 | 9.2 | 16 |
| 400 | 18.3 | 2.0 | 8.0 | 10 |
| 450 | 16.3 | 1.8 | 7.2 | None |

Excessive fluid phase effects will affect quality of products and application services. Sticky fertilizer particles will adhere to machinery, causing problems with cleanup and contamination. If you want an illustration of this effect on the environment, let such residues accumulate and drop from the return rolls of the outside loading conveyor which is located upslope of vegetation. Neighbors will notice too and then regulatory people will become concerned about groundwater effects. Sticky particles do not spread the same way as dry granules and buildup of materials on spreading equipment components will affect performance. High liquid phase causes higher concentrations of the herbicides to be absorbed by smaller fertilizer particles resulting in uneven chemicals distribution patterns in the field. Some chemicals must be incorporated into the soil after application to prevent excessive loss by volatization or decomposition. Excessive fluid phase increases the potenital for loss from the fertilizer granule.

Yes, many high fluid phase mixes will convey and spread and the "jocks" may "get by" with handling and spreading such mixes for a while but they'll reap what they sow and the complaints will come; poor weed control, spotty weed control, crop damages and environmental pollution.

Our field experience indicates that these guidelines, if followed, will minimize problems caused by excessive fluid phase.

| Fluid Phase % of Mix | Add "Microcel-E" Lbs./Ton Fertilizer |
|---|---|
| 0.50 to 0.75 | 0–10 |
| 0.75 to 1.00 | 10–15 |
| 1.00 to 1.25 | 15–25 |

These are average ranges for fertilizer ratio of 1-1-1, 1.8-1-1.5, 1-2-2 and 2-1-1. Mixes containing large quanties of urea may require more microcel than indicated by these guidelines.

Most "flowable" type chemical formulations are viscous and require addition of water and premixing before they can be pumped and sprayed. Less water will be needed if the flowable's viscosity is lowered by storing the chemical at or above room temperature well in advance of use. Referring to the previous slide, it is evident that less water would change the fluid phase significantly. Many adjuvants are used in the various "flowable" type products and their viscosity and other physical characteristics will vary widely, so determine minimum water dilutions individually.

Wettable powder type chemicals may be used in some cases to control fluid phase by using fluid pesticides to bind the dust particles to the fertilizer. Careful processing is required to avoid loss of chemicals by dust evolution and to get good adherence of chemical powders to the fertilizer.

A sprayable fluid mix of wettable powders and water can be prepared to add to fertilizers, but such mixtures would be desirable only when the fluid forms of the herbicides were not available. The water required varies by product and ranges from 0.65 to 1.15 lbs. per pound of WP herbicide. In most cases, the quantities of required water are equivalent to the fluid phase generated by the use of the fluid "flowables" formulations.

### *Manufacturing Equipment & Procedures*

Uniform absorption and mixing is essential to the production of quality fertilizer-pesticides combos and the type and design of blending equipment influences quality control significantly. Many mixer designs are in use and performance varies appreciably. Our impregnation experience is limited to the use of rotary-drum blenders with lifting-mixing flights and rotary concrete-type mixers. The drum mixers are charged at the axial center on one side and discharged at the axial center on the other side without changing rotation. These mixers were selected initially by testing performance for fertilizer blending. Our comparisons have shown better mixing uniformity for the conventional rotary-drum but the concrete type is adequate. There are some horizontal single-shaft paddle type batch mixers that perform excellently. They are top fed and would have to be covered to enclose the pesticides spraying operation. They may fit well into some systems.

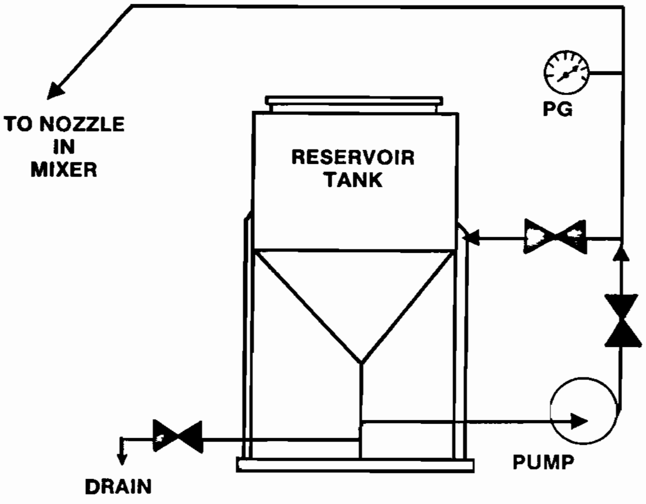
Nozzles and spray patterns must be matched to the mixing equipment and production rates. Satisfactory impregnation is based on uniform application of the pesticides or sticker fluids to the fertilizer particles. Therefore, distribution of the lesser volume of pesticide in a much greater volume of fertilizer must be controlled by proportioned feeding and mixing operations. Either fluid or solids pesticides are incorporated with the fertilizer through the physical actions of adherence, adhesion, absorption and adsorption. If the addition of pesticides and mixing rates are not properly controlled, then the physical reactions will not be uniform and some particles of the fertilizer will have either too much or too little pesticide incorporated. The surface area of a Tyler Test Sieve No. 7 particle is about six times that of a No. 14 sized particle and the volume of a No. 7 sized particle is about 14 times the volume of a No. 14 sized particle. Therefore, with this type of surface area-volume ratio there will be more absorption per pound of fertilizer for the smaller sized particles and absorption can be excessive if fluids are added too rapidly or if there is excessive total fluid phase.

We recommend that industrial grade full cone type spray nozzles be used and sized to deliver at 10–20 psig, 3 to 5 gal/min. A single nozzle should be used and installed to give good impingement of fluids on the fertilizer with minimum impingement on mixer flights and internal surfaces. Make the nozzle installation so it can be removed for cleaning or replacement quickly and mark the correct spray position for ready reinsertion.

A 60°–70° spray angle should be satisfactory for most rotary drum blenders but much lesser spray angles (15° to 30°), should be used in concrete type blenders to avoid excessive spray contact with internal surfaces. The angle required will vary by capacity and design so determine angle by measuring under load.

The fluids pesticide preparation, pumping and spraying system is relatively simple and can be constructed locally or packaged units can be purchased. The guts of any system is a pump that will deliver the fluids through your nozzle at desired rates and nozzle pressures, and with enough extra capacity to circulate several gallons per minute from the pump to the reservoir tank for agitation. Materials of construction must be corrosion resistant to a variety of chemicals. Follow the recommendations of the basic suppliers of the chemicals handled. Polyolefin plastics have been found adequate for many chemicals and 304 stainless steel is excellent for most pesticides chemicals. Use quality valves, piping and fittings to minimize leaks and potential spills.

### FLUIDS PESTICIDES PREPARATION PUMPING AND SPRAYING SYSTEMS



Some plants store and dispense fluid chemicals in bulk. Those plants have the capability of pumping from storage through meters directly to the mixer. However, because of potential metering and control problems with direct piping we recommend that all chemicals be handled through a batch preparation system and using manual gravimetric or volumetric measuring systems for the chemicals. The results of bad handling and mistakes are just too expensive to justify anything other than positive and controlled measuring methods.

Calibrate equipment before use; establish best nozzle placement, measure fluid retention in piping system to determine flushing requirements, mark valve settings for certain flow rates and install feed systems for pesticides and "Microcel-E" that will not generate dust in the working atmosphere.

If powdered pesticides are added to fertilizer, the powder should be added to the mixer only after half or more of the sticker fluid has been sprayed on the fertilizer.

Special attention must be applied to housekeeping to avoid cross-contamination.

- Install nozzles inside the mixer so no herbicide spray escapes to the outside.
- Clean up any leaks or spills of herbicides or impregnated fertilizer immediately.
- Place cleanup material in drums or other dedicated containers that can be secured for handling and disposal.
- Label each container of cleanup material.
- Processing and application equipment must be purged and cleaned of impregnated residues before handling fertilizer blends.

*Special Procedures & Controls*

You must give extra attention to the prevention of cross-contamination of fertilizers with chemicals such as Atrazine which has strong residual effects on many crops.

Results from samplings and studies during production have shown that the residual amount of pesticides remaining in the blending system after impregnation can be excessive for chemicals such as Atrazine if the next batch of fertilizer is to be applied to a crop that is sensitive to Atrazine or other chemicals.

The data indicates that the following conditions can cause excessive residual chemicals in the system after impregnation:

- High liquid phase mixes.
- High concentrations of urea or potash.
- Small volumes of pesticide-fertilizer mixes (less than 50% of mixer capacity).
- Use of wettable powder type chemicals.

Fertilizer contamination and potential crop damages can be avoided by:

- Allowing running time for equipment to empty after discharge of the batch of impregnated fertilizer.
- Uniform spray application in the mixer with adequate mixing time.
- Using "Microcel-E" in accord with fluid-phase guidelines.

- Limiting mix quantity to no less than 50% of the mixer capacity, particularly when high fluid phase will be present.
- Scheduling production so fertilizer blends that are made immediately after impregnation runs are applied to crops not sensitive to the chemicals in the impregnated fertilizer: Two successive fertilizer batches of full mixer capacity are recommended for purging. Or; clean all handling equipment after impregnation so there is no significant residue—which means that any residue must be restricted to that quantity which in the case of Atrazine would represent a concentration of less than 100 parts per million (0.01%) in the fertilizer mix that follows the impregnated batch. Because any residues will normally be of small particulate sizing and much higher in pesticide concentration than the formulated concentration of the total mix, we estimate that 10 to 20 times the concentration of the formulated chemical concentration will be found in the residue. Therefore, on this basis only about 4 to 8 lbs. of residue would be allowable in the system when a two-ton batch of fertilizer follows an impregnated mix that contained 0.5% Atrazine.
- Observing extra precautions when purging the blending system after several batches containing Atrazine, Bladex, Sencor, Simazine or others with high crop sensitivity residuals have been impregnated successively. Concentrations of pesticides in the residue and the quantity of residue will increase with the number of impregnated batches because of buildup and recycle treatment, particularly this will be noticeable for the higher fluid phase mixes.
- Clean and purge bulk spreading equipment as done with blending equipment.

### *Safety & Environmental Controls*

All employees should be trained in the safe handling of pesticides. Material safety data sheets for each chemical handled should be available and safety recommendations of these data sheets and pesticides labels should be followed. Many sources of information are available for guidance in the development of a personal protection program and most basic suppliers of pesticides and trade associations are very helpful.

Most blend plants' electrical systems are not explosion proof. Therefore, liquid pesticides with low flash points should not be impregnated. NFPA standards and our insurance people say not less than 100°F TAGG closed cup flash point unless systems are explosion proof.

As mentioned in the beginning, most herbicides are of relatively low toxicity and engineering controls are not needed in most blend plants to safely handle them. Higher toxicity pesticides must not be impregnated in blend plants unless properly designed control equipment is used and special personnel protective procedures are enforced. In most cases, you cannot economically justify the necessary investments and operating costs for such protective systems.

Solids materials cleaned from equipment should be collected and contained and, if in satisfactory physical condition for mixing, it can be added to the next batch of same type pesticide-fertilizer mix.

Cleanup material resulting from leaks and spills, or material from equipment that is not recoverable, and pesticides containers should be disposed of in conformance with procedures and locations approved by local and State regulatory authorities. All cans, pails, jugs and drums should be triple rinsed as soon as empty. Drain the rinseates into the reservoir tank of the spray-pumping system and use as flushing fluid when the fertilizer-pesticide mix can tolerate this added liquid phase. If not, store the rinseates in containers and use on a drier mix.

In case of environmental problems involving spills or wastes disposal, your first and primary regulatory official contact is your local agency, next the State then the Federal agencies. However, you should minimize such problems by developing and instituting emergency and pollution incident prevention plans. Such plans can be developed with the assistance of regulatory officials, trade associations, basic raw materials suppliers and inhouse or outside consultants.

### *Application Procedures & Equipment*

All pesticide-fertilizer mixes should be custom applied by the producer. This provides alpha-omega quality control and minimizes the potential of misuse.

There has been considerable debate as to whether these mixes should be single or double spread. My opinion is that if the spreading equipment is properly calibrated and operated and the mix is properly prepared, single spreading should be satisfactory. If your equipment is lousy or poorly operated, then it is questionable whether any type of spreading pattern will be satisfactory. If you are going to indulge in excessive fluid phase mixes, then it is doubtful if the best equipment and operators can consistantly do the right spreading job.

Know your customer! Customers must be amenable to certain constraints such as: the mix is made in bulk only to the order of the user; the mix is shipped directly to use and cannot be held in inventory; acreages must be accurately measured and identified, and spreading schedules must correlate with weather and soil conditions. If you have any doubts about proper spreading conditions call the customer before you make the mix.

*Labeling, Registrations & Records*

Be sure the request for a certain fertilizer-pesticide combo fits within the allowable limits of the label and EPA registration for the pesticide. The label should include "end-use" directions and suitability for use of the chemical in pest control as an ingredient of a fertilizer-pesticide mixture.

EPA regulations generally exempt custom blended fertilizer-pesticide mixes from product registration if the following conditions are met:

- The mix is prepared in bulk only and to the order of the user and is not inventoried.
- Pesticide in the mix must have end-use labeling.
- Blend is delivered to user with a copy of the end-use labeling of the pesticide and a statement of the composition of the mixture.
- Blend is prepared in a registered EPA establishment.

EPA establishment numbers must be obtained for any plant producing custom fertilizer-pesticide mixes. In addition, some states require business permits or licenses for either or both the manufacturing establishment and the application operations.

Most states require Commercial Certified Pesticide Applicator licenses or permits. In some states, requirements are satisfied by licensing one person responsible for all application activities, but more often each truck driver-applicator has to be licensed. Licensing or permitting usually includes written testing and application fees.

In addition to normal accounting and operating records, a log sheet should be kept on each shipment of impregnated fertilizer. The log should include data about the mix, application rates, acreages, soil, topography, crops, boundary lands and crops, weather and many usual conditions. Accounting systems should include provisions for filing the annual EPA establishment report and State reports.

*Summary*

In summary, we are in the business of producing fertilizer-herbicide combos and presently plan to continue in this business. In a synopsis I have said:

- Efficacy of these products is proven.
- Use proper formulations and mixing techniques.
- Prevent cross-contamination.
- Give special attention to application operations.
- Develop and enforce safety rules.
- Properly dispose of wastes.
- Comply with regulatory statutes.
- Keep good records.
- BE REALISTIC ABOUT COSTS.

Look at our recommendations, then use realistic accounting and volume projections to make an operating cost analysis. You may or may not want to get into this business.

And finally, if you have no experience with pesticides and your people are not knowledgeable in the quality control and chemistry of pesticides, then obtain the services of qualified people to assist you with training and development of your people and operations.

## Fertilizer Placement: Improved Efficiency for Reduced Tillage Crops

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### Introduction

No two terms characterize the future of crop production under reduced tillage systems as well as the combination "higher yields" and "increased efficiency". Farming today is a special kind of business that depends on narrow margins, has little control over production input costs and little influence on commodity prices.

Profit potential in such a situation depends on producing enough bushels, pounds or tons of crop per acre to keep the production costs below the selling price. Farm management records show that average yields frequently fall below the cost of production, a fact which is no surprise to anyone familiar with the agricultural sector. Higher yields that are required to lower production costs below the selling price demand an increased commitment to *best management practices* and close attention to production details. Higher yields in any type of a tillage system aren't all a matter of fertilizer rates or methods of application but *fertilizer placement* is a tool that can help improve nutrient availability.

While higher yields are better for farmer profits, market development in the fertilizer industry is also benefited from the higher amounts of nutrients required for higher yields. This may sound like double-talk, efficiency of nutrient use through placement, higher yields and higher nutrient requirements, but that is actually the case. Better nutrient use efficiency through placement does not necessarily imply an automatic reduction in rates of application but rather an increased yield from better use of the same amount of nutrients.

### *Why Placement?*

The positive effects of nutrient placement in some specific location relative to the plant have been recorded for years (5, 17). In the older literature, nutrient placement was generally considered to imply locating the nutrients close to the plant at seeding, improving the probability of roots encountering the nutrient supply early in the growing season. The use of starter fertilizers is a prime example of this type of placement. Besides the close proximity to the developing plant, utilization of phosphorus (P) in particular was considered, in fact is still considered, to be improved due to reduced soil contact, subsequently slowing the rate of P fixation reactions which lower water solubility.

Temperature has also been an important factor in the use of starters. It's a fact that nutrient absorption processes operate at a slower rate at lower temperatures and that the rate of P diffusion to roots is slower (3, 15). With large amounts of surface residue, soil temperatures can be easily 5 degrees F lower, maybe more. High concentrations of nutrients close to the developing seedling help to overcome the slow development of roots and the low level of energy production in the roots. Energy expenditure is required by processes which concentrate nutrients in the roots, particularly the negatively charged phosphate, nitrate and sulfate ions.

