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The Fertilizer Industry Round Table Award of Merit

Presented to Frank P. Achorn by Harold Blenkhorn

The Fertilizer Industry Round Table Award of Merit is awarded to individuals who have devoted a major part of their working career to the fertilizer industry, and are considered by their peers to have made a significant contribution to the industry. This year, we recognize the outstanding achievements of a man whose name is almost a household word in fertilizer circles. I am referring to Frank Achorn.

Frank P. Achorn is a native of Biloxi, Mississippi. His aptitude for engineering developed early in life, and started out on United States Navy destroyers where he served as chief engineer from 1942 to 1945. (In later years, Frank remained active in the U. S. Navy Reserve, retiring with the rank of Commander). Frank attended the University of Louisville, Louisville, Kentucky, graduating with a Chemical Engineering Bachelors Degree in 1947. Following graduation, Frank joined the staff of the National fertilizer Development Center of the Tennessee Valley Authority, Muscle Shoals, Alabama, where he remained until retirement in 1989.

Frank played a major part in the excellent research and development work on fertilizer manufacturing processes which was carried out by TVA during the period from the 1950s to the 1970s. Once of his notable contributions as a process engineer was the development of the TVA process for the manufacture of diammonium phosphate - a product which revolutionized the fertilizer industry in North Amercia and around the world. In fact, we have just missed the twenty seventh anniversary of this momentous achievement by one day! Today is October twenty-first, 1991. Patent number 3, 153, 614 - "Process for Production of Diammonium Phosphates" was granted to inventors Frank P. Achorn, Ronald D. Young, and Gordon C. Hicks, on October twentieth, 1964.

An additional achievement was his work in the 1970s on the TVA pipe-cross reactor. This process was developed as a means of reducing energy costs in the productions of granular fertilizers, and is still widely used in fertilizer manufacture.

Aside from his accomplishments in chemical process development, another facet of Frank's long career was his outstanding work on national and international consulting assignments, and his participation in various scientific and a trade organizations.

Frank has provided technical assistance to fertilizers manufacturers (bulk blend, fluids, basis producers) throughout the United States and in many far-flung corners of the world, including Afghanistan, Brazil, China, India, and several European countries.

Frank is a director and past chairman of the Fertilizer Round Table, and has served on various committees of the National Fertilizer Solutions Association, receiving a Life Membership Award in 1989. Other rewards which Frank has received include the NFSA award of Excellence, 1970; TVA Engineer of the Year, 1983 and 1987; Federal Energy Efficiency Award, 1983.

Frank has published over 200 papers relating to fertilizer production and use and has contributed to numerous manuals and text books which serve as a legacy from the vast store of knowledge acquired during his outstanding career.

It is with pleasure that we present him with this framed certificate which bears the inscription:

"The Fertilizer Industry Round Table Award of Merit - presented to Frank P. Achorn in Recognition of a Lifetime of Outstanding Service and Technical Contributions to the Fertilizer Industry, Farmers, and People of the World."

Opening Remarks

Paul J. Prosser, Jr., Chairman

Welcome to the Forty-First Annual Meeting of the Fertilizer Industry Round Table. For the first time in its history, The Round Table has come to Tampa, Florida in the heartland of America's Phosphate Industry; and, we are most happy to welcome all of you that are here from all over the United States and to welcome, particularly, those of you that have come long distances from all parts of the earth.

It would be presumptive of me to discuss, in the presence of all these experts, the history of the Florida Phosphate Industry, but permit me to give you just a word or two about this by way of introduction to our program. Most of this came from the *Port Charlotte Florida* newspaper, earlier this year.

This information indicates that the first phosphate in Florida was found in 1860 on the *Peas* (now *Peace River*) a few miles south of *Zolfo Springs*. One of the members of the group that found the material, William H. Meredith wrote: "It seemed to cleanse our hands as well as a bar of soap. It would be a pleasing affair could it be substituted for soap, as it would be much cheaper. But, alas, it would be *appropriated* to human monopoly and speculation." So it started as soapy stone. Rediscovery of Florida phosphate came 20 years later when Capt. J. Francis Le Barron of the U.S. Army Corp. of Engineers, while surveying for a cross Florida Canal, the *Peace River* from Fort Meade to its mouth found out cropping of high grade phosphate. This was in 1881. In 1887, G. W. Scott, a fertilizer manufacturer in Atlanta, assessed Le Barron's findings, confirmed the quality of phosphate pebbles in the river and bought thousands of acres of land on each bank south of Arcadia - price about $2.00 an acre. So it began.

You will note that our program pays particular attention to phosphates - but still addresses all phases of our industry. We are delighted you are here - we hope you enjoy the program and the other events, details of which will be given you as we move along.

Now to introduce our keynote speaker and to preside at this morning session, I present Mr. Garry Pigg, a Round Table Director from Agrico Chemical Company in New Orleans, LA.

Monday, October 21, 1991

Session 1
Moderator:

Garry Pigg

Keynote Address

The Future of World Phosphate Production

Billie B. Turner
IMC Fertilizer Group, Inc.

Just two years ago, I was asked to speak to the 12th Phosphate-Sulphur Symposium.. to discuss the "future of world phosphate production."

As I recall that event, I began with an observation that bordered on the obvious...

I told that 1989 audience that the one constant throughout the historic cyclicality of the fertilizer industry continues to be "change."

Year in and year out, the need for change, the fact of change has been seen in our global business operations and strategies.

Ladies and gentlemen. . That same fact remains true today.

To speak of change impacting our industry is nothing new. However, we cannot ignore the fact that our business environment never stops changing.

Demand for phosphate fertilizer products is strong. and that demand is forecast to continue well into the new year. In the Middle East, recent events have caused the postponement of capacity expansions due onstream as early as 1993 and 1994. Supply sources calculated into future plans by conventional wisdom were suddenly and dramatically changed.

Things never remain static, so any review of our industry, including my assigned look at world phosphate production, must be taken as a "slice in time," subject to the many variables that affect our decisions and operations.

This morning, I will review the production side of the phosphate business.

While significant, exciting events have taken place at various points around the world, it is extremely important to keep our perspective; to remain focused on the future while, at the same time, operating in a manner that best assures us an opportunity to participate in that future.

Consider just one example of this need for guarded optimism:

Despite general optimism within our industry, market conditions are not yet encouraging enough to stimulate profit-oriented investment in new capacity.... capacity we believe will be needed to meet increasing demand in the years ahead. More about that later....

Let's review some basic facts and figures to put this topic into perspective: First, a review of phosphoric acid capacity by regions around the world:

World phos acid capacity has grown to about 36 million metric tons P_2O_5. Since 1985, about 55 percent of that increase in capacity has occurred in Morocco. Total African share of world capacity expansion since 1985 is estimated at about 70 percent.

North America ranks first in capacity, with about 12 million metric tons P_20_5. The Soviet Union is second, with about seven million tons, followed by Africa and Europe at five million tons, and Asia, with four million tons.

Latin America, Socialist Asia and Oceania remain minor players in this product area.

World phosphate fertilizer production has undergone some dramatic changes in the past 10 years. Output has increased some 36 percent during that period.

Most of this increase has come in two countries; the Soviet Union and China. As you might expect, the two largest producing countries, the United States and the Soviet Union, account for nearly 47 percent of total world phosphate fertilizer production.

Following the two leaders, we find China, India, Brazil, France, Poland and Morocco. Tunisia and Romania each produce about one million tonnes a year.

Looking at the world's phosphate exporting countries, we find that, except for the United States, Morocco and Tunisia, most other producers concentrate their sales efforts in their own regional markets. Phosphate fertilizer trade is growing at a much faster rate than consumption; 60 percent over the last 10 years.

The United States' share of that international business is about five million tons P_2O_5, or about 47 percent of total world trade.

Our share is down slightly, from 52 percent 10 years ago. Morocco ranks second, followed by Tunisia, Belgium and the Netherlands. Before the Persian Gulf War, Iraq was the world's sixth largest phosphate chemicals exporter.

Morocco, with the completion of its Jorf Lasfar complex, continues to grow as a major phosphate fertilizer producer. It's expected to expand that effort for an increased share of the global market for those products.

Most of the gains in phosphate exports have resulted from a growing demand for ammonium phosphates and phosphoric acid, while triple superphosphate has remained relatively stable in recent years.

As we'll see in a few minutes, exports of upgraded phosphates are expected to grow faster than the more traditional rock trade.

Focusing briefly on the United States' production picture, we find that the five major producers account for nearly 60 percent of total capacity. IMC Fertilizer and Agrico currently rank as the top two producers. Each company has about 15 percent of total U.S. P_2O_5 capacity.

CF Industries, Texasgulf, Occidental, Gardinier, Seminole, Cargill, Farmland, Royster and US Agrichem account for most of the remaining output, based on 1990 data.

Turning now to phosphate rock:

Reviewing capacity by region, North America and Africa are on top with 52 and 47 million metric tons respectively. The Soviet Union ranks third, followed by Socialist Asia, Latin America and Oceania.

A tabulation of expansion plans indicates total world rock capacity will increase about four percent by 1995. Expansions in Africa and Asia are really offset by mine-outs in the United States and the Soviet Union.

World rock production was about 156 million metric tons in 1990, a four percent drop from the previous year but still 13 percent higher than 1979/80.

Breaking down that production, we find the business is dominated by a small number of countries. The top 10 producers accounted for 93 percent of total world production in 1990. The top three producing countries accounted for 66 percent of total output.

The United States remains the largest producer despite a slight decline over the past decade, due largely to a reduction in both rock export demand and domestic P_2O_5 consumption. In second place is the Soviet Union, which has increased its production significantly since 1980.

Morocco ranks third, and china, with a dramatic gain in output, is fourth. Other countries with substantial rock production include Tunisia, Jordan, Israel, South Africa, Brazil and Togo.

Again focusing on the United States, Florida/North Carolina rock capacity is now about 57 million tons a year, a decline of nearly eight million tons from 1986.

Estech's Watson mine exhausted economical reserves in March, 1989, and its Silver City mine closed later that year, as did Mobil's Fort Meade operation.

Overall, U.S. rock capacity will continue to decline as additional mines face exhaustion of reserves over the next decade.

There are some expansions under consideration, according to current estimates, but any action on those projects will directly depend upon improved pricing to justify such costly construction... more about that subject in a few minutes.

Meanwhile, producers are seeking to extend the productive lives of existing mines by securing nearby reserves where possible.

One company, CMI, has proposed a new mine in South Florida, but the current status of that program is unknown.

IMC Fertilizer, with an annual capacity of some 23 million tons, is the largest single U.S. producer of rock.

Other U.S. rock producers, in order of their current estimated capacities, are Agrico, Texasgulf, Occidental, Mobil, Cargill, Seminole, US Agrichem, Royster and CFI.

So much for the current status of phosphate fertilizer production. What about the future of that vital segment of our global industry?

We all have heard the news about the world's population growth.. .surpassing six billion people by the year 2000, just nine years from today. Population will grow even faster than predicted for the 1990s.

Consider the recent United Nations warning that our population could triple in the next 100 years.

Of more immediate concern, we'll add about 90 million people to our planet each year during the 90s, nearly one billion more people by the year 2000. That's roughly equivalent to the current combined population of all of Europe, the Soviet Union and the Near East.

There's no question that population growth during the next 10 years will be greater than in any comparable time frame in history.

Those people will expect, no, demand food in greater volume and variety than ever before.

Experts tell us we will have to produce about 300 million metric tons more grain by the year 2000... 300 million metric tons. ... about the same amount of grain that Africa, Latin America and India produced in 1990. More food per acre must be produced...higher yields... increased productivity.

Fertilizers will play a key role in achieving that increased productivity. If we accept that the International Fertilizer Association's latest and more conservative phosphate demand forecast, about five and one-half million metric tons more P_2O_5 will be consumed in the year 2000. This is equal to the total use of phosphate fertilizers today in Canada, the United States, and all of central America.

Recognizing the dwindling rock production due to exhausted reserves and other factors, and the fact that North American phosphate fertilizer producers are operating at or near capacity.. where will farmers find the crop nutrients they will need to feed future generations?

The phosphate industry will change again. It will act to increase production to meet demand, but it won't be easy....and it won't be cheap!

In truth, fertilizer production will have to undergo a dramatic expansion to keep pace with projected demand growth.

Thinking differs on how much our industry will have to invest to secure the needed new capital, but everyone agrees it will be substantial.

About a year ago, our experts did a computer study to project future product needs. . and how much it would cost to increase capacities to meet that anticipated demand by the year 2000.

We believe the actual numbers are probably even higher today than when we did the study, but I want to give you a rough idea of what we're facing, given current prices for our major products. . .and why we believe those prices will move higher in the months and years ahead.

Let's start with concentrated phosphates. We believe the industry will be called upon to produce an additional 8.1 million metric tons P_2O_5 by the end of this decade.

That could cost 5.2 *BILLION DOLLARS* in new capital!

Phosphate rock is equally dramatic. With a projected annual need for an additional 31.3 million metric tons by the year 2000, meeting that demand could require an investment of 4.4 *BILLION DOLLARS.*

Note that we're talking *BILLIONS* of dollars. . .big money by any measurement, and those mines and plants take time to build, to secure needed permits etc.

Meanwhile, the clock is ticking toward a new world market, with new challenges and opportunities.

For now, the big question in most minds remains how the industry will find the money to build that additional capacity.

It's clear that prices must increase dramatically if we are to add those capacities that will be demanded by world agriculture in years ahead.

By the end of this decade, we expect to see prices in the range of $250 for DAP and $40 plus for rock. FOB production site in today's dollars.compared with today's prices, those numbers may shock many in this audience. However, we believe they are realistic, and we expect to see those levels if our industry is going to continue to supply the crop nutrient needs of our customers.

Also important in preparing to meet future customer demand for our products will be such things as maximizing productivity of our production facilities, utilizing the newest technology and cost-reducing systems.

Productivity is more than just a catch word today. Indeed, it encompasses much more than just production efficiency. It involves every element of our industry; distribution, marketing, financial management. . even the environmental aspect of a modern, complex business.

Speaking of the environmental side of business today, it has become a two-pronged issue for many of us.

For a mining company, it involves a variety of elements within our total operation, from strategic planning to reclamation of mined lands. Environmental controls and concerns come into play throughout the process.

But a company must consider its environmental responsibility in other terms as well, measuring its performance in relation to its various markets.

In the case of fertilizer producers, that means working toward and supporting improved agricultural practices and greater productivity in an environmentally sound manner.

It's just one more example of how change continues to impact our industry, but rest assured, the environmental aspect of doing business is with us for good. That will not change.

Ladies and gentlemen, I hope this discussion about the production side of the phosphate industry has generated thoughtful and, perhaps, innovative ideas that will stimulate positive decisions within our industry.

As we all know, the fertilizer industry has had a history of over-production, of "anticipatory expansion," or building capacity in expectation of tomorrow's presumed demands.

Those previous bad experiences are well-documented in the ledgers of our industry's memory. And today, we again find ourselves looking at projected increases in demand for our products.

However, this time, sound logic supports the premise that the world will require more nutrients to feed a rapidly growing population.

I believe our industry will respond to this latest challenge, viewing it as another opportunity for growth, providing we act in a practical, responsible manner and provided we can generate pricing levels to support the huge investment required to meet future market demands.

Two years ago, I told participants at the 12th Phosphate/Sulphur Symposium that: "The opportunity has never been better. The outlook has never been brighter. The challenge has never been greater."

Some of you here today may have heard me make that statement.

Speaking as a producer of phosphate fertilizers, I believe those three statements are still fundamentally true today.

I would be remiss if I let you think it will be easy. Producers, distributors and marketers will find it difficult to cope with all of the changes taking place in our industry.

Consider the added cost to secure rock reserves, the cost of energy, terminal expenses, not to mention the other expenses of doing business today.

Add to that a broad range of agronomic changes involving crop production technology and crop protection issues.

Speaking of technology, we must recognize the need to educate farmers and consumers alike on the benefits. . .no, the fundamental necessity for higher yields per acre; yields that can only be made through proper use of fertilizer.

There's more to the equation, and it can be summed up in a single word.. regulation.

We see clear signals from federal, state and local government that our industry will continue to be faced with a growing array of laws which impact the way we do business.

The regulations range from environmental and conservation issues to noise and traffic controls. The result is added cost in most cases, or increased pressures to find the delicate balance between meeting corporate strategies and following a maze of guidelines, laws and, in too many cases, regulations which are ill-conceived and/or fail to really deal with a proven or imagined problem.

I believe our industry has grown to where it can handle this challenge, but success will depend upon mature judgment, a commitment to productivity, sound financial management and hard work.

The market will be there. Only time will tell who of us have the will to turn those challenges into opportunities.

World Nitrogen Outlook

Kurt M. Constant
The World Bank

A significant surplus in ammonia capacity persisted through the last decade. More recently, a more balanced nitrogen fertilizer supply and demand situation has developed. As almost all new nitrogen demand will be in Asia, most new investment will take place there also. The on-going political and economic changes in Eastern Europe and especially in the USSR have already shown a major impact on the international nitrogen fertilizer industry and will continue to do so in the long term.

1. DEVELOPMENT OF THE NITROGEN FERTILIZER INDUSTRY

Until about 1960, most of the world's nitrogen industry was located in industrialized developed countries. Plants were small by international standards and the industry used a variety of feedstocks.Only a small amount of nitrogen fertilizers was traded. In the 1960's and 1970's, the production capacity grew rapidly, in large part as a result of the so called "Green Revolution". Nitrogen fertilizer consumption between 1960 and 1980 grew from 9 million tons to 57 million tons - an average growth rate of nearly 10% per annum. Addition of new production capacities reached a peak during 1975 - 1980, when 120 plants with a total output of 28 million tons nitrogen per year were constructed. These figures do not include the large number of small Chinese plants erected during this period.

(Figure 1.) shows the regional and global development of ammonia capacities over 5-year periods. The major development took place in the centrally planned economies where about 28 million tons of new capacity were added between 1975 and 1980. This resulted in a substantial world surplus capacity since annual nitrogen fertilizer demand growth rates fell sharply to an average of 3.5% throughout the 1980's. As fertilizer and industrial nitrogen requirements grew, a significant part of the increasing demand was met mainly from improvements in utilization rates (effective capacity) of existing units. (Figure 2.) shows how average world-wide fertilizer plant operating rates have improved over the last decade from about 75% to 85%. Most of these improvements took place in developing countries. In India, for example, the utilization of ammonia capacity of 4.6 million tons in 1980/81 represented a utilization rate of only about 53%, whereas by 1988/89, an installed nominal capacity of 8.1 million tpy N operated at 83% utilization. Global figures indicate that most of the new nitrogen fertilizer demand will have to be met from new capacity as it will become increasingly difficult to improve average operating rates much higher than 85%. About 40% of world ammonia capacity is in Eastern Europe, the USSR and China, where substantial increases in utilization rates in the next few years seem rather unlikely.

2. RECENT DEVELOPMENTS AFFECTING THE NITROGEN MARKET

Three major events in the recent past will continue to have a major impact on future developments of the international nitrogen industry:

(i) The 1989 political developments in China.
(ii) The Gulf War in 1991.
(iii) The current political and economic changes in Eastern Europe and the USSR.

(i) In China, sanctions on international financial assistance after the events of June 1989 have caused a serious delay in the Government's long term plans to increase its ammonia capacity. Although many of the sanctions have now been lifted, a considerable delay has occurred and momentum has been lost. Several large ammonia plants with a total capacity equivalent to at least 1.5 million tons of nitrogen have been affected and their erection has been be delayed by at least 2 - 3 years.

(ii) The Gulf War is perhaps the easiest of these events to assess: As general reconstruction in Kuwait is of highest priority, it seems unlikely that Kuwait's ammonia plants will be put back into operation in the foreseeable future, if at all. Unconfirmed reports indicate that the ammonia plants at Khor-al-Zubair and Baijal in Iraq have been badly damaged. However, taking into account the rapid recommissioning of ammonia plants in Iraq and Iran after the Iraq/Iran war, it is assumed that the damaged plants in Iraq may be brought back on stream within about two years.

(iii) The recent dramatic political and economic changes in Eastern Europe and the USSR are likely to have both a major short term and long term impact on the international nitrogen industry. The most immediate effect has been a sharp fall in nitrogen fertilizer consumption in the region in the last two years and this decline seems likely to continue for a further few years before the trend is reversed. Consumption of nitrogen fertilizers has declined by about 10% and it may be the end of the decade before consumption increases again to its pre-1989 level. Production of ammonia and nitrogen fertilizers is also reported to have fallen in Eastern Europe, but to what extent is not known. In the USSR, it is believed that the fall in demand may exceed a drop in production and thus the export potential of the USSR may be enhanced in the short term. However, in the longer term, the closure of non-economic plants and the reduced investment in new plants may reverse this situation. In other Eastern European countries, the export potential is expected to diminish, mainly due to much higher USSR gas prices which must be paid for in hard currency. In this situation many of the older inefficient plants in Eastern Europe will no longer be competitive in the export market. At this stage, it is very difficult to prepare forecasts of the overall nitrogen balance for Eastern Europe and the USSR. Most of the projections made in this outlook assume only minor supply and demand changes compared with the current situation.

3. *OUTLOOK FOR NITROGEN DEMAND, SUPPLY AND TRADE*

The forecasts presented in this paper reflect the latest work prepared by the World Bank/FAO/UNIDO/Industry Fertilizer Working Group in May 1991 and published in the World Bank Technical Paper No. T1 44 in June 1991.

Nitrogen Fertilizer Demand

Preliminary results for the year 1990/91 indicate a small growth in nitrogen consumption of less than 0.5% which was mainly influenced by a major fall in consumption in the USSR and Eastern Europe. Through 1995/96, the net increase in nitrogen consumption should be about 9 million tons N equivalent at an average growth rate of about 1.7 % per year.

As indicated in (Figure 3.), little increase, if any, is forecast in North America, Western Europe or Japan within the next five years.The situation in Eastern Europe and the USSR may be similar. The largest growth in fertilizer demand will take place in developing countries of Asia and to a much lesser extent in Latin America.

Future Ammonia Capacity

Within the next years, most new ammonia capacity will be built in Asia.This is not surprising considering that Asia has the highest growth in fertilizer demand, the region is well endowed with natural gas resources and many countries already have established nitrogen fertilizer industries.

In the next five years, 7 new plants comprising more than 2 million tons N are expected to come on stream in India, 3 new plants in Indonesia, 2 in Bangladesh. Two more plants in West Asia are in the planning stage. Taking into account the delays in China, 6 - 7 new plants totalling 1.6 million tons nitrogen should be completed in the next 5 - 6 years.

Outside Asia, little new capacity is expected. One new ammonia plant is being built in Canada, one in Nigeria and one plant may be built in Venezuela. A regional breakdown in new capacity over the next five years is given in (Figure 4).

Nitrogen Supply/Demand Balances

Comparing nitrogen fertilizer balances in absolute terms can often be misleading as different assumptions are often made for calculating losses, operating rates and supply potential. However, measuring a projected trend in balances based on consistent assumptions against an existing or past situation can provide an important indication of future availability.

With so many factors influencing both fertilizer supply and demand, it is a very difficult time to come forward with a definitive view on future balances and forecasts are frequently based on various scenarios usually involving different assumptions on oil prices, agricultural prices etc.

Following is a five-year outlook for the nitrogen fertilizer industry assuming stable oil prices below or around $20/bbl. The outlook is illustrated in (Figure 5).

After an increase in apparent world consumption of about 5% in 1988/89, consumption in 1989/90 declined slightly by about 0.5%. Plant utilization in 1988/90 was about 83% and supply capability seemed able to cope well with demand as prices remained low. In 1 990/91, about 3% of the world's total nitrogen supply capability (15% of export capability) was no longer available due to the Arab Gulf crisis. This had a marked impact on prices, indicating a much tighter balance, even though there was virtually no increase in world demand due mainly to events in the USSR and Eastern Europe.

Recent exports from these regions remained fairly stable despite a significant decline in production in East Europe, which, however, was to a large extent balanced by a drop in local consumption.

A rather tight world balance for nitrogen has developed and could continue for the next few years. In 1994, there may be a slight easing of the situation as new capacity comes on stream. However, recent assessments indicate that new capacity in India and elsewhere will be delayed and that improvements in the supply situation will be relatively small and temporary. One may therefore expect that the next five years will see a period of longer and tighter nitrogen balances than we have seen for some time and that this is likely to be reflected in higher prices.

Trade

As can be seen from (Figure 6.) the global supply and demand situation is fairly balanced, with the exception of the USSR and Asia.

(Figure 7.) illustrates the deficit areas in Asia, particularly China, which will continue to be the main fertilizer importers. Shortages may even increase further as result of major delays in domestic production projects. However, financial constraints could limit the Chinese ability to adequately increase imports to meet real requirements. About 80% or 7 million tons of all incremental nitrogen fertilizer demand in the next five years is expected to develop in Asia, predominantly in South and East Asia and this situation is likely to continue through the remainder of the decade.

It is estimated that about 80% of all new nitrogen fertilizer demand will be required as urea. This will put special pressures on the urea market in the short term. Most of this demand in the longer term will be met from new plants in Asia. Both China and India are building new capacity to meet their domestic needs, but the main export plants are likely to be built in the Near East; mainly on existing sites that have inexpensive gas, an established infrastructure for urea manufacture and comparative freight advantages.

The surplus in West Asia will remain depressed for several years as result of the Gulf war. In the longer term, however, the region has a good potential for expanding and increasing its export capability.

Western Europe (Figure 8.) will maintain a major and probably increasing nitrogen deficit as ammonia plant closures outstrip the decline in demand. The trade situation for Western Europe will depend very much on future oil prices. Generally, natural gas feedstock prices in Europe are linked to oil prices and with oil prices of the order of $20/bbl, gas prices are around $2.5-3.0/MMBtu. At this level of energy costs, the West European plants will find it difficult to compete in domestic, let alone overseas markets. With a stagnant domestic consumption and ageing plants there has been a decline of ammonia capacity which seems likely to continue. Some of the capacity is being replaced by imported ammonia, but imports of urea have also been increasing.

Although remaining one of the largest ammonia importers in net nitrogen terms, North America will more or less remain in balance (Figure 9.). The situation in the USA is more favorable to producers than in Europe as gas prices are not directly related to oil prices. With gas prices at current levels of under $2.0/MMBtu (in February 1991, US Gulf gas prices fell to $1 .3/MMBtu), the USA is a competitive ammonia producer but it still depends on imports of about 3 million tons N as ammonia to meet its needs for both domestic production and re-export as diammonium phosphate. The USA is probably the most competitive producer of diammonium phosphate and its imports of ammonia will increase to meet the increasing international demand for DAP. Because the domestic nitrogen market is more or less stable and there is uncertainty regarding future gas prices, little new ammonia capacity is expected in the USA.

The USSR will continue to maintain a major surplus of nitrogen and remain the largest exporter for many years to come in spite of the current internal problems. Eastern Europe will also maintain a significant potential surplus, but this will decline sharply as the region becomes less competitive.

Generally, the balances indicate that the growth in urea demand will be much greater than that of ammonia. There will also be a trend in some regions to replace imported ammonia by imported urea. The urea market is generally expected to be much stronger than the ammonia market in the next few years.

4. ECONOMICS OF FUTURE AMMONIA AND UREA PRODUCTION

In evaluating new ammonia and urea projects, it is not only important to assess the economics of the project on the basis of a forecast selling price but other considerations have also to be taken into account. The most important is to ascertain that the project is the most competitive in the preferred market when compared with other potential projects taking into account all costs including inland transport, freight, and, in some cases, tariffs. It is also important to make sure that the project can operate with a low cash cost which normally means a low feedstock cost. This is particularly important in the export market where nitrogen fertilizer prices fluctuate considerably and sometimes reach very low levels. This implies that the feedstock cost must be low.

The capital charge on a new project is high and at current international prices it would be extremely difficult to justify a project on a new site because of the high investment cost. Therefore, there is a major advantage in building plants on existing sites. Economies of scale may also have a major impact on the viability of ammonia and urea projects. In export based projects, freight is a major consideration and a high freight cost could easily outweigh a low gas price.

(Tables 1 and 2) summarize an evaluation of potential projects to meet the needs of the main markets in South Asia and China. The comparison of the results indicates the advantages of plants located in the Arab Gulf and in South Asia such as Indonesia and Malaysia.

5. DEMAND FOR FUTURE AMMONIA CAPACITY

Based on the current assessment of the supply/demand situation for ammonia, there is now little surplus supply capability and new capacity will be required to meet growing demand. Assuming a nitrogen demand growth rate of 1.7% per year and taking into account application and processing losses of about 8% and a plant utilization of 90%, about 2 million tons (N) of ammonia capacity will be required on average each year through the 1990's. Additional plants will be required to replace obsolete or inefficient units but are difficult to quantify. It is estimated that 25% of existing ammonia capacity is now older than 20 years and 40% older than 15 years. The closure rate of ammonia capacities has been about 1.5 million tons per year over the last decade and this will increase to 2 million tons per year or more by the end of he decade, as plants get older and need replacements.

6. POPULATION GROWTH, FOOD SUPPLY AND NITROGEN

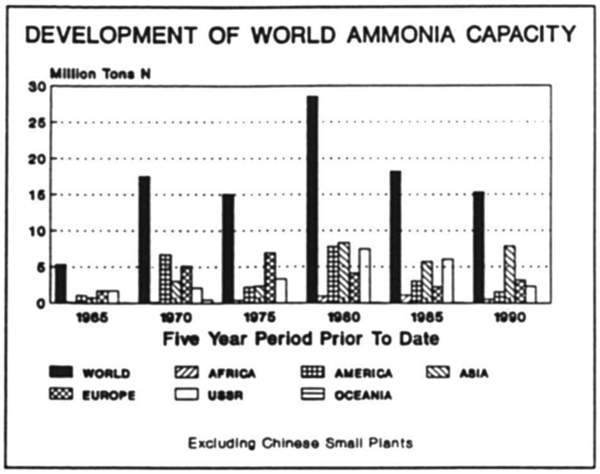
It should be noted that the nitrogen demand forecasts used in estimating the balances in this paper are basically forecasts of effective consumption and not potential nitrogen fertilizer needs. The question remains whether they indicate sufficient nutrient to meet future food needs as there is considerable doubt as to whether they do.

As illustrated in (Figures 10 and 11), world population is expected to increase from about 5,000 million in 1990 to more than 6,000 million in the year 2000. More than 90% of this increase will be in developing countries, in particular in the Asia region, and this is where the greatest demand for increased food supply will be. It seems unlikely that there will be any major breakthrough in genetic engineering that could have a major impact on food production through the year 2000. In addition, few countries have significant land left that could be brought into cultivation. A major issue debated at a recent Fertilizer Commission meeting is whether or not the projected increase in fertilizer consumption will be sufficient to provide a satisfactory level of agricultural production; the conclusion was that it would not. Reference was made to the fact that effective fertilizer consumption was falling short of the projections made of fertilizer needs in the FAO revised study of "Agriculture Through The Year 2000" that was published in 1990.

FAO indicates in its "Food Outlook" that the world food situation is still finely balanced despite the bumper harvest in 1990/91.

For the first time in many decades, there is a situation where projected nitrogen fertilizer growth will be only equal or possibly less than population growth. This implies a serious question about the adequacy of global food supplies. The international nitrogen fertilizer industry will therefore continue to play an important role in helping to feed the world in the next decade and probably thereafter.

Figure 1



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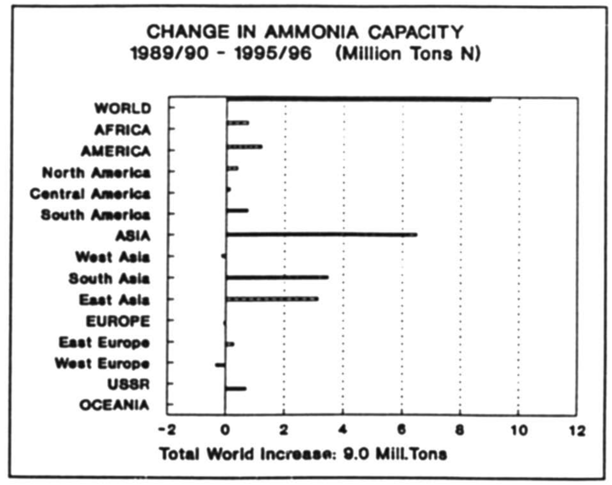

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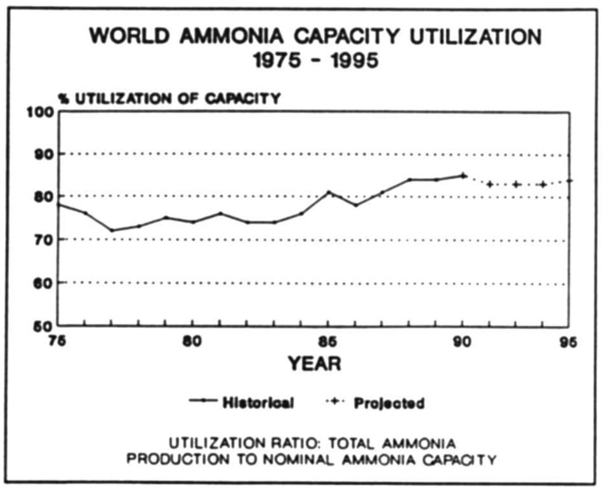

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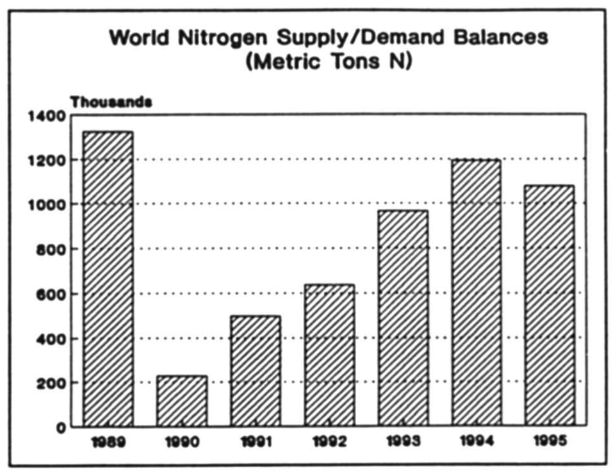

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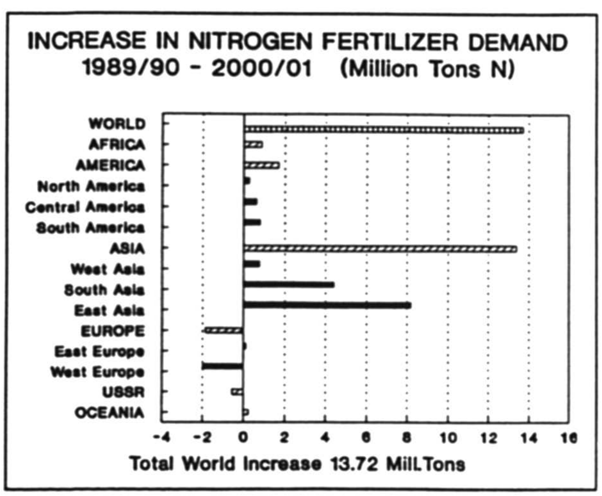

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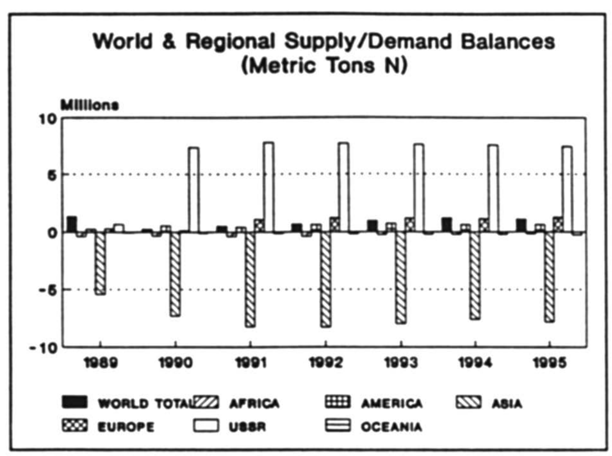

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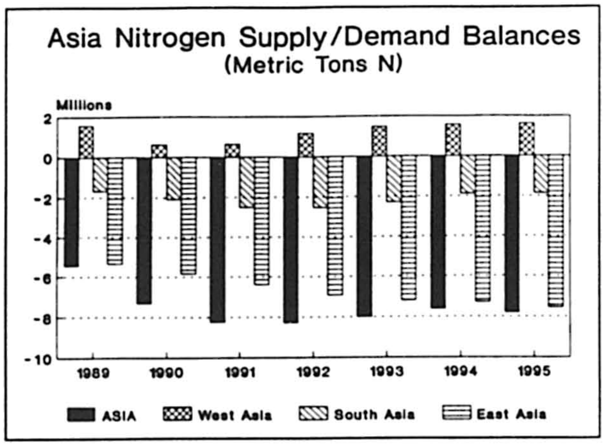

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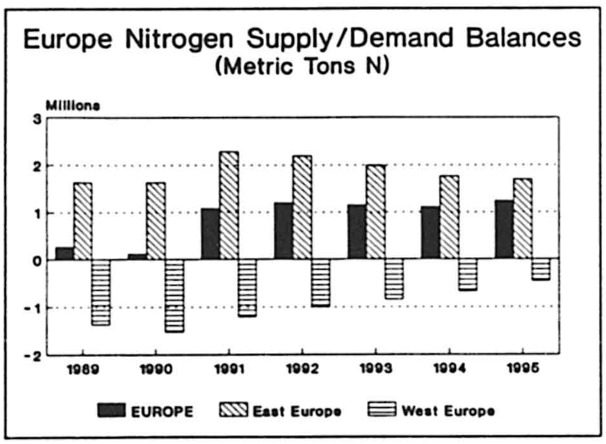

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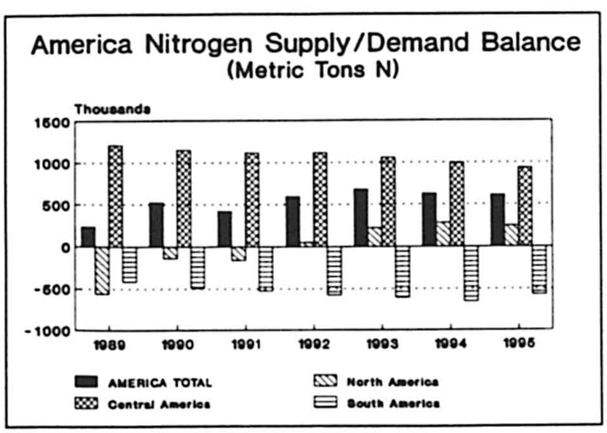

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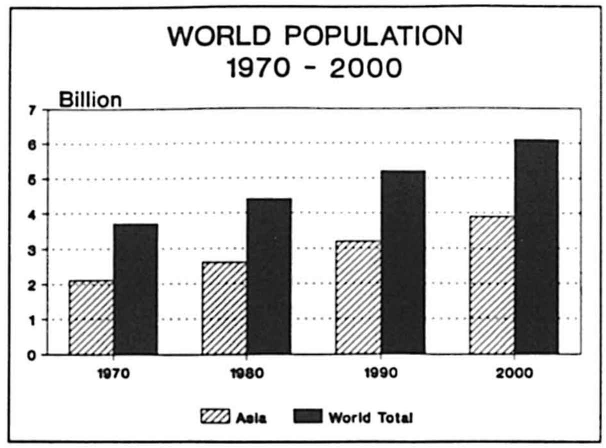

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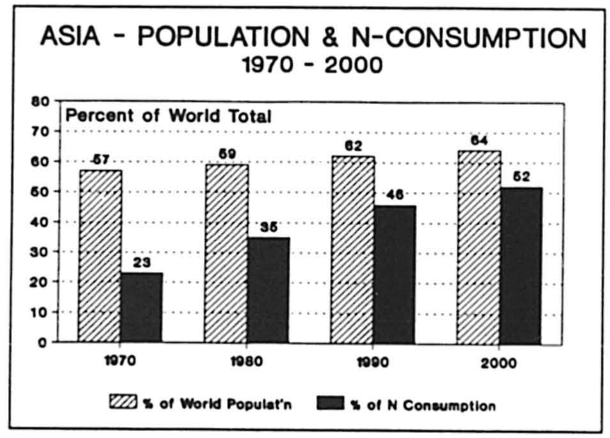


Table 1

Total Delivered Cost for Urea US$/ton
New Site

LOCATION	USA	NETHERLANDS	USSR	SAUDI ARABIA	INDONESIA
FOB Cash Cost	86	108	66	64	77
FOB 15% IRR	175	201	182	172	185
CIF Cash Cost					
South Asia	133	149	99	89	94
China	125	159	109	97	92
CIF 15% IRR					
South Asia	222	237	210	192	197
China	214	247	220	200	195

Table 2

Total Delivered Cost for Urea US$/ton
Existing Site

LOCATION	USA	NETHERLANDS	USSR	SAUDI ARABIA	INDONESIA
FOB Cash Cost	86	108	66	64	77
FOB 15% IRR	154	179	155	146	159
CIF Cash Cost					
South Asia	133	149	99	89	94
China	125	159	109	97	92
CIF 15% IRR					
South Asia	201	220	188	171	176
China	193	230	198	179	174

Outlook For Phosphates Survival In The Nineties

Kenneth F. Nyiri
Texasgulf Inc.

In 1987, at the American Chemical Society's annual meeting in New Orleans, I presented a paper entitled, "The U.S. Phosphate Industry - Life After Death."

Four years and dozens of speeches later, I'm happy to report that the U.S. phosphate industry survived that day. As Mark Twain might have put it, "The reports of the industry's death have been grossly exaggerated."

What saved the U.S. phosphate industry from this slow and painful death? At least three things contributed to the recovery. A major consolidation (rationalization) of U.S. phosphate producers, an improvement in international phosphate trade, and most of all, a substantial decline in investment in new or expanded phosphate fertilizer capacity worldwide.

Reduction in Phosphate Demand

One of the most disturbing features of the last decade was the unexpected slowdown in phosphate demand, both in the U.S. and worldwide. As seen on this graph, world phosphate demand had been growing at about 7% per year during the 1960's, slowing to 4% per year during the 1970's, then fell to just under 2% per year during the 1980's. (Figure 1.)

This sharp decline in worldwide phosphate demand growth was triggered by declining demand in the large developed regions of North America, Western Europe and Oceania.

Unfortunately, phosphate producers, both in the United States and abroad, were expanding capacity in anticipation of a stronger growth in worldwide demand. And why not. The old argument of an ever increasing world population (more mouths to feed) with improving diets, would guarantee continuing increases in worldwide food demand, crop production and fertilizer consumption.

This table shows that nearly 14 million tons of new phosphoric acid capacity was commissioned in the 10 year 1975-1985 period. Acid production or demand increased just over 9 million tons in this same period. Suffice it to say, when the growth rate for demand slowed, the phosphate industry suffered through a period of excess capacity and reduced profitability. A period of adjustment occurred in the late 1980's when the growth in new capacity slowed and production exceeded supply capability. (Figure 2.)

The Outlook

Globally, forecasters are now expecting a continuation of the slow to moderate growth in worldwide phosphate demand. Shown here are the recent phosphate fertilizer demand forecasts from five of the major forecasting organizations. The forecast demand during the early 1990's is expected to be even slower than in the 1980's. (Figure 3.)

While the overall worldwide phosphate demand forecasts are relatively close, significant regional differences exist. There is no "consensus forecast."

Regional Phosphate Demand

The forecasters expect developing Asia, China, the Middle East, Africa and Latin America to experience the highest growth in phosphate demand during the next five years. Farmers in these regions will continue to increase fertilizer application rates and wherever possible, plant more land in their effort to become self-sufficient in food production. They may, however, in some regions, be limited by their ability to pay for all the fertilizer they want or need.

As you can see from this chart, political and economic changes taking place in Eastern Europe and the USSR have added a considerable amount of uncertainty to forecasting demand in these regions. The switch to a more market driven economy will initially reduce fertilizer availability and force their farmers to become more efficient in fertilizer application, limiting growth in phosphate demand or, as some believe, reducing phosphate demand. (Figure 4.)

And finally, the farmers in the developed market economies in North America and Western Europe will experience relatively flat to declining phosphate demand. Their farmers are lowering application rates and taking crop land out of production to comply with stricter environmental rules, to reduce costs, or to comply with a variety of government programs for managing excess crop production.

Phosphate Production

Total world phosphate production in FY 90/91 is estimated at about 43 million tons P_2o_5. Total phosphate production includes production for fertilizers, feed ingredients and industrial uses, as well as estimates for production and shipping losses.

The FY 95/96 forecast shows that nearly all of the growth in phosphate production will be attributed to two products, wet-process phosphoric acid (WPA) and normal superphosphate (NSP). (Figure 5.)

A recent survey conducted by the International Fertilizer Industry Association (IFA) indicates that the number of new phosphate fertilizer projects is very limited. Two countries, China and Morocco, should represent the bulk of this increase in new phosphate production capacity.

China has ambitious projects to increase its phosphoric acid capacity by about 0.6 million tons P_2O_5 over the next five years. Most of the acid will be converted into DAP. Nevertheless, this is not expected to significantly affect its position as the world's largest DAP importer as China is striving to improve the $N:P_2O_5$ ratio of fertilization. Moreover, delays in the implementation of such projects may occur. (Figure 6.)

In Morocco, the Jorf Lasfar plant will be expanded. The Maroc Phosphore 5&6 project at Jorf Lasfar will include phosphoric lines, with a total capacity of 1.4 million tons P_2O_5/yr and DAP lines with a total capacity of 1 million tons P_20_5/yr.

Outside of these two countries, the IFA survey indicated a new phosphoric acid plant was to be built in the United Arab Republic. In addition, the reopening of a currently idled plant in the United States at Pascagoula and planned expansions in Venezuela, Israel and India are possible. (Figure 7.)

Overall, these new or expanded plants will add a net increase of 1.9 million tons P_2O_5 of new phosphoric acid capacity by 1996.

World Supply/Demand Balance

Currently, the supply of merchant grade phosphoric acid is ample while that of DAP is rather tight. However, the supply/demand situation for both products depends largely on the purchasing policy of India and China. India is the world's largest importer of phosphate fertilizer, principally phosphoric acid, while China plays a very important role as it is the world's largest importer of DAP.

Indian phosphoric acid imports reached 1.1 Million tons P_2O_5 in 1990 representing about 41% of total world merchant grade phosphoric acid trade. (Figure 8.)

China, on the other hand, imported a record 1.3 million tons P_2O_5 in the form of DAP in 1990, about 26% of total world DAP trade. Chinese DAP imports should exceed the 1990 level as first-half DAP imports are already over the 1.0 million tons P_2O_5 level. Indian DAP imports reached 0.8 million tons P_2O_5. (Figure 9.)

Forecast supply/demand balances for the coming five years shows a shrinking worldwide supply surplus. This surplus will be further reduced if new projects are delayed. (Figure 10.)

An estimated capacity surplus of 2.7 million tons P_2O_5 in 1991 is expected to decrease to 1.4 million tons in 1995/96, i.e. less than 6% of the potential supply, in spite of the forecast startup of part of the new Moroccan capacity.

U.S. Phosphate Demand

The United States is a major player in the world phosphate industry, while representing just 10% of world phosphate consumption, it accounts for about 29% of world phosphate supply and more than half of world phosphate trade. As such, it can both influence and be influenced by world events in the phosphate market. (Figure 11.)

This year, fertilizer year 1991/92, phosphate fertilizer consumption in the U.S. is expected to increase between 1-2%. Reduced crop yield from last spring's drought and improving export demand have left grain stocks very low. The government will therefore encourage U.S. farmers to plant more acres, lifting fertilizer demand, including phosphates, above last year's level. This table shows my phosphate estimates by major crops. (Figure 12.)

The estimated increase of 1-2% represents the uncertainty concerning the degree to which U.S. farmers choose to use residual phosphate left in the soil because of lowered drought yield versus new phosphate application to maximize yield.

Nevertheless, with more than half of U.S. phosphate production exported, the international market could have an even greater impact on the U.S. marketplace. (Figure 13.)

China and India are not only the two largest world phosphate buyers, but also represent about half of U.S. phosphate exports. China may purchase a record 1.8 million tons of P_2O_5 as DAP in calendar year 1991, 1.7 million from the U.S.

India may purchase an estimated 2.2 million tons P_2O_5, roughly 50/50 MGA/DAP; also a record level of P_2O_5 purchases, 1.1 million from the United States. Should either of these major buyers reduce their imports, it would have an obvious negative impact on the U.S. phosphate supplier. While there is no indication that either country will reduce phosphate purchases in 1992, their buying patterns have been erratic in the past, and after four consecutive record import years for China and very strong shipments into India, anything could happen.

It may appear somewhat wishy/washy, but my present view is that U.S. P_2O_5 exports will be flat in 1992 when compared to 1991, holding at about 5.5 million tons P_2O_5.

U.S. Phosphate Supply & Balance

The U.S. should produce a record 11.6 million tons of phosphoric acid in calendar year 1991, operating at around 100% of effective operating capacity. Could they produce more? Probably. In addition, the 350,000 tpa Pascagoula acid plant will reportedly open in December, 1991. (Figure 14.)

Barring any unforeseen problems on the supply side or up tick on the demand side, there should be adequate U.S. phosphate capacity to cover demand in 1992. However, U.S. plants will be running virtually full-out and the market will remain rather snug.

Longer term, U.S. domestic phosphate demand is expected to trend slightly upward over the next five years, growing at around 1% per year. An improvement in U.S. agricultural trade will bring some of the idled U.S. cropland back into production during the 1990's. In addition, the downward trend in phosphate application rates has bottomed out, or is close to bottom, and increasing crop yield will require somewhat higher phosphate application to maintain yield. (Figure 15.)

In the phosphate export markets, the trend is flat or declining slightly. Additions to Chinese phos acid capacity should eventually offset any growth in U.S. DAP imports into China, while the additional Moroccan P_2O_5 capacity should begin to enter the export market in 1994 and beyond. These events will likely cap the growth in U.S. P_2O_5 exports, probably lowering them by the end of the forecast period.

Conclusions

What have we learned from this brief review of the phosphate market outlook? First of all, there is no consensus. Forecasters can't agree on how much growth or where. Does this surprise you? It shouldn't. Remember that the major areas of uncertainty are the areas about which we have the least information (Eastern Europe, the USSR and China). The political and economic changes in these regions have been mind boggling.

Nevertheless, they all agree that the growth in phosphate demand will be slow to moderate, at least through the mid 1990's, slower than even the turbulent 1980's.

Secondly remember that forecasters have often been overly-optimistic in the past. This optimism may have contributed to the overexpansion in phosphate capacity during the early 1980's.

Given these projections of a modest growth in demand, phosphate supply should be more than adequate to cover project demand, at least through the mid-1990's This is true, in spite of the projected limited growth in new phosphate capacity worldwide. As always, differences in regional supply and demand could create some spot shortages, but overall, supply is adequate to cover projected demand.

The only thing that can be said for certain is that more than 5.5 billion inhabitants of this earth depend on plants for our food, and plants depend on mineral nutrients for their growth and development (Norsk Hydro). Fertilizers have been and will continue to be, the key to feeding the world's people. Yes, the phosphate industry will survive the nineties and beyond.

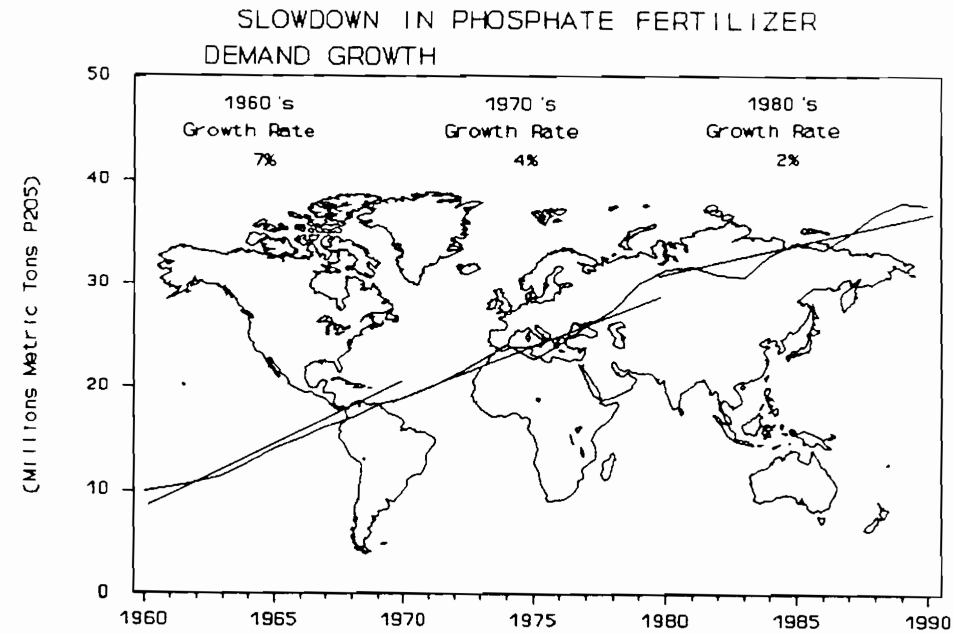
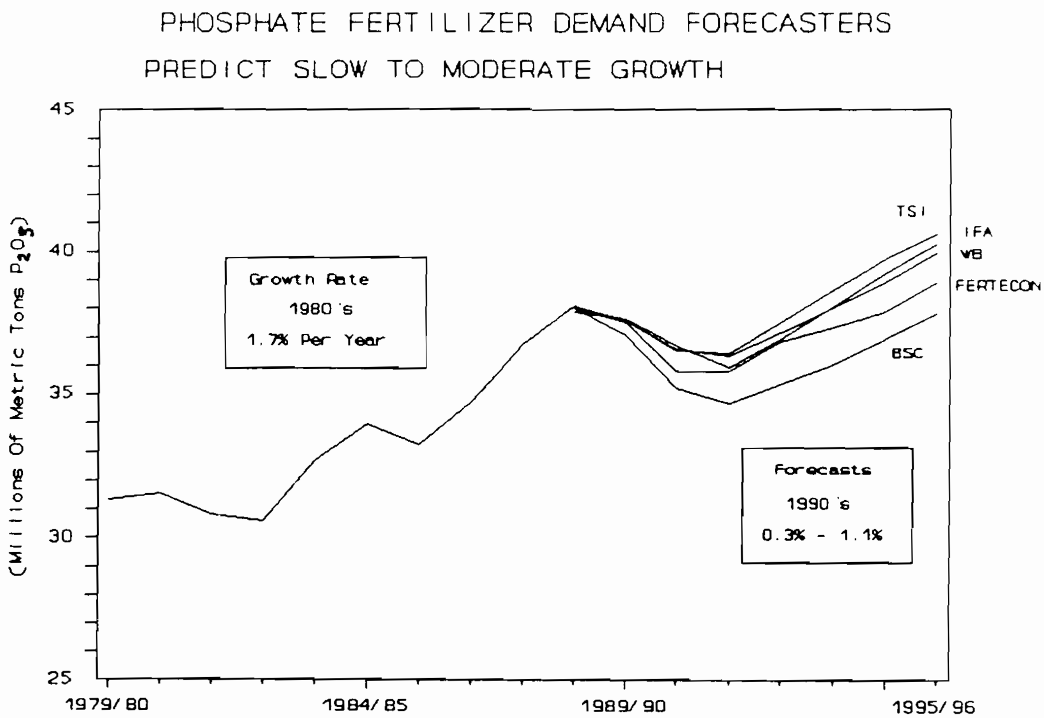


Figure 1

WORLD WET ACID CAPACITY GROWING FASTER THAN ACID DEMAND

	Capacity	Production/ Demand	Surplus
	(Millions Of Metric Tons P_2O_5)		
1975-80	8.3	7.0	+1 3
1980-85	5 6	2 4	+3.2
1985-90	2.3	3.6	-1.3

Figure 2



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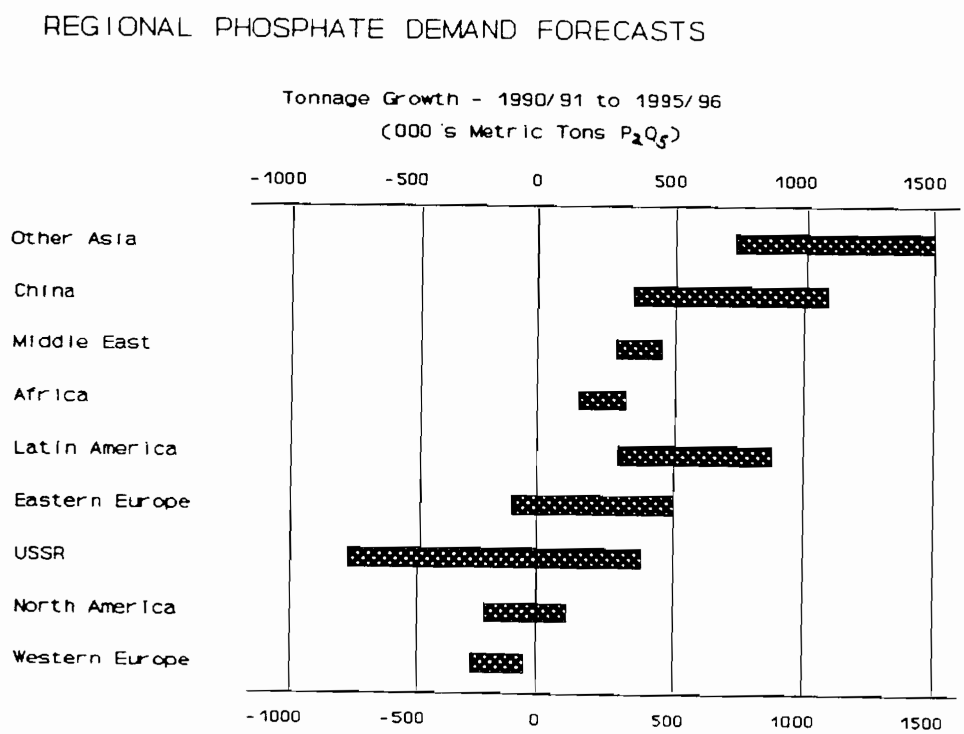

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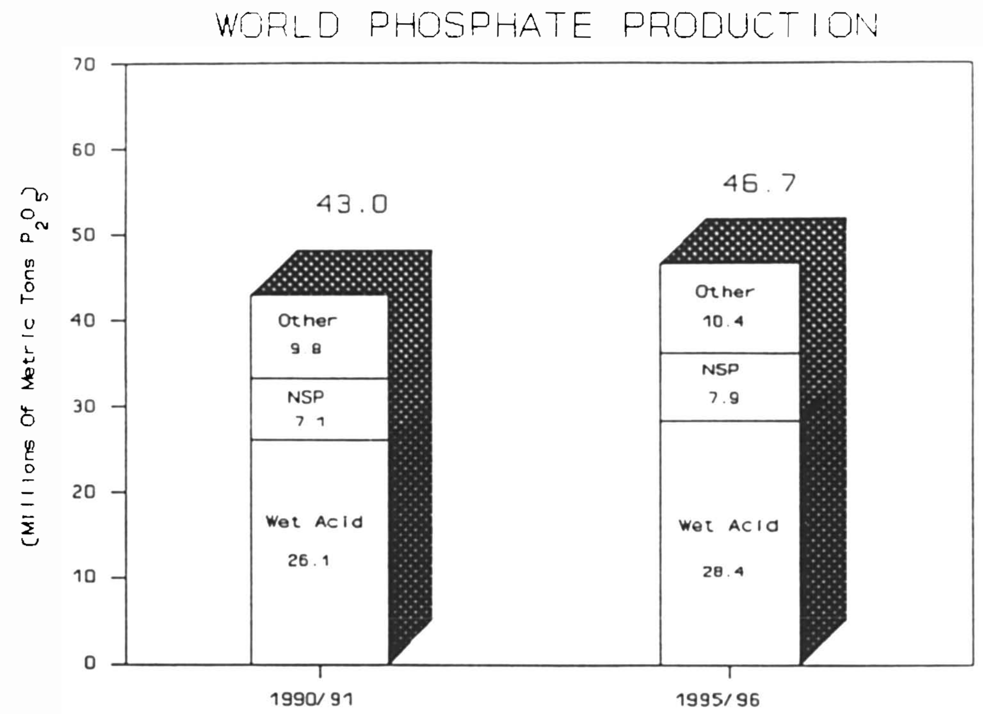
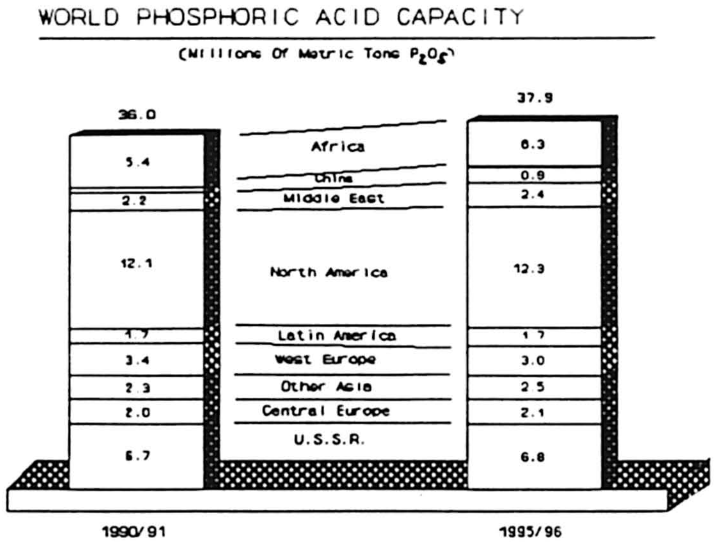


Figure 5

PHOSPHORIC ACID CAPACITY ADDITIONS

	Capacity Additions (000'S Metric Tons)	Expected Start-Up
China	+ 561	1992-95
Morocco	+ 1,405	1994-96
UAE	+ 165	1994-95
U S	+ 280	1992-93
Venezuela	+ 75	1994
Israel	+ 55	1993-94
India	+ 33	1994

Figure 6



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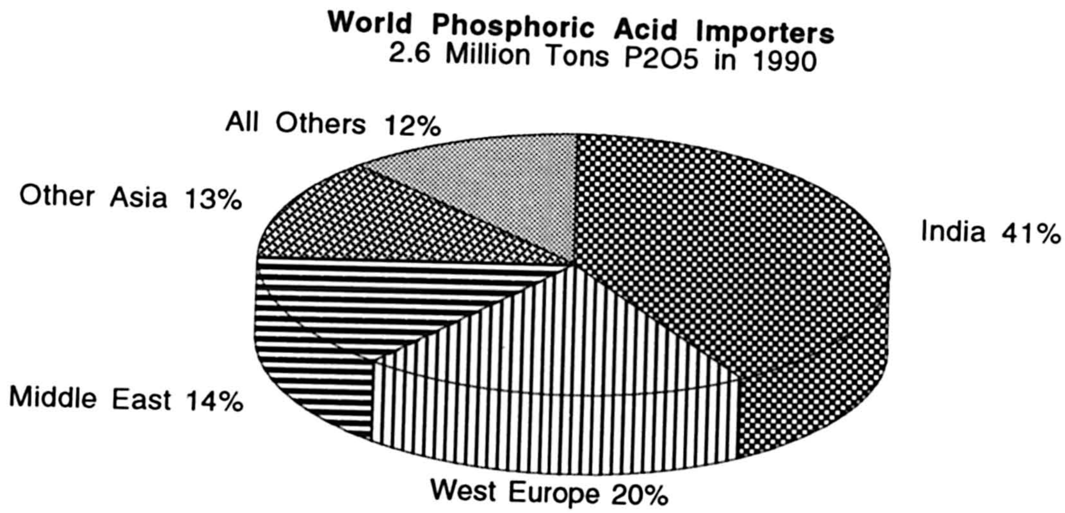

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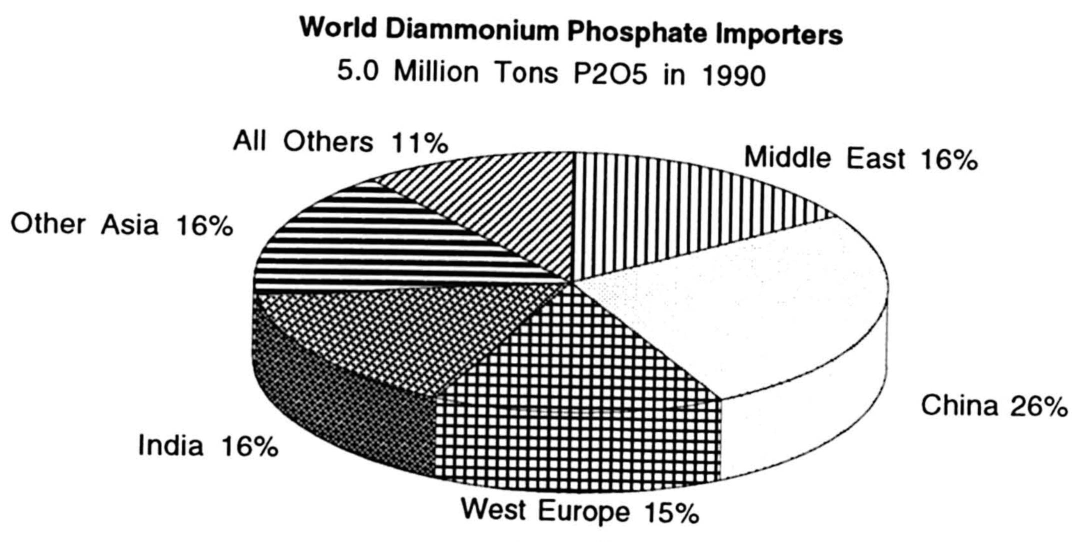

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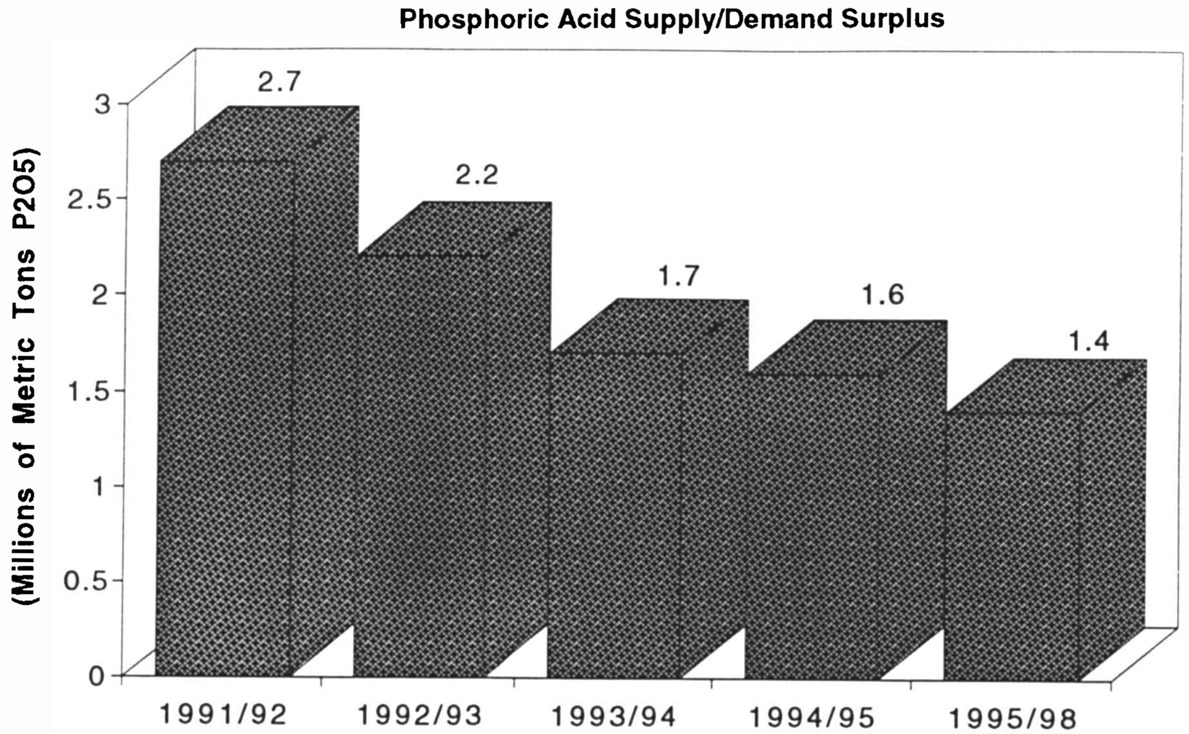


Figure 10

U.S. SHARE OF WORLD PHOSPHATE INDUSTRY

	World	U S	U S Share
	(Millions Of Metric Tons P_2O_5)		
Consumption	37.7	3 9	10%
Production	43.0	12.4	29%
Trade	10.5	5.4	51%

Figure 11

U.S. PHOSPHATE CONSUMPTION FORECAST

- Corn & Wheat ARP at 5%
- Phosphate Consumption Up 1-2%

	Acreage Planted (Millions Of Acres)		Phosphate Consumption (Millions Short Tons P_2O_5)	
	1990/91	1991/92	1990/91	1991/92
Corn	76	78	1.9	2.0
Wheat	70	76	0.7	0.7
Soybeans	60	58	0.4	0.4
Cotton	14	13	0.1	0.1
Total Major Crops	220	225	3.1	3.2
All Other Crops	99	99	1.2	1.2
Total Consumption	319	324	4.3	4.4

Figure 12

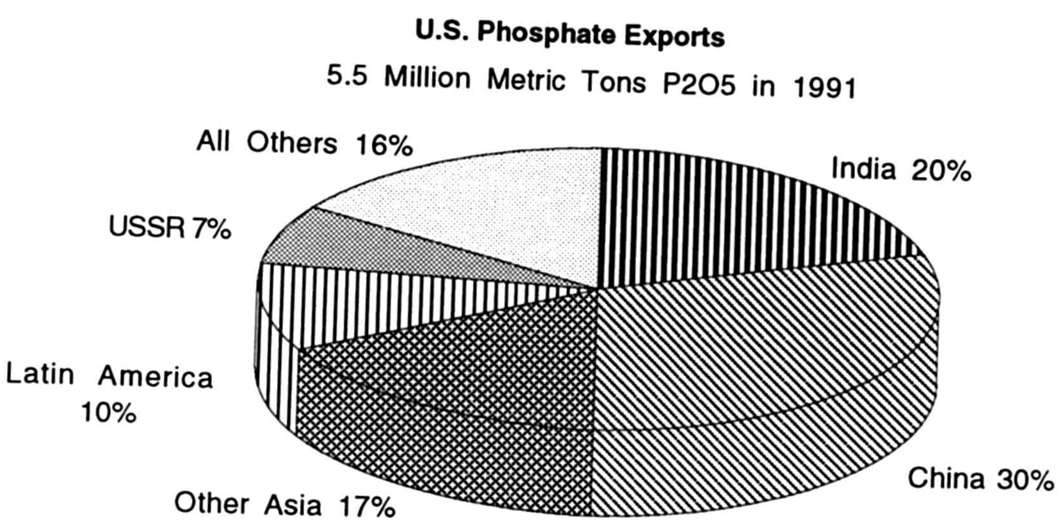


Figure 13

U.S. PHOSPHORIC ACID PLANTS

RUNNING FULL-OUT

	Production (Millions ST P_2O_5)	Effective Operating Rate (% Operating Capacity)
1st Quarter	2,850	99%
2nd Quarter	2,909	101%
3rd Quarter	2,916	100%
4th Quarter	2,905	99%
Total 1991	11,580	100%

Figure 14

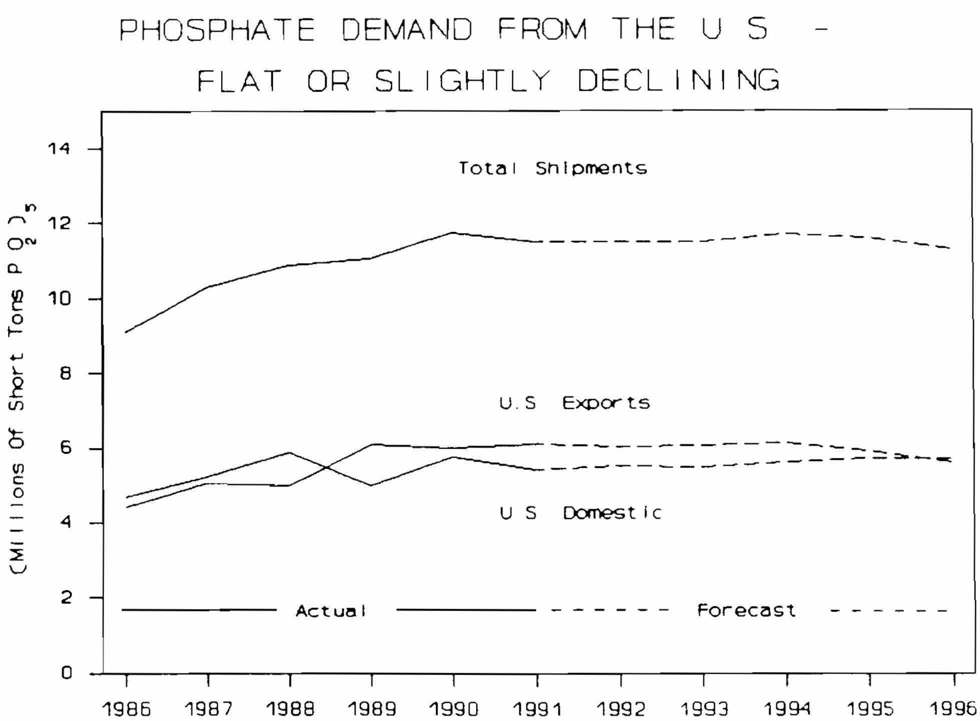


Figure 15

Outlook For Potash

Dale Massie
Cominco Fertilizers

I will attempt to set the current status of the potash industry as it exists in the world today. From this we will have a base line to project a five year outlook as well as a near term or one year outlook.