Soil compaction also depresses nutrients availability. Compaction means that there is less oxygen in the soil, plant roots do not respire normally, energy production is curtailed and nutrient absorption is depressed. Since there is a tendency toward higher bulk density (greater compaction) in soils that are untilled, there is additional nutritional stress under those conditions and plant responses to starter fertilizers are increased.

Recently, increased attention has been given to improved nutrient use efficiency especially for reduced tillage systems (13, 14) through the use of techniques which concentrate nutrients in specific soil zones *prior* to planting (9, 10, 11). Higher nutrient use efficiency from such pre-plant banding has been largely measured through higher yields compared to conventional broadcast applications. Reasons for these differences and the possibilities they hold for reduced tillage crops will be examined further.

### *Placement Terminology*

Before we go further into the subject, let's sort out the various labels that have been used in conjunction with fertilizer placement.

The term "starter" needs little definition for most people. Starter placement implies concentations of nutrients close to or in direct contact with the seed. "Banding" has been more vague. It has usually meant the same thing as starter but recently "banding" has taken on a new and broader meaning including pre-plant placement. "Dual application" is a term that has developed in the past few years to refer to pre-plant applications of ammonia and liquid mixed fertilizers which place the ammonia and the liquid in the soil in the same zone by means of two separate lines on the applicator shank. Usually N and P have been used in "dual" application but other elements can be involved, depending on the needs of the situation.

Since dual application places the nutrients below the soil surface, synonymous terms such as "deep placement", "deep banding", "knifing", "pre-plant banding", "double shooting", and "root zone banding" have come into use. These other terms, exclusive of dual application, do not necessarily imply the use of ammonia with some other form of nutrients. Solid, liquid or suspension fertilizers can all be placed below the soil surface with equipment now available.

"Strip placement" and "dribble applications" have been coined to refer to surface, strip applications of liquids or suspensions for new crops, small grains or grasses. These applications may or may not be incorporated, depending on the cropping system involved. Solids can also be applied in the same manner with new, specialized equipment. To complicate things even further, applications of large amounts of nutrients at seeding to the side and below the seed may produce essentially the same effects as pre-plant banding and are sometimes termed "starters" even though the amount of nutrients involved are much higher than conventional starter applications.

Let's simplify the situation by using only two of these terms for the remainder of this discussion. Pre-plant banding and banding of large amounts of nutrients at planting will be "deep placement" regardless of the forms of fertilizer or type of equipment used. Surface band placement will be "strip" applications regardless of cropping system or form of material applied. Depending on the type of cropping system, those strip applications may or may not be incorporated into the soil.

### *Why Placement for Minimum Tillage Systems?*

It's logical to have some concern for the efficiency of nutrient use in tillage systems that leave a large amount of plant residue on the surface. That concern is based on impaired penetration of plant nutrients to the soil surface, concentration of nutrients in a limited amount of soil and rooting zone, positional unavailability of nutrients due to concentration at the surface, marked changes in soil chemistry at the surface such as substantial drops in soil pH, colder soil temperatures at the surface due to the presence of residue and possible losses of nitrogen by ammonia volatilization or denitrification.

*Surface Accumulations of Nutrients.* Tillage systems have tremendous effects on the distribution of nutrients in the soil. Data in Table 1 demonstrate how lack of mixing in a no-till system and to some extent in chisel and disk systems create nutrient accumulations near the soil surface compared to a moldboard plowed area.

**Table 1. NUTRIENTS ACCUMULATE IN THE SURFACE SOIL WITH REDUCED TILLAGE**
**5 Years—Iowa**

| Soil depth inches | Available P ppm | | | |
|---|---|---|---|---|
| | Moldboard | Chisel plow | Disk | No-till |
| 0–1 | 23 | 58 | 68 | 88 |
| 1–2 | 25 | 46 | 62 | 82 |
| 2–4 | 22 | 40 | 47 | 32 |
| 4–6 | 22 | 22 | 22 | 13 |
| 6–8 | 24 | 16 | 13 | 11 |
| 8–10 | 14 | 9 | 8 | 9 |
| 10–12 | 6 | 7 | 6 | 8 |

D. C. Erbach, Iowa State Univ.

**Table 2. TILLAGE SYSTEM EFFECTS ON SOIL pH**
**10 Year Study—Minnesota**

| Soil Sample Depth | Fall moldboard | Fall chisel | Spring disk | No-till |
|---|---|---|---|---|
| inches | | | | |
| 0–1 | 6.6 | 6.6 | 6.1 | 5.7 |
| 4–6 | 6.7 | 6.9 | 6.9 | 6.9 |

Randall, Univ. of Minnesota (16)

When nutrients accumulate at the soil surface, particularly ammonium-N, soil pH can be dramatically affected (15). Nitrification of the ammonium N produces acidity which accumulates where it is produced. Lack of mixing causes a greater pH drop in the surface layer of soil (Table 2).

That pH drop at the surface in a reduced or no-till system creates problems both in plant nutrition and weed control. Several herbicides are less effective at low pH's and thus low pH at the surface further contributes to low yields by weed competition.

*Nutrient Concentrations.* Minnesota studies indicate that accumulation of nitrate nitrogen in the soil can be affected by tillage systems (16). Less nitrate was found in the soil under a no-till system than any other tillage system compared when all had received equal amounts of N annually. Soil which had been moldboard plowed regularly had the highest N concentrations. These differences may be due to a number of different factors. Some states particularly in the south have reported higher incidence of denitrification losses of N under no-till conditions due to the soil remaining wetter longer. Studies have also shown that soil bulk density is higher under reduced or no-till systems which means there is less pore space, less air and under high moisture conditions, a great possibility for denitrification of nitrate-nitrogen. Greater aeration of plowed soils can also enhance organic matter decomposition and subsequent release and nitrification of nitrogen in plant residues.

*Cooler Soil Temperatures.* With a covering of plant residues, soils tend to evaporate water less rapidly and remain cool longer in the spring. This fact has been widely accepted. Also recognized is the fact that starter applications of P and K are particularly effective under low soil temperatures and often produce large yield increases even when the soil test levels for these nutrients are medium to high (Table 5).

**Table 5. STARTER P HAD DRAMATIC EFFECTS ON CORN YIELDS UNDER REDUCED TILLAGE IN THIS WISCONSIN STUDY EVEN WITH HIGH SOIL TEST P**

| Soil Test P ppm | Lb per acre starter $P_2O_5$ | |
|---|---|---|
| | 0 | 40 |
| | Yield, bu/acre | |
| 30 | 103 | 136 |
| 35 | 119 | 144 |
| 80 | 122 | 148 |

Source: E. E. Schulte, Dept. of Soil Science, Univ. of Wisconsin.

*Nitrogen Placement in Reduced Tillage Systems*

In many areas, N use efficiency under reduced tillage has been questioned because of the possibility of ammonia volatilization losses, possibly increased leaching or denitrification in humid areas and tie-up of nitrogen in the plant residues at the soil surface. Just how important any of these factors are in N use efficiency will vary depending upon soil and climatic conditions. Still, recent data indicate that placement techniques can have a substantial effect on N use.

Purdue University researchers recently reported on a series of studies which indicated that selection of a form of N and a method of N application could have significant effects of corn under reduced tillage conditions. Comparisons of ammonia, deep placed N solution (UAN), and surface (broadcast) applications of UAN and solid area indicated that deep placement of N produced both higher concentrations of N in corn ear leaves and higher yields (12). A summary of seven studies indicated a 17–20 bushel advantage for deep placement of N for no-till corn (Table 3).

Studies at the University of Maryland have provided similar results. From 1979 through 1982, deep placement (knifed) applications of N have shown generally consistent advantages over similar broadcast applications. It is also interesting to note that surface "strip" applications of UAN in 1982 were only slightly less effective than knifed treatments under no-till conditions (Table 4).

**Table 3. NITROGEN PLACEMENT HAD SIGNIFICANT EFFECTS ON CORN YIELDS UNDER REDUCED TILLAGE IN PURDUE UNIVERSITY STUDIES.**
**1978–1980, 7 Studies**

| N treatment | Yield, bu/A | Ear leaf, N, % |
|---|---|---|
| $NH_3$ | 139 | 3.06 |
| UAN knifed | 135 | 2.85 |
| UAN surface | 118 | 2.48 |
| Urea surface | 123 | 2.57 |

147 lb N/A
Mengel et al., Purdue Univ. (12).

**Table 4. DEEP PLACEMENT AND SURFACE BANDING OF N PROVED TO BE MORE EFFECTIVE THAN BROADCAST APPLICATIONS IN MARYLAND NO-TILL CORN RESEARCH.**
**Maryland–1982**

| N Source and Placement | Yield bu/A |
|---|---|
| No N | 33 |
| Ammonium nitrate broadcast | 112 |
| Urea broadcast | 111 |
| UAN broadcast | 99 |
| UAN dribble | 120 |
| UAN knifed | 124 |
| UAN surface band | 121 |

120 lb N/A
V. A. Bandel, Dept. of Agronomy, Univ. of Maryland, personal communication.

Touchton and Hargrove reported that Georgia studies also indicated higher efficiencies for deep placement of nitrogen in no-till corn (19). Broadcast nitrogen solution resulted in lower corn ear leaf N concentrations and lower yields.

Deep placement of N or surface strip applications are apparently avoiding some loss mechanism which probably varies with climatic and soil conditions. These methods of N application may be more effective by avoiding organic matter or microbial immobilization of N, ammonia volatilization from surface hydrolysis of urea and positional unavailability of N. Penetration of the surface residue is obvious when materials are knifed into the soil and surface strip applications may be more effective because of better penetration of the residue by the coarse droplets of the N solution and the large amount of material that is applied at each point. In any event, results indicate that there is ample reason to believe that these methods improve N use efficiencies for reduced tillage systems.

### *Phosphorus Placement*

The value of starter P is well recognized. Cold soil temperatures, low soil test values and P fixation in the soil have contributed to the need for high P availability early in plants' growth cycles. Reduced tillage crops have responded especially well to starter P.

Climatic conditions which produce cool temperatures after planting may even overwhelm high soil test values for phosphorus and dictate a need and response to starter P (Table 5).

In the 1960's, Kansas State University agronomists began to study tillage implement applications of nutrients, specifically N and P, for winter wheat. Tillage implements for stubble-mulch farming were found to be effective for applying ammonia and coupled good ammonia retention with economy of time and fuel by doubling up on operations. Later, Kansas researchers began agronomic evaluations of the simultaneous deep placement of ammonia and mixed liquids through two delivery lines on tillage implement shanks.

Deep placement of N and P under both conventional and reduced tillage conditions proved to be generally more effective than more conventional methods of application which placed most of the N and P at different positions in the soil (Table 6). The Kansas studies also indicated that the fertilizer material used in deep placement of N and P was not critical as long as high concentrations of ammonium nitrogen were present in the N source.

**Table 6. DEEP PLACEMENT OF P WAS MORE EFFECTIVE FOR WHEAT THAN BROADCAST OR SEED PLACED P ON THIS LOW P SOIL.**
**Dickinson Co., Kansas**

| | lb $P_2O_5$/a | | | |
|---|---|---|---|---|
| | 20 | 30 | 40 | 50 |
| | bu/a | | | |
| P Knifed Preplant | 53 | 60 | 70 | 60 |
| P Broadcast Preplant | 44 | 49 | 57 | 57 |
| P Banded at Seeding | 45 | 61 | 57 | 68 |

Soil test P: low
D. F. Leikam, Kansas State Univ. (9)
Ammonia was main H source.

Similar deep placement results with wheat have been reported from Montana, Idaho, Nebraska, Oklahoma, North Dakota, Alberta and Sakatchewan (13).

The presence of large amounts of ammonium-nitrogen in the soil band with P may be important in improving P availability. In Kansas, 4 to 8 bushel wheat yield increases were noted from application of 0.5 lb/acre active ingredient *N-SERVE*,[1] a nitrification

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[1] Product of Dow Chemical Company, 2-chloro-6-trichloromethyl pyridine.

inhibitor, in ammonia in deep placement with liquid ammonium polyphosphate. *N-SERVE* slows the nitrification process but eventually the effects of the compound disappear and the reactions are completed.

Similar *N-SERVE* effects were also noted when both nitrogen solution (UAN) and ammonia were used (10) as N sources (Table 7). Not all studies have shown positive effects from the inclusion of *N-SERVE* and other nitrification inhibitors such as *DWELL*[2] in deep placement. Still, nitrification inhibition could affect plant responses to P only through the extended presence of ammonium-N in the soil.

**Table 7. NITRIFICATION INHIBITOR (N-SERVE) EFFECTS ON WINTER WHEAT IN THIS STUDY OCCURRED ONLY WHEN N AND P WERE DEEP PLACED (KNIFED)**
**Osage County, Kansas**

| | | | Yield | |
|---|---|---|---|---|
| | | | 0 P | 40 $P_2O_5$ |
| | | | (bu/A) | |
| 75 N | $NH_3$ + N-SERVE | Knifed | 59.1 | 75.5 |
| 75 N | $NH_3$ | Knifed | 59.4 | 62.6 |
| 75 N | UAN + N-SERVE | Knifed | 46.3 | 63.5 |
| 75 N | UAN | Knifed | 44.0 | 49.4 |
| 75 N | UAN + N-SERVE | Surface Strip | 37.3 | 48.1 |
| 75 N | UAN | Surface Strip | 44.0 | 29.8 |
| 75 N | UAN + N-SERVE | Surface Broadcast | 37.1 | 42.9 |
| 75 N | UAN | Surface Broadcast | 50.6 | 58.9 |
| 0 N | . . . | . . . | 12.7 | . . . |

UAN—N solution 28-0-0. Strip application—coarse stream of liquid fertilizer on soil surface followed by disking.
All $P_2O_5$ supplied as liquid, 10-34-0.
Liekam et al. (10)

Improved P use due to the presence of ammonium N in fertilizer or soil, has been recognized for years (6). Recently, studies at Colorado State University (7) have indicated that the extended presence of high concentrations of ammonium N in the soil with applied P can modify soil reactions of phosphorus with the effect of extending P availability.

Additional evidence for enhanced phosphorus availability through placement of high cncentrations of ammonium N and P in the same soil zone has come from Kansas wheat studies. One study indicated that when P was deep placed but most of the applied N was broadcast, yields were 8 bushels per acre less than when both nutrients were deep placed together (Table 8). Nutrient concentrations in these bands are much higher than those resulting from broadcast applications followed by tillage. However, strip applications followed by tillage may also produce higher nutrient concentrations in soil bands.

**Table 8. PLACING LARGE AMOUNTS OF N AND P CAN HAVE A DRAMATIC EFFECT ON WHEAT YIELDS. NOTE THAT DEEP PLACEMENT OF P AND ALL OF THE N (KNIFED) WAS MORE SUCCESSFUL (64 bu/A) THAN DEEP PLACEMENT OF P WITH A SMALL AMOUNT OF N WITH THE REMAINDER OF THE N BROADCAST (56 bu/A).**
**Dickinson County, Kansas**

| Method | | | Wheat | |
|---|---|---|---|---|
| N | lb/A | $P_2O_5$ | Yield | Plant P |
| 75 | | 40 | bu/A | percent |
| Knife | | Knife | 64 | .27 |
| Knife | | Broadcast | 53 | .22 |
| Broadcast | | Knife | 56 | .23 |
| Broadcast | | Broadcast | 53 | .23 |
| | LSD (.05) | | 6 | .01 |

Soil Test P: Low. Leitkam et al. (10)

*Placement for Row Crops*

The information on small grains provides some basis for evaluating possibilities for better nutrient use efficiency for row crops through placement.

Much of the row crop work with strip or deep placement is based on research carried out at Purdue University (2). The Purdue work has shown that strip placement of both P and potassium (K) may be superior to row or broadcast applications (Table 9). Apparently, the fixation or reaction of K with soil components is reduced by lowered soil-K contact and yields increased due to higher K availability. The same explanation is offered for the improved efficiency of P applied in a similar manner. More attention has been given to N and P availability in the discussion of strip and deep placement but the Purdue K work greatly expands the options for improved efficiency with this type of placement.

Nitrogen, P and K placement for no-till corn has been evaluated by Bandel (1) at the University of Maryland. In addition to the significant benefits of deep placement of N reported earlier (Table 4), deep placement of P and K also benefited nutrient use efficiency and yields (Table 7).

A study by USDA-ARS and Iowa State University (18) involving three tillage systems and four methods of NPK application has produced interesting results. Data (Table 11) indicate that deep placement of N, P and K was sometimes more effective than other placement combinations. Deep placement advantages tended to be more consistent under no-till conditions.

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[2] Product of Olin Corporation, 5-ethoxy-3-trichloromethyl-1,2, 4-thiadizole.