THE WORLD OF POTASH

It truly is a world wide industry and market. Currently there is approximately 35 million K_20 metric tonnes of production capacity in the world. The world Bank and FAO estimate this established capacity could only produce 32 million metric tonnes today. This slide (Figure l) shows that the U.S.S.R. has the largest capacity with some 12 million K_20 tonnes of capacity, followed closely by Canada with 11.3 million tonnes, then dropping dramatically to Western Europe with between 7 and 7.8 million tonnes, the middle east and U.S. capacity of 2 and 1.5 million tonnes respectively are the other significant world producers.

Now lets look at Capacity, Production and Consumption. The average world operating rate as a percentage of capacity is about 78. Further analysis shows Canada is operating at two-thirds capacity while the balance of the world is producing at an average of 85% of capacity. This would suggest that Canadian production today represents the swing tonnage in the world market. The world production of potash dropped by nearly 2 million metric tonnes from 1989 to present, mostly in Europe. We expect world demand to grow at a modest 2% per annum over the next five years (Figure 2). Major factors affecting potash growth are:

1. World Grain Inventory levels.
2. Political Stability or conversely Instability in developing countries as well as Eastern Europe and U.S.S.R.
3. Speed and effectiveness of the economic restructuring of Eastern Europe and USSR.
4. Population growth and more importantly, the ability to pay for increased food to supply the larger population.

Major growth markets over the next few years will be in Asia, including China and also India which are large consumers utilizing some 1.2 and 1.1 million metric K_20 tonnes of potash respectively. The ratio of nitrogen to potash consumption in China is l to 0.08 and India 1 to 0.15 versus the average on a world wide basis of l to 0.4. The ratio for these two countries should be at least at the world average. The Deputy Director of the Soil and Fertilizer Division, Chinese Ministry of Agriculture, has set a "Target Ratio" for balanced fertilizer application of l N, 0.4 P_20_5, 0.25 K_20 by 1995. Should this be achieved, annual consumption would be nearly four million K_20 tonnes, up from 1.22 million tonnes consumed in l 990. Should India reach the world average they would increase potash use by 70%, or about l million metric tonnes. I doubt that either country will reach these levels by 1995, but economics and the pressure to feed their people will drive consumption toward these levels.

In North America most agricultural forecasting firms are projecting relatively flat potash consumption. We generally agree with this outlook. I personally believe there is a reasonable chance of some increased consumption in North America because of the major political changes going on in Eastern Europe. Traditionally the "haves" of the world have taken care of the "have nots" and I would expect this to continue and at least partially by providing food directly or indirectly. This could and should mean further reduction in grain carryover stocks held in North America. Most experts are projecting world carryover grain stocks to be at or near the lowest levels of the last decade with the exception of 1983/84. Our farmers have consistently reacted to low grain stocks by producing more corn, soybeans, wheat and other cereal crops. This slide (Figure 3) shows that corn and soybeans consume 62% of the potash utilized in U.S. agriculture, thus my ray of optimism for increased potash consumption for the upcoming crop year here in the U.S.

For the first time in several years we in North America can look forward to modest annual production growth to supply an expanding world market. As a producer, we look forward to meeting increased world consumption of potash. The capacity exists today to take care of the expected world growth, including a modest increase in the U.S. — should that come to fruition. This slide (Figure 4) shows that Canadian producers should benefit from this expected growth in consumption by increasing production by about l million K_20 tonnes over the next five years, thus producing at a rate of about 85% of capacity. By the late 90's we would expect potash supply and demand to be in a near balanced state.

It appears the North American market should be well supplied with potash for the foreseeable future.

Figure 1

World Potash Capacity by Region
(million tonnes K_2O)

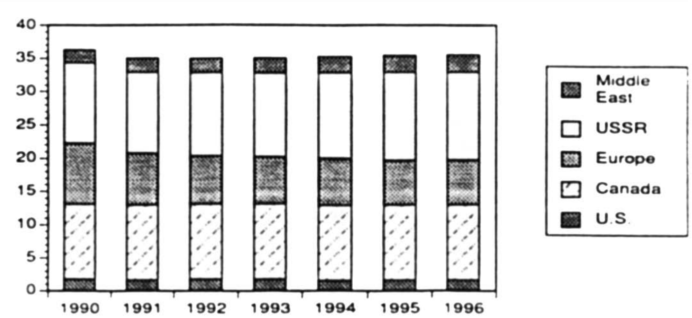


Figure 2

World Potash Supply and Demand Balance
(million tonnes K_2O)

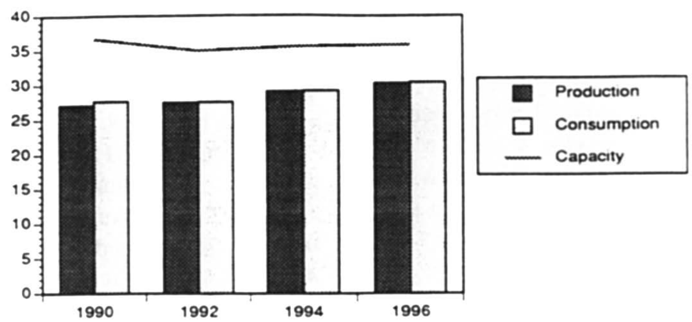


Figure 3

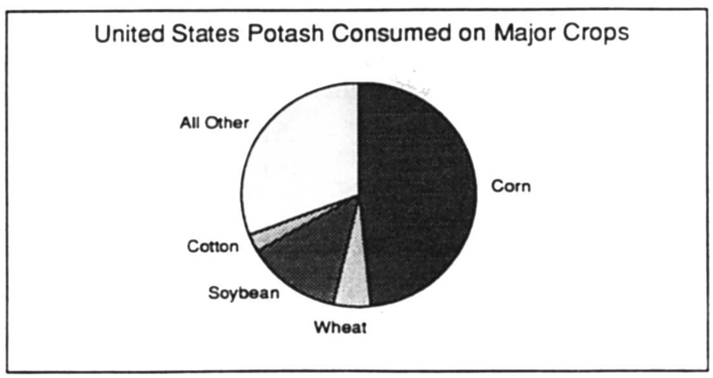
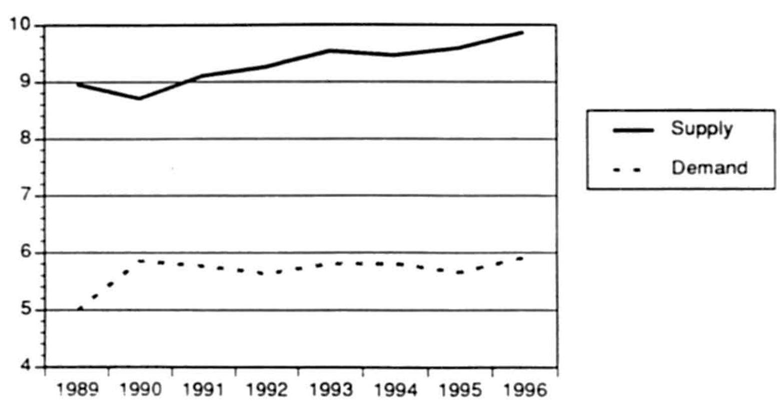


Figure 4

North American Potash Supply and Demand Balance
(million tonnes K_2O)



The Outlook for Sulphur Supply and Demand

J. R. Combs
Freeport Sulphur Company

Good Morning. It is a pleasure for me to be here today and I would like to thank the Round Table committee for inviting me to present the outlook for sulphur.

Although I've never attended a Fertilizer Round Table conference before, I personally believe the situation and outlook reports given by the previous speakers covering nitrogen, phosphate, and potash are of great benefit. An annual review helps us realize how central events such as last year's Persian Gulf conflict and this year's happenings in the Soviet Union have profound consequences for this assembly. It truly is a small world.

At the start of 1991, the Persian Gulf war disrupted the supply of sulphur and sulphur marketers were rejoicing about the outlook for price. But before the party ever got started, the beginnings of economic chaos in the Eastern Bloc were having a greater impact on sulphur demand. Someday, researchers will look back upon 1991 and try to determine what caused the turbulent market conditions we've seen this year. I'm referring to the most precipitous sulphur price declines ever recorded. I doubt anyone would believe me if I told you we're still in the midst of a shortage of sulphur - but we are! That's what puzzles many people in the sulphur business. The economists profess to have this all sorted out.

I intend to do two things today. First is to provide you with some of the top-side factors which those of us in the sulphur business have come to recognize as the make-or-break variables in the supply/demand outlook. That's what I've been asked to do. But I would also like to share something which we are in the process of building that is considerably more tangible than the market outlook. That is, the development of our new Main Pass Sulphur and Oil and Gas operation off the Louisiana coast.

SUPPLY/DEMAND OUTLOOK

First let's look at the supply/demand situation. For the sake of time, we'll look at the demand-side and supply-side developments separately.

DEMAND

World sulphur demand has slowed considerably over the past decade and has been anything but level. As shown in this chart, world sulphur demand has risen from around 55 million metric tons to 60 million tons last year. But demand fell last year by about a million tons, due largely to reduced demand in Eastern Europe.

As you might be able to discern from this chart, North America, Western Europe, Latin America and Oceania are mature, stable demand regions.

Sulphur demand in North America will probably never reach the level recorded in 1980. The reasons for this statement are simple. Demand in Canada has declined by over a million tons since 1980, primarily due to the closure of high-cost fertilizer production facilities. And although U.S. demand in 1991 is very close to the level reached in 1980, especially in the copper and phosphate sectors, it is doubtful we will see any new grassroots operations constructed this decade which could cause sulphur demand to increase. Quite to the contrary, it is more likely we could see at least two of the phosphate plants operating here in Florida shut down when supplies of phosphate rock from existing mines are exhausted; but not before 1995. And I haven't even factored in any impact that environmental pressures could cause to limit fertilizer use in the U.S such as we're seeing take hold in Western Europe. Again, I believe the chances of this occurring before 1995 are remote.

We've adopted the view that sulphur demand inside North America will remain level over the next four years.

Other than a continued slight decline in sulphur demand in Western Europe and Australia, the overall outlook is one that demand will remain fairly static in the mature developed economies over the next five years. However, annual changes will take place when weather and/or government policies prove disruptive to fertilizer demand. That's not something we can foresee but only recognize it will occur. But there will be demand changes taking place in some other regions of the globe.

A focus on Eastern Europe makes one wonder what will be the upside of the economic and political upheaval present throughout this region. While the transition to meld the two Germanies has been both swift and expensive, it is doubtful the changes within the remainder of Eastern Europe will come as fast; or for that matter, as cheap. The Soviet Union hangs on the edge of both democracy and communism today, not to mention civil chaos. We don't know what will transpire in the Soviet Union; no one does. Clearly, the world sulphur balance hinges on what will take place, and not just from a demand standpoint. As I'll show you in a few minutes, potential world sulphur supply, or I could say whether or not we'll have a surplus as everyone predicts, depends largely on the Soviets. Our view is East European sulphur demand will fall further until a free-market economic system takes hold. How long that will take is the hard question.

Another area which seems just as perplexing is Africa. Those of us that sell sulphur look at the country of Morocco with hope that new phosphate plants will bring higher demand, and opportunities. However, something's not quite right. Originally, Morocco's OCP intended to start construction of an additional 1.4 million tons of phosphoric acid capacity by 1992/93. This was part of an announced plan by OCP to add a further 5 million metric tons of P_2O_5 capacity which would boost Morocco's phosphate chemical manufacturing capability to 7.8 million metric tons of P_2O_5. So far, those additional units are still only on the drawing board. In fact, instead of sulphur demand rising, it's been going the other way since 1988.

In 1990, Morocco imported 2.4 million metric tons of sulphur needed for phosphate chemical manufacturing. That's still about 500,000 tons lower than the highest level reached in 1988. Based on OCP's announced expansion plans, before the turn of the century Morocco's need for sulphur will rise to near 4 million tons annually. But it's doubtful those new phos acid units will be built before 1995. Tunisia is the second largest consumer of sulphur in Africa and imports around 1.2 million tons of sulphur per year. However, there are no plans at the present to increase sulphur burning capacity.

Asia is the third largest sulphur consuming region in the world and generally considered one of the bright spots in terms of increasing demand for sulphur. Of course Asia is the most populated region in the world. Sulphur in all forms demand increased over 50% from 1980 to 1990 and most forecasters expect demand to continue trending upward, albeit at a much slower rate; around 250,000 metric tons per year compared to an average increase of approximately 375,000 tons during the previous 10 years. Demand will occur primarily in China as it further develops its phosphate production from either imported brimstone or from indigenous sources of pyritic sulphur.

Latin America and the Middle East are smaller consuming regions making up less than 10 percent of total world demand. In the case of Latin America, in time the debt crisis in Brazil and countries may be solved to foster new development in fertilizer and industrial sulphur burning projects. Until the Persian Gulf war, sulphur demand in the Middle East was expected to get a boost from a the expansion of the Al Qaim phosphate complex in Iraq. Instead of an expansion, it appears it was more of an explosion which in fact decreased the demand for sulphur in Iraq in 1991. In time, we assume this facility will be rebuilt and will cause demand to rise modestly.

An while I have only touched lightly on demand, the total world demand outlook calls for increasing sulphur demand at the rate of between 600,000 to 800,000 metric tons per year depending on the outcome in Eastern Europe. It is important to note that depending on which years you select, world sulphur demand during the 1980's, one of the slowest growth decades in history, averaged nearly one million tons per year. Up until last year, my company believed sulphur demand would continue to increase at the higher rate of just under one million tons based on the switch from lower analysis phosphate materials to higher analysis materials based on wet phosphoric acid routes which would accelerate the demand for sulphur. But we, nor anyone foresaw the Persian Gulf War nor the developments in Eastern Europe.

SUPPLY

But these developments have not just caused demand curves for sulphur to be changed. But the supply outlook has been altered as well. Let's take a look at the supply situation in more detail.

Keeping with Eastern Europe for the time being, there are several sulphur projects on the ledgers which have been causing forecasters to proclaim "the sky is falling" the past few years. Among the more notable projects are, the giant Astrakhan and Tenghiz sour gas plants, and Poland's new Frasch sulphur mine called Osiek. Combined these projects were supposed to be producing between 4.5 to 4.9 million tons today. That hasn't happened yet. However, the Tenghiz plant was recently started after experiencing some problems, but the output is relatively small. From what reports we have received, Astrakhan is operating at less than a million tons a year due to design and other technical difficulties and Osiek is still just a geologic resource. And Poland has had other setbacks with mined sulphur production dropping from the 5.0 million ton level in 1988 to a projected 3.6 million tons for 1991. Besides a tremendous need for money to re-design the Astrakhan plants and finish the Osiek power plant, a groundswell of new environmental pressures have handicapped these projects.

And it could be several more years before the investment capital will be found to bring these operations on-stream. In the meantime, the Russian sulphur mining ventures will be facing even greater problems which might further limit East Bloc sulphur production. Also, sulphur from pyrites operations are reported to have dropped sharply the past two years.

It's against this backdrop that any forecast of East European sulphur output is certainly going to be wrong. If anything, I'll guess high. Our view is East European sulphur output will drop to around 13.0 to 13.5 million ton range during the next five years compared to a level of 15.8 million last year. Compared against consumption, Eastern Europe will not have as much of a surplus compared to previous years.

Switching to the Middle East, Iraq and Kuwait exited the world market last year and neither have returned. While Iraq continues to have sanctions imposed against it, not to mention other impediments which will keep Iraqi sulphur from the market for probably at least another two years, the oil wells continue to burn in Kuwait and it is highly unlikely we'll see Kuwaiti sulphur present in significant quantities before 1995. Iran has.increased sulphur production from a new gas plant and production is projected to rise further. Although in the grand scheme of things, the increase is small compared to what Iraq and Kuwait were producing. Saudi Arabia remains the largest sulphur producer in the Middle East and output is slightly under 2.0 million tons. Saudi sulphur production is not expected to increase during the time frame. Looking at the Middle East in total, sulphur production in 1995 will probably be around one million tons higher than the record level set in 1989. However, in order to meet this forecast, the Iraqi's will have to overcome many obstacles.

Moving to Latin America, Mexico accounts for nearly 90% of brimstone production and about two-thirds of total Latin American sulphur in all forms output. Mexico produced two million tons of sulphur last year of which 1.4 million came from its Frasch operations. Unfortunately for APSA, problems appear to have set in at the Jaltipan mine and production is down sharply in the first six months. Presently, there are four Frasch mines producing sulphur in Mexico. Jaltipan is the oldest operation and has produced nearly 34 million tons since 1954. Production at Jaltipan peaked in 1974 at nearly 1.5 million tons but has been declining ever since. Reserve depletion will likely cause Mexican sulphur production to drop to an estimated 1.5-1.6 million tons compared to a recent high of 2.3 million tons in 1987 and 2.0 million tons last year. Only increases in recovered sulphur output from refineries will keep the figure as high as I've indicated.

I'm sure by now you're probably asking yourself is this guy going to tell us the world sulphur balance is going to be in a deficit in 1995 because of the shortfall in Eastern Europe, the Middle East and Mexico? Let's look at some other regions.

In Asia, Japanese refinery sulphur output will continue to rise slightly. However, the real impact could come from pyritic sulphur output in China if trends observed during the 1980's continue. But it's hard to find an expert on China that really knows. In the absence of any hard information, we've assumed sulphur production in China from all sources will rise around 200-300,000 tons over the next five years; not a lot. Korea will see a small rise in refinery sulphur output, but this is insignificant except in the sulphur trade picture between Japan and Korea.

Sulphur output on the African continent is inconsequential and on balance, West European sulphur production will rise only very slightly.

So only North America is left. North America is the largest producer and consumer of sulphur in the world. And based on two new major projects, Shell Canada's development of the Caroline gas field and my company's new Main Pass Frasch mine, North America will remain the largest producer through the end of the decade. Let's look closer at the figures in this region.

First, let's start in the United States. Today, there are three Frasch sulphur producers operating three mines; two in Texas and one in Louisiana. Freeport started 1991 with three mines in operation. However, resources at our Garden Island Bay and Grand Isle mines were depleted and both mines ceased operations this summer.

As detailed in this chart, Frasch sulphur production in the United States has declined significantly over the past 10 years. Production in 1990 was just under 3.7 million metric tons compared to 3.9 million tons the year before. Production last year was less than one-half the highest level of U.S. Frasch production reached in 1980 and the fourth lowest level since 1944.

The question is where is U.S. mined sulphur production headed? Production in 1991 will dip to the lowest mark since 1943 and will only total around 3.0 million tons. However, with the start of operations at the new Main Pass mine in mid-1992, U.S. Frasch sulphur production will rebound and has the potential to reach over 5.0 million tons by 1995. However, production at the higher level will take place only if the market requires such a level. We believe actual U.S. Frasch production will be around 4.0 to 4.3 million tons.

Recovered sulphur production in the United States will likely set another record level in 1991. However, there are emerging signs the rate of growth is slowing considerably. In fact, sulphur production from sour gas processing in the U.S. is falling and will likely drop further given the expectation of depressed natural gas prices which has deterred exploration.

Refinery produced sulphur from processing sour crudes shows no sign of declining and if anything, has gained momentum since Iraq's invasion of Kuwait last year. This drastically altered the slate of crude imports into the U.S. increasing the percentage of heavy sour crudes. Although this trend is not expected to continue, refinery sulphur production will most likely rise at a lower rate during the 1990's than was recorded during the 1980's.

Turning to Canada, sulphur production occurs primarily in Western Canada from sour gas processing operations and has been fairly static over the past ten years. Eastern Canada has refineries which contribute slightly over 135,000 tons of sulphur each year. However, smelters are the principal source of non-elemental sulphur in Eastern Canada. While Eastern Canadian production is forecast to remain fairly flat, sour gas sulphur production in the West will be rising in the short-term. Among the significant developments taking place in Alberta and British Columbia, Shell Canada will initiate operations at the Caroline processing plant which is currently under construction near Sundre, Alberta. The plant is designed to produce 1.4 million tons of sulphur per year and is scheduled to be on-stream sometime in 1993. Had it not been for this development, Canadian sulphur production would have continued to fall during the 1990's.

SUPPLY/DEMAND

So if we add up all the figures on both sides, production and consumption, we get this type of outlook.

World demand will continue to outpace supply for the next two years, as it has since 1978, requiring a drawdown in world stocks. And this outlook has a reduction in East European demand of over 3.0 million tons from the level registered in 1989. And our conclusion is, IF sulphur is long at all, it will be only slightly so in 1993-1995 by around one million tons or so; not anywhere near the levels the "experts" foretold five years ago that yielded the conclusion the world would be drowning in sulphur starting in 1988. The problem isn't that they were wrong, it's simply today was the future back then. And the future is hard to predict. But those same "experts" are back today with the same tune telling us that beginning next year, we'll be drowning in sulphur. But so far we still continue to take sulphur out of the vats as we have since 1978 and will do so again in 1991. Here's what our view of inventories will look like in 1995 if indeed sulphur is produced only to be vatted.

Of course many of you may be trying to understand if the world still has a "shortage" of sulphur which requires producers to draw down inventories to meet demand, then why have prices fallen so sharply this year? Not an easy question to answer.

However, we believe the reasons are as follows.

The decline in sulphur demand in Eastern Europe caused Polish sulphur exports to the USSR and demand within Poland to drop sharply; down over 50% in the first six months.

This caused the Poles to look elsewhere to place the tonnage and the primary targets were Morocco, Tunisia and Brazil - markets traditionally supplied by Canadian sulphur.

Western Canadian suppliers tried to maintain high exports in the face of weak demand in some of their key markets such as the USSR and Australia. This came at a time when sharply lower natural gas prices beginning in the first quarter of this year created a "cash crunch" for many Canadian oil and gas firms. This situation caused marketers to "force" sulphur into the marketplace at any price to maintain cash flows. In less than one week, three Canadian firms dropped the price around $10 per metric ton trying to place one cargo of sulphur into Brazil.

Sulphur prices from Saudi Arabia were cut to maintain an equilibrium to Canadian prices into competing markets such as India and Morocco.

U.S. marketers chose to reduce prices in Tampa to keep Canadian sulphur via rail out of Alberta from displacing U.S. sales into Florida.

In short, it's a dog-eat-dog business at times.

I hope the first section helped you better understand our company's view of the market outlook over the next several years, now I'd like to briefly cover the development of our Main Pass project. I believe you'll find it more interesting than the sulphur outlook.

MAIN PASS

The Main Pass Block 299 dome was one of 11 domes Freeport and its partners secured the sulphur rights to in the Outer Continental Shelf Sulphur and Salt lease sale held by the Minerals Management Service in early 1988. Oil and gas rights were not included in the sale.

At Main Pass Block 299, Chevron has held the oil and gas rights since the early 1960's and has produced in excess of 57MMBO and 38 BCF of gas; but only from the flanks of the dome. Oil companies learned in the Fifties not to drill directly on the top of salt domes because hydrocarbons in producible quantities are a rare occurrence on the top of Gulf Coast salt domes. However, three wells had been drilled on the edge of the dome which indicated the presence of a caprock layer. The presence of this caprock layer indicated that there could possibly be sulphur at Block 299. But the characteristics of caprock over the dome could not be confirmed using common seismic techniques because of distortion caused by shallow gas in the upper sediments, commonly found over salt domes.

Freeport's exploration drilling began on December 1st, 1988 and was completed the following March. In total, 19 wells reached the target depth with one well lost prior to reaching the sulphur horizon. After Chevron was informed that oil was found in the caprock during the exploration effort, Chevron drilled and logged a well which tested at 8,000 BPD. All of the sulphur wells were logged and cored.

Based on the exploration effort, the commercial sulphur horizon varies up to 230 feet thick with the greatest caprock layer and sulphur horizon located to the southeast of the center of the dome. The upper caprock in the central and southeastern areas contains oil and gas.

Overall, the exploration program proved a deposit of at least 67 million long tons of recoverable sulphur, making it the second largest sulphur discovery made in North America and the largest known existing deposit.

THE MINING PLAN

The Frasch process, used for the last 80 years to produce most of the sulphur mined world wide, will be used at Main Pass, with all the refinements developed with that experience. The process is a matter of injecting 325 degree superheated water into the formation through the annulus between the larger and smaller piping in the well. The sulphur melts and pools near the well bore and moves up into the smaller pipe due to its hydrostatic head. Finally, the sulphur is lightened by the injection of compressed air through the smallest tubing, allowing it to flow to the surface.

As in our other offshore operations, Main Pass will utilize Freeport's proprietary seawater process as mine water. The mine would not be feasible without the ability to treat and heat seawater to this 325 degree temperature and deal with all the scaling and corrosion problems the elevated temperature causes. A total of 10 million gallons of water per day will be heated and injected into the formation. This is twice the amount produced by any of Freeport's previous seawater plants. If the energy used by this plant was used to produce electricity instead of heat seawater, it would be enough to supply the needs of a city the size of Baton Rouge, the capital of Louisiana.

An average sulphur well will produce the sulphur from an area of about one acre over a period of 12 to 15 months. This means that wells must be drilled on about 200 foot centers over the entire ore body. At Main Pass, over 1500 wells will be drilled over the life of the mine, and over 40 wells each year. These wells must be drilled essentially from two platforms at any given time, directionally angling the wells to cover as large an area as possible while hitting bottom hole locations plus or minus 25 feet.

From the results of our exploration program, and what we know from past experience, we determined the Main Pass dome will be mined starting in the area of the highest sulphur elevation and progress downflank to take maximum advantage of the heat patterns that will build up in the dome; the highest point of the underlying anhydrite formations must also be taken into account in determining the progression of the active mining area. This is the sulphur version of contour mining. Other important factors in the mining plan were the area that can be covered from one platform location using direction drilling, platform orientation, platform size, the number of well conductors on each platform and the characteristics of the deposit. These factors were used to determine the optimum mining plan which is shown here.

The initial two platforms are located near the center of the orebody and together will produce approximately 20 million tons of sulphur over 12 to 14 years. Each platform has slots for 76 conductors from which at least 3 wells each can be drilled. For the 1,500 to 1,600 sulphur wells required over the life of the mine, nine different platform configurations and locations will be required. As the two initial platform locations near depletion, a third platform will be built, and then the first two will be relocated, ultimately reaching all the mining zones by this process.

The removal of the sulphur results in subsidence over the area mined, in amounts not experienced by other subterranean operations. The anticipated subsidence at Main Pass had a large effect on the design and the materials used in the Main Pass structures. Our studies indicated we could expect over 50 feet of subsidence at the center of the ore body, and the production platforms were engineered and constructed to deal with the process of subsidence. Key platforms which remain in place over the life of the mine, such as the power plant, living quarters, storage and loading platform and the pressure control facility were located in flank areas where the subsidence will be manageable.

Another major complication in planning the project was the oil and gas located above the sulphur. Coproduction provides opportunities as well as complications, however. While we had experienced the coproduction of hydrocarbons in much smaller quantities at three prior sulphur mines, Chevron, who had no such experience, was understandably concerned. This was resolved by purchasing the oil and gas reserves on the top of the dome from Chevron in early 1990 for $150 million, thus allowing for improved synergies from a common operation.

KEY ASPECTS OF MAIN PASS

The list of "first" associated with Main Pass is impressive. For one, it's the first discovery of commercial sulphur that is not a by-product in the U.S. in over 25 years. It's the first sulphur mine which will be produced in over 200 feet of water and the first mine which will concurrently produce oil and gas in significant quantities. It will be the first Frasch operation in the U.S. engineered to have a peak production capacity of up to three million tons of sulphur a year with a sustainable rate of two million tons per year.

In some other categories, Main Pass will be the largest offshore structure in the Gulf of Mexico and, for that matter, one of the largest in the world. No offshore structure has ever been designed to withstand anywhere near the subsidence that will be experienced at Main Pass. Lifting the power plant module into place will require the heaviest lift ever made in the Gulf (5,700 tons). And in terms of size, if you look at Main Pass sulphur production as an energy resource, it equates to an oil field that would produce in excess of 150 million barrels of oil — one of the largest energy finds in Louisiana in many years.

The oil and gas production operation will include one of the most complex processing facilities in the Gulf, including the first use of a Klaus plant for sulphur removal on a platform in the Gulf. It is also the first extensive use of the new technology of horizontal drilling in the Gulf.

This is an artist's conception of what Main Pass will look like in about three months. 18 major structures, 14 of which are connected by bridges to carry the hot water and heated sulphur lines. The connected platforms stretch over 6000 feet.

Of the 18 structures shown here, 12 have been installed as of October 1st. All drilling platforms are in service and wells are being drilled. The oil and gas processing facility platform is in final check out and oil production will begin within a month.

After substantial hookup and testing, water injection is expected by April of next year, with initial low levels of sulphur production shortly thereafter.

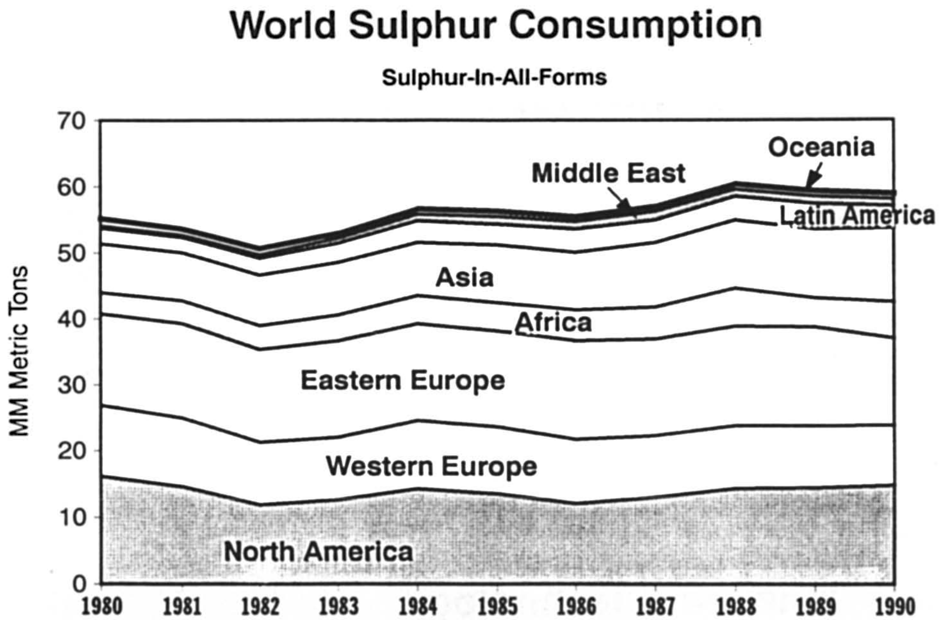
Switching from the concepts of artists and computers, this is a current view of the real thing as it stands today. Taken from the water level, these are the two sulphur production platforms and connecting bridges which will lead to the power plant and other structures. After substantial hookup and testing, water injection is expected by the 2nd quarter of next year, with initial low levels of sulphur production shortly thereafter. We anticipate that it will take 1-1/2 to 2 years for production to reach the nominal two-million-ton-per-year rate. This is because the host rock must be heated to the 240 degree melting temperature of sulphur before fully efficient production is established.

At the minesite, the sulphur will be stored in two 12,000 ton tanks before it begins its journey to Bone Valley. The first step of that journey is in one of two 7,500 ton self-propelled barges, shown here and currently under constructio at Panama City, Florida. Once brought to commercial specification in Port Sulphur, it will be shipped to the Freeport terminal in Tampa using Freeport's reliable marine transportation system for final delivery by truck to the phosphate plants.

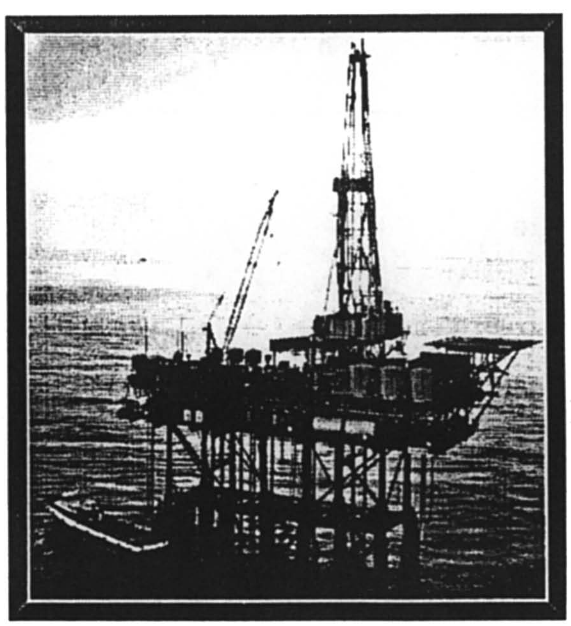
CLOSING

Had it not been for the discovery and development of Main Pass, I might not have been asked to come back in just a few years. (Heck, I might not be asked back anyway). But the production of sulphur from Main Pass will continue for several decades and will certainly permit my company to reach a milestone of over 100 years in the sulphur business; not a claim that can be made by any other firm. But it took an investment by Freeport and it's partners of over $800 million to reach that mark.

And it's because of our long-standing position and commitment to supplying sulphur to the world marketplace that we genuinely take an interest in the world outlook for sulphur. I grant you, and I'll emphasize the IF, supply does exceed demand in the initial years when Main Pass begins production, we're confident it won't last for over 30 years. With the low cost structure that Main Pass will have, this is one mine that will produce under all market conditions good or bad. The most frustrating part of that statement, is the fact that the future is hidden even from the men who will make it.



THE MAIN PASS PROJECT

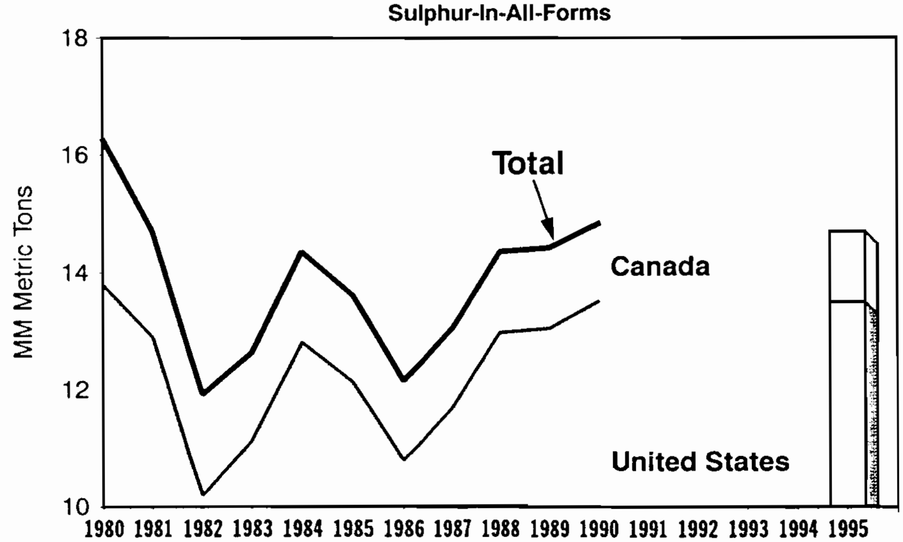


Unique Aspects of Main Pass Mine

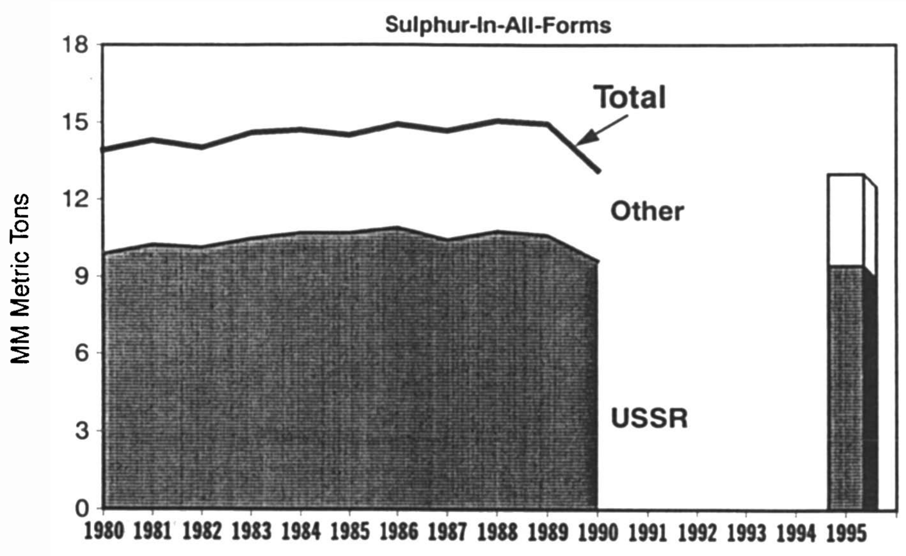
- 1st discovery in 25 years
- 1st mine in over 200 feet of water
- Peak production of 3,000,000 LT
- Largest structure in Gulf of Mexico
- Major oil/gas discovery
- Innovative technology

North American Sulphur Demand Outlook

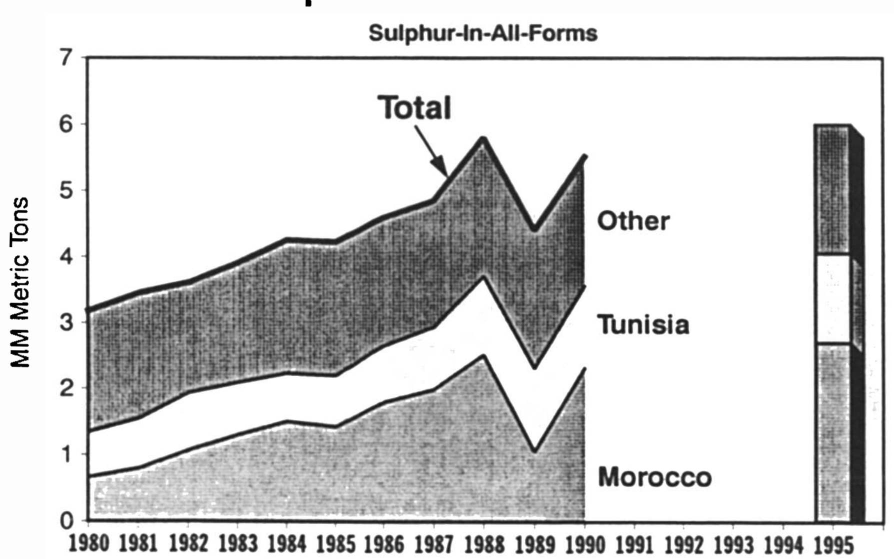
Sulphur-In-All-Forms



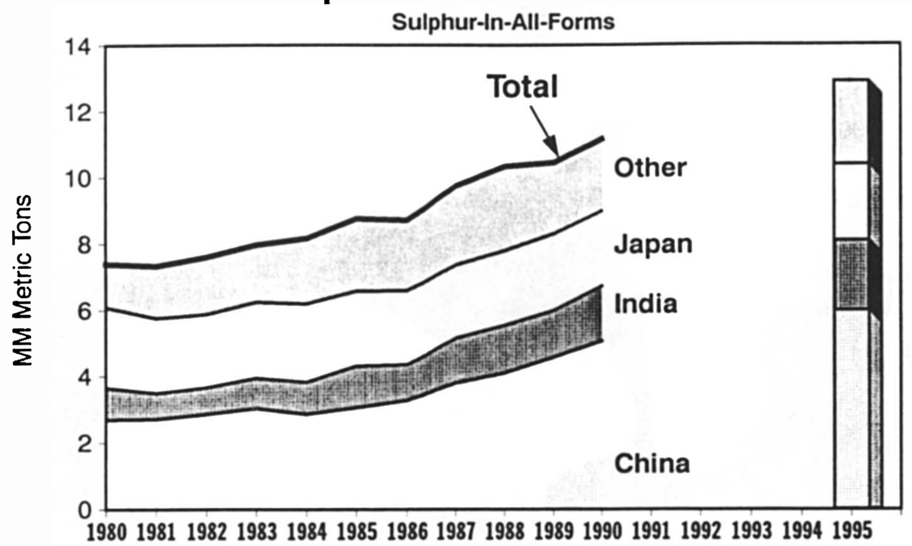
East European
Sulphur Demand Outlook



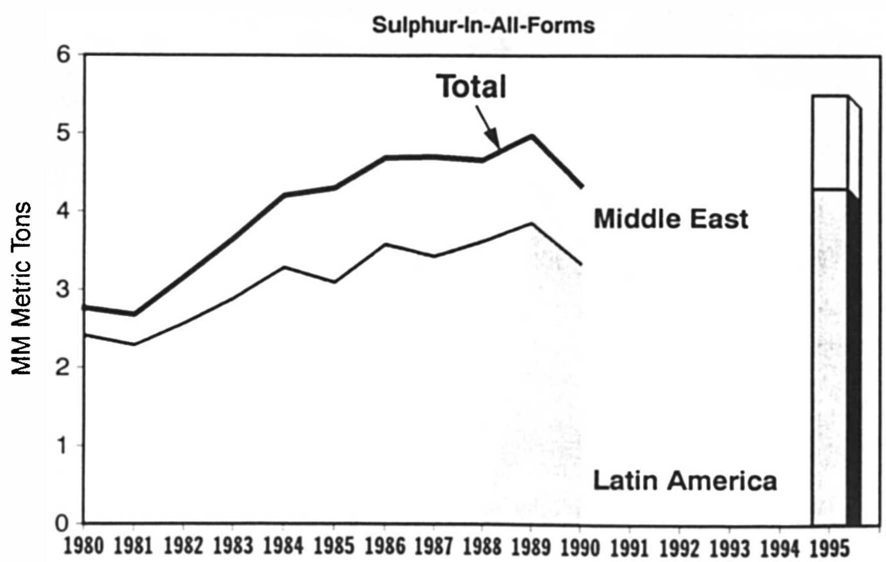
African
Sulphur Demand Outlook



Asian
Sulphur Demand Outlook

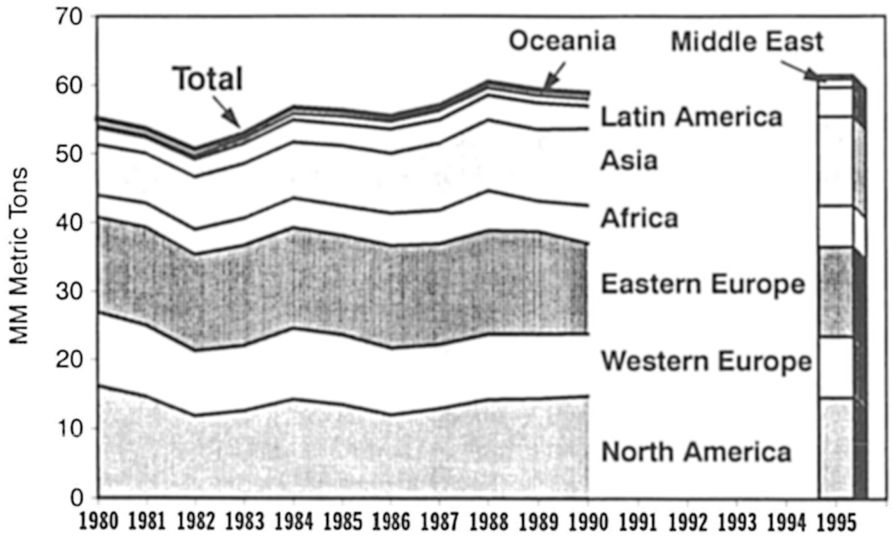


Latin America/Middle East
Sulphur Demand Outlook



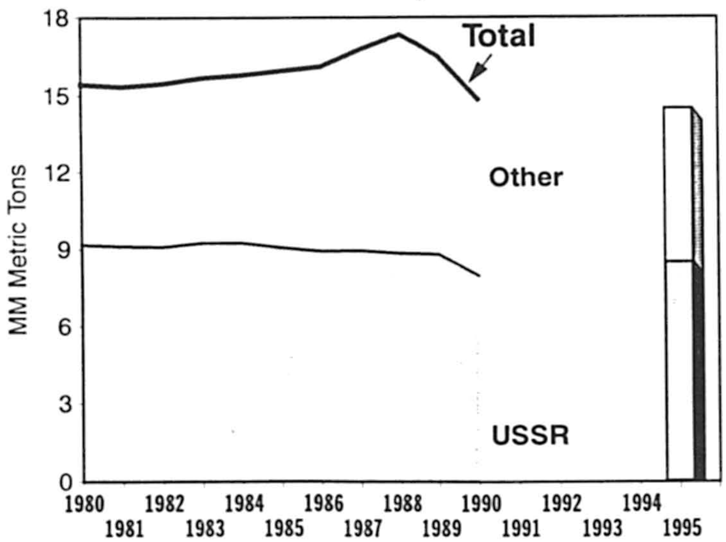
World Sulphur Demand Outlook

Sulphur-In-All-Forms



East European Sulphur Supply Outlook

Sulphur-In-All-Forms

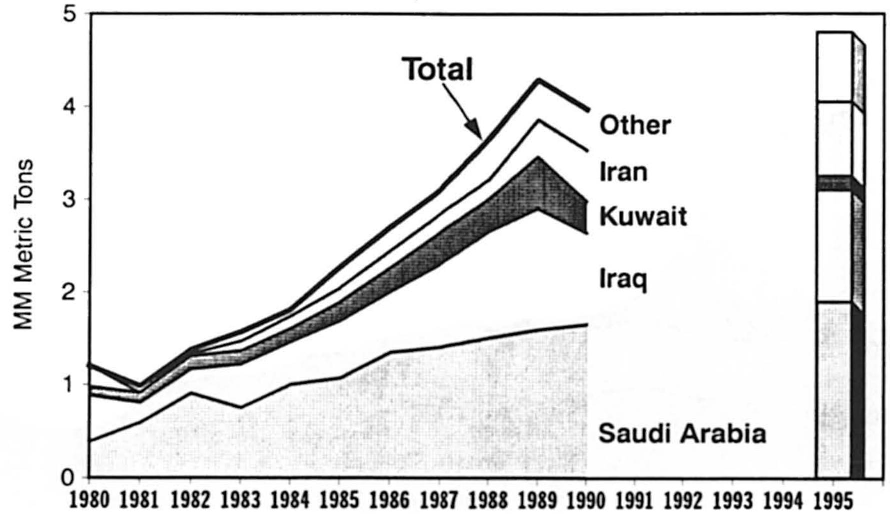


Major Unknowns

- Astrakhan
- Tenghiz
- Osiek
- Pyrites/ Mined Sulphur
- Demand/Outlook for Exports?

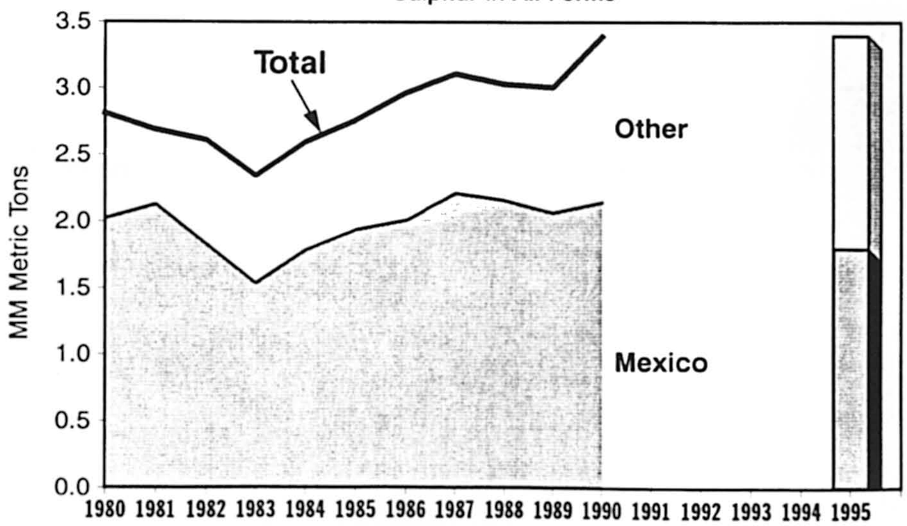
Middle East Sulphur Supply Outlook

Sulphur-In-All-Forms



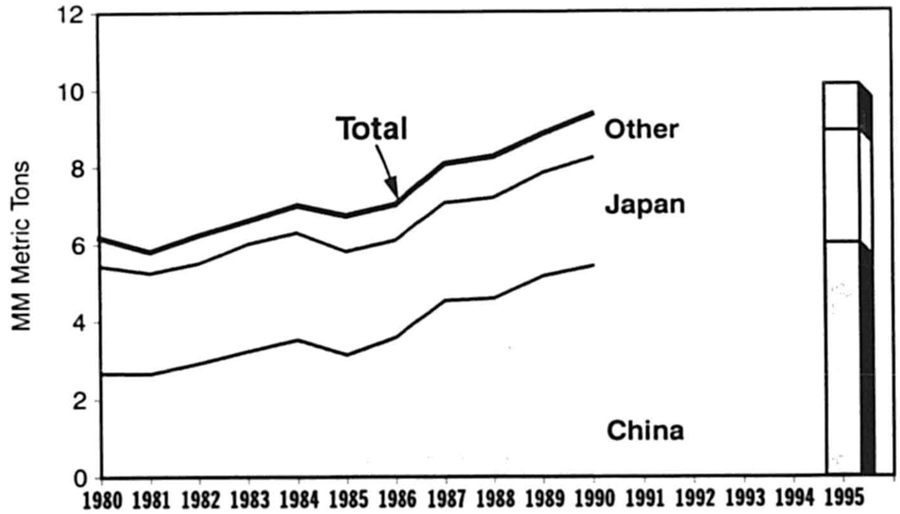
Latin American Sulphur Supply Outlook

Sulphur-In-All-Forms



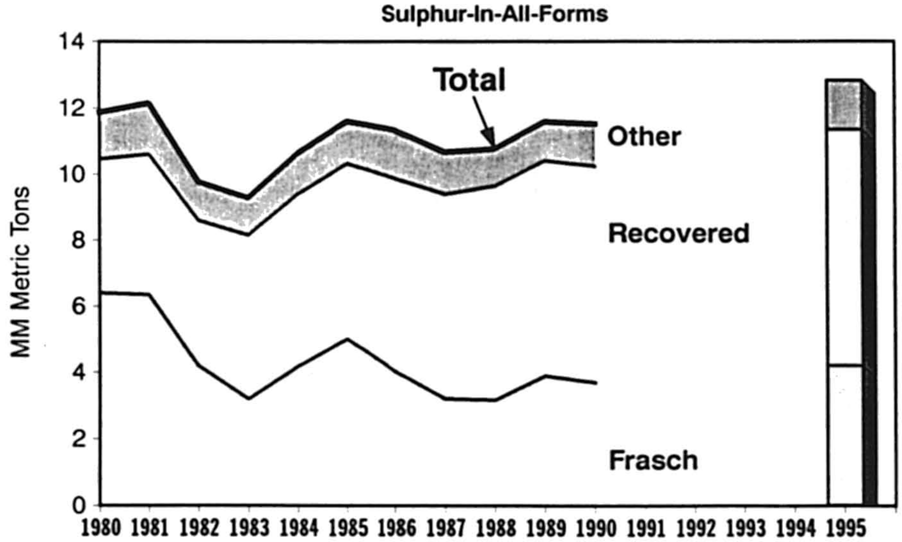
Asian Sulphur Supply Outlook

Sulphur-In-All-Forms



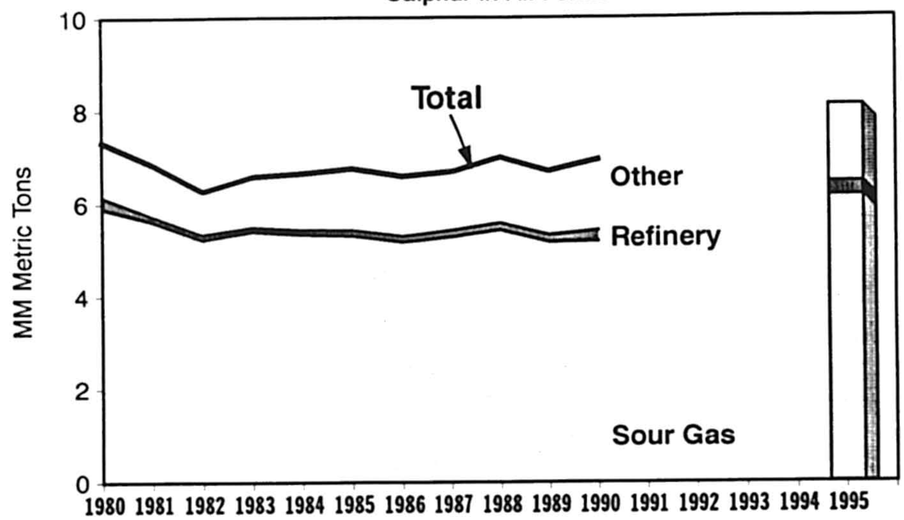
United States Sulphur Supply Outlook

Sulphur-In-All-Forms



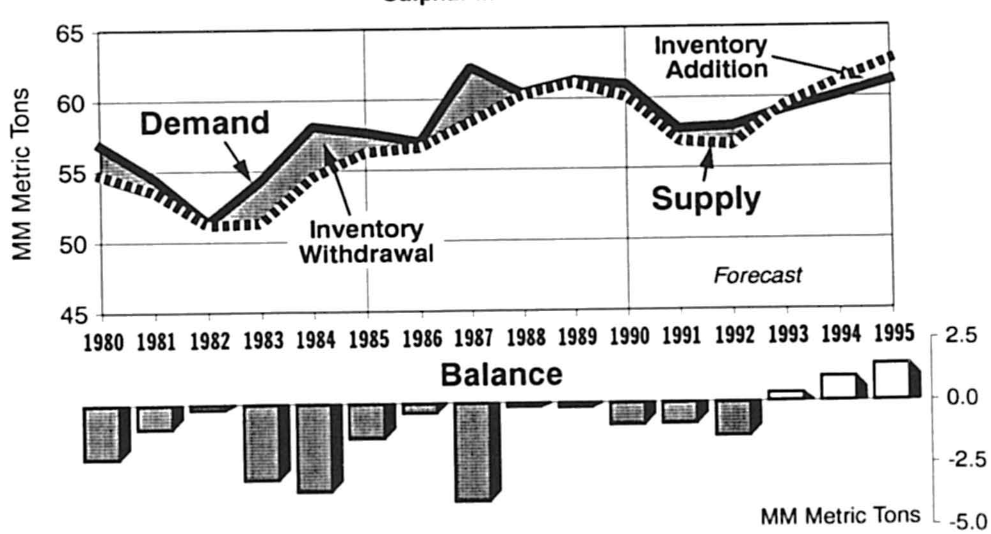
Canadian Sulphur Supply Outlook

Sulphur-In-All-Forms

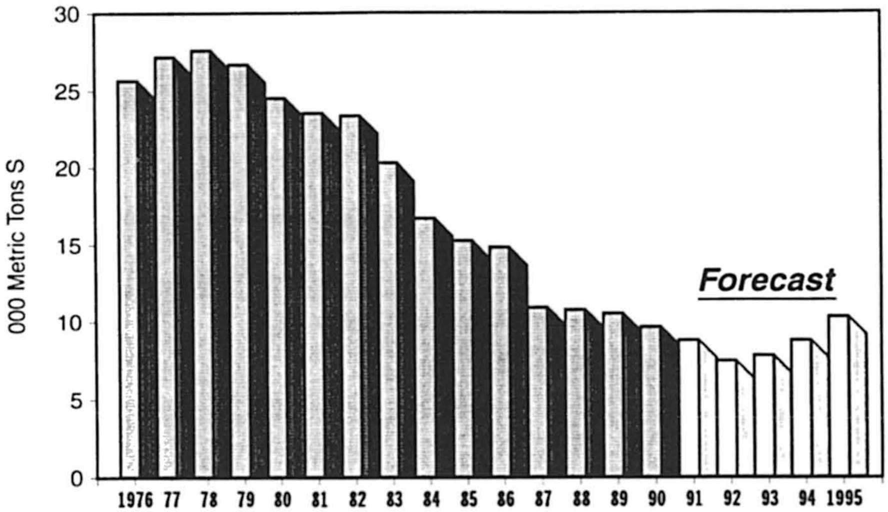


World Sulphur Supply/Demand

Sulphur-In-All-Forms

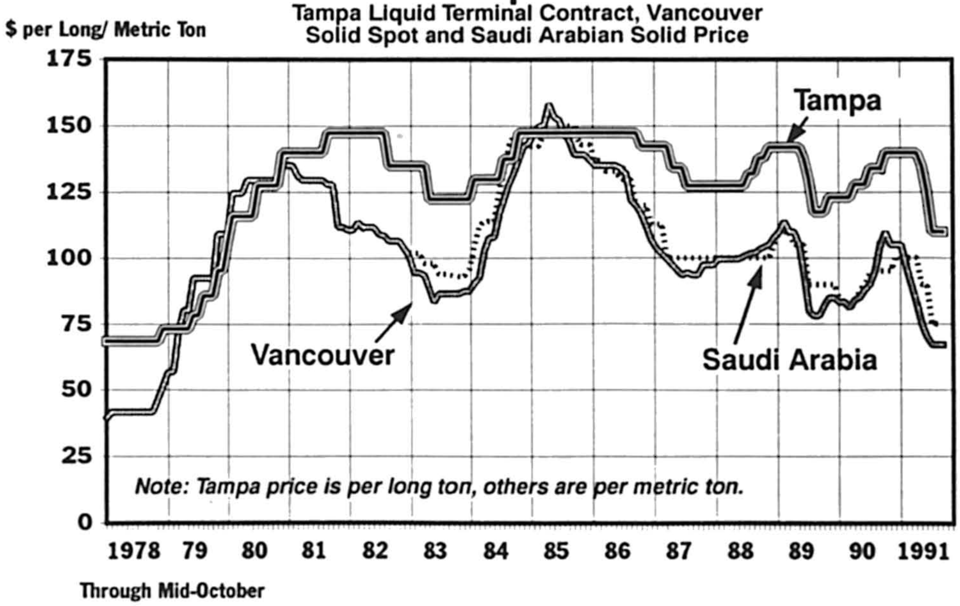


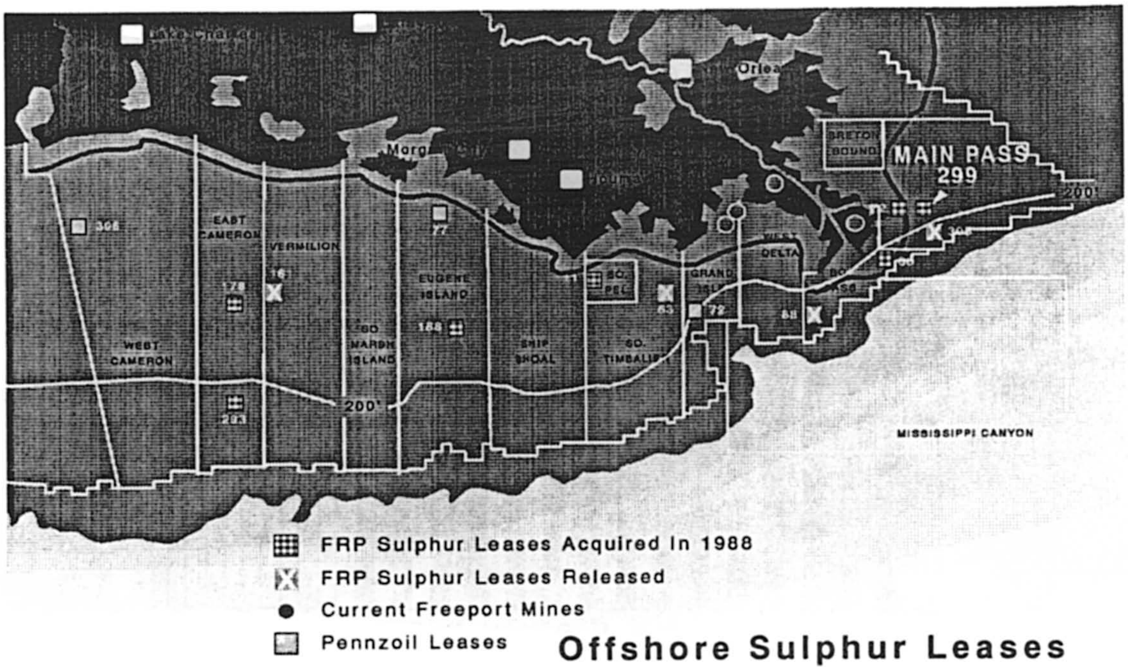
World Sulphur Inventory



World Sulphur Prices

Tampa Liquid Terminal Contract, Vancouver Solid Spot and Saudi Arabian Solid Price