**Table 9. PURDUE UNIVERSITY RESEARCH HAS SHOWN THAT STRIP PLACEMENT OF P AND K MAY BE SUPERIOR TO ROW OR BROADCAST APPLICATIONS**

| Placement | Corn yield, bu/acre 5 year average |
|---|---|
| Row P | 115 |
| Broadcast P | 121 |
| Strip P | 122 |

| lb $K_2O$/a | 30 | 60 | 120 | Average |
|---|---|---|---|---|
| | bu/acre | | | |
| Row K | 115 | 127 | 117 | 120 |
| Broadcast K | 113 | 129 | 116 | 119 |
| Strip K | 120 | 133 | 128 | 127 |

Source: S. A. Barber, Purdue University. (2)

**Table 10. PLACEMENT OF N, P AND K HELPED NO-TILL CORN YIELDS IN MARYLAND.**

| N Placement | P and K Placement bu/A 1979 | | 1980 | |
|---|---|---|---|---|
| | Broadcast | Knifed | Broadcast | Knifed |
| Broadcast | 116 | 121 | 103 | 111 |
| Knifed | 141 | 145 | 105 | 110 |

120 lb N/A
Bandel, Univ. of Maryland (1).

Investigations of methods of NPK placement for dryland grain sorghum in southeastern Kansas over a three year period compared conventional, reduced and no-till systems. Data from that study indicate that significant differences were attributable to tillage system and methods of fertilization (8). Broadcast applications tended to be less effective but there was variation in effects between years. Large nutrient accumulations were noted in the surface soil under reduced and no-till systems.

A subtantial amount of evaluation of fertilizer placement for both reduced and conventional tillage systems is being conducted by farmers and fertilizer dealers (4). WaConda Soil Service of Washington, Iowa and its customers compared fall strip applications of suspensions to broadcast applications of the same formulation in a series of farm trials (20). Both strip and broadcast applications were incorporated by tillage operations which varied between farms. Corn yield differences (Table 12) ranged from 4 to 14 bushels per acre in favor of strip applications.

In recent years, some large, reduced tillage, irrigated farming operations in western Kansas and Nebraska have, based on their own large scale field trials (Table 13), converted to deep placement of N-P-K-S for corn. Much of their N is still sidedressed and applied through the irrigation system to avoid leaching on sandy soils.

### *How Do Soil Test Values Fit In?*

Researchers suggest that greatest differences between P and K placement methods should be expected on the lower testing soils. University of Nebraska data show that differences between seed-placed P and broadcast P for wheat diminish rapidly as the P soil test increases. North Dakota State University research shows the same trend between broadcast and deep placement applications of N and P for spring wheat and barley (13). Lowest soil test P values were associated with greatest differences between methods of application.

On the other hand, one Nebraska study with reduced tillage irrigated corn indicated a strong positive benefit of starter P over deep placed N and P even with a very low soil test P level. 1982 Purdue University studies indicated only slight positive benefit to deep placement of P on high P soils with four tillage systems but at the same time reported an excellent P starter effect from a P fertilizer high in N, 28-28-0. Pre-plant band applications of 4-10-10 liquid

**Table 11. FERTILIZER PLACEMENT EFFECTS DIFFERED WITH TYPE OF TILLAGE SYSTEM IN THIS IOWA STUDY. NOTE THAT PLACEMENT WAS GENERALLY MORE EFFECTIVE UNDER REDUCED TILLAGE.**
**Nashua—1981**

| Fertilizer Placement | 105-Day Hybrid Conv | Chisel plow | No-till | 110-Day Hybrid Conv | Chisel plow | No-till |
|---|---|---|---|---|---|---|
| $NH_3$, P-K Surface | 134 | 137 | 120 | 160 | 153 | 154 |
| $NH_3$, P-K Deep band | 144 | 136 | 138 | 151 | 154 | 147 |
| UAN, P-K Surface | 132 | 143 | 116 | 144 | 152 | 134 |
| UAN, P-K Deep band | 147 | 143 | 143 | 161 | 166 | 147 |

250 lb N, 58 lb $P_2O_5$, 90 lb $K_2O$/A
Timmons, et al. Iowa State Univ. and USDA (18).

**Table 12. STRIP APPLICATIONS OF SUSPENSIONS WERE MORE EFFECTIVE THAN COMPARABLE BROADCAST APPLICATIONS FOR CORN—Iowa 1981.**

| $N+P_2O_5+K_2O+S+Zn$ lb/acre (fall applied) | Yield, bu/acre | | Grain moisture, % | | Soil test P |
|---|---|---|---|---|---|
| | Strip | Broadcast | Strip | Broadcast | ppm |
| 100-25-80-10-3 | 205 | 190 | 31.2 | 32.7 | 48 |
| 100-80-130-25-3 | 176 | 171 | 23.6 | 25.6 | 16 |
| 100-50-120-25-5 | 175 | 166 | 22.4 | 22.0 | 41 |
| 100-80-130-25-3 | 155 | 146 | 22.7 | 23.3 | 22 |
| 100-70-110-25 | 163 | 149 | 21.0 | 23.2 | 19 |
| 70-45-90-15-2 | 161 | 152 | 18.2 | 18.6 | 21 |
| 70-10-90-25-4 | 142 | 139 | 18.5 | 18.8 | 47 |
| 140-100-160-30-6 | 167 | 160 | 21.6 | 22.3 | 14 |

Source: George van Houten, Wa Con Da Soil Service, Washington, Iowa. (20)

**Table 13. DEEP PLACEMENT OF NUTRIENTS PROVED TO BE MORE EFFECTIVE THAN BROADCAST APPLICATIONS IN THIS LARGE-SCALE IRRIGATED CORN PROJECT IN WESTERN KANSAS**

| | Broadcast | Deep Placement | Difference | Avg. Yield 24 Pivots |
|---|---|---|---|---|
| Yield | 147 bu | 158 bu | 11 bu | 152 |
| Cost/A | $37.19 | $39.98 | ... | ... |
| Rate | 75+60+70+15+5 | 65+51+36+18+0 | ... | ... |

Charles Sauerwein, Cimmaron, KS; Bob and Larry Landon, Deerfield, KS; Gary Beneda, Garden City, KS.

fertilizer in the Purdue study contained relatively low amounts of nitrogen.

Some results have indicated substantial differences between broadcast and strip or deep placement of P when soil test values are medium to high. Such was the case in the Iowa evaluations by WaConda Soil Service (Table 12). Clearly, there is a need to further research this area to determine where, under what soil test conditions and what tillage conditions methods of fertilizer application tend to be equated.

*Equipment Availability?*

Equipment for fertilizer placement is too broad a subject to be adequately covered here. Some points may be helpful in evaluating where placement fits into existing operations.

Several manufacturers are on the market with adaptor kits for conversion of tillage tools to fertilizer application. Most if not all of those kits are for ammonia or liquids or combinations of ammonia and liquids. If a home-engineered conversion is planned and ammonia and liquids are to be used, it's important to keep the ammonia release point separated from the liquid release point by about 1.5 inches vertically to avoid plugging the liquid line with a precipitate. Small spacers between the two lines will help avoid problems with freezing.

Spacing between release points is an important factor in strip placement or deep banding regardless of the type of fertilizers being used. When spacings are too wide, yields probably suffer although yields may still be higher than with broadcast applications. Streaking in small grains frequently occurs with spacings greater than 15 inches. If surface strip applications are followed by tillage, 20 inch spacings may be acceptable for either row crops or small grains because the "slobbering" effect of the original application produces a wider application swath. Thirty inch, pre-plant applications for row crops are being tried but limited data available indicate lower effectiveness than narrower (15 inch) spacings (13).

Spacing considerations are not a concern when planting equipment is being adapted for heavier rates of fertilization than normally practiced in starters. About the only consideration in adapting planting equipment is where the fertilizer should be placed relative to the seed. It's important to recognize that heavy rates of nutrients close to the seed can cause germination damage. But new developments with air seeding equipment for reduced or no-till small grains have indicated that heavy rates of fertilizer high in N and K can be placed close to the seed if the design of the equipment assures some definite separation of seed and fertilizer.

An entire new generation of applicators for dual application of ammonia and liquids, injection of suspensions, deep or strip placement of solids is now available. Recently, custom flotation application equipment has also been adapted to strip applications or deep placement. Modification kits are available for existing flotation applicators allowing that equipment to be used for either strip or broadcast applications.

### *In Summary*

Where does fertilizer placement fit in and why does it seem to work as well as it does? Reduced tillage is particularly adapted to fertilizer placement because of the difficulty of incorporating nutrients adequately and due to residue immobilization of nutrients. Overall, placement may have advantages because of the following:

(a) Possible delay of fertilizer P and K reactions with the soil due to diminished fertilizer-soil contact.
(b) Deeper placement of nutrients into soil where moisture is less limiting to uptake (positional availability).
(c) Possible delay in fertilizer P reactions with soil components due to the very high concentrations of ammonium-nitrogen present.
(d) Forced plant uptake of ammonium nitrogen causing a more acid condition at the root surface.
(e) Greater P availability at the root surface due to the acid environment there produced by ammonium-N absorption.

*Advantages*? Besides the agronomic advantages already considered, doubling up on tillage and fertilization operations is attractive. For the custom applicator, strip applications of solutions or suspensions on the soil surface followed by some tillage may give some of the same advantages while allowing operations on windier days. For reduced tillage systems, this technique may overcome problems associated with large amounts of residue on the soil surface.

*Disadvantages*? There are more logistical problems in handling two materials in ammonia-fluid or ammonia-solid combinations. For the custom applicator, deep placement means covering less acres per hour compared to broadcast applications. It also means competition for weed and feed combinations. Mounting liquid rigging on existing ammonia applicators means increased maintenance problems. Farmers will be faced with the initial costs of equipping tillage implements for handling fertilizers and the maintenance that goes with it. Farmer applications of suspensions can also be a problem.

*What's the final analysis*? Recognition that higher yields per acre affect production costs per bushel and overall profitability is a strong incentive for doing a better job in production. More research is needed to better pinpoint where deep placement, strip applications or fertilizer placement in general fits best particularly in relation to high P and K testing soils. While that work is underway, fertilizer placement has demonstrated that it does have a place in efficient crop production and can affect yields and profits.

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# Effect of Granule Size on Application

*Michael F. Broder*, **Agricultural Engineer**
**and**
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**Division of Agricultural Development**
**National Fertilizer Development Center**

Sixty-two percent (29 million tons) of the fertilizer applied in the U.S. in 1982 was in the form of dry fertilizer (1). Most of this fertilizer was applied with spinner spreaders. Though most spinner spreaders have the disadvantage of producing uneven distribution, their high capacity, simplicity, and low maintenance have made them the most popular machine for broadcasting dry fertilizer. More than 20 years ago, particle size was recognized as the most important factor for maintaining uniform swaths among raw materials in a blend (2). Small particles travel a shorter distance from the spinning discs than do large particles. This has discouraged the use of materials smaller than conventional granular products. Advantages of broadcasting larger-than-conventional materials has, up to this time, not been explored. Work described in this paper was aimed at determining the advantages of broadcasting materials larger than the typical minus 6- plus 16-mesh materials.

### *Literature Review*

Hoffmeister conducted a series of tests to determine the extent to which particle shape, density, and size affected segregation of raw materials in blends (2). The overall conclusion was that particle size was by far the most important property that had to be matched to prevent segregation from ballistic action.

Mennel and Reece investigated particle trajectories from spinning discs and were able to predict the distance that spherical particles travel (3). Their equations predicted that a 1/8-inch-diameter particle (6-mesh) would travel roughly twice as far from a spinner 3 feet above ground than would a 1/64-inch-diameter (35-mesh) particle. Irregular shaped crystals did not travel as far as spherical particles.

Reints and Yoerger suggested that, if granular fertilizer particles had a wide size range, they would be better distributed laterally from the spreader (4). Cunningham and Chao chose to use discs having blades pitched at different angles to produce more divergence among particles leaving the spinners, thus improving broadcast uniformity (5). Mennel and Reece had already shown that the irregularity of fertilizer particles produces trajectories at large angles to the plane of the disc, thus causing large variation in the distance that particles travel (3).

More recent work by Pitt, et al has shown that variability in particle size has little effect on spread pattern (6). Median particle size is important; however, size variability merely tends to smooth out edges of the distribution pattern.

Facts that can be deduced from previous work is that mathematical modeling of fertilizer spread patterns is made difficult by particle irregularity. Large particles travel farther because their mass increases with the cube of the diameter while the frontal area on which drag forces act increases with the square of the diameter. Spherical particles travel farther than irregular shaped particles because they have smaller drag coefficients.

### *Equipment and Procedure*

Field spreading tests provided the data for this study. A double-spinner spreader was used for all but two tests. A sketch showing the relative position of the fertilizer delivery system and spinners is shown in figure 1. The delivery chute had three adjustments to control the placement of fertilizer on the two spinners. The entire chute could be moved forward or backward. Depth of the two openings in the bottom of the chute could be varied by moving the rear plate. Width of the two chute openings could be varied by adjusting the width of the inverted vee. Widening the inverted vee placed fertilizer nearer the center of the spinners and decreased the width of the two openings.

The spinner discs were 24 inches in diameter and their axes were tilted 5 degrees from vertical. The outer edges of the discs were, therefore, 2 inches higher above ground than the inner edges. Height of the spinners above ground was about 35 inches.

The other spreader was a high flotation applicator with a single spinner about 36 inches above ground.

Three different sizes of urea were used in the tests. The sieve analyses of the three materials are shown in figure 2. The large sizes were curtain-granulated urea from TVA's pilot plant. The prilled urea was produced commercially. The materials were denoted forestry grades 1 and 2 and prilled urea. Forestry grade 2 was the largest and was nominally minus 2- plus 4-mesh (U.S. Sieve Series). Forestry grade 1 was minus 3- plus 5-mesh. Median particle sizes of the three materials were, respectively, 4.7, 3.94, and 1.71 mm. These materials were chosen because their density, shape, and surface roughness were similar. Variations in spread patterns could, therefore, be attributed to differences in granule size.

Spreading tests were conducted in a level field with wind speeds below 5 mph and relative humidity below 70 percent. Ambient temperatures ranged from 80 to 95°F.

The test pans were rectangular, 17-½ by 14 inches, and 4 inches deep. Compartments for preventing fertilizer ricocheting were square, 3-½ inches on a side, and the same depth as the trays. Pans were spaced five feet between centers with their long dimension parallel to the applicator path. Twenty-one pans were used and the spreader was driven astride the center pan. A spreader speed of 5 mph as maintained during tests and the pan samples were weighed to the nearest 0.1 gram.

To compare spread patterns of different particles, urea granules were spread with several spreader adjustments. This was necessary since some adjustments could favor one size particle. Figure 1 shows a sketch of the applicator with normal settings. Two spinner rotational speeds were used, 600 and 800 rpm.

The chute location shown in figure 1 was denoted the central positon and was based on the spreader manufacturer's recommendation. Three other chute locations were used; 9/16 inches forward of the central position and 9/16 inches rearward and 1 inch rearward of the central position. These chute locations were, respectively, denoted forward, rearward, and rearward-plus.

The rear plate was always adjusted so that the depth of the chute opening was double the height of the gate opening. Gate openings of 1 and 2 inches were used.

Two settings of the inverted vee divider were used. The vee was widened from that shown in figure 1. The wider setting increased the width of the vee from 8 inches to 9 and ½ inches.

*Results*

Spread patterns were analyzed using a computer program. The program superpositions a spread pattern upon itself and the overlapped segments are summed to simulate field application. The driving interval (swath width) must be a multiple of the pan spacing. The optimum swath width is determined iteratively by selecting the driving interval which yields the lowest coefficient of variation. The coefficient of variation is defined as the standard deviation of the sample weights divided by the mean and multiplied by 100. More specifically:

$$\text{C.V. } (\%) = 100((\sqrt{(\Sigma\, (x_i - \bar{x})^2)/n - 1})/\bar{x}$$

Where $\bar{x}$ = mean of samples
$x_i$ = individual sample weights
$n$ = total number of samples

A single test consisted of three passes of the applicator over the test pans. Three passes were necessary to produce samples large enough to measure. Tests were originally replicated three times but since results were very reproducible the replications were later omitted. Figure 3 shows the reproducibility of a pattern produced with prilled urea. Each curve is the sum of three passes.

Ballistic segregation of urea granules was observed by accumulating the samples from spread tests of the prilled and forestry grade 1 urea. Accumulated samples from each pan were sieve analyzed and the median particle size plotted against pan location in figure 4. The median particle size is smallest near the spreader and largest at the outer edges. This shows that small and broken granules remain near the spreader.