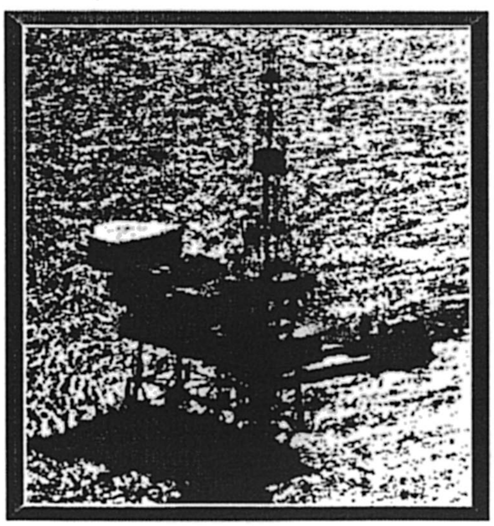




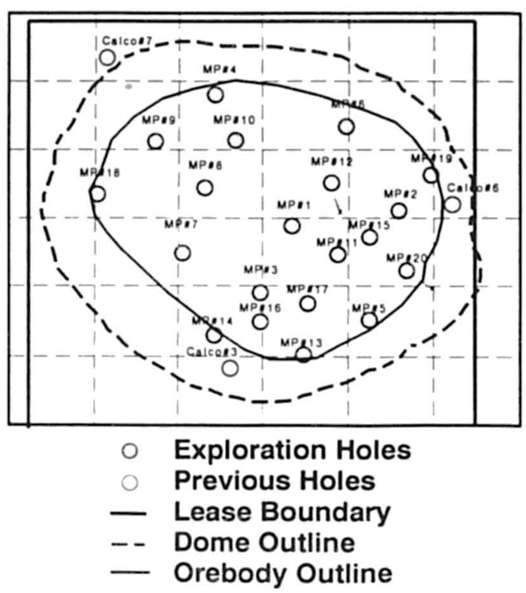
Offshore Sulphur Leases

Exploration Period

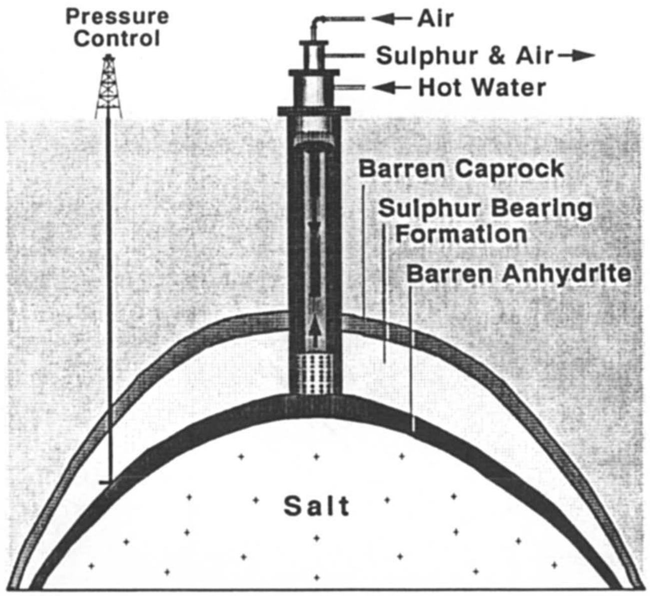
December 1988 to March 1989



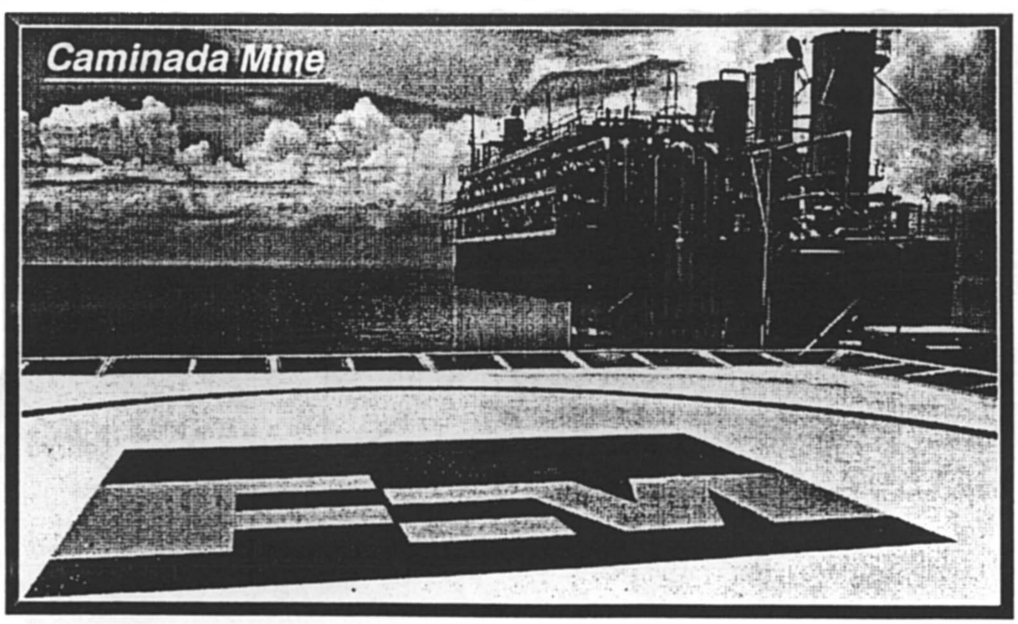
Drill Hole Locations

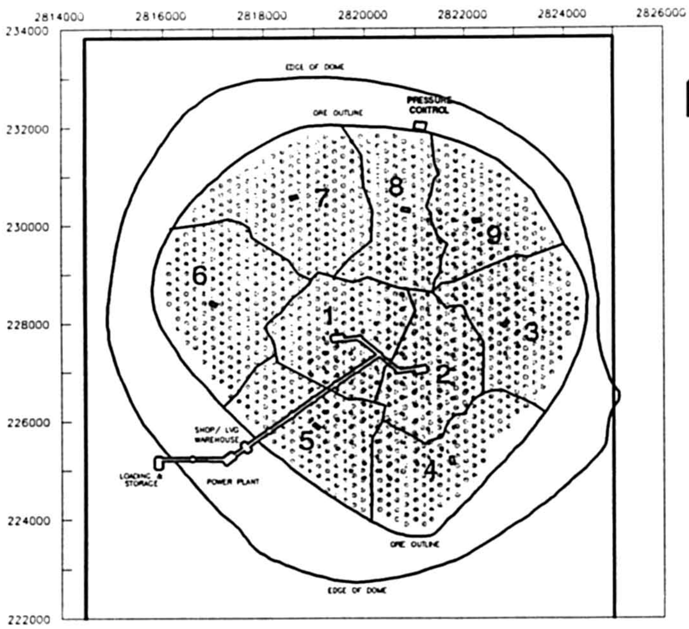


Frasch Process



Freeport - Proprietary Seawater Process

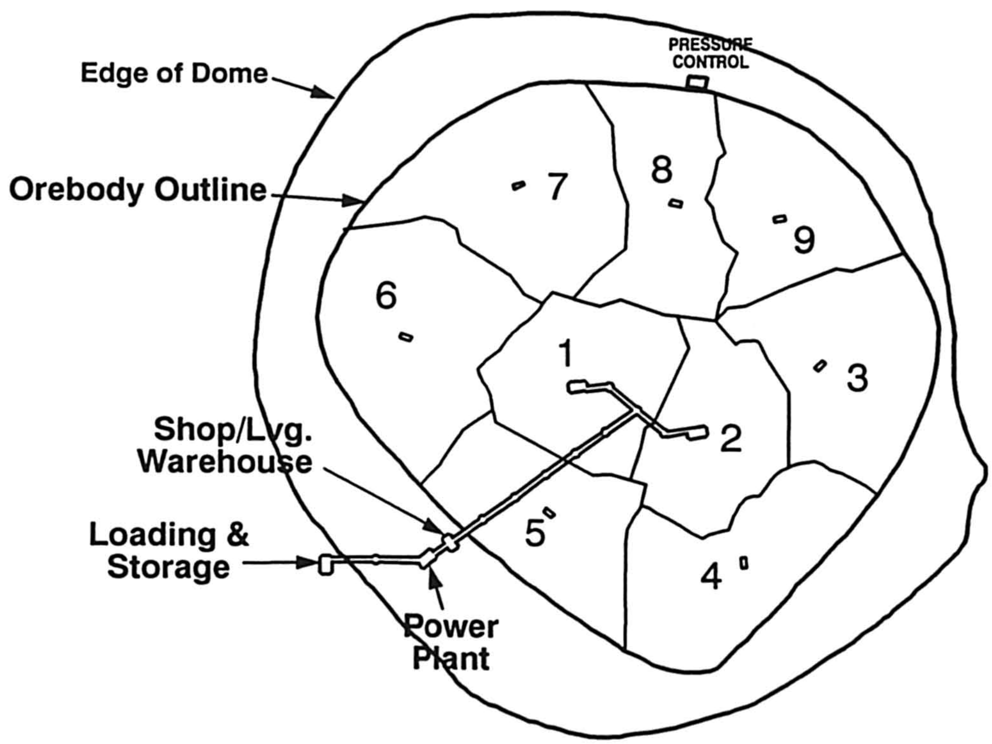


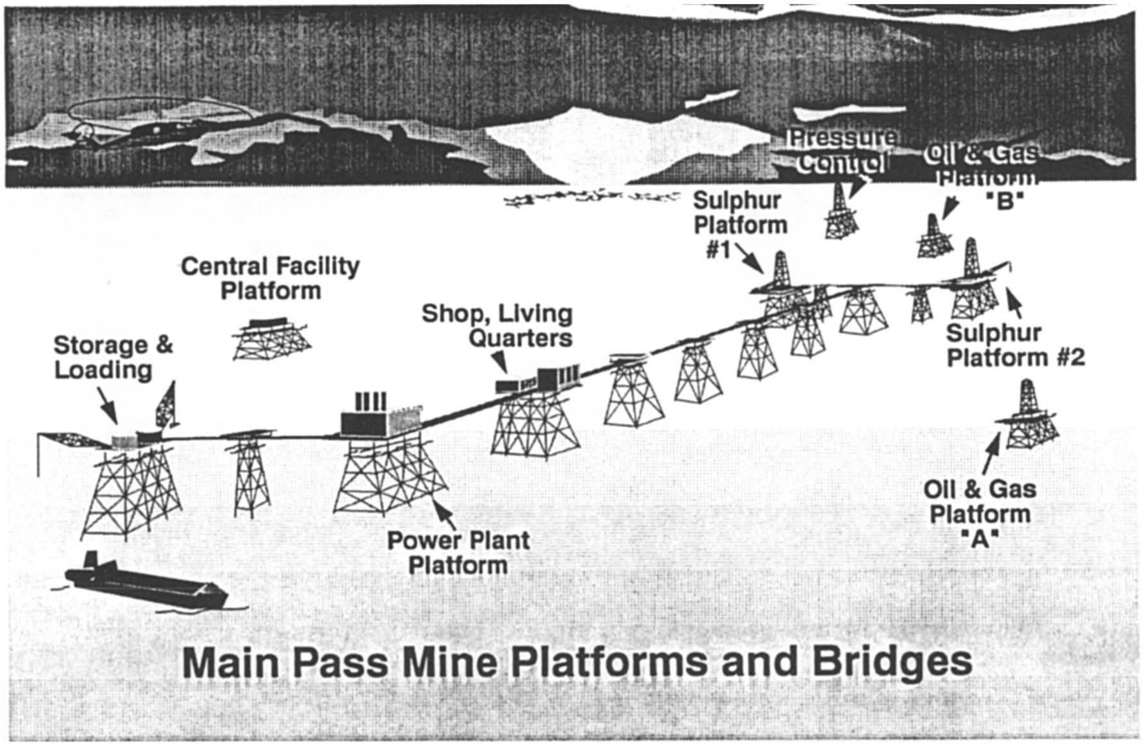


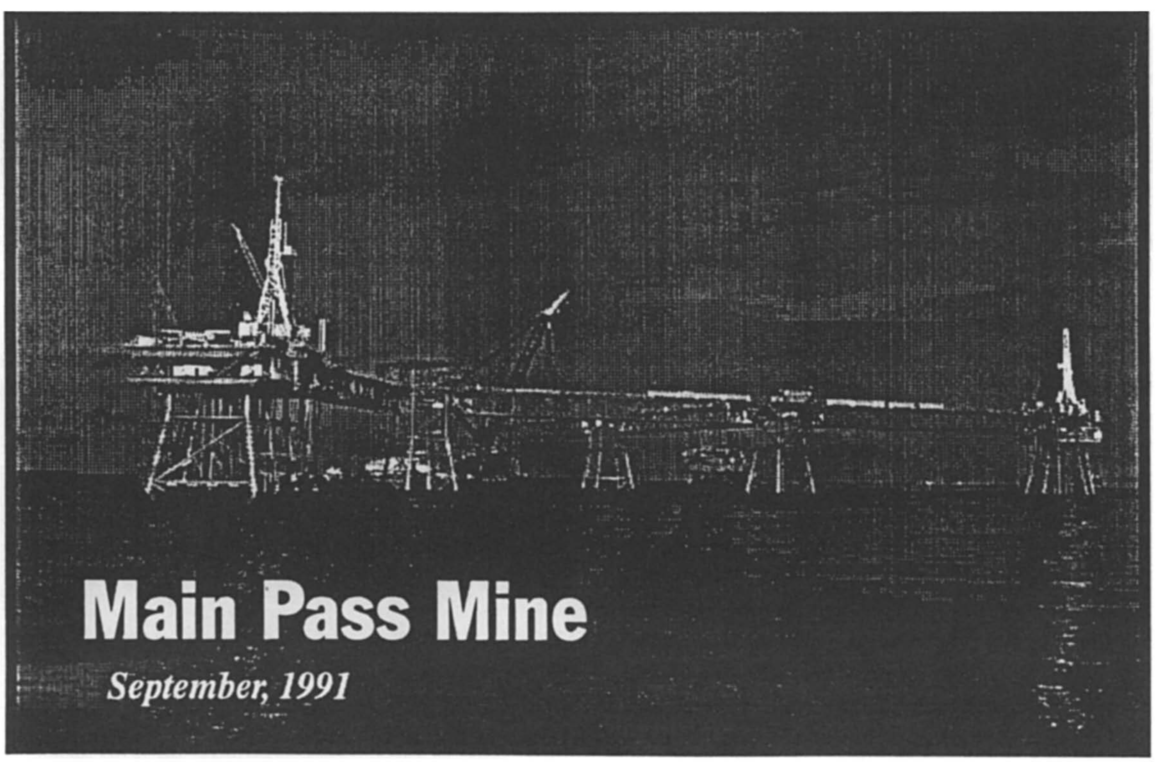
MAIN PASS MINE

Sulphur Well Plan

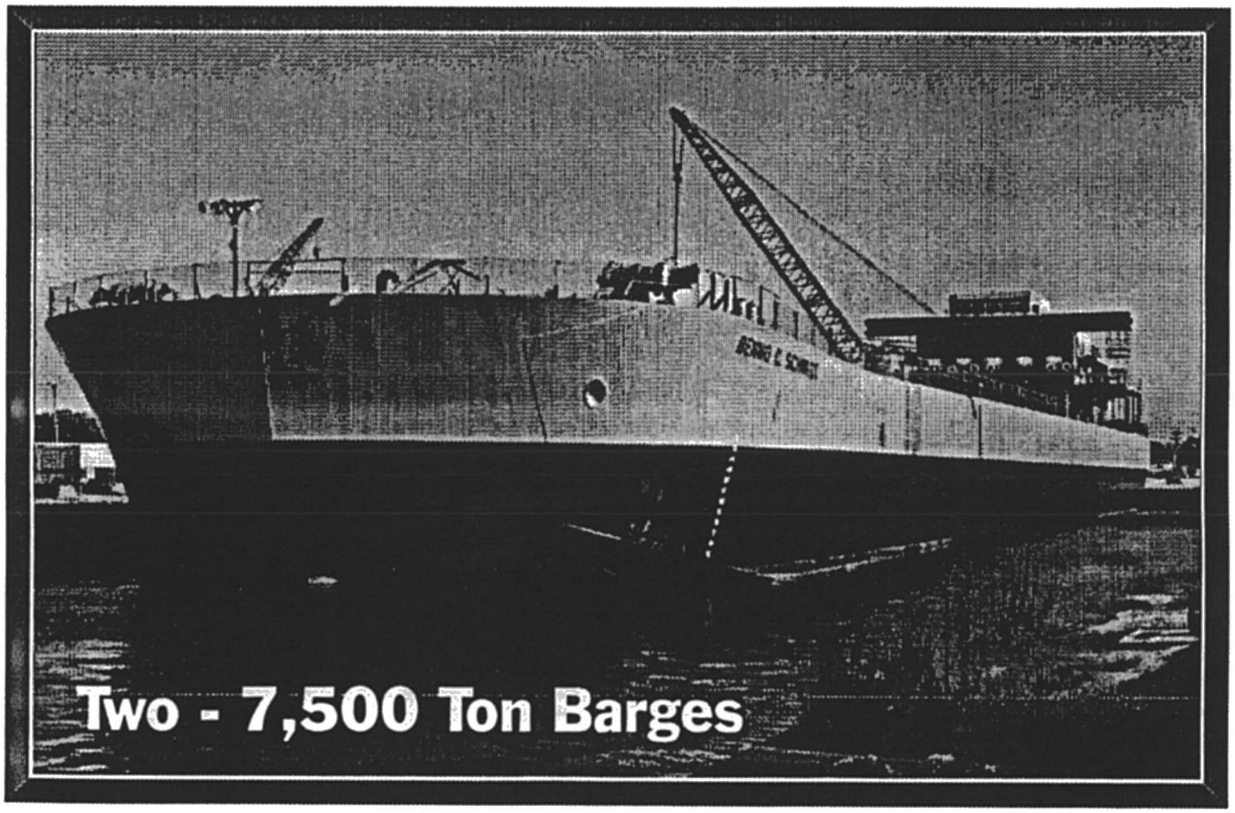
Total number of wells: 1592




Pressure Control
Oil & Gas Platform "B"
Sulphur Platform #1
Central Facility Platform
Shop, Living Quarters
Storage & Loading
Sulphur Platform #2
Oil & Gas Platform "A"
Power Plant Platform
Main Pass Mine Platforms and Bridges


Main Pass Mine
September, 1991

Main Pass Transportation



Monday, October 21, 1991

Session II
Moderator:
Richard Harrell

Providing Agronomic Services to Farmers/Growers in the Future

Panel Discussion:

Ford West
The Fertilizer Institute

USDA announced on November 3, 1989, a new ASCS pilot program to encourage farmers to adopt Integrated Pest Management (IPM) and Integrated Crop Management (ICM) Plans. The program, known as SP-53 was designed to cut fertilizer and pesticide use by at least 20% to protect ground and surface water.

State ASCS offices picked five countries for the program, and up to 20 farmers per country. If the farmer entered the program, he was compensated $7 an acre for row crops and $14 per acre for specialty crops. Money for this project came from the $900,000 budgeted in FY 90 for the Water Quality Initiative Projects. Also, retail fertilizer dealers were excluded from assisting farmers develop plans for the program.

The program was recommended by USDA's National Conservation Review Group (NCRG) at the February 17, 1989 meeting in Washington, D.C. NCRG consists of approximately 40 USDA officials, mainly from ASCS, SCS, ERS, and FS.

In August 1990, ASCS revised its SP-53 guidelines and places emphasis on "efficient use and demonstration of ecological benefits" rather than simply the reducing of pesticide or fertilizer. However, dealers continue to be excluded from assisting farmers in the program.

In January, USDA budget proposed to Congress requested $5 million to fund the Water Quality Intensive Program, authorize in the 1990 Farm Bill, to further expand the management plans outlined in the SP-53 program.

In July 1991, the House Appropriations Committee did not fund the WQIP; stating the committee would wait to see final rules and regulations for the program. However, $3.5 million was added to fund the WQIP program during the House floor debate on the Ag Appropriations.

In September 1991, the Senate Appropriations Committee approved $3.5 million for the WQIP indicating that retail fertilizer dealers should not be excluded from assisting farmers to apply for the program. The funding was increased to $10 million during Senate floor debates.

The final Appropriations Bill signed by the President funding $6.7 million for the WQIP program with instruction to USDA not to exclude retail fertilizer dealers from the program.

Dr. Charles Mellinger
Glades Crop Care

I am honored to have the opportunity to participate in this important meeting. I'm grateful to be able to share with you my ideas about how independent consultants can discuss and work together with the fertilizer industry and others to best meet our common goals of serving production agriculture. Our jobs, both yours and mine, have gotten tougher the last few years. Our growers are being squeezed by a tight and volatile farm economy and society's environmental and food safety concerns.

The Nature of Core Services

My company, Glades Crop Care, is a service-only company. We sell or profit from no product representation. We are members of both National Alliance of Independent Crop Consultants and American Society of Agricultural Consultants, and adhere to both societies' codes of ethics. The services our clients expect from us have evolved with the times. Our clients expect us to help them stay abreast of the latest technology, to make proper agronomic and pest problem diagnoses on a timely basis so that something effective and economical can be done about them, and to help them make money.

Farmers look to us for crop management advice that cuts across agronomics, pest control, water management, and production. Before the term became fashionable, Glades Crop Care had been devising ***integrated crop management*** plans for our clients. Our general focus and responsibility is targeted toward intensive crop protection programs of high cash value crops. We and our clients have learned the hard way that often fertility recommendations can't be separated from pest management needs, or disease scouting from water table fluctuations. Success in the end is determined not by the wisdom of a farming system's component parts, but by how well the parts fit together.

We provide growers timely, accurate, and perceptive site specific services. This is clearly a major part of what our company does best. We improve clients' profitability when we empower them with information they can use to increase yields, improve quality, reduce losses or cut costs. To accomplish this task, I have listed five major areas of service:

1) Monitoring foliar nitrate levels and availability; and watching out for trace element deficiency symptoms

2) Tracking our major pests and pest complexes' life cycles, population levels, and interactions, particularly insects that can function as plant disease vectors

3) Assuring proper water management, both to sup port optimal plant growth and to reduce the incidence of soil borne disease problems and fertilizer leaching

4) Advising on compliance with applicable pesticide product label provisions, restrictions, and precautions, as well as maintaining appropriate "paper trails" to make sure that we know what has been sprayed when, where, and how, along with actual application technology recommendations

5) Tracking key pest movement across our major producing areas where different clients operate; as sessing, and in some cases forecasting, when a pest new to an area will be a problem and what to do about it

I think we do an excellent job in these areas and take time to really stay on top of what is going on in a cropping system. However, it is a tough management decision for a small company like Glades Crop Care to allow technical staff to allot several weeks of time each year to non-client (and therefore not directly profit producing) scouting, taxonomic type research, and trouble-shooting activities that benefit all of Florida agriculture, including those many, many growers who are not our clients. Some of our clients do actually have some questions about this too, since they end up paying for Glades Crop Care's "public service" activities.

Whims of Mother Nature

We have also gained a lot of experience in the last few years in dealing with the unexpected. Regardless of how sound your planning and monitoring, wild swings of weather or unanticipated changes in pest pressure —or the loss of some key pesticide — can throw things into a first class panic. We are spending more and more of our time in what most people would call "crisis management".

I will discuss one example and highlight the new activities and services called for in dealing with unexpected challenges, and, indeed, some ethical dilemmas with which we have been confronted.

The Arrival of *Thrips palmi*. This new insect became established in the continental U.S in our area, south Florida, in early 1991. It was first identified by a Glades Crop Care staff entomologist. It is a voracious feeder, thrives on a wide range of crops, and is responsible for serious economic damage on crops in several areas of the world. It is also very difficult to kill. As we tracked the insect's spread across south Florida, we became more and more concerned about its impact on our control programs.

This identification could have placed us in an unexpected ethical bind. Because this pest triggered all the quarantine regulations of the Florida Department of Agriculture and Consumer Services (FDACS) and the USDA, we were responsible for reporting our finding to them and did so. Fortunately, our client agreed with the necessity of sharing information with the public, but other less knowledgeable and self-serving growers may not have wanted anyone to know of the pest's presence. One of our sacred credos with our clients is that what occurs on his farm is between us and him.

Before agreeing to work with any client, we discuss and agree up-front about what we will do in a similar situation in the future. We expect that our ethical and professional obligation to report such pest infestations will not cost us any business.

I could cite other examples involving our response to unusual climatic conditions, unexpected changes in pesticide labels, and other difficult choices we have had to make in serving our clients to the best of our abilities.

Emerging Service-Oriented Challenges

Our challenge as agricultural science and technology professionals is to come up with new knowledge-based systems and approaches fast enough to replace the many products and technologies we are losing to production problems, regulation and pest resistance.

Some of the new services we in Glades Crop Care are discussing and feel will be important for our clients in the near future are as follows:

• Pest resistance monitoring on a real-time, field and pesticide specific basis

• Pesticide resistance management planning and implementation and even as this applies to the entire crop protection system. Some of this is already underway and needs to be vastly expanded.

• Monitoring and managing soil physical properties and the water-table with the goal of increasing the efficiency of nutrient retention and uptake and controlling leaching; and, how this relates to plant disease management of soil-borne pathogen levels

• Improving and expanding our fertility monitoring and management program

• Figuring out ways to drive pesticide residues down below "acceptable levels", however and whenever such levels are finally established. Much more science-based experimentation can be carried out with reduced rate applications, use patterns with fewer applications and lower rates and longer preharvest intervals.

I hope I'm being realistic about our ability to stay ahead of this dual nemesis: regulation and resistance. But I have seen major companies make decisions about which labels and use patterns to defend — and which to drop — which have been clearly adverse to the interests of growers and the environment, and in my judgement for not very good reasons.

I would hope that our policy-leaders and government decision makers would temper their well-meaning efforts with a little more good old common-sense practicality. And perhaps most importantly, more realistically educated voters are needed. Yes — we can and indeed must continue to perform "miracles", but society must not ask or expect us to do so on a monthly basis when Mother Nature and the farming systems we work with change according to a time scale measured by years.

The Foundations for Success

You and I should do a number of constructive things to ensure continued grower "success".

Academic scientists must be supported, maybe even cajoled or bribed, whatever gets the job done, into more applied, problem- oriented multidisciplinary research. We need their help to better understand the basic biological and ecological cycles and the interactions that govern nutrient flows, crop-pest interactions, and performance in our major cropping systems.

We often suggest that academic multidisciplinary teams should be organized to work on problems. I also think we need to tap expertise that exists throughout the agricultural industry. For example, there ought to be a way to involve in these teams crop consultants, industry scientists, for sure, the farmers, and other technical experts who often have unique contributions to make. These groups might work on cross-cutting challenges like fertility management as they impact production and environmental quality.

An example of this might be a recent meeting held in the Belle Glade (Palm Beach Co. , FL) ASCS office between a sugarcane grower, his crop consultant and his fertilizer salesman. Among these three, an excellent SP-53 program was worked out. We finalized and delivered it to the District Extension Specialist for his approval and signature (only extension personnel in Florida can sign and approve these programs). He signed, and in conclusion all parties involved had a most satisfactory program.

We have to develop new ways to package, price, and sell more complex and costly analytical and cropping system management services. When we started our business, it was based largely on scouting and recommending when and how to apply pesticides. Our clients know we have helped them achieve increased yields, improved grading performance, and frequently, not always, reduced pesticide expenditures. At the very least, our clients and the public can be certain when agrichemicals are relied upon, they are being used in the most efficacious way and because of crop quality requirements.

With our current fee structure, we cannot keep up with pest pressures, changing technology and regulation, new and stricter environmental/food safety standards, and the growing absence of publicly funded pest monitoring, research, and quarantine efforts. As it becomes tougher to point to tangible, direct benefits from an annual crop expenditure, it becomes harder and harder to convince bottom-line oriented managers to pay increased fees.

We also have to find better ways to convince a skeptical public that production agriculture can responsibly utilize technologies that can pose significant risks when deployed recklessly or negligently. Take aldicarb, carbofuran, arid the EBDC fungicides as examples. These products all have, or could have valuable roles to play in Florida agriculture, and can be used safely, I am convinced. But many others remain unconvinced, and without some major changes in how we in agriculture propose to use these products — and police ourselves -we are not likely to have a chance to continue using the necessary products.

In conclusion, I feel we have an ethical obligation to work in the best interests of our clients and society. The interests of both can best be served by asking ourselves how we can upgrade the performance of the crop protection and production technology delivery and application systems we now use.

We must regain and retain society's respect and trust in our ability to utilize agricultural technologies prudently while remaining committed to environment protection.

How effectively we in the agricultural sector work together to provide the farmers quality products and services will directly impact production agriculture. We need to find better ways to think and act together on behalf of agriculture arid the country. I thank you for your attention and hope you all agree it's a truly worthy challenge.

John T. Woeste
University of Florida

We appreciate the opportunity to visit with you addressing the important question of providing service to producers. In addition to sharing our perspective, we are interested in learning from you. Based on discussions with Ford West, our presentation will be fairly specific and concise. We want to leave adequate time for questions and to hear from you on the subject under discussion.

The early calls inviting my participation on the panel focused on discussions concerning the ICM Program referred to in ASCS as SP 53. We have been involved with that program in Florida. We have also spent a good bit of time discussing some issues concerning implementation of the program.

At the outset we want to indicate our belief that the ICM program is a desirable program since it encourages increased attention to more planned and careful monitoring of plant nutrient management and pest control strategies. We indicated to ASCS and to those wishing to participate in the program our willingness to work with them to help establish and implement the program in Florida.

We understand that there have been questions about the eligibility of those who could develop the plans. We have not been a party to debate of that question in Florida. We do understand the sensitivity of the question. We have also offered to work with interested parties to find an approach or process that would include dealers and product representatives in the program delivery. Our discussions and concern however have been in a different direction. We believe that the mission of Extension is education and that we can best achieve our mission by being focused and pure in adhering to that mission. Specifically, we wish to avoid any regulatory or administrative type activity in order to send a clear signal to the producers and other clientele of Extension that our only interest is providing them with the best available information and advice. We believe that our role is to provide the best available research-based information and expertise within the Land-Grant University System to help people achieve their objectives. Experience around the world affirms the necessity of separating Extension Education from regulatory and administrative activities. Repeated episodes in this country clearly suggest that an objective educational program best serves the interests of agriculture and the larger public community.

Looking ahead, from a Florida perspective we would hope that all ICM plans would be developed by the private sector. We will provide training and technical backstopping within the expertise and resources available for anyone doing the work.

We have a long history in the U.S. of private sector/ public institution cooperation. That is especially true in agriculture. A study of comparative systems around the world clearly indicates that such cooperation is an important element in the accomplishments of our food and fiber production capacity. Much of that public/private cooperation involved suppliers, industry R & D personnel and industry technical personnel.

During the 70s and 80s there emerged an increasing number of private for-fee independent consultants/providers of agricultural information and services. From our perspective they are a logical part of the production system. They have become very specialized in the services offered. They have contracted to perform many of the operational and managerial tasks for the operating unit. Because some of their activities were similar to those performed by Extension faculty both county agents and specialists, some conflicts have evolved. That was to be expected. Over the years, however, discussions and interaction have resulted in both a sorting out of roles and a general consensus on expectations. Although there remains individual points of conflict, there does appear from my perspective a general pattern of roles and relationships that define the interaction between the independent consultants and the Extension faculty. Hopefully, and I am encouraged, that cooperation has been the route to mutual success and a more profitable and environmentally compatible agricultural enterprise for those served rather than the alternative of competition in a winner and loser framework.

Just as the seed company representatives, the feed representatives and the chemical representatives have worked with research and extension so must the private consultants be part of the system. We in Extension need to welcome them into the pool of expertise serving the food and fiber industry. In turn we hope and believe that it will be important to the food and fiber industry for the consultants to maintain a perspective as team players just as their predecessors did. Extension and private industry—to the amazement of the uninformed public—have participated in joint research, joint field studies, joint trials and evaluations, and cosponsored many meetings, tours and educational events that led to an exchange of expertise and information. Through the collective efforts an ever increasingly productive and environmentally compatible food and fiber production system developed. We shared in the development and the use of a common and highly accessible body of knowledge.

As I look ahead, I believe that it is going to be important for independent consultants, industry personnel and the University to join in more collaborative efforts. Meeting the challenges facing the production sector both from a world economic perspective and an environmental compatibility perspective demands nothing less than our best collective efforts.

Speaking to the future in specific terms, we see an expansion of private independent consultants. We also see an increase in services provided by dealers and suppliers. The tasks of scouting insects and diseases, weed identification, soil, nematode and tissue sampling and testing all need to be expanded in use and refined in application. Further, agriculture and thus Extension as well as the public sector are facing a growing number of issues. The production problems are becoming more complex. The environmental, economic, political and social issues confronting producers place new demands on their time and their expertise often beyond their capacity. As a result, I see an increasing number of private sector providers addressing legal concerns relating to labor, market arrangements and financial contracts. Environmentally related demands such as the acquisition of permits, the completion of environmental audits and the establishment, maintenance and use of various reports dealing with chemicals, fertilizer and other materials all beg for specialized individuals to assist the farmer/rancher in meeting the requirements associated with doing business. As a result, we see specialized personnel working with large groups of farmers and ranchers addressing these new demands. The numbers of individuals coming to the Extension office asking for such assistance is dramatically increasing. While we have a role in developing educational programs related to those issues and we are rapidly shifting resources to fulfill the role, it is not the Extension mission to complete the paperwork, defend the application before hearing bodies, formulate situation specific responses to regulatory agency inquiries or address warnings and citations. As we see agriculture evolving in Florida, there is a crying and I fear still growing need for such services. Again, we are committed to providing technical assistance, training and the best information we have within our system to those individuals committed to addressing the service need. The farmers and ranchers are running to keep up, and the climbs are getting steeper. Increasingly the engine sputters.

We look forward to the question and answer session. Again we appreciate the chance to be with you. It gives us an opportunity to learn from you.

Al Giese
CENEX/Land O'Lakes

The Retail Dealer In The Era of Precision Farming

1. AGRICULTURAL ERAS -
Mechanization - Tractors
Genetics - Hybrid Seeds
Chemicals - Fertilizer & Pesticides
Management - Information-Based Precision Farming

2. AGRICULTURAL ISSUES OF THE 90'S -
Many issues will affect agriculture In the 90's and beyond, some of these issues are:
   - Globalizatlon
   - Restructuring/Rationalization
   - Consumer Driven Demand
   - Advancing Technology
   - Cost Competitiveness
   - Diversity vs. Focus and Flexibility
   - Capitalization
   - Strategic Positioning
   - Environmental/Sustainable Issues
   - Farm Policy

3. DR. ROBERT BLACKWELL (OHIO STATE) -
"The future always arrives a little before your ready to give up the present.

4. EVOLVING SOCIETY VIEWPOINT -
Positive - Low-Input/Sustainable/Alternative
Negative - Conventional Ag/Fertilizer/Pesticides

5. HOUSEHOLD WORDS -
   - Organic
   - Groundwater
   - Blue Babies
   - Nitrates
   - Chemical Intensive Ag
   - Sustainable Agriculture

6. FARMERS NEEDS ARE CHANGING -
   - Time Limitation Increasing
   - Knowledge and Information Limitations Increasing
   - Advancing Technology Is Complex
   - Increased Efficiency Required to be Competitive in Global Markets
   - Environmental Concern is a Major Issue

7. % OF INCOME -
It Is Important to recognize that Americans enjoy the most abundant, highest quality, and lowest cost food supply the world has ever known; which Is a direct result of "Traditional Agricultural".

8. SUSTAINABLE AGRICULTURE -

9. IS SUSTAINABLE AGRICULTURE -
A management system which reduces or eliminates the use of fertilizers and pesticides, and replaces them with alternative methods?

10. OR IS IT AN ELITIST FOOD POLICY THAT -
Disregards Economic Impact
Disregards Ag Impact
Disregards Effect on World Hunger
Disregards National Security Implications

11. OR IS SUSTAINABLE AGRICULTURE -
A management system which uses inputs, natural and purchased, in the most effective manner possible to farm profitably and minimize effects on the environ ment. If this is what Sustainable Agriculture is, we certainly endorse it, and Agriculturists have been supporting it for several decades.

12. LOB INPUT -

12A. Some experts would advocate, and this chart supports the theory that low-input and sustainable agriculture is not new to the American farmer, and he in fact has been practicing low-input in his crop enterprise.

13. PRODUCTION AGS CHALLENGE IS TO -
Balance economic crop production, environmental safety and global food needs.

14. CROP INPUTS ARE EACH UNIQUE - EACH ESSENTIAL -
Fertilizers - Plant Food, found in nature
Pesticides - Protect plants from weeds and insects - generally man-made

Both essential to sustainable food production.

15. BMP'S ARE THE KEY -
Best management practices applied to agriculture is sustainable agriculture.

16. WE FIND LITTLE, IF ANY, SUPPORTING AGRONOMIC RESEARCH -
For low-Input and sustainable on a macro basis - it is only SUSTAINABLE on a micro or nIche basis.

17. BMP'S PROPERLY RESEARCHED AND IMPLEMENTED CAN -
Preserve a Quality Ag Environment
Maintain an Efficient, Reliable Production Agriculture

18. THE ERA OF INFORMATION BASED PRECISION FARMING -

19. FOCUS ON THE LIKELY BUSINESS STRUCTURE OF THE DEALER -
First of all, let's look at the crop producer segments:
Small farms (significant off-farm Income)
- Account for majority
- Outside income dependent
- Rely on dealers
- Employment availability

20. MIDDLE SIZED "FAMILY" FARMS -
- Double in Size
- Fulltime
- Time/Knowledge Limitations
- Professional Agronomic Assistance
- Will Pay For Knowledge
- Capital/Risk System May Be Altered

21. LARGE FARMS-
- Risk and Capital Sharing
- Professional Management
- Rely on Outside Expertise

22. THE RETAIL DISTRIBUTION SYSTEM -
- Fewer and Larger Sophisticated Dealers
- Innovation for Increased Efficiency and Fewer Physical Facilities.

23. - The Dealer will Maintain a Visible Presence in the Rural Community
- The Dealer Will Maintain Convenience and Accessibility for Crop Producers and a High Level of Service
- The Dealer May Provide Capital to the Farmer
- The Dealer Will Offer Professional Agronomic and Environmental Expertise and will Access an Agronomic Support System

24. OUR BELIEF - SUCCESSFUL DEALERS BILL - Market products, knowledge and professional crop production expertise In the future.

25. THE RETAIL AGRONOMY SYSTEM -
Must focus on the 3 Increments of Agronomlc Professionalism

- Information Gathering
- Information Delivery
- Human Expertise

26. INFORMATION STRATEGY

In Closing, I want to emphasize that the evolution and vision I've talked about today is our view at Cenex/Land O'Lakes, and although we think it is based on knowledge and logic you may or may not agree with parts or all of it. We are certain that significant changes must and will occur to meet the changing needs and concerns of the crop producer and society in general. The debate is only what the changes will be and what effect they will have.

We feel that these changes are irreversible, will be dramatic, and also sometimes painful, but none-the-less necessary for survival and prosperity.

We know that the challenges are real and that your leadership is essential if we are going to focus on rational change in agriculture.

We should also realize that with challenge also comes opportunity. The opportunity to move American agriculture in the direction of achieving the balance - for the farmer - who has an economic imperative of producing at peak efficiency and for the consumer who expects a low-cost abundant and safe food supply.

Our future actions as agriculturists will help determine the ultimate outcome.

End of Panel Discussion

Rheology Modifiers For Phosphate Rock Slurries

John T. Malito
Nalco Chemical Company

Introduction

In the early 1970's, dry grinding of phosphate rock became uneconomical largely due to the escalating cost of fuel required for drying the rock. Wet grinding became even more attractive with the advent of evaporative reactor inter-stage coolers which resulted in significant reductions in water usage. It was quickly realized that the saved water could be returned to the attack circuit by wet grinding without seriously affecting the water balance. Also, for the same throughput, power consumption was found to be less in wet grinding.

Unfortunately, not all the attributes of wet grinding are desirable. The severity of problems associated with wet grinding depends on the rock source and on the specific processing practices at each phosphoric acid plant. In general, the following disadvantages have been identified:

1. The fraction of oversized rock, particularly the +35 and +20 mesh fractions, is difficult to control even in closed-loop grinding. The immediate result is incomplete extraction of P_2O_5. In closed-loop grinding, the fraction of oversized rock can be reduced by increasing the proportion of slurry recycled to the mill. However, due to relatively poor efficiency in classification, a large number of fine particles are also recycled. The high recycle rate reduces mill throughput and increases grinding costs. The cost of high recycle rate must be balanced against extraction losses.

2. The water used in wet grinding can adversely affect the plant water balance. Figure 1 shows the amount of water that enters the attack circuit with the rock slurry. These graphs were constructed assuming 95% P_2O_5 extraction. Thus, in the region of 65% - 70% solids, each 1% increase in slurry solids results in a savings of about 140 pounds of water per ton P_2O_5.

3. Sort or porous rock is subject to over-grinding that produces a hyperactive rock and attendant poor gypsum crystal formation. This problem usually appears as reduced gypsum filtration rate and high filter losses. Also, over-grinding can, especially in high clay rock, produce a slurry which is difficult to pump.

Most of the above problems arise from the rheological properties of the slurry produced during grinding. Phosphate rock slurries generally behave as Bingham plastic or pseudoplastic fluids. The magnitudes of the yield stress and the viscosity at high shear depend on rock source (mineralogy, particularly clay content), particle size distribution, percent solids, and water-phase chemistry. The rock slurry is generally exposed to high shear conditions in the grinding circuit, slurry pumps, and transfer lines. The shear rate in large slurry surge tanks can vary from high in the vicinity of the agitator to low near the vessel walls. Considerable energy is expended in moving the slurry and keeping the solids suspended.

Perhaps the most important operating parameter in the grinding circuit is the slurry viscosity, which increases rapidly with slurry solids, particularly as the solids content approaches 65 - 70%. Chemical reagents have now been developed which will significantly reduce the viscosity and provide the following primary benefits:

1. Better grinding efficiency, less oversized rock, greater P_2O_5 extraction.

2. Increased slurry solids, stronger acid, lower evaporator costs, more favorable water balance.

3. Increased throughput, lower grinding costs.

4. Lower pumping and slurry agitation costs.

Other benefits, which have been observed in lab and plant evaluations, will be discussed later.

Experimental

Most methods for measuring the viscosity of high-solids slurries containing large particles are not reliable due to the heterogeneity of the slurry and the tendency of larger particles to settle out during measurement. The procedure described here involves measurement of torque on an agitator immersed in the slurry and rotating at different speeds. It is convenient, reproducible, and easily adapted to field work. More important, the viscosity is obtained under conditions of high shear which eliminates problems caused by particle classification.

In developing the test method, use was made of the relationship between the Power Number(N_p) and the Reynolds Number (N_{Re}) in agitated liquids and solid/liquid suspensions. Examples of this relationship are shown in Figure 2, where the lower and upper curves represent Newtonian and non-Newtonian fluids, respectively. The Power and Reynolds numbers are dimensionless and are defined as:

$$Np = \frac{Pg_c}{\rho N^3 D^5} \qquad N_{Re} = \frac{\rho ND2}{\mu}$$

where P = power (2πNT)
ρ = density
N = agitator speed
D = impeller diameter
μ = viscosity
g_c = gravitational constant

The shape of these curves depends on the fluid rheology, size and shape of tank, presence of baffles, and agitator design. For many fluids, the curves are linear with slope -1 at low N_{Re}. This region is called the viscous regime since the power required for mixing is determined primarily by the fluid viscosity

(μ is large and N_{Re} is small). The opposite end of the scale is the turbulent regime, where the power is independent of N_{Re} (μ is small and N_{Re} is large) and is determined only by the kinetic energy of the fluid. In the transition regime, where N_{Re} lies between around 10 and 10^3, the mixing power depends on both the fluid viscosity and kinetic energy.

In the viscous regime, or for sufficiently small intervals in the transition regime

$$\log (N_p) = \lambda og (N_{Re}) + \log (K) \quad (1)$$

where the slope and intercept are given by λ and log (K), respectively. Taking the inverse logarithm gives

$$N_p = kN_{Re}^{\lambda} \quad (2)$$

Substitution for N and N_{Re}, and holding the density and impeller diameter fixed, yields the following relation for the torque, T.

$$T = \frac{K_1 N(\lambda+2)}{\mu\lambda} \quad (3)$$

In logarithmic form, equation 3 becomes

$$\log (T) = (\sim +2) \log (N) + \log (K_1/\mu^{\lambda}) \quad (4)$$

If the slurry is Newtonian, or the measurements are taken over small changes in N_{Re} the viscosity will be independent of the agitator speed. Hence, a plot of log (T) against log (N) will yield a straight line with slope $\lambda + 2$ and intercept log $(K_1/\mu^{\lambda}$. Such a plot is shown in Figure 3. The high degree of linearity confirms that the slurry viscosity does not depend on shear rate over the given range of agitator speed. A study of several different phosphate rock slurries gave λ+ 2 values ranging from 1.6 to 1.9, depending on the slurry source and % solids.

The dependence of viscosity upon torque and agitator speed is given by

$$\mu^{\lambda} = \frac{K_1 N^{(\lambda+2)}}{T} \quad (5)$$

While the absolute viscosity cannot be computed without an explicit value for K1, the relative viscosity can be obtained from

$$\mu/\mu_o = (N/No)^{(\lambda+2)1\lambda}(To/T)^{1/\lambda} \quad (6)$$

where μ/μ_o is the ratio of the test viscosity to some reference viscosity. In determining the effect of additive on slurry viscosity it was necessary to reduce the agitator speed to compensate for lower viscosity. In this way the vortex depth and surface motion were kept more or less constant. Thus, N_{Re} was never allowed to deviate by more than 20%, in keeping with an assumption stated earlier.

Equation 6 has a singularity at $\lambda = 0$ and becomes unstable as λ approaches 0 (slope of the line in Figure 3 approaches 2.0). In this case, N_p is constant (independent of N_{Re}), indicating the turbulent regime in agitation power curve. Clearly, no information about viscosity can be obtained in this region. This situation can result from an unusually low viscosity and can be remedied by choosing a different agitator design.

Results And Discussion

The effects of four Nalco products on the viscosity of phosphate rock slurry having 66.3% solids and a specific gravity of 1.806 are shown in Figure 4. The level of additive in the slurry is given as pounds per ton of dry rock. For this slurry, 25% and 50% reductions in viscosity are obtained using 0.5 pounds and 1.0 pounds of 90DB-018 per ton of dry rock, respectively. At these additive levels, the experimental product LH11 offered an additional 7% reduction. Similar results were obtained with slurries obtained from several other sources. A wide range in activity was displayed by over two dozen products tested to date. Work continues to develop still more active materials. In one particular slurry the application of 1.0 pounds and 1.5 pounds of 90DB-018 per ton of solids allowed an increase of slurry solids from 69% (typical for this slurry) to 71% and 73%, respectively, without increasing viscosity. According to Figure 1, this would result in a front-end water savings of 0.14 tons and 0.28 tons per ton of P_2O_5.

For slurry agitated in the viscous or transition regimes, a reduction in viscosity will be accompanied by a reduction in power required to keep the slurry in suspension, as shown in Figure 5. This graph applies to agitation in vertical vessels such as slurry surge tanks and reactor vessels. The impact on wet grinding power consumption will manifest itself as increased throughput and improved grinding efficiency.

In addition to lowering viscosity, 90DB-018 also inhibited foam in lab digests using plant slurry and recycle acid. Figure 6 shows that this product effectively controlled foam at a level of 120 ppm, based on total digestion slurry. This level is equivalent to 1.0 pounds per ton of dry rock. In these tests, the inhibitors were added to the recycle acid. Excellent foam inhibition was still obtained at one-half of the previous dose when the product was added either to the recycle acid or directly to the rock slurry, Figure 7.

Conclusions

The cost benefits obtained from the use of rheology modifiers such as 90DB-018, depend on the specific operating conditions and practices at each plant. At present, insufficient plant data are available to quantify the key benefits. Furthermore, predictive models for estimating the effect of lower slurry viscosity upon the grinding circuit and subsequent effects on P_2O_5 losses are not available to the author. Nevertheless, the following benefits are expected.

1. A tighter particle size distribution can be achieved. In

particular, a lower +35 mesh fraction will reduce in soluble losses. This advantage is enhanced in those mills which use hydrocyclones in closed-loop grind ing.

2. Grinding can be performed with higher percent solids without sacrificing particle size and viscosity. Assuming the gypsum slurry has the same filterability at the higher solid content (and higher P_2O_5) evapora tion costs will be less and more water will be available for tail end washing, resulting in lower soluble losses.

3. In those plants where particle size and slurry solid are acceptable, residence time in the grinding circuit can be shortened to increase throughput.

4. Less energy will be required for grinding and pumping the rock slurry and also for keeping the solids sus pended in the slurry surge tanks and in the attack tank.

An additional benefit, unrelated to viscosity reduction, is that the current use of defoamers in the attack tank can be dramatically reduced or entirely eliminated. Finally, the chemical properties of 90DB-018 are such that other benefits are possible. Among these are improved gypsum cake dewatering and scale inhibition in the filter pans and evaporators. These potential effects are under investigation at Nalco.

FIGURE 1

EFFECT OF SLURRY % SOLIDS ON WATER USAGE

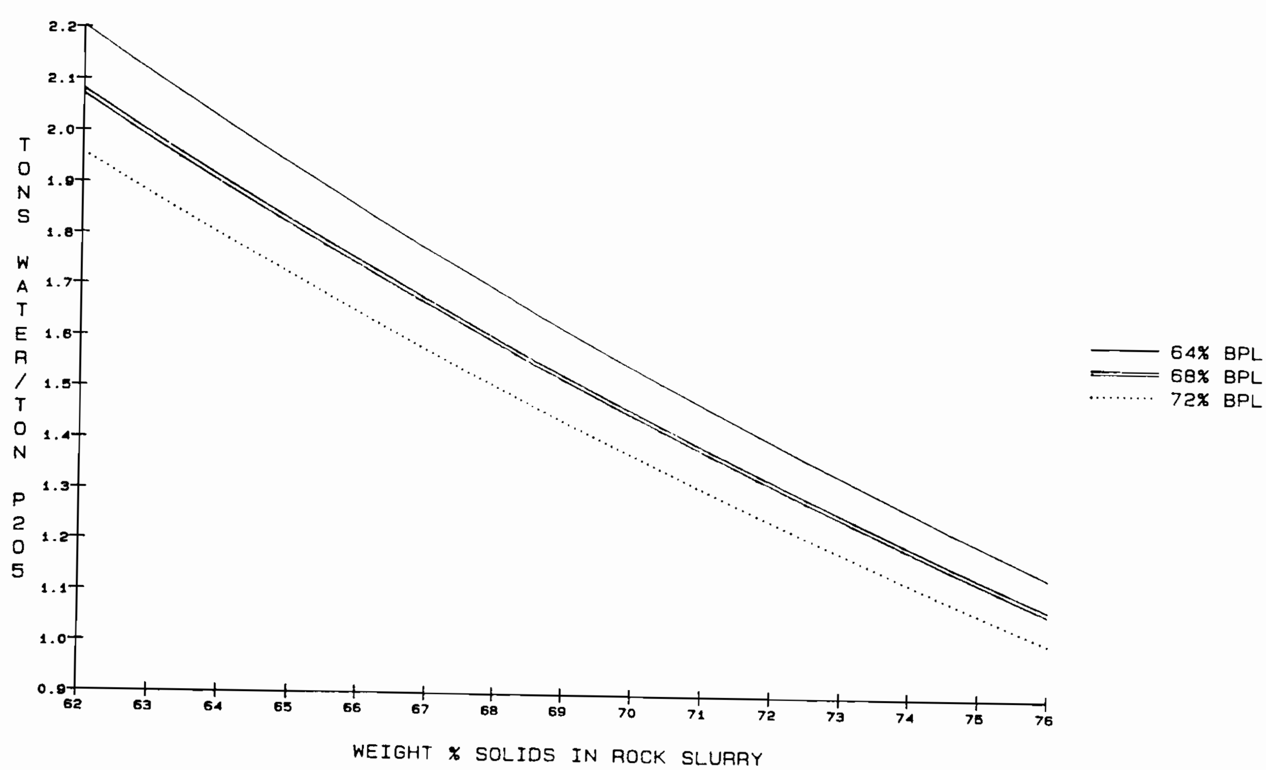


FIGURE 2

POWER CORRELATION CURVES
FOR AGITATED FLUIDS

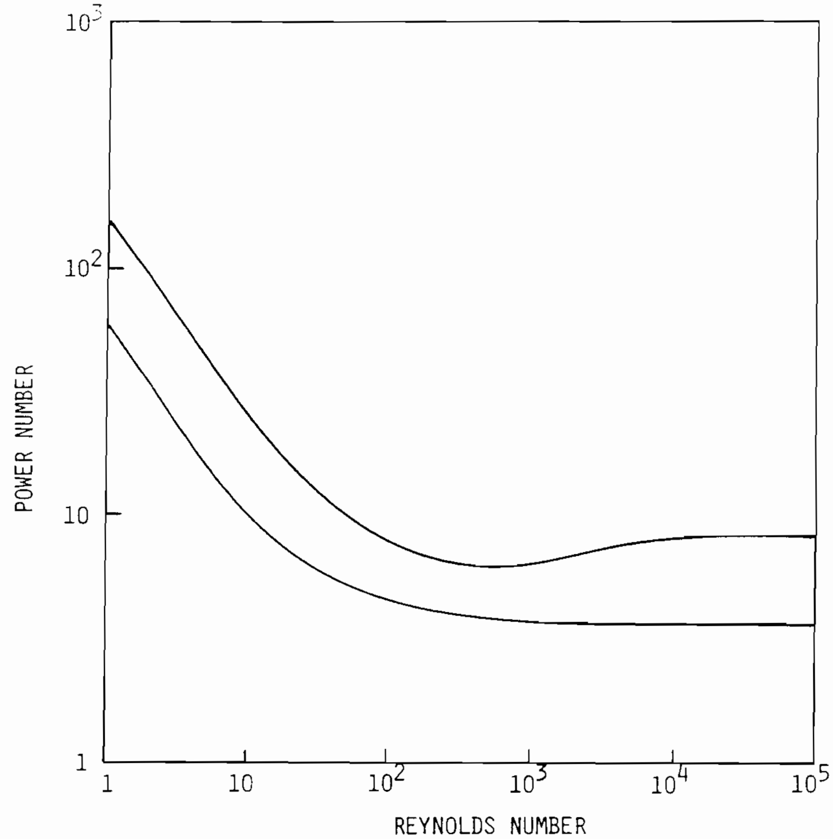


FIGURE 3

LOG10 (RPM) VS LOG10 (TORQUE)

PLANT B. SP.GR. 1.891. %SOLIDS 71.2

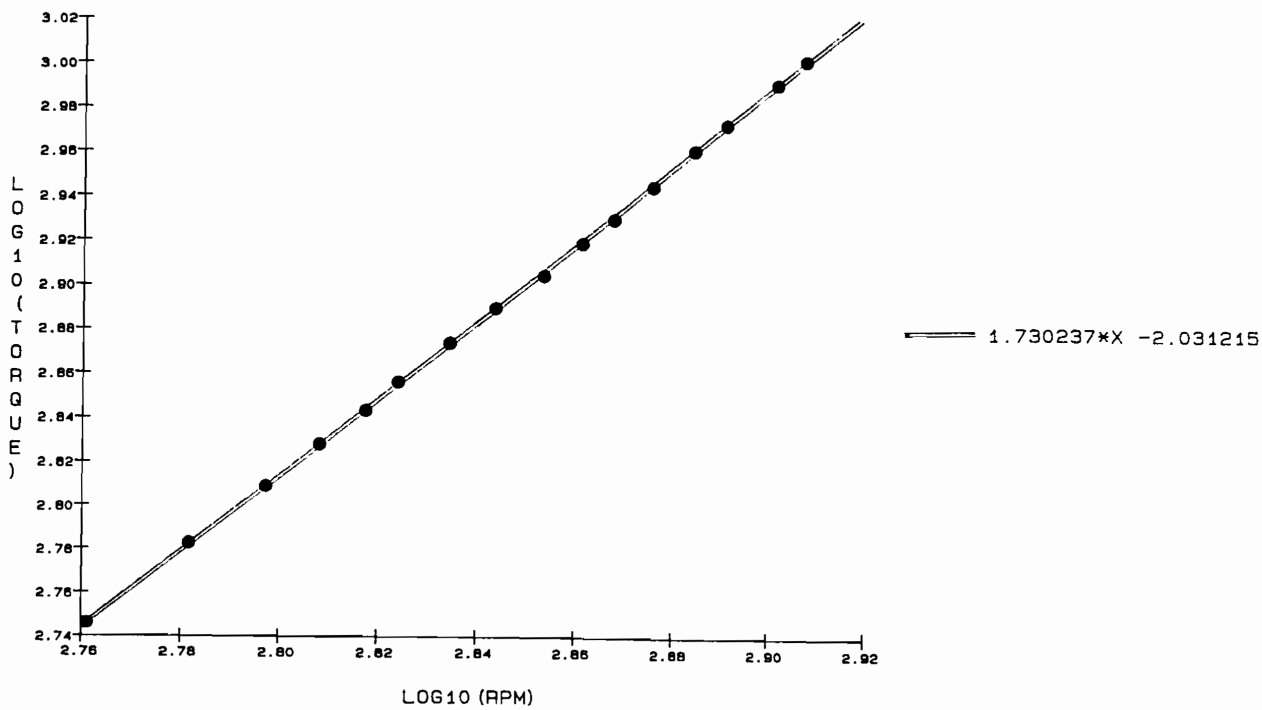


FIGURE 4

EFFECT OF ADDITIVES ON PHOS/ROCK SLURRY VISCOSITY

PLANT A, SP.GR. 1.806, %SOLIDS 66.3

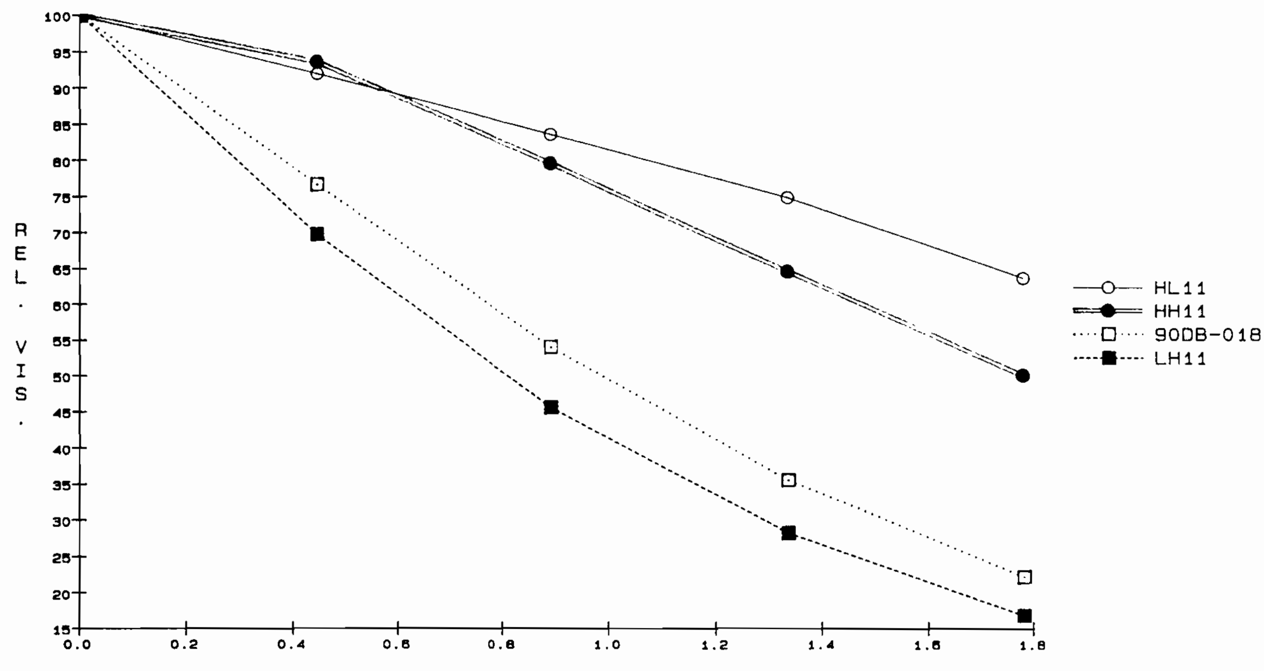


FIGURE 5

EFFECT OF 90DB018 ON POWER REQUIRED
TO SUSPEND PHOS/ROCK SLURRY

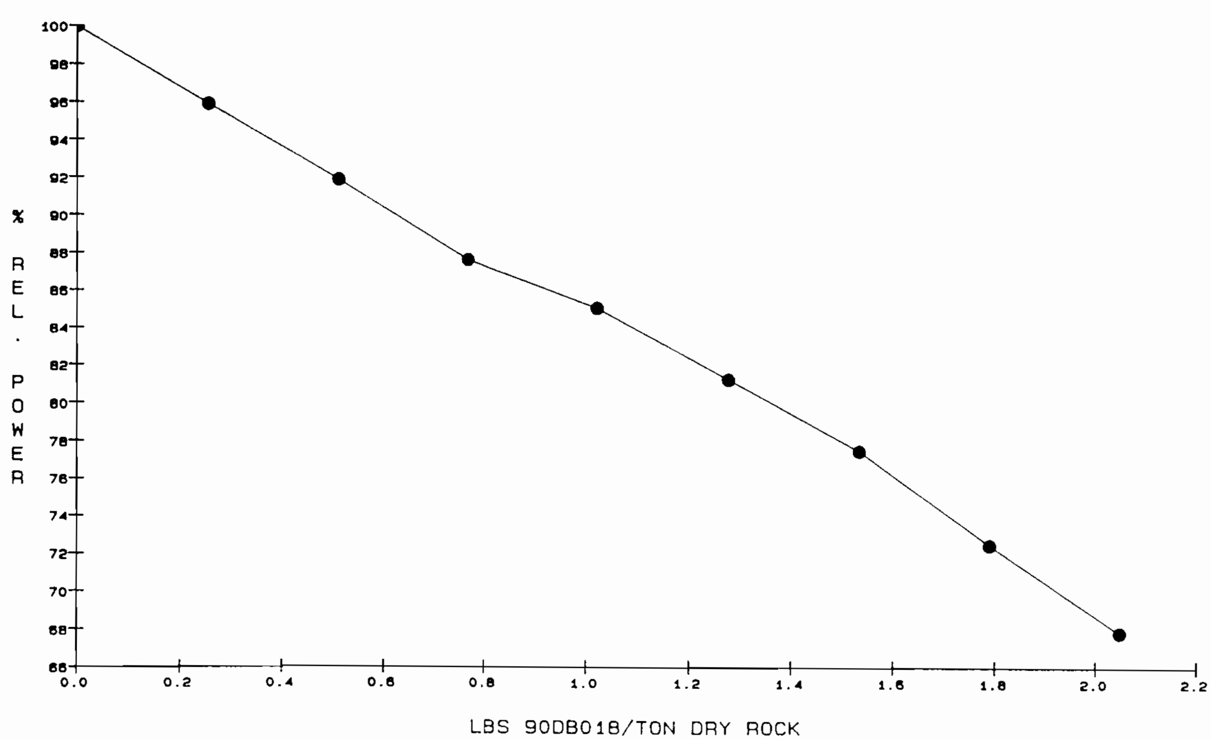


FIGURE 6

FOAM INHIBITION WITH 90DB-018

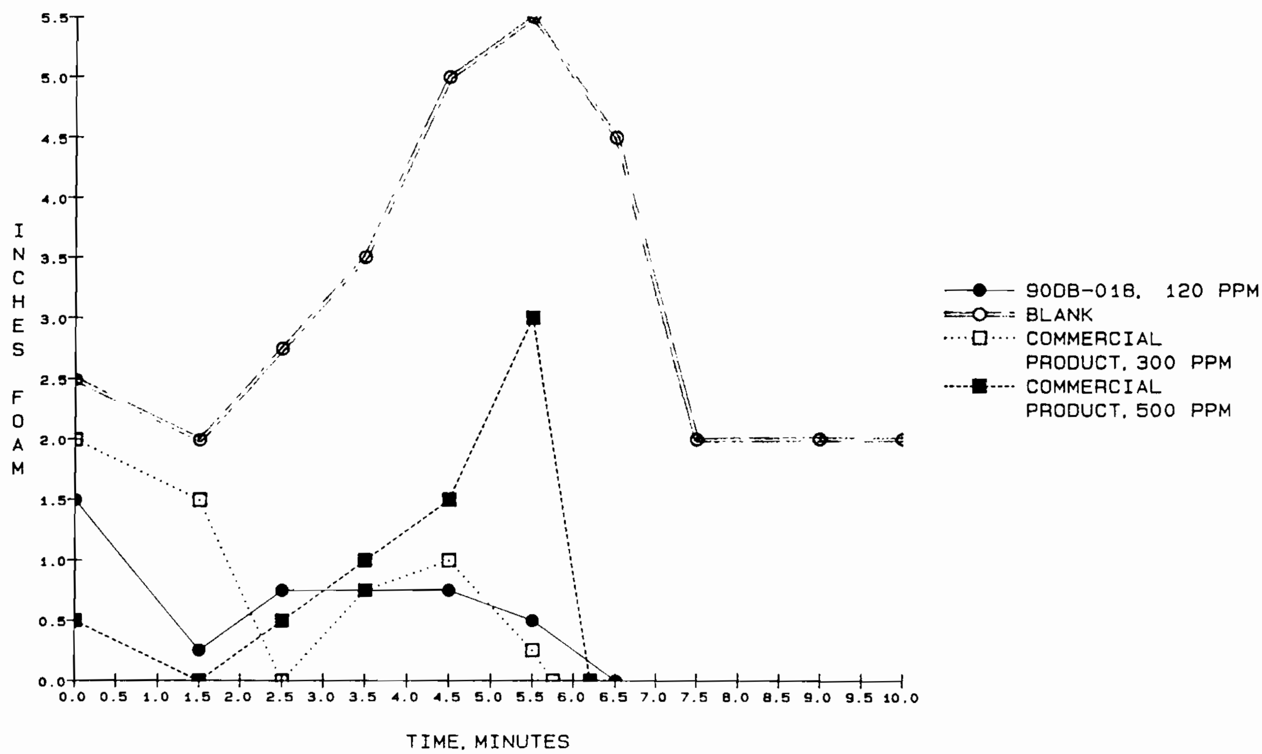
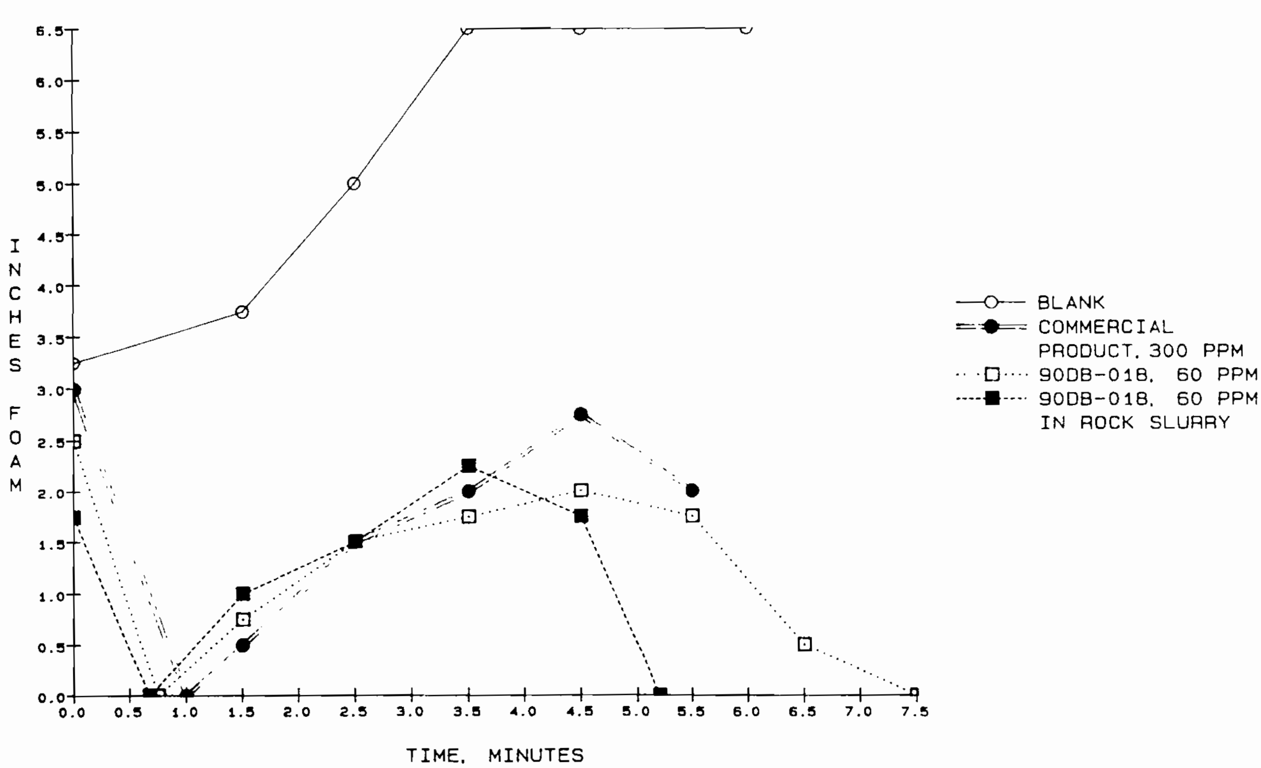


FIGURE 7

FOAM INHIBITION WITH 90DB-018



Environmental Protection Through Best Management Practice

Dr. Jim Thorup
Chevron Chemical Company

A great deal of emphasis is being placed on the environment today, as it should be. Most of us are concerned about maintaining a clean environment for ourselves and our posterity. Unfortunately, many people's perceptions are based upon misleading statements and misinformation often perpetuated by the media and uninformed "celebrities". Scientific data by researchers is frequently discredited as being biased toward industry.

Agriculture has not escaped the critics as a major source of environmental pollution. The use of "synthetic" pesticides and fertilizers has been blamed for pollution of surface and ground water through leaching of soluble nutrients and soil erosion, which deposits nutrients in surface water bodies. Even our food supply is being questioned as being unsafe by many of these same misinformed critics.

Our response to this criticism must be proactive rather than reactive. The answers to problems must come by way of scientific research and education. The public must be convinced that agriculture is doing everything possible to provide the world's safest food supply while at the same time protecting the environment.

Several management practices have been suggested to reduce or eliminate the potential for nutrient losses from soils while at the same time promoting optimum crop production, maximizing farm profits and maintaining or improving soil production. These have come to be known as Best Management Practices or simply BMP's.

It's interesting that agronomists have been promoting these concepts for decades, but obviously the public has been unaware of these efforts. In Chevron, for example, we have used what we call the ***Fertilizer Bill of Rights*** to promote Best Management Practices for thirty years. Simply stated the Fertilizer Bill of Rights says that we must use the ***right kind*** of fertilizer in the ***right amount*** in the ***right place*** at the ***right time.***

As far as fertility is concerned, following these four practices would achieve optimum crop production.

The goals of BMP's for crop production are:

- Optimize crop yields
- Maximize farm profits
- Protect the environment
- Maintain or improve soil productivity

Management practices to achieve these goals include:

Set Realistic Yield Goals

Fertilizer programs should be based on attainable yields. Farmers must recognize their yield limiting factors and design programs accordingly. The addition of excessive amounts of fertilizer trying to achieve unrealistic yield goals costs the grower money and may result in nutrient loss.

It has been suggested that a realistic yield goal might be 10% above the previous five year average. Others have suggested that the highest yield attained over the past five years might be a realistic yield goal.

Soil Testing

Soils should be tested to a depth of at least two feet for nitrate nitrogen. Carry-over nitrogen from previous crops can be used readily by the new crop. Recommendations from soil tests should be made by qualified people who are familiar with local conditions.

Nitrogen Credits

In addition to carry-over nitrogen from previous applications, credits should be given for legumes grown in rotation or as cover crops, manure applications, organic matter decomposition and nitrogen applied in irrigation water. The nitrogen available from all of these sources should be subtracted from the total nitrogen requirement for the new crop. The deficit should be supplied by a fertilizer program.

Split Nitrogen Applications

Greater efficiency can be obtained by applying nitrogen near the time when crops require it. Applying all of the nitrogen preplant may result in sizeable losses before crops can utilize the applied nutrients.

Part of the nitrogen requirement should be applied preplant to insure good early growth. The remainder should be applied in one or more side dressing or top dressing applications.

Fertigation (applying fertilizer in irrigation water) may be effective where water can be applied uniformly and with nutrients which are mobile in the soil such as nitrate nitrogen. Application of non-mobile nutrients such as phosphorus in irrigation water will be of value only with crops having good surface roots and where soils remain moist at the surface much of the time. Roots cannot extract nutrients from dry soil in any significant amounts.

Controlled Release Fertilizers

Various means have been developed to control the release of nitrogen to crops. Responses to these materials have ranged from positive to negative with many results showing no response by crops.

Nitrification inhibitors are designed to slow the conversion of ammonic nitrogen to nitrate by bacteria in the soil. This reduces the loss of nitrate nitrogen by leaching.

Urease inhibitors have been developed to control the loss of nitrogen from urea applied to the soil surface. Volatilization losses can be very high when certain soil conditions exist.

Slow release fertilizers have been developed to improve the utilization efficiency of nitrogen. One system uses coatings of sulfur or plastic to slow the release. Another uses reduced solubility of fertilizers to control the rate of release.