Size variation was greater for the prill than for the forestry grade 1. Median size of the forestry sample containing the largest granules was 15 percent larger than the median size of the sample containing the smallest granules (4.02 versus 3.49 mm). For prilled urea the largest median particle size was 49 percent larger than the smallest (2.04 versus 1.37 mm). This size variation is also reflected in the sieve analyses of the two materials (figure 2). Though the slopes of the curves are similar the prilled urea had a greater size variation. The size range between the 10 and 90 percent retained fractions was 1 mm (2.28 to 1.28 mm). The ratio of this range and the median particle size (1.71 mm) was 0.58:1. The forestry grade 1 had a size range of 1.28 mm but its median size was 3.94 mm. Thus the ratio of the range to median particle size was only 0.31:1. Some researchers believe that size variation is necessary for uniform broadcast application (5).

Comparisons of forestry grade and prilled urea spread patterns are shown in figures 5 through 14. The chute and spinner adjustments of the 10 tests are listed in table 1. Forestry grade 1 urea was used in tests 1 through 7 (figures 5–11). Swath widths which yielded the lowest coefficient of variation for each material in each test are listed in table 2.

The effect of increasing spinner speed is shown in figures 5 and 6. The higher spinner speed (figure 6) caused the fertilizer to leave the spinner sooner thus increasing the application behind the spreader. Increasing spinner speed had the same effect on the spread pattern as did moving the chute forward (figure 7).

In nearly every comparison, there was more forestry-size urea at the outer edges of the pattern than prilled urea. There was often, however, a more severe accumulation of forestry material in the center of the swath which reduced the swath width. In test 4 (figure 8) the forestry grade 1 urea yielded a swath of 60 feet. The widest swath obtained with prilled urea was 50 feet. Prilled urea spread better with the chute in the rearward plus position (figure 9). The forestry material yielded a more uniform pattern with the chute in the rear position.

In tests 6 and 7 (figures 10 and 11) the gate height was raised to 2 inches. Some manufacturers of double-spinner spreaders recommend that the chute be moved forward for higher gate openings. The benefit of this adjustment is shown in figure 11. Movement of the chute from the rear position to the center position helped eliminate the W-shaped pattern.

The rates of application of prilled urea in the first seven tests were higher than those for the forestry grade urea. Whether or not this was caused by imprecise gate adjustment, unmatched applicator speed, or flow characteristics of the two materials is not certain. Some custom applicators say that prilled urea tends to meter at higher rates than other materials. This phenomenon may be common of all spherical particles. The effect of granule size and shape on volumetric metering needs to be further studied.

Figures 12 through 14 are patterns produced with the widened vee. This adjustment eliminated the W-shaped pattern which was prevalent among the previous forestry grade patterns. Forestry grade 2 urea was used in these tests. A 65-foot swath width was obtained with the forestry grade urea using the wider inverted vee and the higher spinner speed. These results suggest that larger granules can be broadcast better if placed nearer the centers of double spinners.

Combinations of chute adjustments other than those listed in table 1 were used but the resulting patterns were unacceptable and were thus omitted.

Observations of the departure of fertilizer from the double-spinner spreader revealed some problems that might be eliminated by altering the fertilizer delivery system or spinner design. A considerable amount of fertilizer is deflected upward during application. This is verified by the abrasive damage sustained by the lower part of the rear plate and the chute adjustment crank. Fertilizer distribution can be better controlled if the path of fertilizer departing the spinner is not obstructed. Raising the discs would help solve this problem. The 17-inch drop from the apron to the discs (figure 1) enables granules to attain an appreciable vertical velocity. Inns and Reece showed that vertical velocity of granules is not lost during impact with the spinners, thus, particles move up or down on the blade surface until they leave the spinner (7).

Tilt of the discs causes granules which bounce upward from the discs to bounce toward the inner edges. The granules then depart from the spinner blades in the rearward direction. Granules bouncing from horizontal discs are not displaced inward and thus are not directed toward the rear of the applicator.

Bolts which hold down the blades are on the side of the blades where they will block the path of sliding granules (figure 1). This adds more randomness to the trajectories of granules and obstructs the path of granules leaving the spinners.

Two pattern tests were made with a single-spinner spreader. A granular urea and forestry-size sulfur-coated urea were used in these tests. Sieve analyses of the two materials are plotted in figure 15. Bulk density of the sulfur-coated material was slightly higher than that of the granular urea (54 versus 49 pounds per cubic foot). The difference was not considered significant enough to influence spreading characteristics.

The applicator was driven at a speed of 12 mph and spinner speed was measured at 800 rpm. An application rate of 200 pounds per acre was chosen. Wind speeds varied with gusts approaching 20 mph. The applicator was driven parallel to the wind direction to minimize the effect of wind on the lateral distribution of fertilizer.

In these tests forestry-size sulfur-coated urea yielded a swath width of 65 feet with a coefficient of variation of 14.3 percent. Granular urea yielded a 35-foot swath width with a coefficient of variation of 20.7 percent. Spread patterns from the two materials are shown in figure 16.

## *Conclusions*

Granular fertilizer with large particles can be applied in wider swaths than can conventionally sized (minus 6- plus 16-mesh) fertilizer. Spread pattern tests yielded increases in swath width of up to 30 feet. Adjustment in drop location on some double spinners is required. Spreading tests indicated that the large material yielded a wider and more uniform pattern if dropped nearer the centers of double spinners. The adjustments required to obtain the optimum pattern with large granules may vary for different spinner designs. A single-spinner spreader tested under normal use by a dealer produced a swath 65 feet wide with large granules and only 35 feet wide with prilled urea.

Larger granules produced significantly less dust when broadcast than did the prilled urea and thus would be less likely to drift. Problems associated with the buildup of urea dust on the chute in humid weather also could be reduced with the larger granules.

More work is required to determine if any differences in metering rates will occur with larger materials. If blended with conventionally sized granules, forestry-size granules will segregate; using such materials in blends is not recommended. The advantage of the large granules can be realized in direct application. The wider swaths attainable with large granules will reduce application costs and shorten the time required to broadcast direct applied fertilizer.

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**Table 1. SPINNER AND CHUTE ADJUSTMENTS FOR SPREAD PATTERN TESTS[a]**

| Test Number | Spinner Speed (RPM) | Chute Location[b] | Inverted Vee[c] | Gate Opening (inches) |
|---|---|---|---|---|
| 1 | 600 | Center | Narrow | 1 |
| 2 | 800 | Center | Narrow | 1 |
| 3 | 600 | Forward | Narrow | 1 |
| 4 | 600 | Rearward | Narrow | 1 |
| 5 | 600 | Rear Plus | Narrow | 1 |
| 6 | 600 | Rearward | Narrow | 2 |
| 7 | 600 | Center | Narrow | 2 |
| 8 | 600 | Center | Wide | 1 |
| 9 | 600 | Rearward | Wide | 1 |
| 10 | 800 | Rearward | Wide | 1 |

a. Applicator speed was 5 mph in all tests. Application rates were 200 and 400 pounds per acre.

b. Center chute location is shown in figure 1. Forward and rearward locations were 9/16 inch to the front and rear of center. Rear plus was 1 inch rearward of the center position.

c. The narrow vee position is shown in figure 1. The wide vee was 9½ inches wide instead of 8.

**Table 2. SWATH WIDTHS[a] AND COEFFICIENTS OF VARIATION[b] OF THE SPREAD PATTERNS**

| Test Number | Prilled Urea | | Forestry Urea | |
|---|---|---|---|---|
| | Swath (ft) | C.V. (%) | Swath (ft) | C.V. (%) |
| 1 | 40 | 12.4 | 35 | 20.6 |
| 2 | 35 | 13.6 | 35 | 13.6 |
| 3 | 35 | 13.8 | 35 | 33.7 |
| 4 | 45 | 14.6 | 60 | 18.9 |
| 5 | 50 | 15.0 | 60 | 22.6 |
| 6 | 30 | 18.4 | 35 | 20.2 |
| 7 | 45 | 17.3 | 35 | 23.0 |
| 8 | 35 | 22.0 | 55 | 31.6 |
| 9 | 45 | 22.8 | 35 | 34.8 |
| 10 | 35 | 22.6 | 65 | 19 |

a. Swath widths are a multiple of the pan spacing (5 feet). A width of 35 feet was the narrowest spacing for which a coefficient of variation could be calculated.

b. Coefficient of variation is the standard deviation of the sample weights divided by the mean and multiplied by 100. Coefficient of variation is used because of the wide variations in the mean.