Right Kind of Fertilizer

Choosing the right form of fertilizer requires attention to many factors. Growers need to consider whether the fertilizer will be incorporated or applied to the surface. Soil texture and rainfall frequency and intensity should be considered. Soil temperature affects nutrient availability and plant root growth. The length of time between application and crop utilization may dictate which form to apply.

Several forms of nitrogen fertilizer are available. They do not all react the same in the soil, however. Care must be exercised to select the best form for the conditions under which it will be used.

The discussion up to this point has centered around fertilizer programming. There are many other areas of importance in Best Management Practices for crop production and environmental protection.

Water Management

Water Management plays a key role in protecting the environment. In areas of irrigated agriculture, water applications must be carefully managed to prevent leaching of mobile nutrients. Irrigations should be designed to fill the root zone to field capacity. Factors to consider include depth of rooting and soil texture.

Eliminating soil losses by erosion in areas of high rainfall is also needed to protect the environment. The use of grassed water ways, terraces, reduced tillage, cover crops, etc. will significantly reduce soil losses and prevent eutrophication of surface water bodies.

Use Best Varieties or Hybrids for Local Conditions

Research is conducted annually by universities, seed companies, local dealers and growers to determine which varieties and hybrids are best adapted to local conditions. It is important to stay updated on the results of this research and use it in making planting decisions.

Crop Rotations

Rotation of crops provides many benefits to growers. It aids in pest control including disease, weeds and insects. It therefore reduces the reliance upon chemicals to control these pests compared to continuous cropping systems. By rotating deep rooted crops with shallow rooted crops, better utilization is made of carry-over nitrogen which may move below the root zone of shallow rooted crops.

Reduced Tillage

Reduced tillage conserves soil by maintaining a protective cover of crop residues. Both wind and water erosion are reduced significantly. Water is conserved by reducing run-off and holding snow in place. Energy conservation also results from reduced use of machinery for seed-bed preparation and cultivation.

New equipment and improved chemicals have contributed greatly to the acceptance and growth of reduced tillage systems.

Balanced Nutrition

To conclude this presentation, I'd like to return to the discussion of crop nutrition. Research has shown the importance of balanced nutrition on nitrogen utilization efficiency. The application of phosphorus and/or potassium, where these nutrients are deficient, increases yields and nitrogen utilization.

Well fertilized crops often remove more nitrogen than was applied in the fertilizer program. This "mines" nitrogen from the soil and reduces nitrate leaching below the root zone.

Judicious use of fertilizer improves the environment while helping to ensure an adequate supply of low-cost, high quality food and fiber for an ever increasing population. This is the message we must get to the public in a convincing manner.

"Green" Opportunities In Agri-Business

Stacy Schmidt
The Andersons

We all know the environment is emerging as *THE* issue of the 1990'S. Environmentalism is at the cutting edge of social reform and is absolutely one of the most important issues for American business. The torch of environmentalism, if not yet bursting into flame, is at least being lit in corporate America.

Environmentalism has become a national fervor. Our society has reached a new consensus that pollution is morally wrong - not just harmful or dangerous, but wrong.

We must also realize, however, that pollution is a byproduct of manufacturing processes, products, and services that have given Americans a quality of life that exceeds any in history.

Pollution is the problem most frequently cited as the most serious threat to the world. Pollution has many sources: spreading urbanization, more widespread use of chemicals, growing quantities of hazardous waste, and degradation of the ozone layer. Unfortunately, many of these problems went unnoticed until they began to affect our economic well-being. As a rule, Americans blame the business community for the environmental problems they see at global, national, and local levels. In fact, recent polls show that more than 80% of Americans feel industrial pollution is the main reason for the world's environmental problems and nearly 75% of the public say that the products businesses use in manufacturing also harm the environment. Furthermore, 60% of Americans blame businesses for not developing environmentally sound consumer products and an equal share believes that some technological advancements made by businesses eventually produce unanticipated environmental problems.

But Americans blame themselves, too. Recent polls also show that 70% believe that consumers are more interested in convenience than they are in environmentally sound products and 50% admit that they would not be willing to pay more for safer products. While "saving the environment" is a high priority for most Americans, a majority are still not willing to act on their beliefs. A recent poll by the Roper organization indicated that over 78% of adults say that we must make a major effort to improve the quality of the environment in this country, but at the same time, they feel that individuals can do little, if anything, to help improve the environment.

Regardless of the polls, increasing numbers of people are concerned and are beginning to do something about these problems. Consumers are beginning to look for products they can feel good about buying. As an environmental professional, I find this encouraging.

We must all begin to realize that the causes of pollution are numerous (cultural, technological, fiscal, political), but they are also correctable. Each of us must do our part to help.

The world is a dynamic place. Pressing global environmental trends shouldn't be minimized or ignored, but the world doesn't need saving. We simply need to help the world correct itself from time to time. We make mistakes and we get into trouble, but then we take the necessary steps to fix them.

Earth's environment is remarkably stable, self-correcting, and able to overcome disturbances that are imposed by man.

The planet's ecological balance is delicate, but many of its problems are less than apocryphal. Any chaos in the conduct of the husbandry of the planet is simply due to our inability to see the "big picture" and a lack of long-term vision and planning.

While the problems are not slight, the present situation is but a microsecond in the long continuum of man's and earth's development. We are too young as a people to understand "how the world works", so we shouldn't panic.

We should be concerned, but we should not become pessimistic. Rather we must calmly and realistically assess the situation, all solutions come from ideas and imagination.

Some people believe that the world's oceans, which cover about 70% of the earth's surface, are in serious trouble from pollution. But a 4 year study conducted by the United Nations Environmental Program, aided by nearly 100 scientists from 36 countries, recently concluded that "the world's oceans are able to assimilate pollution in most areas and remain relatively stable" and that the level of pollution has decreased in many coastal areas. They concluded that the oceans are not in jeopardy for the foreseeable future.

On the other hand, it is much more difficult for smaller land masses to "absorb" hazardous materials. As industry has expanded, thousands of chemical substances have been produced and marketed and the numbers increase every year.

Industrial waste is a major hazard to the environment, but strategies that minimize waste generation now offer cost effective approaches to the problem. According to the Worldwatch Institute, industrial waste can be cut by at least 1/3 within 10 years. Various incentives exist to help us meet this goal (signing minimization certifications on manifests, taxes on virgin raw materials, voluntary reduction programs, etc.). Already we are seeing that air quality continues to improve in this country even though vehicle miles driven continues to increase. This is generally thought to be due to improvements that industry is making.

The three R'S are as important in pollution prevention as they are in education: Reduce, Reuse, and Recycle. Savings from using resources more efficiently can be realized by industry and consumers alike. Industry might achieve greater profits, improved competitiveness, and the ability to stabilize consumer prices. Consumers can also save money by using products and materials more efficiently.

The only lasting solution to environmental problems is to reduce the emissions of pollutants in the first place and to "manage" the environment. Napoleon Bonaparte was quoted as saying that "Under a good administration, the Nile gains on the desert; under a bad one, the desert gains on the Nile". The environment has simply gone through a period of "bad administration" which is now being corrected.

During the past decade, the number of government agencies responsible for environmental protection has grown from less than ten worldwide to include at least one in nearly every country. In this country alone, about 16,000 people work for the EPA, some 27,000 are employed by state governments, and many more at the local level. Likewise, pollution control costs and expenditures in this country continue to rise significantly - rising to the point to where even USEPA is concerned about the effect on our competitiveness in the world market. And as you are no doubt aware, the fines for non-compliance are increasing dramatically. The penalties for not meeting the standards are now starting to exceed the money saved by polluting. But this sounds like bad news for business; where's the good news?

Although "good administration" costs money, restoring the environmental balance also generates wealth because pollution controls save money in the long run.

Getting back to the polls, 90% of Americans want a clean environment and 50% are willing to pay for it. One recent poll showed that more than half of all Americans 18 and older made a decision to purchase or boycott a product last year based on environmental concerns alone. More businesses must realize that environmentalism is a profit-making opportunity. Consumers have demonstrated their willingness to pay a premium for environmentally sound products. R&D must be keyed in so products are environmentally oriented in the first place. Making something "environmentally sound" is a "value-added" approach.

After nearly two decades of grumbling about clean air and clean water laws, foot dragging on compliance, and at times fighting the laws tooth and nail, saavy corporations are going "green" and it's sound business sense.

It may sound ludicrous, but while it used to be "good business" to ignore the environment, helping to clean up the environment will provide substantial opportunities to the business community. Firms that are ahead of the game with the new clean air and clean water provisions will be more competitive. As a student of the environmental regulatory process, I suggest that you invest now to save later. Pollution prevention means "extra points", not only with consumers, but with the regulators as well. Perhaps less emphasis should be placed on the red and black ink in the ledger so that the bottom line might reflect a more "green" cast.

The fact is, "clean" products are becoming essential to competitiveness, both nationally and globally. "Green consumers" already are choosing products or brands that project the most environmentally friendly image. A New York Times/CBS

News poll regularly asks if whether protecting the environment is important enough so that standards cannot be too high and whether improvements should be made regardless of cost. In 1981, only 45% agreed, while 42% disagreed. More recently, nearly 80% of the public agreed.

Products that project an element of environmental friendliness are favored by consumers. In a number of surveys, consumers indicate they're willing to pay up to 5% more for packages made of recycled material or are degradable. Sam Walton, America's richest man, has stated that "business should be a force for social change" and is already highlighting products in his retail chain produced by "environmentally conscious" manufacturers.

Many surveys show that a majority of the public view themselves as environmentalists. A self-proclaimed environmentalist sits in the White House. So it's not surprising that an environmental ethic has made its way into the ranks of corporate leadership. Generations that came of age when the ravages of pollution became plainly obvious in the late 1960's are now gaining positions of power. Instead of fighting industry from the outside, they change it from within.

Public concern about the environment is growing faster than concerns about any other issue monitored by Roper, at least before the Gulf War and the softening of the economy. Some businesses are tuning in to this trend by producing "green" products, services, and advertising campaigns.

If your products and services are not "environmentally sound" and you are not using "eco-marketing" techniques, consider this — over 2,500 manufacturers now make environmentally oriented products and equipment, and more than 3,000 firms offer environmental consulting services. In fact, just last year, 1,357 trademark applications with the prefix "GREEN" were filed, along with another 1,148 with the prefix "ECO" and 586 with the prefix "ENVIRO".

Securities analysts also are giving increasing weight to a company's environmental performance when judging the potential of its stock. A firm that isn't taking strong action to reduce pollution may be profitable today, but carries liabilities for future profits. And consumer groups can control these profits. There appear to be five major reasons for this trend: (1) the environment has become a rallying point for politicians, (2) the corporate/community relationship is impacted by environmental consciousness, (3) corporate managers are increasingly scrutinized by shareholders on environmental issues, (4) environmental liability has the potential to materially impact financial results for many companies, and (5) proactive environmental management can reduce risk and enhance a company's competitive position.

Moreover, financial reporting requirements for environmental liabilities and efforts by the Securities and Exchange Commission have gained the attention of corporate managers and board members. Today there are actually "green" mutual funds which make investment decisions almost solely on companies' environmental and social practices.

Look at the unprecedented media attention the environment is receiving. A recent study showed network news broadcasts contained an average of one environmental story every three nights in 1987, while in 1989, an average of two stories each night had an environmental flavor. Whether a passing vogue or a deeply ingrained movement, the environment has become one of the most important issues of our time.

The impacts of this renewed environmentalism have been substantial on our industry as well, but we've been becoming more "green" too. We recognize that to continue to be successful we are going to have to be part of the solution rather than being perceived as part of the problem. Our industry has been very active in such issues as food safety, proper pesticide container disposal, and surface and groundwater protection. Integrated pest management programs and biotechnology seem to hold particular promise for the future.

But for all of these efforts, the general public still feels that industry, including agriculture, continue to promote economic growth at the expense of the environment. Combine this with the fact that only 15% of the American public trusts what government scientists say and only 6% trust industry scientists and you can see that we've got a tough road ahead of us. Jay Vroom, NACA President, was recently quoted as saying "Everyone is responsible: basic manufacturers, formulator-distributors, dealers, applicators, and farmers. Each must do the best we can, together, in a chain of responsibility, backstopping individual efforts so that agriculture is seen by the public to be concerned and committed to environmental improvement. Through cooperation, acceptance of our joint responsibility, and plain, old-fashioned hard work, we in agriculture can succeed anew in the decade of the environment."

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Session III
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James Kuhle

Containment of Fertilizers and Pesticides at Retail Operations

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Environmental protection has become as important to the fertilizer retailer as the products and services he offers. Emphasis on environmental protection at the dealer level is largely in response to state regulations designed to protect groundwater. The national Clean Water Act of 1987 gave states the lead in developing groundwater protection strategies. Several states have adopted new or stronger regulations and others are moving to do so. Fertilizer dealers need to keep up with these regulations and promote groundwater protection. This paper describes several containment systems for fertilizers and pesticides to help dealers decide how to modify their plants to protect groundwater.

Sources of Groundwater Contamination

Groundwater is precipitation that 'soaks in,' filtering down through many layers of soil and rock rather than running off into streams. More than half of the U.S. population -and 90% of rural America -depends on groundwater from aquifers for their drinking water.

Groundwater is never 100% pure. It picks up minerals as it moves through the soil. Problems develop when additional materials get into groundwater.

Sources of groundwater contamination can be grouped under three headings: (1) water supplies, (2) transfer areas, and (3) storage areas.

Many dealer facilities are serviced by an on-site well. A wellhead that is poorly designed or has a faulty casing can allow contaminants to move directly into the groundwater. Connections to public water supplies must be designed to prevent material from back siphoning into the water system.

Transfer areas are places where fertilizers and/or pesticides are loaded, unloaded, or transferred to and from the mixer. Any spills at such locations likely will find their way into groundwater if not properly contained. Both dry and fluid products are potential contaminants.

The mobility of nitrate in water makes groundwater especially susceptible to leaching of any nitrogen fertilizer. Nitrate in groundwater has been linked to spills of dry fertilizers at many dealer locations.

Storage areas are potential sources of groundwater contamination. Tanks can rupture. Pipes can burst or rupture where they join the tank. Spills can be slow leaks or massive discharges. Either way, spills contaminate surface water or groundwater unless good containment measures are in place.

Sometimes nitrogen fertilizer stored in buildings in low-lying areas gets into surface water during heavy storms. Most storage areas today are not built in flood-prone areas; however, many exiting sites are less than ideal from an environmental standpoint.

Selecting a Plant Site

Environmental considerations should have high priority when selecting a new site or planning modifications to an existing facility.

Fertilizer and pesticide handling facilities should be as far from private wells or surface water supplies as possible. By all means, the well should not be downgrade from a plant handling fertilizers or pesticides.

Flood plain sites and locations with a shallow groundwater depth should be avoided. Sites should have adequate soil hearing capacity to support the loads of buildings, storage areas and vehicle traffic.

The topography and drainage patterns should be studied to determine surface water movement onto and from the site. For example, a loading pad should not be in the path of runoff

Also, since fertilizer mixing and handling operations generate airborne materials it would be smart to locate away from heavily populated areas, or at least downwind. Where urban sprawl has approached or encircled a plant, you may want to consider relocating to a more remote area before making the investment required for a major environmental upgrade of a facility.

When relocating a facility, or part of a facility, it is important to know the extent of contamination from past practices. Contaminated soil should be tested to determine if remediation (clean-up) is feasible. If contaminants are types that break down in a reasonable time, a structure that prevents further downward movement of water may be desirable. Contaminants that do not break down readily should not be hidden under a structure; future clean-up costs could he insurmountable. Long-term salability of the property should be considered in weighing alternatives. Also, someone experienced in remediation of contaminated sites should be consulted.

Containment Is 'No Pollution'

Containment is keeping pesticides and fertilizers where they are supposed to be. Storage vessels provide primary containment. Secondary containment is 'backup' protection against failures of primary vessels and against leaks and spills.

Many people think only of dikes when someone mentions secondary containment. And dikes are a key to containment around fluid storage tanks. But dealers in states with good groundwater protection laws know that containment is more than capturing catastrophic spills from a tank failure. Tanks rarely fail. Contamination is much more apt to occur from spills during product loading and unloading.

Dealers often need to install several kinds to containment measures to be in position to avoid or resolve environmental and legal problems.

Wellhead Protection

Dealers should inspect their water source to make sure the facility is environmentally secure. In some areas, poorly designed wells and water connections are the main causes of groundwater contamination. If an on site well is used, check the wellhead. The concrete pad or clay fill should be elevated to force surface water to drain away from the well. Runoff that ponds at or near the wellhead can easily get into the well by seeping around the well casing or through a crack in the casing. Because of this risk, some states now specify a minimum distance between the well and new fertilizer/ pesticide handling facilities, usually 200 or more feet. Such regulations were implemented by Iowa in 1988 and by Illinois and South Dakota in 1989(4,2,3).

Most states no longer allow installation of frost pits. Dealers having a wellhead in a frost pit should consider extending the casing above the level of the surrounding soil. As a minimum, the pit should be watertight so that no contaminants can get in. Local officials will have information about the requirements for private wells.

Abandoned or rarely used wells can be found on many dealer sites. These should be retired and sealed, which usually requires a permit. The Extension Service or Public Health office should be contacted for information regarding well closures.

Water System Protection

All connections to the water supply system should be inspected to ensure that fertilizers and pesticides cannot enter by back-siphoning. This could happen at the water inlet to the mix tank or where vehicles are filled through a bottom connection. Even hoses submerged in a pool of liquid can back-siphon material if the system loses pressure.

Standard methods for preventing back siphoning are to use an air break tank or a reduced pressure principle zone (RPZ) valve.

An air break tank is merely a water supply tank with an air space between the pipe outlet and the highest water level attainable in the supply tank. Generally, the distance between the pipe and the maximum water level is twice the pipe diameter. A pump is used to boost pressure if the static pressure in the tank is inadequate.

An RPZ valve is a special device with two independently operating check valves and a pressure differential relief valve between the check valves. When there is a loss of pressure in the water supply, the two check valves close, preventing a reversal of water flow.

An undesirable feature of RPZ valves is that they tend to drop the line pressure by as much as 10 psi. RPZ valves may be regulated by state agencies; if so, their installation must be approved and they will be tested periodically.

Containment At Transfer Operations

Any time a fertilizer or pesticide is moved from one container to another, losses can occur. Until recently, the main concern about spillages during transfer operations was the value of lost product–did losses 'eat up' profits? Today, the first concern about any such loss–whether from overfilling a nurse tank or spreader truck, or leaks from valves, pump seals and conveyors–must be its environmental impact.

Transfer losses can contaminate soil. They also can contaminate groundwater. Thus, containment for loading and mixing areas has top priority in many state regulations (2,3,4).

Since it will be impossible to avoid all spills, provisions must be made to capture spilled material before it escapes to the environment. Loading areas should be designed to contain any nutrients or pesticides lost while loading tenders, spreaders, nurse equipment and sprayers.

Concrete pads for loading areas should facilitate collection of spilled materials. Main design features to consider are liquid holding capacity, pad length and width, slope, sump location, sump design and solids collection system.

Equipment often is washed on load pads. Pads used to wash dirt and residues from field equipment should be large enough to catch all the wash water. They also should have a good solids removal system, particularly if the rinsate is to be re-used in making fluid fertilizers.

Most dealers use the same pads for loading operations and for washing equipment. The following discussion applies to pads designed for both uses.

Pad Capacity

Load pads should have the capacity to hold the contents of the largest tank to be loaded. A pad used to load large transports should be capable of retaining the entire load, typically 4,000 gallons. Illinois (2) and South Dakota (3) recently established such criteria. Wisconsin requires that pads used to load fluid fertilizers have a capacity of at least 1,500 gallons (5).

Requirements generally are less stringent for unloading pads. South Dakota (3) does not require a pad for unloading raw materials at the dealer site. Illinois (2) requires that load-in pads have a volume of at least 25 gallons.

Load-in pads should be provided since incidental spills are common during unloading operations. Also, the same pad often is used for both load-in and load-out; in this case, the volume required for load-out will prevail.

Providing the necessary volume on a pad designed to accommodate only one vehicle can be difficult. Figure 1 shows such a pad. Note that to hold 4,000 gallons, it is 12 feet wide by 60 feet long, and is 2.2 feet lower at the sump if all edges are at the same elevation and all slope to the sump. If the pad had a 12-

foot-long trough in the center (Figure 2), the top edge of the trough would be 1.5 feet below the height of the edges.

A bigger pad will provide the necessary volume with shallower walls. However, a bigger pad collects more rainfall. The pad in Figure 1 can hold 9 inches of rain. If the pad was built twice as wide, the walls would need to be only half as high to provide the same volume. With the larger surface, however, the bigger pad would accumulate more gallons of rain and be more likely to overflow in the event of a heavy rain.

Rainfall can be discharged safely from the pad only if the pad is clean. Otherwise, it must he handled as a dilute fertilizer or pesticide mixture. Thus, consider building a roof over the loading pad, especially in areas of high rainfall.

One way to increase pad volume is to form a roll-over curb (one that vehicles can cross easily) on the perimeter. Adding a 4-inch- high roll-over curb to the pad in Figure 1 increases its volume by 45% (see calculations under Figure 1).

Illinois and Wisconsin permit the volume requirement to be met by using an automatic sump pump connected to a storage tank (2,5). A more reliable approach is to provide for overflow to another basin. This is done most easily by locating the load-out pad at a higher elevation than the secondary containment dike.

Buried tanks or pits should not be used to store liquid from loading pads. Any such systems should be removed or retired; this involves a thorough cleaning, sealing all inlets, and filling with sand or clay. Some states, including Illinois (2), South Dakota (3) and Wisconsin (5), permit temporary storage of such liquids. Long term storage in pits or wells generally is prohibited, at least without an approved groundwater monitoring system.

Pad Width and Length

The size of the pad should be based on the work it is to accommodate. A pad for equipment washing should be at least 20 feet wide. If the pad is to be used for both loading and unloading, it should be wide or long enough to accommodate two vehicles. Dealers handling both fluid fertilizers and pesticides may need extra space for loading or unloading mini-bulk containers. Space also must be provided for tanks holding rinsates since they often are stored on the loading pad. Load pads 40 x 60 feet are common.

Pads for loading dry fertilizers must be wide enough to catch all materials spilling over the sides of spreaders or tenders. Pads generally should extend 10 feet beyond each side of the vehicles being loaded. The edges of the pad should be about 4 inches above the center. Pads for dry materials have no volume requirement. If kept clean, a lockable drain can be used to discharge rain or snow melt. As with fluid operations, contaminated rainfall must be handled as a dilute fertilizer/pesticide mixture. A roof over the load pad will avoid problems associated with rainfall.

Spills while filling bins should be collected and kept away from moisture. Some dealers collect spills by placing the boot of portable augers inside a large tray. The most common containment is a concrete pad from which spilled material can be reclaimed easily.

Dry fertilizer spills at railcar unloading areas are difficult to reclaim. The best way to keep the area between the tracks clean is by sweeping up spilled material. This is made easy by paving the area, sloping the pavement away from the conveyor and using a watertight cover to keep rainfall out. This is important to preserve quality of the dry product. It also is important to prevent nutrient escape from the conveyor to the ground if the bottom of the conveyor is not sealed.

Paving between the tracks also is a key to loss prevention while unloading railcars of fluid fertilizers. The pavement should be sloped to channel any escaped product to a catch basin for checking and/or recovery. Prefabricated pans of reinforced fiberglass are available for installation between or on both sides of the rails to collect spills. The pans have built-in sumps.

Pad Slope

Loading pads should have a slope of at least 2%. This minimizes corrosive effects of spilled material and facilitates pad wash-down (1). Lesser slopes are more likely to have puddling areas due to errors in finishing the concrete.

Sump Location

The best location for the sump will depend on how it is to be used and how vehicles travel across the pad. If vehicles are to enter from all four sides, the sump should be near the center of the pad. A disadvantage of centering the sump is that it can interfere with product movement if the sump must he cleaned out or manually pumped out as product is being loaded. It may be better to place the sump near one side of the pad. This way, the pad is still accessible to vehicles from three sides.

Some dealers have a sump in the middle and a deeper sump on one side. The two are connected by a trough or pipe beneath the pad. The sump in the middle of the pad traps most solids while liquid goes to and is pumped from the second sump.

Sump Design

Sump designs vary according to how or whether they are used to handle solids. Suspension dealers typically use simple sumps and pump sediment and fluid directly into applicators. On the other hand, liquid dealers carefully separate solids from liquid being recycled. These dealers use either an extra sump for solids removal or a sediment trap around the sump.

Figure 3 shows a typical concrete sump with a perimeter sediment trap. The sediment trap can be sloped to one side to help concentrate the solids. Sediment traps must be cleaned periodically to keep sediment from overflowing and re-contaminating liquid in the main sump.

Figure 4 shows a pad with two sumps. A pan can be fabricated to fit beneath the discharge of the higher sump. Solids can he removed by dumping the pan. Do not, however, treat collected solids like dirt. Where pesticides are involved, careless discarding can kill vegetation. It often is satisfactory to slurry the solids in a fluid fertilizer or dry the solids and add them to a dry fertilizer; the pesticide-containing fertilizer can then be applied routinely after verifying that crops growing or to be grown on the field are those for which the pesticides in residues are labeled.

Sump Construction

Prefabricated sumps can be used to avoid the labor required to form and pour a concrete sump. Precast concrete sumps are built in a range of sizes and with fittings to accept piping connected to other load pads and operational areas. Concrete sumps usually have a capacity of about 100 gallons.

Stainless steel sumps also are available. They usually are double-walled with ports on top for detecting leaks between the walls. Although they can be fabricated in any size, most have a capacity of about 30 gallons.

The recycling of rinsates at large facilities may he simpler if all materials are collected in a common sump. Pipe inlets should be above the bottom of the sump so that liquid can be pumped to a level below the inlets. This reduces the chance for liquid to leak into the ground around pipe inlets.

Some dealers prefer a large sump and sediment collection system. This allows more time for solids settling and permits less frequent clean-out. A large sump is not desirable if pesticides are rinsed or handled on the pad because of the problems associated with contamination. For example, if you switch from corn herbicides to soybean herbicides, it will be necessary to clean the sump to avoid contaminating soybean make-up water with corn herbicide residues.

The simplest way to avoid unwanted herbicide contamination is to use a small sump and clean it daily or more often. Sumps in areas not protected from rainfall should be kept clean to permit unrestricted discharge of collected rain water.

There are other ways to segregate rinsates. One is to divide the load pad into two or more areas and slope each section to a different sump. Another is to slope the pad to a wall where multiple drains and valves are used to direct spills and rinsates to appropriate sumps for subsequent pumping to designated storage tanks. This system is ideal where rinsate segregation is critical.

Many problems of handling pesticide residues can be avoided by waiting to add pesticides to fertilizer products until the applicator is in the field (away from the fertilizer storage and handling site). Later, the applicator can be rinsed in the field. This practically eliminates the need to segregate rinsates because they normally will not contain pesticides. Other management practices to enhance environmental security are discussed later.

Containment In The Mixing Area

Incidental spills are common in the mixing area. Spills can occur when materials are added manually to the mixer. Fluid piping systems and conveyors of dry materials often leak. Environmental security demands containment of such incidental spills.

Liquid Mixing Areas

Containment for the liquid mixing area usually involves installing a curb along one inside wall of the mix house to force the area to drain onto the loading pad. Containment also can be achieved by installing a curb on all four walls, making sure that the containment volume equals the volume of the mix tank.

Figure 5 shows how a curb can be built on an existing slab. Sometimes, dealers place the mixer on one corner of the load pad. This often is an excellent choice since mixing and loading usually are adjacent operations and both receive all products handled at the facility.

Areas where pesticides are mixed should not be allowed to drain into the fertilizer containment. Mixing area containment should be large enough to accommodate mini-bulk containers and other portable pesticide containers not located in a secondary containment dike. If the containment area serves more than one plant operation (storage, load in/out, etc.), it may be desirable to sub divide with smaller dikes in order to minimize the area affected by small, incidental spills. For example, spills from a leaking pipe or a hose connection frequently can be contained in a pan or inside a separate curb.

Piping from storage tanks to the mixer and to the load pad also should be contained. At most facilities, these areas are adjacent and the piping always is above a contained area or over the load pad. Pipes used to transfer full strength materials should not be buried underground unless they are inside larger pipes. If double piped, the pipes should be sloped so that any leaks will flow to one end where they can be detected.

Buried pipes used to transfer rinsate or material collected in sumps to a larger sump need not be placed in a larger pipe.

Dry Mixing Areas

Dry mixing of fertilizers is best done under roof. Some dealers get weather protection by extending the roof of a fertilizer storage building so it will cover the blender and load out conveyor. Other dealers keep the blender inside the storage building and build a concrete pad to collect material falling from the conveyor or spilling over the sides of spreaders and tenders.

Blending towers—systems having a cluster hopper, weigh hopper, and blender stacked vertically in a tower—should be enclosed and have a roof over the loading area. The pad beneath the tower should he large enough to catch material spilling over the sides of spreaders and tenders as well as leaks in the blending system.

Facilities where dry fertilizers are impregnated with herbicides must have containment for pesticides. Spills must be confined to prevent pesticide loss and contamination of fertilizer raw materials. Impregnation and load-out should he done under roof; otherwise, rainfall contacting pesticide residues in the blender or conveying system must be collected and handled as a dilute pesticide/fertilizer mixture. Spilled materials and product cleaned from the blender should be stored inside and added in small proportions to other blends. This will dilute pesticide residues enough to allow them to be applied to land without exceeding labeled rates. Any water that is used to clean the blender must be handled and disposed of as a dilute pesticide.

Dealers without liquid application equipment may not want to use water for blender decontamination. Limestone or potash can be used to purge the system of pesticides, provided it is applied to a crop for which the pesticides in residues are labeled. The Federal Insecticide, Fungicide and Rodenticide Act prohibits the application of pesticides (including those in residues) in excess of labeled recommendations.

Containment In The Storage Area

The major difference in secondary containment for fertilizers and pesticides is the construction material. Dikes lined with clay or synthetic materials are satisfactory for secondary containment of fertilizers, but are not allowed for pesticides (2). Dry fertilizer containment involves storing material in a building that has a roof, walls, and floor that prevent fertilizer from coming in contact with precipitation or surface water.

Liquid Fertilizer Containment

Secondary containment for liquid fertilizer consists of a basin with a floor and walls that are essentially impervious to liquids. The basin usually is sloped to a sump where the liquid can be pumped from the basin. Volume of the secondary containment, excluding the space taken up by tanks, must be 10 to 25% greater than the volume of the largest tank in the containment (3, 4, 5, 6). Illinois requires that the secondary containment be sized to hold 6 inches of rain in addition to the contents of the largest tank (2).

Most states do not allow in-ground pits for primary containment of fertilizers or pesticides. If allowed, the pits will be regulated as underground storage tanks and must be double-lined and have a means to check leaks in the primary liner.

In-ground systems are well suited for secondary containment (discussed later). Contact local regulatory officials about this use of in-ground pits.

In secondary containment systems, piping runs should be over, NOT through, the containment wall. If piping must pass through the containment wall, a watertight seal should he made between the pipe and the wall. The structural integrity of the wall must not be compromised and the containment volume must not be reduced.

Rain accumulation should be pumped out with a manually controlled pump. Any drains should have lockable valves and be strictly managed to prevent inadvertent release of fertilizer (3). Some states prohibit the use of drains (2,4).

Sight gages used to monitor liquid levels in tanks are a liability. A damaged or broken gage will release contents of the tank. Sight gages should be used only if a stainless steel valve, which is normally closed, is installed between the bottom of the gage and the tank.

The most difficult aspect of retrofitting secondary containment at a facility is selecting dimensions that will conserve space without interfering with vehicle and employee access to the tanks.

Tank Clusters—Typical facilities have one or more clusters of tanks. If possible, tanks should be grouped in one cluster. With a larger grouping, containment wall height will be minimized since containment volume is based on only one tank—the largest one. Putting tanks close together will minimize floor area, but add to wall height and create problems of access.

In general, 36 inches is the highest practical wall height.

Figuring secondary containment dimensions requires determining the volume of the biggest tank (converting gallons to cubic feet by dividing by 7.5), adding a 10 to 25% margin of safety (freeboard factor), determining the volume displaced by other tanks in the containment, and selecting the combination of length, height and width that best supplies the required cubic footage. For example:

Assume: Four 25,000-gallon tanks
Each is 12 feet in diameter
and 29 feet high
Containment floor is 20 x 60 feet
Containment volume must be
110% of the largest tank

Formula: RV = LTV x FF / 7.5

where RV = Required volume
LTV = Largest tank volume

FF = Freeboard factor (1.1 for
110%; 1.25 for 125%)
7.5 = gallons per cubic foot

Calculation: RV = 25,000 gal x 1.1/7.5 gain cu ft
RV = 3,667 cubic feet

Next, it is necessary to determine the Net Containment Area (NCA), in square feet:

NCA = Total area - tank area
NCA = (20 x 60) - (3 x 113)
NCA = 1,200 - 339 = 861 square ft

Note: Only the area for three tanks is subtracted; spilled liquid will still occupy space in the leaking tank.

Now, wall height (WH) is calculated:
WH = RV / NCA
WH=3,667/861
WH = 4.3 feet, or 52 inches

Because this is higher than preferred, you may want to increase width or length of the containment—if space permits.

Tanks should be anchored to keep them from floating in case of a spill when they are empty. A floating tank can collide with and damage plumbing and other tanks, causing additional spills.

Anchoring Tanks—The simplest way to anchor tanks is to weld three or more brackets to the tank where the sides meet the floor. Each bracket is then bolted to the concrete with anchoring bolts. Chains and tie-down cables can be used with brackets welded above the tank bottom.

In clay-lined earthen dikes, weights can be added to the tanks or cables can be used to secure the tank to anchors outside the dike. Anchors in the soil beneath the liner or cables connected to concrete deadmen can be used if the area where the liner is penetrated is properly sealed.

Neglecting to anchor tanks in secondary containments presents a much greater hazard than one might guess. A typical carbon steel tank 12 feet in diameter and 29 feet high weighs about 13,000 pounds when empty. One inch of ammonium polyphosphate solution in the tank weighs 825 pounds; 16 inches of the fertilizer weighs 13,000 pounds, the same as the empty tank.

Thus, an empty, unanchored tank will float any time it is surrounded by more than 16 inches of ammonium polyphosphate. A 36-inch- high containment wall filled with the fertilizer would 'push' upward with a buoyancy force equal to 20 inches of solution in the tank, or 16,500 pounds.

Stainless steel tanks weigh slightly less than those made with carbon steel. Fiberglass tanks of the same size are much lighter, and thus will float with much smaller spills.