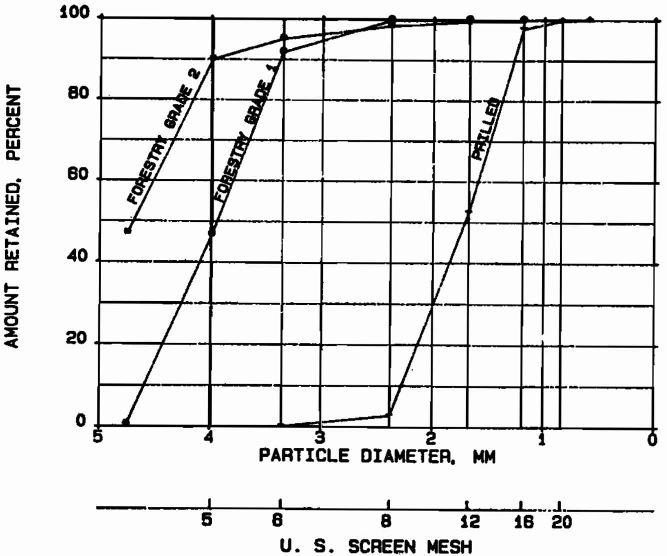


FIGURE 2

SIEVE ANALYSES OF UREA

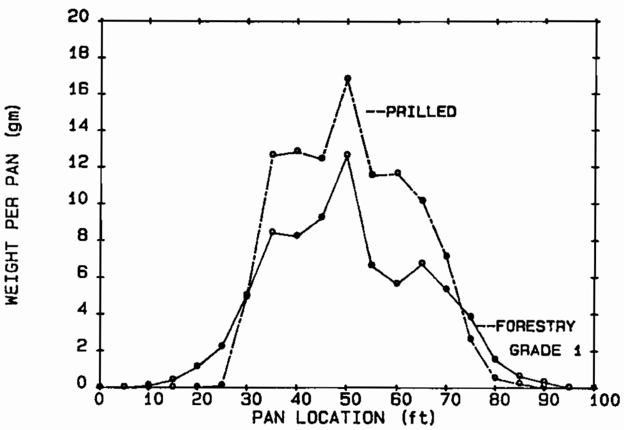


FIGURE 5 SPREAD PATTERN TEST 1

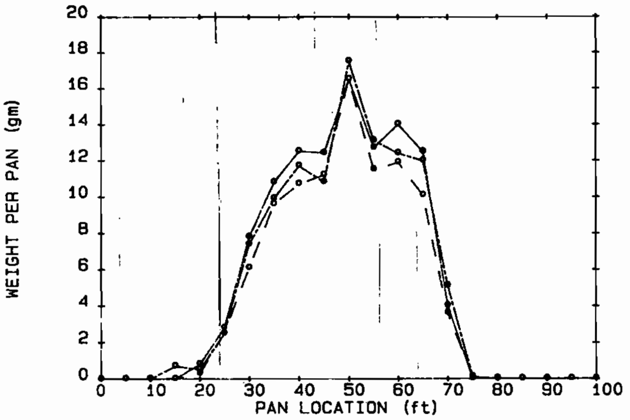


FIGURE 3

REPLICATIONS OF SPREAD PATTERN PRILLED UREA

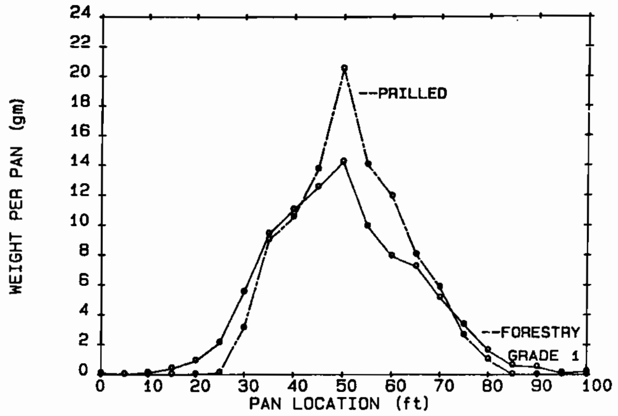


FIGURE 6 SPREAD PATTERN TEST 2

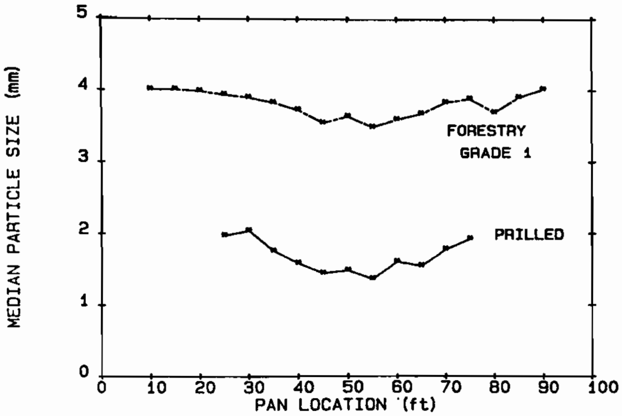


FIGURE 4
BALLISTIC SEGREGATION DUE TO SIZE

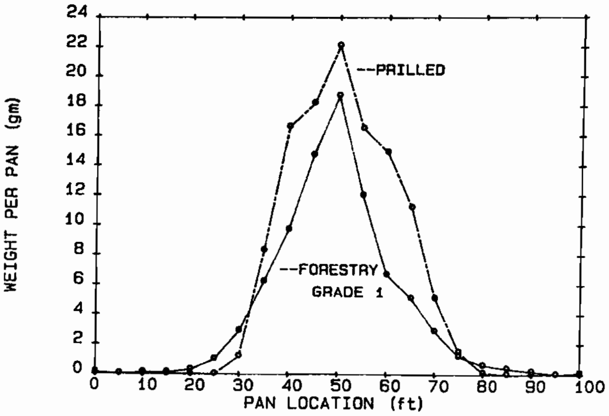


FIGURE 7 SPREAD PATTERN TEST 3

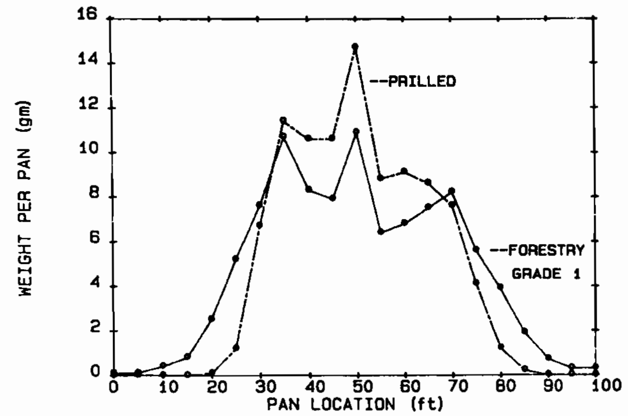


FIGURE 8 SPREAD PATTERN TEST 4

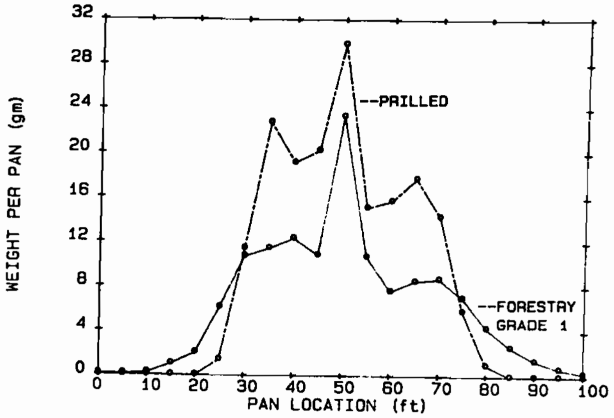


FIGURE 11 SPREAD PATTERN TEST 7

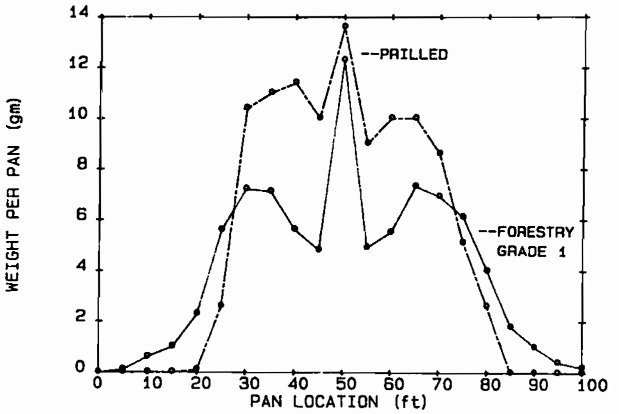


FIGURE 9 SPREAD PATTERN TEST 5

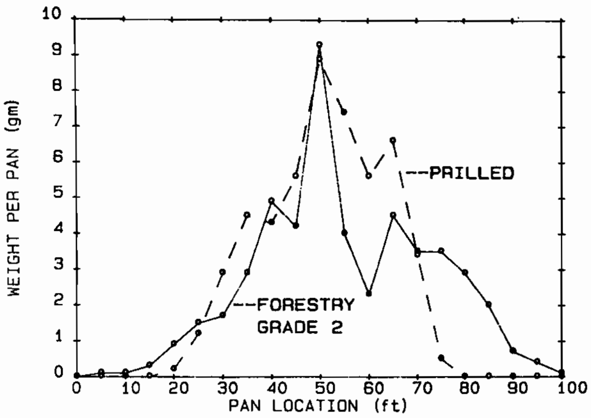


FIGURE 12 SPREAD PATTERN TEST 8

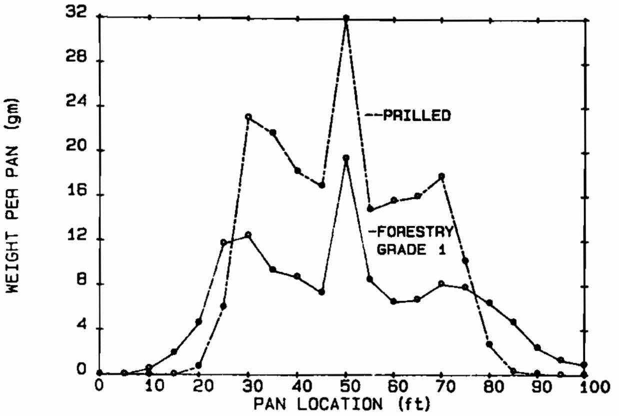


FIGURE 10 SPREAD PATTERN TEST 6

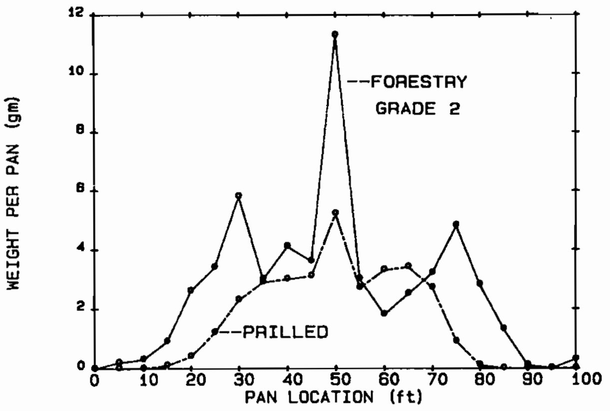


FIGURE 13 SPREAD PATTERN TEST 9

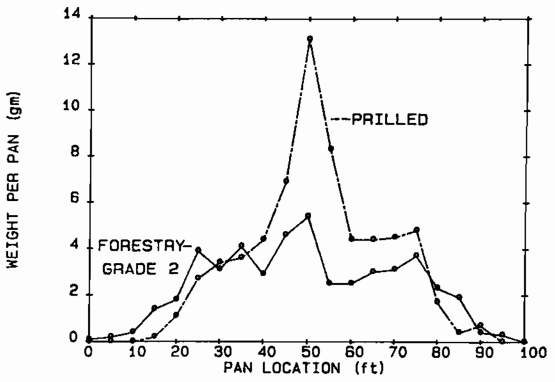


FIGURE 14 SPREAD PATTERN TEST 10

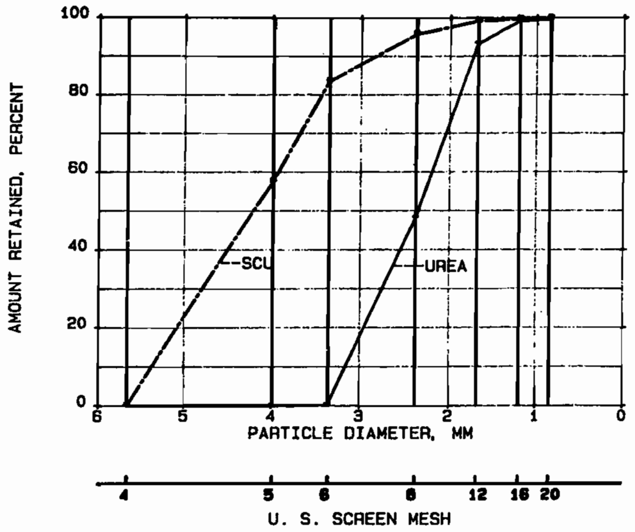


FIGURE 15
**SIEVE ANALYSIS OF SCU**

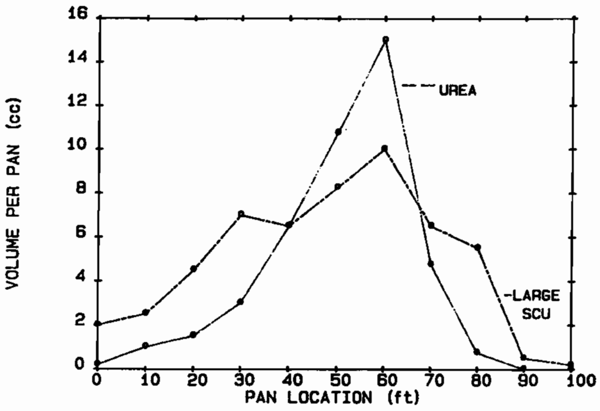


FIGURE 16
SPREAD PATTERNS SINGLE SPINNER

# Thursday, October 27, 1983

## Final Session Moderators:

## Paul J. Prosser, Jr. - Joe S. Drewry, Jr., P.E.

## Summary of Business Meeting:

Chairman Blenkhorn addressed the meeting briefly. Vice Chairman Medbery commented on the passing of the following members of the Round Table, mentioning their contributions to the fertilizer industry and The Fertilizer Industry Round Table:

Leo Cohen
Dean R. Gidney
Richard Powell
O. H. Sale
Derrick H. Stassfort

Moderator for Business Meeting - Paul J. Prosser, Jr., Secretary-Treasurer

1) The following Financial Statement was read to the membership:

### * FINANCIAL STATEMENT *

*October 22, 1982 to October 24, 1983*

| | | |
|---|---|---|
| CASH BALANCE—October 22, 1982 | | $23,118.31 |
| **Income October 22, 1982—October 24, 1983** | | |
| Registration Fees—1982 Meeting | $14,754.00 | |
| Sale of Proceedings | 2,072.81 | |
| Contribution—Cocktail Party Fund | 300.00 | |
| Total Receipts October 22, 1982 to October 24, 1983 | | $17,126.81 |
| Total Funds Available October 22, 1982 to October 24,1983 | | $40,245.12 |
| **Disbursements October 22, 1982 to October 24, 1983** | | |
| 1981 Proceedings, including postage, etc. | $16,132.88 | |
| 1982 Proceedings, including postage, etc. | 19.74 | |
| 1982 Meeting Expenses | 2,900.19 | |
| Miscellaneous Expenses, including postage, stationery, etc. | 363.50 | |
| Directors Meetings | 1,121.03 | |
| 1983 Meeting—Preliminary Expenses | 1,198.55 | |
| Disbursement Cocktail Party Fund | 90.72 | |
| Total Disbursements October 22, 1982 to October 24, 1983 | | $21,826.61 |
| CASH BALANCE—October 24, 1983 | | $18,418.51 |
| Less Reserve for Cocktail Party Fund | | 432.74 |
| Total Cash Available October 24, 1983 | | $17,985.77 |

Respectfully submitted,

PAUL J. PROSSER, JR.
Secretary-Treasurer

2) Mr. Prosser reported that the registration for the 33rd Annual Meeting is 182, off about 25% from the 1982 meeting.
3) Mr. Prosser reported that, for budgetary considerations, the printed Proceedings for the 33rd Annual Meeting would not carry the questions and answers sessions as in previous years.
4) Mr. Joe Reynolds, Jr.—Chairman of the Nominating Committee—presented the following slate for consideration as members of the Round Table Board of Directors:

   Pierre Becker—COFAZ (France)
   Donald P. Day—Texasgulf Chemicals Company
   Michael R. Hancock—The Andersons
   Mabry M. Handley—I.M.C. Corporation
   Dr. Ole H. Lie—Norsk Hydro (Norway)
   William H. Paulson—Royster Company
   John E. Rednour—Mississippi Chemical Corporation
   Roy D. Space—Agrico

   Upon motion made and seconded, the Round Table members present elected these gentlemen to the Board of Directors.
5) Mr. Tom Athey, Chairman of Meeting Dates and Places Committee, as well as the Entertainment Committee, informed the membership that the 34th Annual Meeting of the Round Table is scheduled for October 30, 31 and November 1, 1984 in Baltimore, Maryland at the Hyatt Hotel. He further thanked the following hosts for the previous night's cocktail Party:

   ATLANTA UTILITY WORKS
   BECHTEL, INC.
   BIRD MACHINE COMPANY, INC.
   COMMONWEALTH LABORATORIES, INC.
   DAVY McKEE CORP.
   FEECO INTERNATIONAL, INC.
   FESCO, INC.
   J&H EQUIPMENT, INC.
   JACOBS-DORRCO DIVISION
   GILMAN BAG COMPANY
   KIERNAN-GREGORY CORP.
   PETROCHEMICALS COMPANY, INC.
   THE PROSSER COMPANY, INC.
   RENNEBURG INTERNATIONAL, INC.
   THE A. J. SACKETT & SONS CO.
   STEDMAN FOUNDRY AND MACHINE CO., INC.
   UREA TECHNOLOGIES, INC.
   D. M. WEATHERLY COMPANY
   HAVER FILLING SYSTEMS. INC.
   SUBSIDIARY OF HAVER & BOECKER, WEST GERMANY
   WEBSTER INDUSTRIES, INC.

6) Mr. Walter J. Sackett, Jr., Chairman of the Public Relations Committee, reported that press releases regarding the Round Table activities are going to 28 publications, and that advertising in 1983 was printed in Farm Chemicals and Fertilizer Progress.

# Update on Operating Experience of Jacobs-Dorrco Two Phosphoric Acid Plant at Gardinier

*David W. Leyshon*, **Technical Manager**
**Jacobs-Dorrco Div.**
and *Paul S. Waters*, **Technical Manager**
**Jacobs Engineering Group, Inc.**

In September 1982, Jacobs Engineering Group Inc. announced the successful startup and initial operation of their new JACOBS-DORRCO TWO phosphoric acid reaction system. The reaction system is an integral part of a $39 million phosphoric acid expansion and modernization project which was completed for Gardinier, Inc., near Tampa, Florida.

The project included the totally new JACOBS-DORRCO plant, which employs wet rock grinding and which also includes two single stage evaporation systems with fluosilicic acid recovery. In addition, Jacobs did the conceptual design and engineering for the conversion of an existing phosphoric acid line to wet rock slurry feed.

## *ONE OF WORLD'S LARGEST PHOSPHORIC ACID LINES*

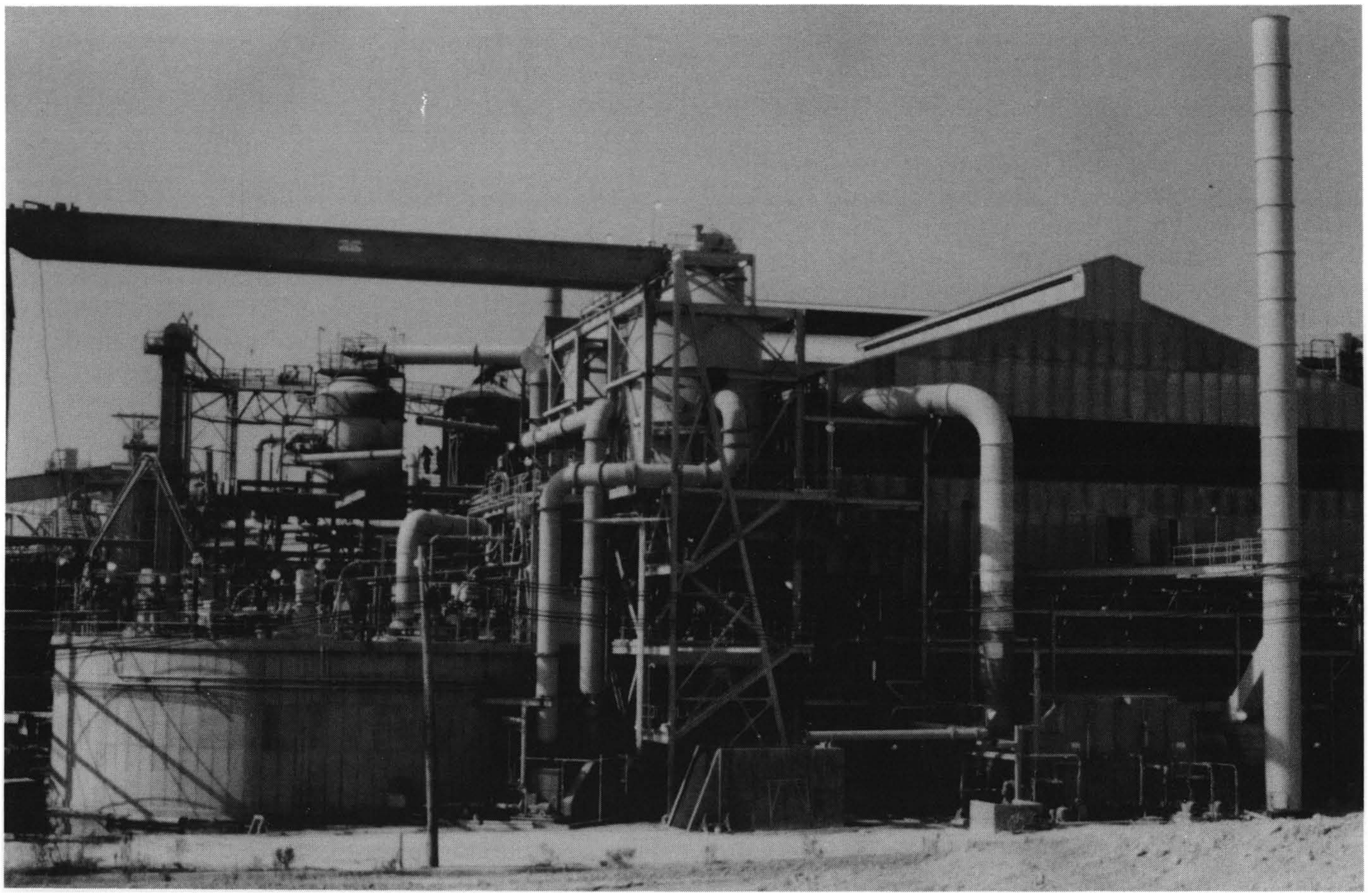
The JACOBS-DORRCO TWO Phosphoric Acid Plant is rated at a nominal 1,300 short tons of $P_2O_5$ per day. Currently, the plant is operating normally at about 1,800 short tons per day which may well make it the world's largest single line plant in terms of $P_2O_5$ output.

The plant consists of a JACOBS-DORRCO TWO annular concrete reactor, two vacuum coolers in parallel and a Bird 30-D tilting pan filter. A view of the reactor, coolers and filter building is shown in Figure 1. The plant is equipped with an overhead crane for reactor maintenance and a cross flow scrubber shown on the right.

## *SMALL BUT EFFICIENT REACTOR*

The JACOBS-DORRCO TWO reactor is similar in configuration to over twenty-five Dorrco Single Tank Reactors built since 1963. It represents an optimization of modifications made by Jacobs and the owners of many of the reactors, particularly in Florida.

Figure 2 shows the flow pattern as it exists in the Gardinier Reactor and indicates where rock slurry and 98% sulfuric acid are added. The Reactor provides a controlled combination of slurry recirculation



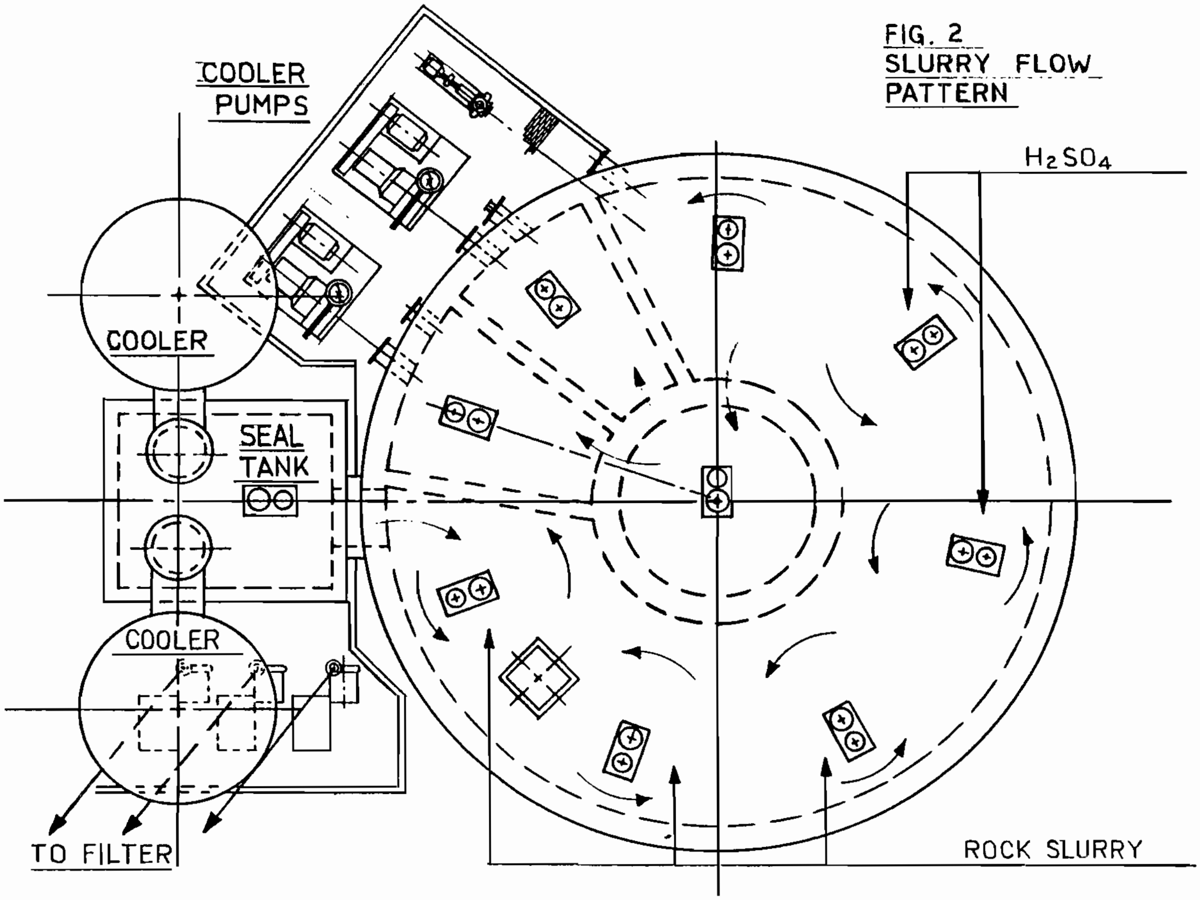


FIG. 2
SLURRY FLOW PATTERN

by means of the cooler feed pumps and by back-mixing from agitator to agitator. The combination is a very effective utilization of energy and makes it possible to use a smaller reactor than would otherwise be possible.

Dye studies were conducted on the Gardinier reactor, with and without the cooler pumps in service. For the level of agitation and back-mixing existing in that system, approximately half of the effective slurry recirculation is due to back-mixing and half due to the external slurry flow through the coolers. The mixers in the annular digestion zone are relatively under loaded, drawing only about 65% to 70% of motor full load. This is somewhat less than the design called for but since plant performance has been excellent there has been no consideration given to either speeding up the agitators or enlarging the impellers. The mixers, six at 300HP, supplied by Philadelphia Gear, run very smoothly at steady amperage with no evidence of interaction.

After about 9 months of operation the reactor was drained and inspected. The annulus was particularly clean and no scaling or abrasion was evident. A Dorrco annular reactor of similar concrete construction, with Atlastic membrane and carbon brick, has been in operation in India for over 15 years without incident.

The Gardinier reactor is currently operating at less than 3 hours detention, at 29% $P_2O_5$ product acid strength and relatively high $P_2O_5$ recovery considering that the filter loading is about 1.0 $STP_2O_5$ per sq. ft. (about 10 $TP_2O_5$/SQM. of effective area). At 1,800 STPD the reactor volume is about 0.90 to 0.95 $M^3/MTP_2O_5$ to put the figures another way.

## *EASE OF PROCESS CONTROL*

One of the very pleasing aspects of the JACOBS-DORRCO TWO reactor has been the ease of process control, including product acid strength, and particularly the free or total sulfate level of the liquid phase.

The reactor has handled relatively hard, coarse rock with over 6% + 35 mesh at high rates without problems. The Gardinier operator runs a sulfate titration once per hour by a proprietary (Gardinier) "TXS" method. These determinations are used to adjust the $H_2SO_4$ feed stream. Seldom do the readings during a 24 hour period vary by more than $\pm 0.2\%$ to $\pm 0.25\%$ from the control figure which is usually about 2.6% total $H_2SO_4$ in the liquid phase. The plant also has an Albright and Wilson Sulfate Analyzer located to sample slurry from the vacuum cooler feed compartment. The results are plotted in the control room and used as a backup to the TXS Method. Readings by the A & W instrument are even more uniform.

While the reactor is relatively small, it does have a substantial body of uniform liquid and this helps to maintain good sulfate control even though the rock feed slurry can vary in moisture content from about 60% solids up to 68% solids. The Dorrco annular reactors at other plants in Florida have also worked well on wet rock slurry feed and in fact were the first phosphoric acid systems to use slurry feed.

## *MAINTAINING PRODUCT ACID STRENGTH*

Generally, many plants which run high rates on Florida rock do so by allowing the product acid strength to slip to 28% or even 27% $P_2O_5$. The Jacobs-Dorrco Two Plant has several features to hold acid strength.

First, during the start up and performance testing, there was a very effective cloudy port configuration on the filter valve (a 30-E on a 30D filter). The cloudy port had its own seal compartment in the filtrate seal tank which made possible the collection of liquor samples and a rough evaluation of the flow. This made it possible to adjust the coudy port bridge properly. The dilution across the filter at design rates has been low, about 0.5% to 0.7% $P_2O_5$, as shown on Table 2.

In addition, the vacuum cooler pumps are Warman slurry pumps, which have a partial dynamic seal, resulting in only about one gpm dilution water for each seal. Also double mechanical seals on filter feed and filtrate pumps keep pump dilution at a minimum.

## *ENERGY SAVINGS*

The reactor configuration, with a center compartment, cooler feed compartments and a bottom slurry feed point for the cooler feed pumps, has resulted in a relatively low quantity of $CO_2$ and non-condensibles existing to the vacuum system. This has meant that only one vacuum pump of 250HP was required for the entire cooling at the 1,800 TPD rate.

At the higher output rates of 1,800 $TPDP_2O_5$, the power consumption in the reactor, coolers and filter remains essentially the same as at the design rates. The power savings are, of course, substantial, the net resulting being a KWH consumption for the battery limits equipment of about 40KWH/T $P_2O_5$ or less.

Jacobs now offers an improvement over the Gardinier arrangement, a further optimization of power, by using high flow type mixers (except at No. 1 and No. 2 positions where high shear is required for the rock addition). In addition, the cooler elevation is reduced and the cooler vacuum is used to assist in moving slurry through the cooler. In the Jacobs design, the circulating pumps can be located on either the feed or discharge side of the cooler and are specified with adequate head to handle the wide range of boiling pressures, and liquid levels necessary for proper process control. The lower level cooler further reduces pumping power by 400 to 500HP in large (1,000 to 1,800 TPD $P_2O_5$ plants). A further advantage

### TABLE I
### NOVEMBER 1982 RUN
### Jacobs Phosphoric Acid Plant at Gardinier 1372 STPD
### PRODUCTION DATA
### Rock: 30.7% $P_2O_5$, 45.5% CaO

| Date | Rock TPH | Grind %+35 | $P_2O_5$ LOSS | Product %$P_2O_5$ |
|---|---|---|---|---|
| 11/6 | 200 | 3.7 | 4.02 | 29.2 |
| 11/7 | 200 | 3.8 | 3.41 | 29.0 |
| 11/8 | 200 | 3.8 | 3.95 | 29.1 |
| 11/9 | 200 | 4.0 | 3.67 | 29.1 |
| 11/10 | 188 | 4.8 | 3.75 | 28.8 |
| 11/11 | 200 | 4.7 | 4.14 | 28.9 |
| 11/12 | 175 | 3.3 | 4.11 | 29.9 |
| 11/13 | 200 | 3.0 | 4.46 | 29.1 |
| 11/14 | 200 | 3.3 | 4.14 | 28.2 |
| 11/15 | 142 | 1.6 | 3.91 | 29.1 |
| 11/16 | 196 | 3.4 | 4.60 | 28.4 |
| 11/17 | 200 | 4.0 | 3.94 | 29.7 |
| 11/18 | 200 | 3.7 | 3.84 | 29.6 |
| 11/19 | 200 | 4.7 | 3.41 | 28.4 |
| 11/20 | 200 | 5.6 | 3.58 | 29.5 |
| Average | 196 | 3.9 | 3.92 | 29.1 |
| | | | | 1388 TPD $P_2O_5$ |

### TABLE 2
### FEBRUARY TEST RUN
### STRENGTH AND RECOVERY
### Rock: 30.5% $P_2O_5$

| Date | Shift | Mill + 35% | Product Tons $P_2O_5$ | Product %$P_2O_5$ | Reactor %$P_2O_5$ | Filter Loss % |
|---|---|---|---|---|---|---|
| 2/24 | 2 | 5.6 | 440.2 | 28.7 | 29.6 | 5.63 |
| | 3 | 4.6 | 447.5 | 29.4 | 29.2 | 5.27 |
| 2/25 | 3 | 5.3 | 452.1 | 28.6 | 29.4 | 4.52 |
| 2/26 | 1 | 6.7 | 472.5 | 28.8 | 29.5 | 3.89 |
| | 2 | 5.1 | 471.6 | 29.2 | 29.8 | 4.31 |
| | 3 | 5.2 | 411.0 | 29.0 | 30.1 | 3.61 |
| 2/27 | 1 | 6.1 | 455.1 | 28.7 | 29.6 | 4.18 |
| | 2 | 4.1 | 468.4 | 28.1 | 28.8 | 4.81 |
| | 3 | 4.8 | 467.8 | 28.7 | 29.5 | 4.14 |
| Average | | 5.3 | 454.0<br>(1362TPD) | 28.79 | 29.49 | 4.48 |

is that the down legs, which are full at all times in this arrangement, require less descaling.

## *PERFORMANCE TEST RESULTS*

After commissioning in mid September, 1982, the plant was producing at design rates in less than 10 days. During November, 1982 plant performance was measured over a 15 day period while operating on 67–69 BPL rock. As shown in Table 1, the plant performed above design rate with recovery across the filter above 96% of the $P_2O_5$ feed and product acid above 29.0% $P_2O_5$.

The official performance test run was made in February using the rock shown in the last column of Table 3. This 65 BPL material was two to three meshes coarser than the design rock, contained an excessive amount of slimes, about 3.6% minus 200 mesh and had a harder Bond Work Index. The performance on this material is given in Table 2. The plant performed exceedingly well on even this material. A comparison of the rock expected with that used in both periods is given in Table 3.

**TABLE 3**
**GARDINIER ROCK**

| Mesh | Specification | Cumulative % + November 1982 | February 1983 |
|---|---|---|---|
| 3 | 5.9 | 8.3 | 17.9 |
| 8 | 23.6 | 34.0 | 45.9 |
| 14 | 44.2 | 54.0 | 74.4 |
| 28 | 61.1 | 70.0 | 85.9 |
| 48 | 77.9 | 82.5 | 91.6 |
| 100 | 95.2 | 95.0 | 95.8 |
| 200 | 99.2 | 97.5 | 96.6 |
| Hardness BWI | 15.4 | — | 16.1 |
| $P_2O_5$ | 30.0 | 30.7 | 30.1 |

The grinding system, 200 TPH open circuit, was designed to produce less than 4% + 35 mesh. However, due to the coarser and harder feed in February, the acid plant feed was over 5% + 35 mesh.

In subsequent months since the February performance test, the plant has reached operating rates of 260 TPH of rock, above 1,800 TPD $P_2O_5$, at product acid strengths and recovery close to that at design rate.

## *IMPROVEMENTS AND MODIFICATIONS*

A few modifications have been made in both the attack system and the filter system by Gardinier. In the attack system, steam ejectors were installed on both flash coolers due to the availability of high pressure steam and the corrosion problems with the cast iron vacuum pumps. Gardinier has also installed a special pump tank to use only the amount of water required for filter wash to condense the ejector steam so that the amount of low pressure steam required is reduced dramatically.

A sulfuric acid mixer has been added at the No. 1 Agitator where 50–60% of the sulfuric acid requirement is mixed with recycle acid from the filter. The dip tubes which are used to add the balance of the sulfuric acid at Agitators No. 4 and No. 5 have been a problem. They were originally 14 feet long of 316 ss lined and covered with thin Teflon. The thin Teflon buckled and the stainless was attacked by the hot sulfuric. Even thicker Teflon linings were not available in one piece longer than 10 feet, and threading the tube to the flange has been a problem. A shorter tube with a molded flange presently appears to be the best solution.

The major changes on the filter were associated with the cloth wash system. The timing crown was modified to bring the cake discharge on earlier. A second spray bar was installed to provide more wash water and allow a full pattern to be directed at both edges of each pan. The wash water is heated by ejector steam.

The gypsum pumps were changed from a single stage high head refractory lined pump to two rubber lined pumps in series with somewhat higher head from the two pumps.

The cross flow scrubber has performed very well in terms of emissions. However, the mesh mist pad has been a cleaning problem and was replaced with a Chevron type entrainment separator.

As always, in order to maximize production, a few pumps and motors were changed to allow operation at about 140% of the guarantee rate. Both recovery and product strength are acceptable and Gardinier tells us that, as production pressures mount, more of their engineering ingenuity and operations expertise may well result in their operating the first 2000 TPD single train phosphoric acid plant.

# Innovations in Potash Warehousing

*Andrew Elliott*
Manager, Planning
Potash Corporation of Saskatchewan
Sales Limited

## I. *INTRODUCTION**

Until very recently, potash producers stored product almost exclusively at minesites. Minesite warehouses were generally of necessity quite large to allow continuous mining and processing throughout the year and to meet pronounced seasonal fertilizer demand. At present, an increasing number of producers are storing product in the market.

This shift in potash storage is a major innovation in marketing potash. The purpose of this paper is to discuss the reasons for this development, to identify the kinds of warehouse structures which have made in-market warehousing possible, and to speculate on the future implications of this development.

## II. *THE GENESIS OF IN-MARKET STORAGE*

The major impetus for in-market storage came from the changing nature of the potash distribution system. Throughout most of the 1970s, potash moved from mine to market on a single car basis, primarily in 100-ton capacity covered hopper cars. The major problem during this period was a recurring shortage of rail cars. The most disturbing feature of the potash distribution system was rapidly escalating rail rates. Between 1975 and 1982, single car freight rates from Saskatchewan to the U.S. midwest increased at an average annual rate of 10.7 per cent. Today, the single car rates from Saskatchewan and New Mexico to Illinois are U.S. \$48.83 per short ton and U.S. \$51.32 per short ton respectively.

For a low-value, high volume, and competitive bulk commodity like potash, such rates are simply unbearable, particularly with respect to competition from imported potash. In order to prevent market erosion and freight rate escalation, to ensure a guaranteed supply to the market place on a year-round basis and to reduce dependence on rail car availability, efforts began in Canada several years ago to find more efficient ways to deliver potash to customers.

Taking the lead from initiatives developed by CN Rail in the mid-1970s, we at PCS Sales developed a solid train/distribution center concept. This concept has various implications for the distribution system and for the operation of warehouses. The basic implication is that transportation costs are lower; it is significantly less expensive for rail carriers to operate a solid train in continuous service from several origins to several destinations than to move single cars to several thousand destinations. This is revealed in the fact that the single car rate from Saskatchewan to Illinois reflects a premium of US $15–16 per ton over the solid train rate.

A related development in potash distribution is a shift to multimodal transportation systems. A major system associated with potash warehousing is a rail/water system. Under this system, trainloads of potash move from our Saskatchewan mines to Thunder Bay where product is transferred to lake carriers which haul up to 30,000 tons of material to various ports on the Great Lakes and the St. Lawrence River. At these ports, potash is discharged by self unloading vessels either onto a pad or into a building at rates of up to 5,000 tons per hour.

The establishment of more efficient transportation systems was only one portion of the distribution puzzle. There remained the questions of where to go and what characteristics to look for in a storage building. The answers to both of these questions define the nature of the warehouse/distribution center itself. This will be discussed in greater detail in the following sections.

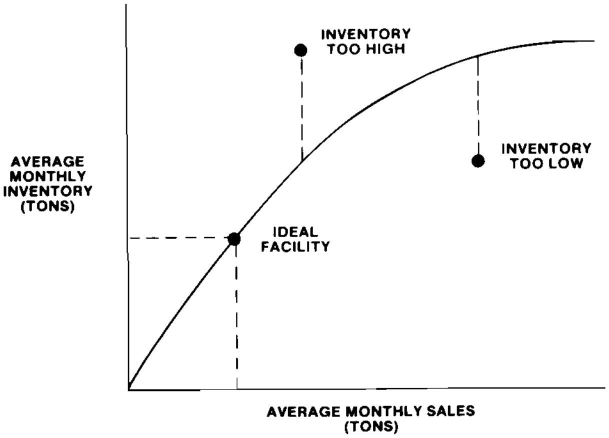
In short, potash warehouses in the marketplace are the logical consequence of efficient transportation systems. They have the added advantage of shifting peak transportation requirements from the rail mode to the truck mode which is more capable of handling peaks. For customers, it means that potash is available when it is required.

## III. *THE DESIGN OF POTASH WAREHOUSES*

A typical warehousing strategy attempts to relate anticipated sales with an optimum inventory. Figure 1 shows a standard approach based on a non-linear relationship between average monthly sales and average monthly inventory. Any deviation from the function shown represents a need to adjust inventory. This relationship also shows that as sales increase, the inventory/sales ratio decreases; in terms of the warehouse operation, this means increasing turnovers. While no "magic number" exists for turnovers, it is generally considered that two to three turns per year is a minimum. As for a maximum, some grain terminals in the U.S. midwest have reported up to 25 turns per year; potash marine terminals at Vancouver, B.C. have experienced up to 17 turns.

The potash industry deviates from this "standard" in two respects: first, demand is seasonal and second, there is a requirement to store several grades of material. The first problem is met by sizing warehouses to meet peak demand and second is met by separate bins or buildings.

**INVENTORY - SALES RELATIONSHIP: TYPICAL WAREHOUSE**



To illustrate the strategy in designing warehouses, the approach taken by PCS Sales in serving the Ontario market for potash has been chosen for several reasons. The size of the market, the dimensions of available land, and the economics of existing transportation systems combined to result in a unique set of circumstances. The property selected by us was at Port Stanley, Ontario, located on Lake Erie. While potash has been and continues to be stored at this site on outside pads, covered storage to give the best protection to the product from the elements was preferred.

This property could have accommodated a long "barrel" shaped building; however a structure of the required size would have used up most of the available land. A "dome" style of building was selected and three domes were erected to accommodate grade splits.

Port Stanley is not accessible by rail. Even if it were, it is likely that a rail/water combination from Saskatchewan via Thunder Bay, Ontario to Port Stanley would be a lower cost system. The fact that this site is accessible by water and the fact that existing Great Lakes carriers use self unloading vessels meant that modifications to the standard dome (commonly used within the Province of Ontario for storing road salt) would be required for unloading directly into the building.

The dome structure has a number of attractive features as a potash storage facility. The structure can be designed to envelop a natural pile of material. With a retaining wall rising about 6 feet (as is the case at Port Stanley) to withstand both material and handling equipment pressure, potash never touches the shell of the building. In addition, the high, clear span interiors give unobstructed operation of materials handling equipment.

The particular style of dome structure used by PCS Sales is known under both U.S. and Canadian patent legislation as the "Fitzpatrick System." The storage system is manufactured in Canada exclusively by The Bulk-Store Structures Ltd. of Erin, Ontario. Project management, including design and construction for the Port Stanley operation were handled by Sub-Con Industries of Erin, Ontario.

The dome structure is totally self-supporting and factory produced panels are simply bolted together ring by ring. This dome is available from 50 feet to 150 feet clear span. Even on the largest structure, panels never exceed 8 feet in width. The shell can be covered with either asphalt shingles or aluminum siding. The dome sits on a floating concrete ring or wall foundation placed directly upon an asphalt or concrete pad. This system requires a minimum of excavation and foundations are easily installed using pre-engineered forms. The standard construction time of a 100 foot dome is estimated to be about 5 days with three persons after site preparation and the laying of the retaining wall.

The superstructure itself derives its economy from its unique behaviour as a thin shell. In this manner, the applied snow and wind loads are carried to the foundations, primarily as axial forces in the lumber and plywood skin rather than as bending and shear forces requiring heavy glulam sections. Indeed, the system so efficiently utilizes the plywood cladding's inherent strength that horizontal and vertical stringers need not exceed 6 in. in depth for the standard dome.

Each dome is designed for a particular volume and type of material. In the case of Port Stanley, there are three domes which can each store about 9,000 tons of potash and about 6,500 tons of urea, 7,500 tons of DAP & 7,000 tons of MAP. They are 136 feet in diameter and 55 feet high. The domes are located on 2.7 acres of land immediately adjacent to water. The decision to use the capability of self unloading vessels to fill the buildings had the benefits of maintaining product quality and avoiding any detrimental impact of double handling. For inland domes, a covered conveyor to unload product either overhead or through the door would be required.

The fact that the structures are filled from self unloading lake carriers entailed a major structural design change, that of a pressure ring on top of the structure. On top of the ring is a hatch for loading potash into the structure from the boom of a self-unloading lake vessel. These compression rings serve to hold the structure together by transferring shell pressure from the walls to the ring.

Hydraulically operated top opening doors were developed to accommodate self-unloading vessels. Door height above grade was selected to suit both the vessel's draft and our product's angle of repose. Fully open, the doors provide a 14 × 20 ft. opening that can accept the fastest unloading rate and largest boom size of any of the vessels in the fleet. The opening's orientation relative to the vessel has been set for each dome to suit its particular set-back from the wharf-face. Design took due account of the presence in the fleet of both stem- and stern-mounted booms.

Unlike a barrel shaped storage facility, the dome structures are completely free of any conveyance equipment. This results not only in a lower initial cost building but also in a building which does not need to support heavy equipment. This in turn leads to lower costs.

Today, single or multiple dome facilities are generally considered to be cost effective up to 30,000 tons of total required storage. Beyond that level, barrel or A-frame type structures appear to be the best way to proceed. To transfer large volumes at high speeds from solid trains high capacity conveyor systems, typically 800 tons/hour, are required. In these situations, structures which can support conveyors are needed.

Potash is loaded out from the domes at Port Stanley by 5 cubic yard front end loaders to trucks with typical loads of 25 tons. The layout provides for truck traffic to move around the perimeter. Provided there is sufficient room within the structure, trucks can be loaded inside during inclement weather.

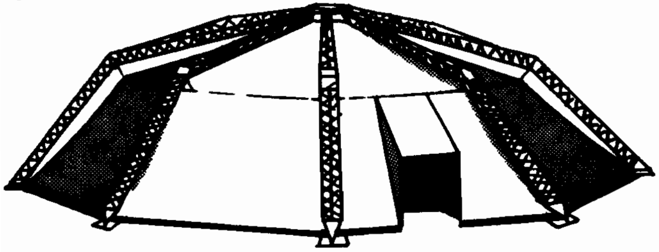
The value of the dome structure as a potash warehouse is evidenced by the fact that PCS Sales is now erecting two 9,000 ton domes at Montreal and is planning to do so at a U.S. location in the near future. The advantages lie in the simplicity of the structure, in a facility that is maintenance-free, in a facility that can be easily modified to suit various kinds of transportation systems, and in that the structure can be taken apart and moved elsewhere.

## IV. *ALTERNATE WAREHOUSE SYSTEMS*

Various warehouse designs are available to persons involved in the distribution and storage of bulk materials such as potash. Discussed below are three typical designs which can serve specific needs of bulk materials storage.

For storage requirements which are extremely uncertain or which are known to be short term in nature, structures which are capable of being erected quickly and which can be dismantled rapidly are particularly well suited. Two such structures are the Maple Instant Structure manufactured by Maple Structures Limited which is affiliated with TBO Ltd. and Sprung Instant Structures of Calgary, Alberta.

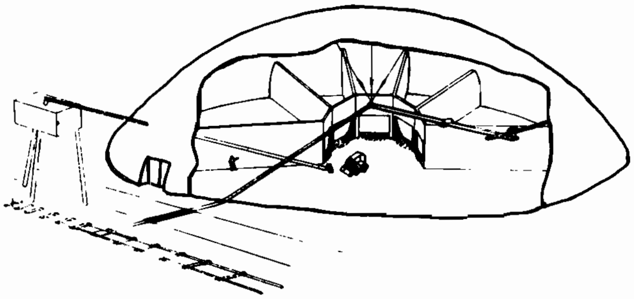
The Maple structure is a lower cost, portable, and weatherproof structure designed for temporary and semi-permanent storage. It consists of a superstructure from which a polyester fabric is hung. It is erected using cables, specially designed hooks and grommets and heavy-duty straps and buckles. The frame is available in either a gable or dome style and is prefabricated according to the specific design required.



The Sprung Instant Structure incorporated the principles of "membrane stress theory". It provides an efficient and stable building with free span coverage. The structure is comprised of fabric panels tensioned between specially designed aluminum arches. The fabric is fire retardent and is a P.V.C. coated polyester scrim. The structure will withstand snow and wind loadings to 60 lb. per square foot and 140 m.p.h. respectively. Standard structures are available in widths from 30 to 120 feet and infinite length. The company claims that about 2000 square feet of structure can be erected per 8 hour working day. Dismantling is about one half erection time.

The Maple and Sprung structures provide ideal bulk storage for short term or uncertain storage requirements. They are also sufficiently strong that they can be turned into permanent structures if necessary.

Another type of storage facility which can meet certain requirements is the Monolithic Dome. This structure is a free span steel reinforced concrete building with a unique construction. First, a membrane of reinforced plastic coated fabric is inflated. Next, urethane insulation is applied to the interior and concrete reinforced with steel is applied to the interior of the insulation to form the structure. The building is firesafe, highly insulated, durable and relatively rapid to construct.



These structures are just a few of the many systems available to meet bulk storage requirements. They reflect the varying needs of distributors for speed of assembly, portability and flexibility as to size.

## V. *SUMMARY*

In retrospect, in-market storage was initially a response to two factors. First, high mine operating rates combined with seasonal demand generated the need for more storage either at the mine or in the market. PCS chose to expand storage in the market to better serve customers. The second factor was price signals from the transportation industry that lower cost distribution systems were available. Producer warehouses are also evidence of a producer's commitment to particular markets, that we are in business for the long term. The availability of storage structures which can dovetail with various transportation modes (both inbound and outbound) has contributed to the expansion of in-market storage which can be tailored to the volume and grade characteristics of individual markets.

Looking ahead, it is likely that we will consolidate in-market storage and increasingly tailor warehouses to the advantages of various transportation systems in order to provide an efficient distribution system responsive to customer requirements. Overall this will translate into a reduction in the volume of producer held inventory in the market and fewer locations as buyer confidence in the potash market returns. The fact that specific transportation advantages may be temporary in nature (such as low barge rates during 1981 and 1982 due to declining coal and grain markets) may also allow temporary and portable storage systems to become part of the market storage system.

While the reduced potash demand of the past few years has not been our preference, it has nevertheless allowed a "breathing space" during which we have been able to reinforce the foundations of our distribution network with innovative ideas and state of the art techniques which benefit customers and producers alike. This will be our strength as our prospects for future potash sales improve.

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*The co-operation and assistance provided by Sub-Con Industries, Sprung Instant Structures, Maple Structures Ltd. and Monolithic Constructors Ltd. is hereby gratefully acknowledged. Helpful advice and assistance was also provided by Messrs. W. R. Caithcart (PCS Sales) and J. Knight (Morrison Hershfield Ltd.). The author alone is responsible for interpretation and conclusions.

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# Draft-Tube Production of Ammonium Phosphate for Granulation or Spray Drying

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## 1. *INTRODUCTION*

Over the last twenty years, much has been written on equipment for bringing about the reaction between ammonia and phosphoric acid, especially by TVA. Many precise details have been published about atmospheric reactors, pressure reactors and, more recently, pipe reactors. Each type has its advantages and limitations.

Norsk Hydro Fertilizers Limited (formerly Fisons Fertilizers) has now incorporated the well proven draft-tube mixing principle into the pressure reactor, the Draft-tube Reactor.

The new design is now operational on a commercial scale and we are glad to have the opportunity at this meeting of The Fertilizer Industry Round Table to make a brief presentation on progress so far achieved.

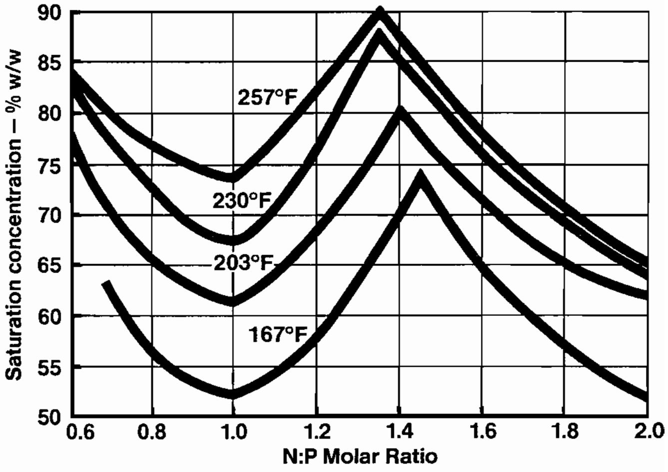
The paper explains the motivation for the development. It outlines the pilot plant and prototype development stages, and the resulting main design parameters. Application of the draft-tube reactor in the Minifos powder MAP and the Norsk Hydro Fertilizers (NHF) DAP process is described in some detail. Finally, the advantages compared with conventional systems are listed.

## 2. *PRESSURE NEUTRALISATION*

Production of fertilizer based on ammonium phosphate became commonplace in the early 1960's. The usual process route practised then, and still employed in many plants today, was to react phosphoric acid with ammonia in a tank at atmospheric pressure.

To maximise the output of a given granulation plant and to minimise the product drying requirement, it is desirable to operate with the lowest possible water content in the ammonium phosphate slurry. The solubility of ammonium phosphate reaches a maximum at a N:P molar ratio of about 1.4:1 and therefore at this point the slurry can be made to flow at the minimum water content. (See Figure 1). Thus the industry established the practise of producing a 1.4:1 molar ratio slurry for subsequent ammoniation to DAP, or alternatively subsequent acidulation to MAP.

**Figure 1. Solubility of Ammonium Phosphates in Water**



A further method of increasing the solubility of ammonium phosphates is to increase the temperature. (See Figure 2). Starting in 1964, Fisons Fertilizers (now Norsk Hydro Fertilizers) explored this possibility and confirmed expectations that, by operating the neutralisation at pressures above atmospheric, increased temperatures could be achieved and a slurry produced with reduced water content. This led to the invention of the Minifos process for powder MAP which by now is very well known and widely used. The technique of pressure ammoniation is also applicable to the production of granular DAP and NPK, and this has been exploited commercially in several plants.

The use of pressure neutralisation is widely protected by Patents.

The operating conditions for several processes producing ammonium phosphates are given in Table 1, below.

Figure 2. Solubility of MAP in Water

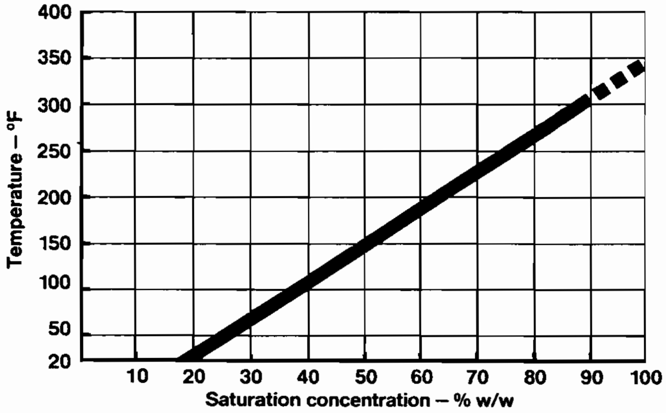


TABLE 1

| | Minifos | DAP | |
|---|---|---|---|
| | | Pressure | Conventional |
| Operating pressure, psig | 30 | 15 | atmos. |
| Operating temperature, °F | 335 | 290 | 250 |
| Molar Ratio | 1.0:1 | 1.4:1 | 1.4:1 |
| Slurry moisture, %$H_2O$ | 10 | 15 | 20 |
| Granulation Recycle Ratio | — | 4:1 | 5–6:1 |
| Drier fuel, lb/t DAP | — | 12 | 18 |

Apart from the obvious advantages of producing a lower moisture ammonium phosphate solution in the reactor, there are several other benefits of the technique. The lower specific volume of the steam evolved from the reactor reduces the cross sectional area required for disengagement of slurry droplets. This results in a smaller reactor which also reduces space requirements within the plant. Operation under pressure also avoids the need for ammonium phosphate slurry pumps. When, on discharge from the reactor, the ammonium phosphate solution is let down to atmospheric pressure, steam flashes-off, thus lowering the moisture content of the material still further. Thus, the moisture level in the solution does not represent that of the discharged ammonium phosphate. In the case of the Minifos process, the ammonium phosphate solidifies into a powder without the need for a separate drying stage at all.

The pressure ammoniation method has been extended to the use of pipe reactors which have been installed for MAP based operations. However the application of pipe reactor technology to DAP systems has not been demonstrated on a significant scale commercially.

## 3. *DRAFT-TUBE REACTOR*

### 3.1 Background

The usual type of vessel employed within the industry for neutralisation of phosphoric acid is the Continuous Stirred Tank Reactor (CSTR). (See Figure 3).

It is normal to have a single central agitator shaft with a single turbine impellor. Phosphoric acid is fed to the surface of the liquor and ammonia introduced through one or more sparge pipes. The ammonium phosphate slurry is discharged from the bottom of the reactor and fed by pump or by gravity to the granulator.

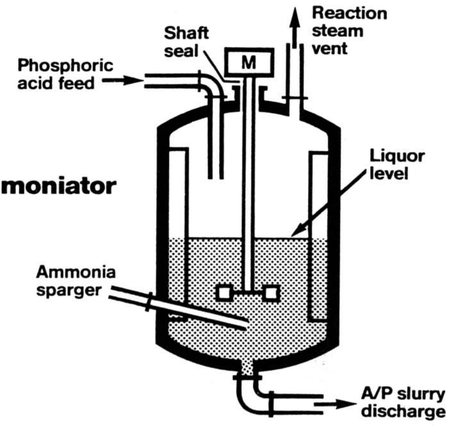


**Figure 3. Pressure Ammoniator**

With a pressure reactor an effective and robust seal is required where the agitator shaft passes through the top of the reactor. Minifos plants have employed a wide range of seal, from the simple stuffing-box to sophisticated steam flushed double mechanical seals. Almost universally the seal has been a problem to maintain in a sound condition and has led to maintenance expense and plant downtime, especially in less developed countries.

The capital cost of agitators and the seal maintenance problem gave us a strong incentive to develop an agitatorless reactor. The Draft-tube Reactor is the outcome.

### 3.2 Outline Description of Draft-tube Reactor

The objective was to exploit the energy released during the reaction to mix the contents of the reactor. This has been achieved by incorporating a draft-tube into the reactor.

The draft-tube section consists of two concentric tubes (see Figure 4). The outer one is closed at the bottom and forms the wall of the reactor. The inner tube is supported to form an annular channel and with equivalent clearance from the bottom of the reactor.

The outer tube is connected at the top to a wider cylindrical section which forms the upper part of the reaction vessel.

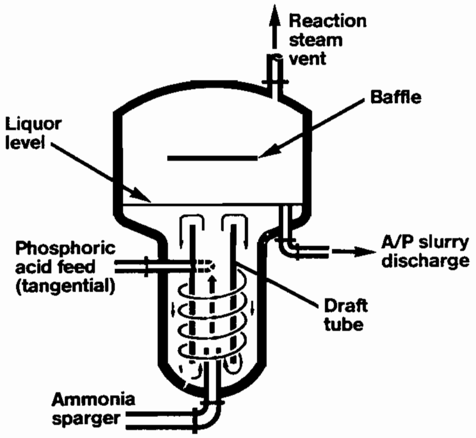


**Figure 4. Norsk Hydro Fertilizers Draft-Tube Reactor**

The reaction mixture fills the reactor to a level part way up the wider upper section. The volume above the liquor level acts as a disengagement space for reaction steam which is discharged from the top of the reactor through a pressure control valve.

Phosphoric acid is fed tangentially into the annulus of the lower section and ammonia is injected through a sparge pipe inserted into the lower part of the inner tube. The exothermic reaction occurs in the draft-tube and causes a reduction in density which creates an upward movement of the reacting mass. The liquor rises up the central tube and descends through the annulus in a continuous circulating motion. A baffle plate is mounted above the draft-tube to avoid excessive entrainment of slurry in the steam.

A high degree of internal mixing is achieved which ensures a very high reaction efficiency.

### 3.3 Development Stages

The first experiments were carried out at our Levington Research Station on the Minifos pilot plant, starting in about 1974. The scale of operation can be judged by the dimensions of the reactor:

Diameter of upper section : 12 in
Diameter of lower section : 4 in
Length of draft-tube : 60 in

and the output from the reactor of about 400 lb/h.

The results were sufficiently encouraging for a replacement reactor required in 1975 at the Fison-UCB factory in Belgium to be designed with a draft-tube. It also had provision to revert to the standard agitator design if necessary.

The leading dimensions are

Diameter of upper section : 64 in
Diameter of lower section : 18 in
Length of draft-tube : 115 in

Ammonium phosphate solution is fed from the reactor to the granulator for incorporation into NPK products.

The output of the plant equates to nearly 8 tons/h of ammonium phosphate. The plant normally operates with a reactor temperature of 310°F and molar ratio of 1.2:1, equivalent to a pH of 5.7. It has operated successfully from the outset, with no serious scaling problems and with low ammonia losses. Installation of the agitator has never been seriously considered.

Tests were carried out when the Fison-UCB plant started up in 1976 to measure the reaction efficiency at a range of output rates, pH and product moistures. The length of the ammonium sparge pipe was varied to simulate different effective lengths of the draft-tube itself.

Investigations at pH 4 to 6.2 showed ammonia losses of less than 1% at the lower pH rising to about 2½% at the normal operating pH of 5.7, and higher at pH 6.2.

Losses of ammonia increased as the operating temperature was raised. The normal value of 2½% at 310°F increased to 4–5% at 320°F.

This sensitivity demonstrates the advisability of minimising the operating temperature to that consistent with obtaining the required solubility. Contrary to Fison-UCB practice, our preferred conditions are 290°F maximum for molar ratios up to 1.4:1 (pH 6.2). Under these conditions, we expect a reactor loss of 2–3%, which is of course recovered in the ammonia scrubber.

The effective length of the draft-tube had little impact on the ammonia efficiency provided it exceeded a minimum value. The optimum length for the Fison-UCB plant was considered to be about 60 in.

The first unit to be incorporated into a new plant was for the Minifos plant built in Turkey and operated by Toros Fertilizer and Chemical Industries. The plant was designed in 1977 and started up in 1981. More details are given later.

## 4. *IMPORTANT DESIGN PARAMETERS*

The principal parameters to be considered in the design of a draft-tube reactor are the diameter and height of the disengagement section, the diameter and length of the inner draft-tube and the diameter of the lower section of the reactor.

### 4.1 Disengagement Section

As with the atmospheric reactor, the cross sectional area of the disengagement section is fixed by the maximum superficial velocity of the reaction steam acceptable without excessive entrainment. By operating under pressure, the specific volume of the steam is reduced and very high steam release rates can be achieved. Typically the range is 130 to 160 lb/ft$^2$/h depending on the product being produced and the operating conditions.

For small reactors, the vertical height is fixed at 1.25 times the diameter. For larger reactors, a fixed height between tangents of about 7 feet has been adopted.

### 4.2 Inner Draft-Tube

It was found during the development stage that the efficiency of ammonia absorption was affected by the recirculation ratio (defined as the ratio of the flow rate of circulating ammonium phosphate to the phosphoric acid feed) and by the flow regime in the inner tube.

As the recirculation ratio rises to about 20:1, the ammonia reaction efficiency increases and thereafter tends to level out. Thus we have elected to design for a recirculation ratio of between 20 and 30:1, which for a given production rate fixes the volumetric flow required through the draft-tube.

Providing these recirculation ratios are achieved, the major factor determining ammonia efficiency is the velocity in the inner tube. We have found that "churn flow" is required for optimum efficiency.

Churn flow is a turbulent form of slug flow in which bubbles of gas constantly collapse and re-form. The velocity at which this occurs is proportional to the inverse cube root of the diameter of the tube.

Combining the required volumetric flow with the criteria for churn flow determines the diameter of the inner draft tube.

The minimum acceptable length for the draft tube has been found to be about 60 in, but in practice we currently allow a safety margin and have fixed 79 in as a standard length.

### 4.3 Outer Diameter

The outer annulus is sized to allow the preferred recirculation ratio with the pressure drop made available by the reaction. Currently this is the least exact part of the design and consequently a safety margin is allowed to ensure that any deviation from the preferred flow rate is upward. This avoids the risk of falling below 20:1 re-circulation ratio and its adverse affect on ammonia efficiency.

## 5. *APPLICATION OF THE DRAFT-TUBE DESIGN*

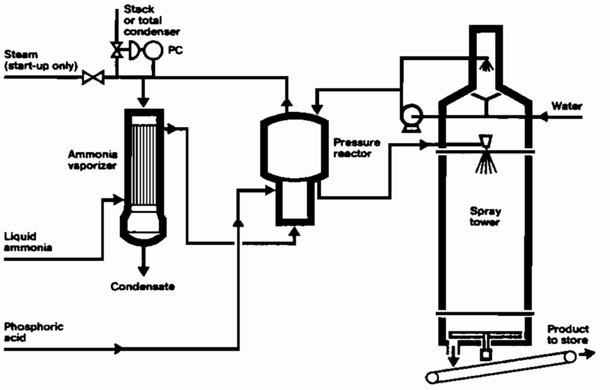
As indicated earlier, the use of the draft-tube reactor covers the range of applications for conventional CSTR designs. There are two principal applications; the Minifos process for powder MAP and the slurry granulation process for DAP and other ammonium phosphate based fertilizers.

The Minifos process and NHF DAP process are described below.

### 5.1 Minifos

This process has been described many times before, including at the Fertilizer Industry Round Table in 1968. In Figure 5 the main equipment items are shown.

**Figure 5. Norsk Hydro Fertilizers Minifos Process**



Wet process phosphoric acid with a concentration of 46–54% $P_2O_5$ is fed to the outer annulus of the draft-tube reactor. Liquid ammonia is fed through the sparge pipe to the lower part of the central draft tube. Under some circumstances, gaseous ammonia is employed. The reaction occurs in the draft-tube and causes the mixing action as described earlier.

Steam evolved from the surface of the liquor is discharged through a control valve which is adjusted to maintain the reactor at 30 psig.

The reactor produces a solution with an N:P molar ratio of 1.0:1 at a temperature of 335°F. The ammonium phosphate slurry is fed to a natural draft spray tower where it is discharged through a specially designed nozzle. Steam flashes off and the MAP solidifies as it falls to the bottom of the tower, from which it is recovered for storage.

The first new Minifos plant to be installed with a draft-tube reactor was the unit built in Turkey and operated by Toros Fertilizer and Chemical Industries. The important dimensions of the reactor are:

Diameter of upper section : 120 in
Diameter of lower section : 55 in
Length of draft-tube : 79 in

Operation of the plant began in 1980 and the 3 day test run had been completed within 11 days of initial start-up. The official opening was in May, 1981. Operation has proved easier and cheaper than the equivalent CSTR, thus justifying the decision to use the new design. The principle and the design parameters have been further confirmed by this plant.

The overall nitrogen and $P_2O_5$ efficiencies have been determined by measurement of stack losses (there being no liquid effluent) and found to be consistently in excess of 99.5%.

Output from the plant has regularly exceeded the design capacity of 440 t/d of MAP using a variety of acid sources including Florida. All the Minifos is used as a solid feed to the granulation plant with which it is integrated.

### 5.2 DAP

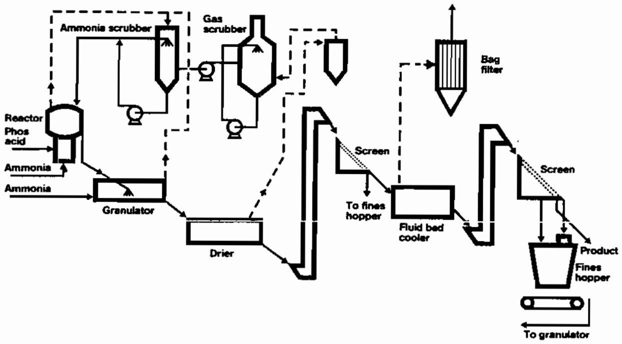
The outline flow diagram for the NHF DAP process is given in Figure 6.

Phosphoric acid and ammonia are fed to the draft-tube reactor, the pressure of which is controlled at 15 psig.

Ammonium phosphate liquor from the reactor, with a molar rate of 1.4:1, is fed with recycled fines into the rotary granulator. Ammonia is added to achieve the required product analysis.

Granulated material is dried and then elevated to the primary screening section.

**Figure 6. Norsk Hydro Fertilizers DAP Process**



The primary screening section has double-deck cloth-vibrated screens that separate fine material which is conveyed to the fines hopper. A proportion of the hot product sized material can be diverted to the fines hopper.

Product and over-size material is cooled in a fluid bed cooler and elevated to the secondary screening station which again incorporates double-deck cloth-vibrated screens. Oversize is removed, crushed and fed to the fines hopper. Residual fines are also removed and recycled to the fines hopper and, if required, a proportion of the product can be crushed and returned to the fines hopper. Fines are metered back to the granulator at a constant rate so that granulation is maintained at the optimum conditions at all times. The process operates with a recycle ratio of about 4:1 compared with 5–6:1 for plants with atmospheric reaction systems.

Steam discharged from the reactor and the air-stream from the granulator are scrubbed with a phosphoric acid solution in the ammonia scrubber to remove the majority of the ammonia. The exhaust from this vessel is led to the counter-current gas scrubber, together with the air stream from the drier cyclones. A dilute solution of phosphoric acid is used to clean the gas stream which is then discharged to atmosphere.

The dust in the air stream from the cooler and dust extraction air are fed to bag filters for recovery of the dust. The air streams leaving both bag filters are sufficiently free of dust to be discharged to atmosphere without further scrubbing.

The first DAP plant to incorporate the Draft-tube Reactor will be installed for Hindustan Lever in India. Detailed design work is currently being performed and the plant is expected to start-up in 1985.

However, a granulation plant recently started up by Hellenic Chemical Industries in Cyprus incorporates many of the above features but has a CSTR pressure neutralizer rather than a draft-tube. It produces NPK compounds as well as DAP. Details have been published.*

## 6. *ADVANTAGES OF THE DRAFT-TUBE REACTOR*

The main advantages of the draft-tube reactor are:

### 6.1 Compared with atmospheric reactors

(a) An ammonium phosphate solution with lower moisture content can be produced. This results in fuel savings for drying the product.

(b) The lower moisture ammonium phosphate results in a lower granulation recycle ratio which reduces capital cost and power requirements.

(c) No slurry pumps are required.

(d) The volumetric steam discharge is reduced giving a smaller reactor cross section.

### 6.2 Compared with pressure CSTRs

(a) The capital cost of providing an externally driven agitator is eliminated.

(b) The energy requirement for a conventional agitator is saved.

(c) Maintenance expenditure and plant downtime for agitator repairs, especially the seal, are avoided.

Note that these advantages apply equally to atmospheric reactors.

### 6.3 Compared with pipe reactors

(a) The draft-tube reactor is suitable for DAP production.

(b) Optimum operating conditions are controlled independently from the plant production rate. The pressure is controlled, not determined by the back pressure created by the flow of reactants.

(c) The retention time in the reactor is in the order of 20 to 30 minutes, thus acting as a buffer to smooth out fluctuations in feeds and thereby maintaining the optimum operating conditions.

(d) Having wide clearances, the draft-tube reactor is not susceptible to blockages caused by scale formation. It does not need routine cleaning.

(e) The reactor has a longer operational life—over 10 years.

### 7. *CONCLUSION*

To avoid the costs associated with electrically driven agitators in ammonium phosphate reactors, whilst retaining the advantages of pressure neutralisation, Norsk Hydro Fertilizers has introduced the Draft-tube Reactor.

Investigations have been carried out at the pilot plant scale and on a prototype unit which has now been operating for 7 years feeding ammonium phosphate solution to a granulator. Design data has been developed for the installation of several new plants. The first, a Minifos unit in Turkey, has been in successful operation since late 1980. A DAP unit using the technique is currently being engineered for India.

There are significant cost, energy saving and operational advantages compared with the alternative reaction systems atmospheric and pressure agitated reactors and the pipe reactor. These advantages are expected to lead to wider adoption of draft-tube reactors in the future.

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* Recent Experiences in the Granulation of Ammonium Phosphates by K. J. Barnett, D. M. Ivell and S. F. Smith, presented to the Fertiliser Society, London, 19th October, 1983.

# COMMENTS ON 1983 PROCEEDINGS

As is the case with many of the major meetings and conferences connected with the fertilizer industry, the attendence at the Round Table during the past two years has been reduced due to the economic downturn which our industry is experiencing at the present time. Consequently, our revenues from registration fees (our only source) have been reduced. At the same time, the cost involved in printing the proceedings of our meetings has increased.

In considering ways to reduce expenses, it was decided at the July 1983 Directors Meeting that we discontinue the practise of including in our proceedings the remarks of the chairman, session moderators, and questions and answers relating to the presentations. This eliminates the considerable expense of tape recording the meetings and serves to reduce the number of printed pages. It also saves the time involved in editing the tape transcriptions, a task which in the past has been diligently and effectively carried out by Mr. Albert Spillman.

The 1983 Proceedings are therefore presented in a simplified format. However, they should serve the basic purpose of preserving a record of the many relevant topics which were covered at the Thirty-third Annual Fertilizer Industry Round Table.

Harold D. Blenkhorn, Chairman 1983–84