Leveling—Tank leveling can be a problem since concrete containment floors usually have a slope of at least 2% to minimize corrosive effects of fertilizer on the floor and to ensure proper drainage. The simplest way to level a tank is to place it in a metal ring filled with coarse, washed gravel. In addition to making leveling easy, the ring provides a space for detecting leaks and keeps moisture away from the tank bottom, thus reducing corrosion.

One problem with gravel is the difficulty in cleaning it after a spill. Rainwater quality can be affected by the gravel long after the spill is recovered.

Another way to get tanks level is to pour raised concrete pads beneath each tank. This is done most easily by pouring tank foundations first, then making a second pour for the space between the tanks. However, this is not the preferred method because of the sealing required around tank foundations.

The best method is to make the sloped and level surfaces in one pour. The second best method is to pour the bottom of the pad first and then use dowels to attach the tank foundations, which are made in a second pour.

Many dealers have had success using level secondary containment floors and placing tanks directly on the floor. The key is to keep the floor dry and free of fertilizer.

Reinforced concrete is the most common construction material for secondary containment. Major considerations are that the walls and floor he strong enough to support the gravity loads of the tank and the hydrostatic loads of a massive spill, with a minimum of cracking. It is very important to provide a watertight seal between the floor and wall connection.

Figure 6 shows a typical concrete containment floor and wall construction. Figure 7 shows a containment wall on a floating slab. Floating slabs are common in colder areas where frost depths are such that deep footings are required.

Figure 8 shows a typical secondary containment with tank foundations and anchors (7).

Dealers not knowledgeable in watertight concrete construction should secure the services of an experienced contractor. Recommended concrete specifications are given in another section.

Concrete blocks can be used for secondary containment walls. However, they must be reinforced with steel and filled with concrete to withstand expected loads. Also, blocks should be coated with a watertight sealer.

Containment for Large Tanks

Designing secondary containment for tanks with capacities of more than 100,000 gallons presents special engineering challenges. Such tanks usually are built on sand. They cannot be lifted with cranes and placed inside containments. Sometimes new tanks can be built within a concrete containment or some other watertight basin. However, dealers often do not have enough space to build secondary containments for these large tanks.

State regulations regarding large tanks are quite varied. One state grants experimental permits for designs not explicitly defined in the regulations (2).

Leak Detection—A key objective is to be able to detect leaks from the tank. This calls for special construction to get a barrier to downward movement of leaking material, which is not an easy task. The most common way is to build a false bottom in big tanks. The false bottom is a steel floor welded inside the tank over a thin layer of sand.

Before installing a false bottom in a tank, the sump must be cut out and replaced with a steel plate. The welds around the plate and the existing bottom must be tested and made leakproof. Then, a layer of sand is placed over the existing bottom. Angle iron can be welded around the inside of the tank just above the sand layer, and the false bottom welded to the angle iron. Or, slits can be cut in the tank wall and protruding steel plates welded to the wall, inside and outside, to create the false bottom. Holes or valved fittings are placed in the sand layer for leak detection.

An alternative to false bottoms for leak detection involves subsurface drainage that delivers any spills to a sump or containment basin around the tank. Equipment used by utility companies to bore beneath roads can be used to install the piping. The containment would resemble a moat with perforated piping discharging any leaked material into the moat. Consult a specialist in subsurface drainage to determine the suitability of this type of approach.

Liners for Containment Areas—In most states, clay-lined earthen dikes usually are made by uniformly incorporating clay into the top 6 inches of soil; Illinois, however, requires 12 inches. Large rocks, gravel and soil high in organic matter must be removed. Soils with more than 2% organic matter are not suitable for use in soil-clay liners (5). The soil must be analyzed thoroughly to determine the amount of clay required per square foot of soil. The amount of clay should be based on a recommendation from an engineering firm or state regulatory agency. Generally, the clay liner must have a permeability no greater than 1 x 10— cm/sec (one millionth of a centimeter per second) (2,4, 5). Minnesota has a maximum seepage rate of 0.125 inches per day (6).

The clay seal should cover the area inside the dike and up the inside slope to the top of the dike (figure 10). The top of the dike should be 3 feet wide and the sides should slope no more than 1 foot for each 2 feet of run. A 6-inch layer of gravel should be placed over the clay liner to protect it from erosion and desiccation.

Synthetic liners can be substituted for clay liners. Sheets of synthetic liner material are bonded to form a solid barrier inside the containment. A properly installed synthetic liner may be guaranteed for up to 20 years.

Packed earth can be used for the floor and walls. Or, earth can be used for the floor, with concrete or prefabricated panels for walls. The panels must be bolted together and anchored in concrete.

Clay and synthetic liners cost less than concrete or steel. Difficulty of clean-up in case of a spill is their main disadvantage.

Tank in a Tub—Sometimes large tanks are contained in a large steel tub to conserve space. Although the idea may sound bizarre, it can he quite practical. With a 3-foot-high wall, a one-million-gallon tank will require more than one acre for containment. Containment with a steel tub sometimes called an 'elephant ring'—will require less than one-fifth acre.

The elephant ring typically is one-half the height of the tank. With this ratio, 110% of the tank volume can be provided by a tub with a diameter 1.5 times that of the tank. A tub diameter 1.6 times the tank diameter provides 125% of the tank volume.

The tank and tub require nearly twice as much steel plate for construction as does the tank alone. Walls of the ring must be reinforced with braces attached to the tank. Also, the tank should rest on a 2- to 4-inch layer of sand or gravel to reduce corrosion and provide for leak detection.

As with other secondary containments, plan to deal with rainwater. One possibility is to install a roof over the space between the tank and the ring.

Moving a Tank–Large tanks are difficult, but not impossible, to move. In fact, movement into a containment basin may be preferred to installing a false bottom. One way to move a big tank is to float it. However, an engineer or experienced contractor should be consulted before trying this.

Large tanks often are made of steel only three-sixteenths of an inch thick. Such a tank will float in 10 inches of water. To move the tank, a clay-lined dike is built and filled with water. When the tank floats, it is pushed to its new location, and the water is drained or pumped from the diked area, The area where the tank previously was located is sealed with clay.

To reduce the chances of tank damage, it is a good idea to remove the sump and any other projections before the move is begun. Interior braces may be needed to support the tank bottom against the buoyant force of the water.

Tanks as large as 300,000 gallons have been moved by house-moving methods. Large beams are slid through holes cut in the tank and semi-trailer axles with lift jacks are used to raise the tank by lifting the beams.

Four 300,000 gallon tanks were moved two miles in Nebraska using dollies made from semi-trailer axles and a framework that was welded to the side of the tank. The specially built dollies permitted the raising of the tanks without cutting holes in the tank wall.

An air cushion also can be used to move a big tank a short distance over a relatively smooth surface. This is done by attaching a skirt around the bottom of the tank and using large blowers welded to the tank to provide the cushion.

Large tanks must be anchored since buoyant force can exceed 100,000 pounds. Weights can be attached to the tank or the tanks can be constrained with cables attached to anchors outside the dike (7). Concrete deadmen or earth anchors can be placed beneath the liner if the clay or synthetic liner is sealed properly.

Another approach is to let the tank float, but restrain any lateral movement. This requires flexible plumbing. Also, it is good practice to leave fittings and manholes open when tanks are empty to equalize liquid levels inside and outside the tank in the event of a spill or rainfall accumulation.

Containment for Stored Pesticides

Earth structures are not allowed for secondary containment of stored pesticides. Also, pesticide containment must be separate from fertilizer containment. They can be adjacent, and the wall between pesticides and fertilizers can be lower than the outside wall to permit the two areas to mix in case of a catastrophe.

Pesticides should be kept under roof. Packaged pesticides should be kept in a separate warehouse and not inside a containment for either bulk pesticides or fertilizers. Flammable pesticides should be kept separate from nonflammable product, and the warehouse should be curbed to contain water that might be required to extinguish a fire.

Dry Fertilizer Containment

Dry fertilizer storage buildings should be on elevated ground to prevent rainfall runoff from entering. Floors should be paved with concrete and cracks should be repaired to prevent downward movement of nutrients. The roof and walls should be free of leaks. Floor sweepings and scrap fertilizer materials should be stored under roof. Limestone generally is the only fertilizer material that can be stored outside.

Wood has been the material of choice, but some new buildings are being made primarily of reinforced concrete, largely to reduce labor costs.

The floor is poured with slots to accommodate wall panels. Wall sections are poured horizontally on the floor, with reinforcement steel and clips for connecting sections positioned accurately in each. A crane is used to erect the walls and connect adjoining panels. Bin walls are supported laterally across the top with steel or concrete beams.

Watertight Concrete Construction

The following specifications are recommended to ensure that concrete for load pads and containment structures will resist penetration by moisture and chemicals and have a durable finish (7):

* Use Type 11A or Type II cement with air entrainment, at 4,000 - 5,000 psi compressive strength. Type II provides moderate sulfate resistance. ('A' denotes air entrained; Type II must be air-entrained.)
* Use a water-cement ratio of 0.40 - 0.45 for a stiff (1.5" - 3" slump), relatively dry mix for maximum strength, chemical resistance, freeze/ thaw resistance, and watertightness.
* Use 5.5% to 7% air entrainment in cement to improve workability at placement and to improve watertightness and strength of low slump concrete.
* Vibrate concrete at 5,000 to 15,000 frequency range during placement to get minimum aggregate segregation.
* Finish the surface with a powered steel trowel to minimize coarseness of texture and make washing and cleanup easier.
* Immerse or moist-cure concrete for at least 14 days (28-day immersion or moist cure gives maximum strength).
* Allow no more than 30 minutes between loads of concrete during pouring.
* Mix concrete at 70 - 100 RPM, then agitate at an additional 200 - 230 RPM (maximum of 300 total RPM).
* Discharge mixed concrete within 1.5 hours (per ACI C94).
* Minimize discharge drop distance by using a discharge

chute.

* Use large (1- to 1.5-inch), clean, impervious aggregate, or aggregate one-third the size of the slab thickness, for maximum strength and watertightness.

* Use clean, drinkable mixing water having a pH of 5.0 to 7.0.

* Oven-test aggregate for excess moisture and adjust water added accordingly. If oven- testing is not possible, assume 3.5% excess water in sand and 1.5% excess in aggregate.

* Complete all continuous pours of concrete in one day; 'cold' joints are to be avoided.

Joints and Barriers

Expansion joints should be spaced close enough to prevent cracks from forming in undesirable places. Joints should be machine cut to a depth of one - fifth to one-fourth the slab thickness. The rule of thumb for minimum joint spacing in feet is 2.5 times the slab thickness in inches. Thus, an 8-inch slab should have joints no more than 20 feet apart.

Joints should be located where they can be monitored—not under a tank, for example. They should be sealed with a material resistant to fertilizers and pesticides, and the seal should be checked periodically for repair or replacement. Sections between joints preferably should be square; if not square, the length-to- width ratio should not exceed 1.5.

Vapor barriers should not be used beneath concrete pours; the barriers can cause the concrete to retain moisture and increase degradation from freezing and thawing.

Problems of frost heaving can be reduced by keeping the area around concrete slabs dry. The area beneath the concrete should be higher than the surrounding area and surface drainage should keep water from standing near containment structures. Drainage around concrete structures should be monitored for two or three years after construction to ensure that the area is well drained after the structure settles. Curbs and gutters should be used to keep runoff from buildings and paved areas away from containment sites.

Reinforcement

Steel reinforcement bars are recommended for containment structures. Wire mesh or fiber additives will not provide resistance to cracking over the life of the facility. Reinforcement rods usually are spaced 12 inches apart in both horizontal directions. Bars in sumps usually are spaced 6 inches.

Waterstops are needed between containment floors and walls to keep fluids from seeping under containment walls. Molded vinyl waterstops, which must be embedded in the concrete floor beneath the wall, are available in several shapes. Other waterstops can be placed on the perimeter of the slab after it has cured.

Many fertilizer and pesticide handling facilities have concrete slabs beneath tanks. If the concrete is in good condition and free from cracks it can serve as part of the containment floor and the pad can be extended. The wall can then be built above new concrete.

It is important when joining new and old concrete to seal the crack between the two slabs and to anchor new concrete to the old with dowels inserted into holes drilled in the existing concrete. Even when existing concrete is in good condition, the best decision may be to remove the concrete, particularly if the slope is incorrect or the pad is too low due to settling. An engineer experienced in concrete design should be consulted regarding the use of existing concrete.

Management Practices

Containment systems are an essential part of environmental security at fertilizer/ pesticide dealerships, but they are no substitute for good management. Environmental management involves (1) proper handling of fertilizers and pesticides, (2) security of the facility during nonoperation, and (3) reliability of equipment used to transport or contain these materials.

Proper materials handling begins with employee training and education. Employees should understand how groundwater can become contaminated and the importance of keeping fertilizers and pesticides contained. The rinsate storage scheme should be understood by all, and all storage containers— including rinsate containers—should be labeled.

A typical scheme might involve separate storage tanks designated for rinsates from corn, cotton, and soybean operations, plus a tank for pesticide-free make-up water. Schemes will vary according to the number of crops treated and the amount of rinsate handled at the facility. To prevent contamination of materials, spills should be cleaned up immediately. To minimize the amount of rainwater that must be collected and used, the loading pad and containment system should be cleaned and sumps should be pumped out at the end of each working day or prior to rainfall.

Where to Mix

Two approaches are used in pesticide handling: mixing pesticides with the carrier in a batch mixer at the plant, and mixing in the applicator.

Mixing at the facility is common practice. Formulation accuracy is enhanced since all mixing can be done under supervision of an experienced mixer operator. Also, less equipment is needed since pesticides are not mixed and handled in equipment separate from fertilizer.

The main disadvantage of plant site mixing is the amount of equipment that must be cleaned to prevent contamination when switching products. All equipment - mix tank, nurse equipment, and application equipment must be purged of the particular pesticide. Another disadvantage is the hazard associated with transport of large volumes of pesticide containing product.

Many dealers now wait to mix pesticides until they are in the field. The pesticide is mixed with the fertilizer in the applicator. This practically eliminates pesticide-laden rinsate if the applicator is rinsed in the field.

On-board rinse systems with nozzles mounted inside the applicator tank are available to clean the tank walls and baffles. Portable sprayers also are available for cleaning pesticide residues from the outside of applicators.• To ensure formulation accuracy, pesticides should be premixed at the facility and transported in separate containers on nurse equipment. The containers should be approved by the Department of Transportation for transporting pesticides.

In still another system, pesticide is kept outside the applicator tank. It is added to the applicator's output stream by on-board injection or impregnation systems. These systems are near ideal for reducing rinsate. However, direct injection and impregnation systems are limited in the number of products they can handle. Also, some dealers are skeptical of their accuracy.

Regardless of where pesticides and fertilizers are mixed, the amount of rinse water handled at the plant can be reduced by rinsing as much equipment as possible in the field. To reduce the chance of contaminating surface water, rinsing should be done well away from ditches and creeks. Applicator rinsate from onboard rinse systems should be broadcast over the field, not dumped in one spot.

Rinsate Handling Tips

Other methods for reducing the volume and cost associated with handling rinsates include (8):

* Group jobs using similar fertilizers and herbicides so that equipment need be cleaned only once a day.

* Modify equipment to reduce the amount of residue left after tanks are emptied. The pump on large application equipment, for example, is driven by a belt from the engine and is nearly 10 feet from the tank drain. As an option, the pump could be driven hydraulically and placed directly beneath the applicator tank.

* Use high-pressure rinse equipment to reduce rinsate generation. Though centrifugal pumps are well suited for handling liquid fertilizer, their high output and low operating pressure make them poorly suited for washing out equipment. High-pressure washers clean better with less water.

* Calibrate equipment properly and know the exact acreage to be treated. This will minimize the amount of pesticide mixture that must be either rinsed from the applicator or hauled back for recycling.

Plant Security

Facility security during periods of nonoperation requires daily inspections. Where theft or vandalism is a problem, the plant should have a security fence and gates with locks, or be patrolled regularly. At the end of operations, the facility should be locked up and all valves on tanks and all pumps should be turned off. Some facilities have a single switch that breaks circuits to all pumps and electrically driven valves.

Facilities not especially subject to vandalism may not require a security fence; however, all valves on tanks should be locked in a closed position. Since valves on tanks and valves at the bottom of external sight gages both need to be locked, the two can be positioned near each other on the tank so that one lock can be used to secure both.

Gravity drains are not recommended for containment areas, although they sometimes are permitted for discharge of rain water. Discharge of rain water must be supervised closely; except when discharging rain water, valves should be locked at all times.

Storage areas and containment systems should be checked frequently when the plant is shut down. Winterize the facility prior to cold weather. Remove water trapped in lines and in containment basins to prevent freeze damage.

Check regularly the integrity of containment systems, storage containers, and other equipment designed to keep fertilizer and pesticides out of water supplies. Inspect tanks, valves, piping, and containment systems for leaks.

Some proposed regulations would require several inspections of these systems and documentation of inspections. Even if not required, documentation is recommended as part of an overall program of vigilance and maintenance. Tanks and plumbing should be inspected annually for leaks. Trouble areas should be tested physically by either a vacuum or pressure test.

A strict maintenance schedule should be followed, not only to protect water supplies but also to reduce down - time during the busy season.

Cost and Work Scheduling

Containment of materials can be costly, but it is a necessity.

Concrete slabs usually can be poured for about $100 per cubic yard. A survey of dealers in the Midwest and Great Plains showed a cost for loading pads—including site preparation, reinforcement, form work, and finishing of $140 to $200 per cubic yard of concrete. This high cost was due, in part, to the special requirements for retrofitting new and existing concrete, site preparation, and the labor associated with forming sumps. Other costs associated with a load pad include the cost of tanks to hold rinsate and pumps and plumbing to transfer material to and from these tanks.

Most facilities need three or four 500- gallon tanks for rinsates. The total cost for a rinsate recycling system should be around $2,500, depending on the amount of materials that must be purchased.

Cost of secondary containment will depend on the materials used for construction. Concrete has the advantage of conserving space but is more costly than synthetic or clay liners. The following cost comparisons for alternative diking systems were presented by Hansen (9):

* A typical secondary containment for six 12-foot-diameter tanks, with the largest having a capacity of 30,000 gallons, costs about $26,000 if made of concrete. Concrete dikes cost about $11 per square foot of floor area.

* A clay - lined earthen dike with the same floor area cost about $14,000. Due to its sloping sides, the earthen dike can contain a tank with a volume up to 45,000 gallons for about $6 per square foot of floor area.

* A similar dike with a hypalon liner sandwiched between polypropylene liners will cost about $19,500, or $8.25 per square foot of floor area. The polypropylene liners, or geotextile liners, are needed to protect the main liner from damage during installation.

In each of the above alternatives, security fencing at $10 per inear foot and a 10% contingency were included in the total cost.

Dealers typically spread plant modifications over a wo- or three-year period; regulations generally have a similar ompliance schedule. Regulations usually prioritize areas and naterials requiring containment; dealers should establish the ame priorities for making changes.

Containment generally is prioritized as follows: water ystem protection, pesticide storage containment, loading/ nixing/ equipment washing area containment, and fertilizer torage area containment.

Conclusions

Before designing a containment system, dealers should isit several sites and study several systems. Dealers with good ystems are valuable sources of information, particularly if they ave operated a system for some time. Experience and hindsight re invaluable.

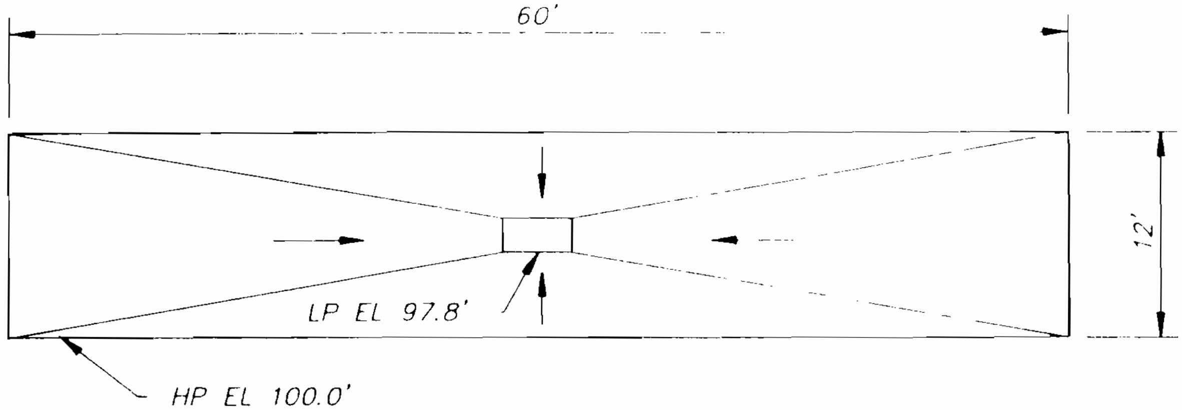
A good system design should provide for future expan-ion. Provisions also should be included in the long-range plan or construction of roofs over areas subject to incidental spills.

Even in states with no containment regulations, it is dvisable to contact local agencies involved with water sup-lies—such as the Health Department, Emergency Management gency, and Environmental Regulatory Agency—when plan-ing facility modifications.

For assistance in containment design, the Cooperative xtension Service, State Department of Agriculture, fertilizer nd agchemical dealer organizations, or TVA's National Fertil-zer & Environmental Research Center should be contacted.

Fertilizer and pesticide containment provides opportuni-es for the retail fertilizer industry to take a leadership role in vater resource protection.

Water resource protection is everyone's responsibility; fter all, we are only borrowing water from our descendants. lso, more, not less, regulation likely will be the rule in the uture.



Liquid Holding Capacity in Gallons

$$LHC = \frac{7.5 \times L \times W \times D}{3}$$

Where,

L = pad length in feet
W = pad width in feet
D = depth at sump inlet in feet
7.5 = gallons per cubic feet

$$LHC = \frac{7.5 \times 60 \times 12 \times 2.2}{3}$$

$$= 3960 \text{ gallons excluding sump}$$

By adding a 4" high rollover curb around the pad the LHC is increased by 1800 gallons. LHC of the curb is computed as follows:

$$LHC = 7.5 \times L \times W \times CH$$

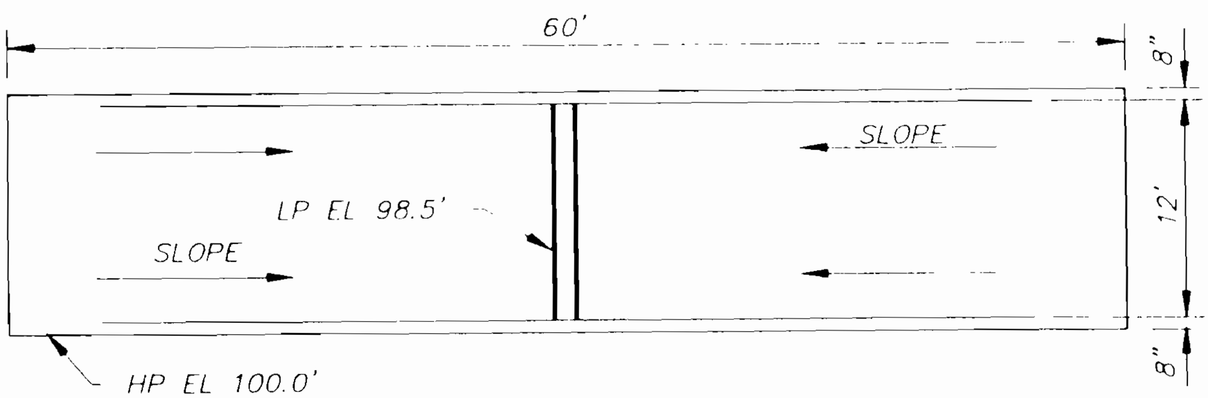
where,

CH = curb height in feet

$$LHC = 7.5 \times 60 \times 12 \times 0.33$$

$$LHC = 1800 \text{ gallons}$$

Figure 1. Load pad for a single vehicle.



The Liquid Holding Capacity for this pad is computed by the equation

$$LHC = \frac{7.5 \times L \times W \times D}{2}$$

$$LHC = \frac{7.5 \times 60 \times 12 \times 1.5}{2}$$

$$LHC = 4{,}050 \text{ gallons excluding the trough}$$

Figure 2. Single vehicle load pad with trough.

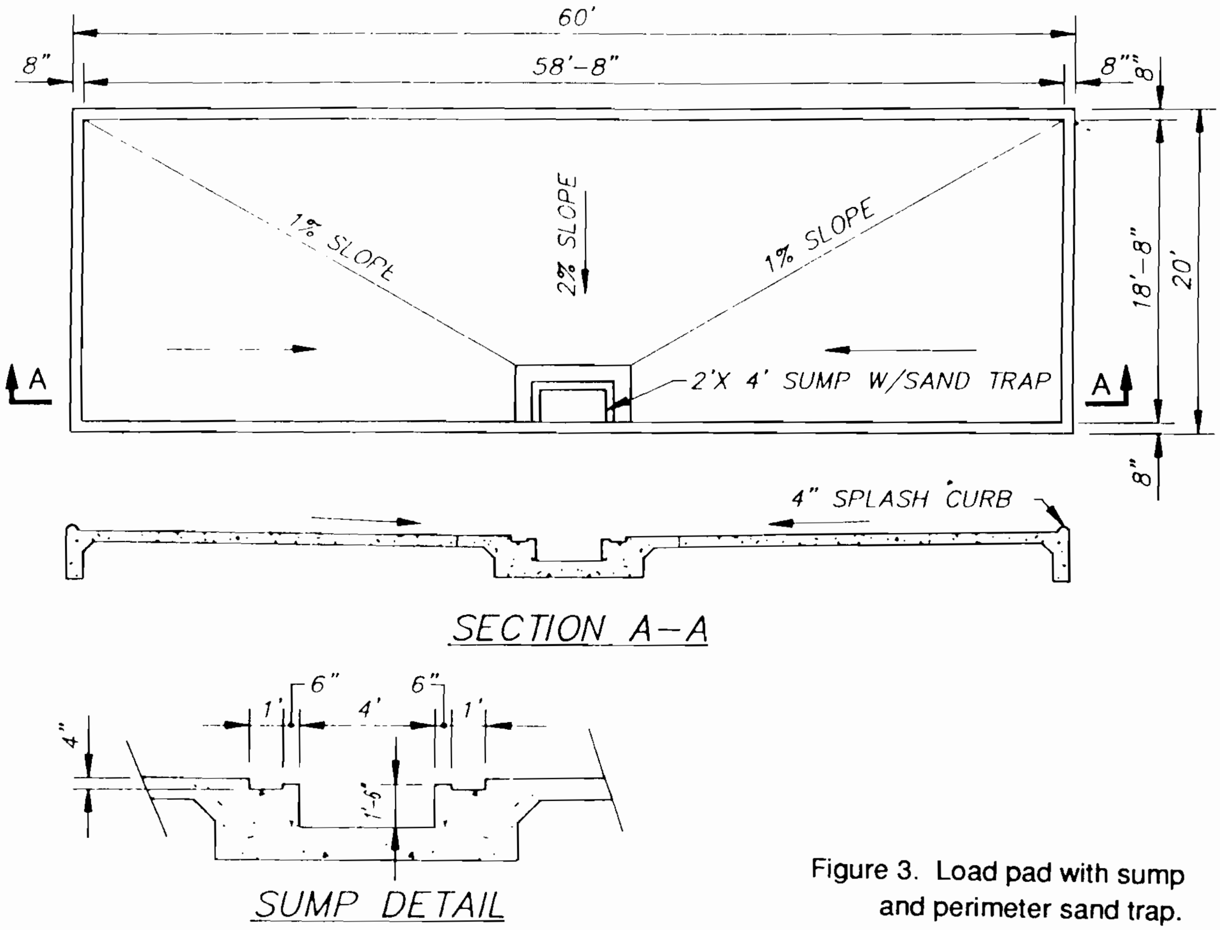


Figure 3. Load pad with sump and perimeter sand trap.

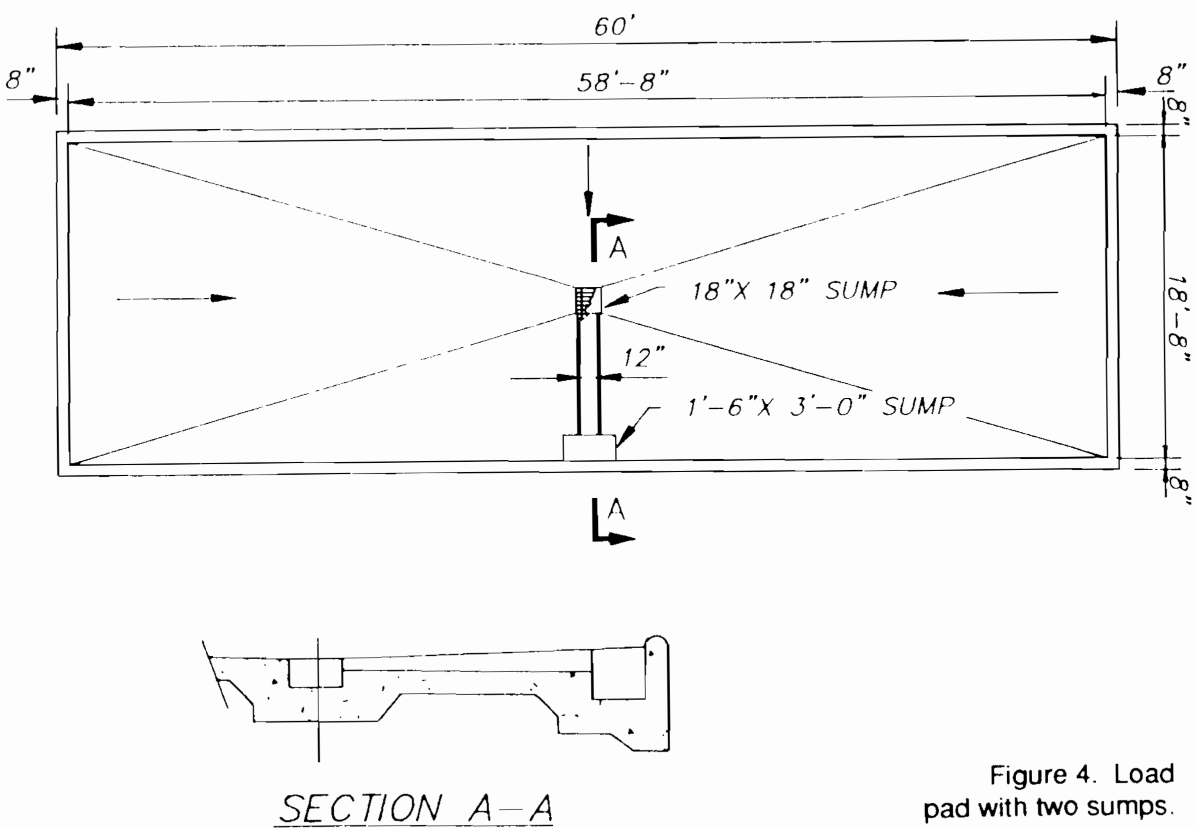


Figure 4. Load pad with two sumps.

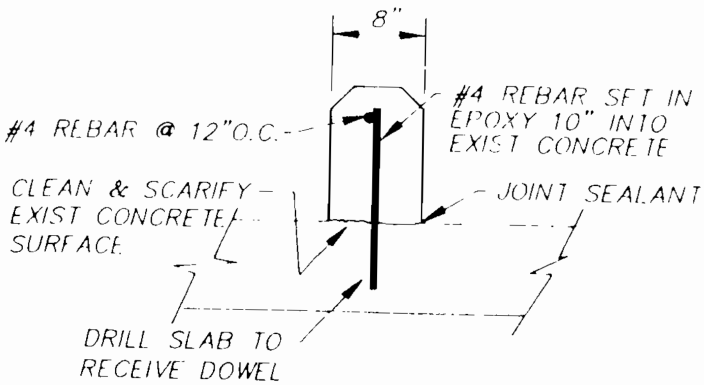


Figure 5. New curb on existing concrete.

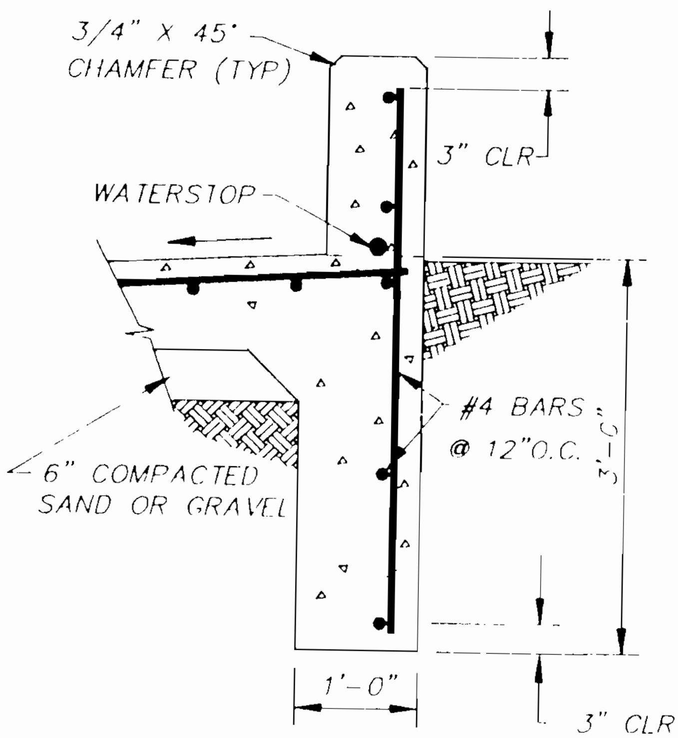


Figure 6.
Containment wall.

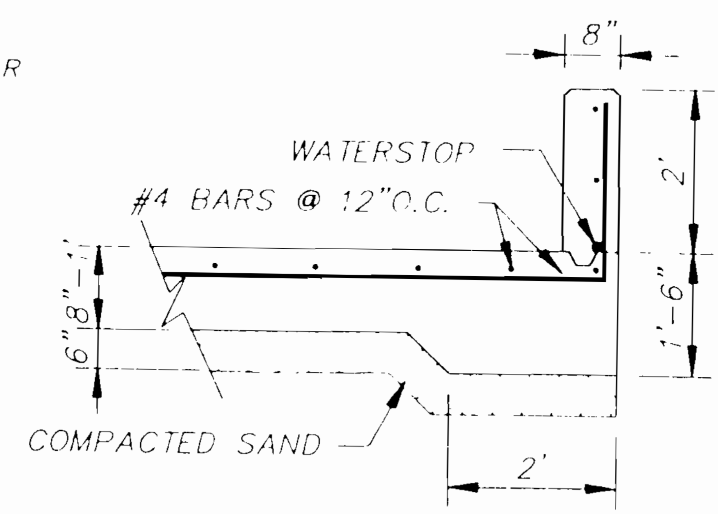


Figure 7. Floating slab

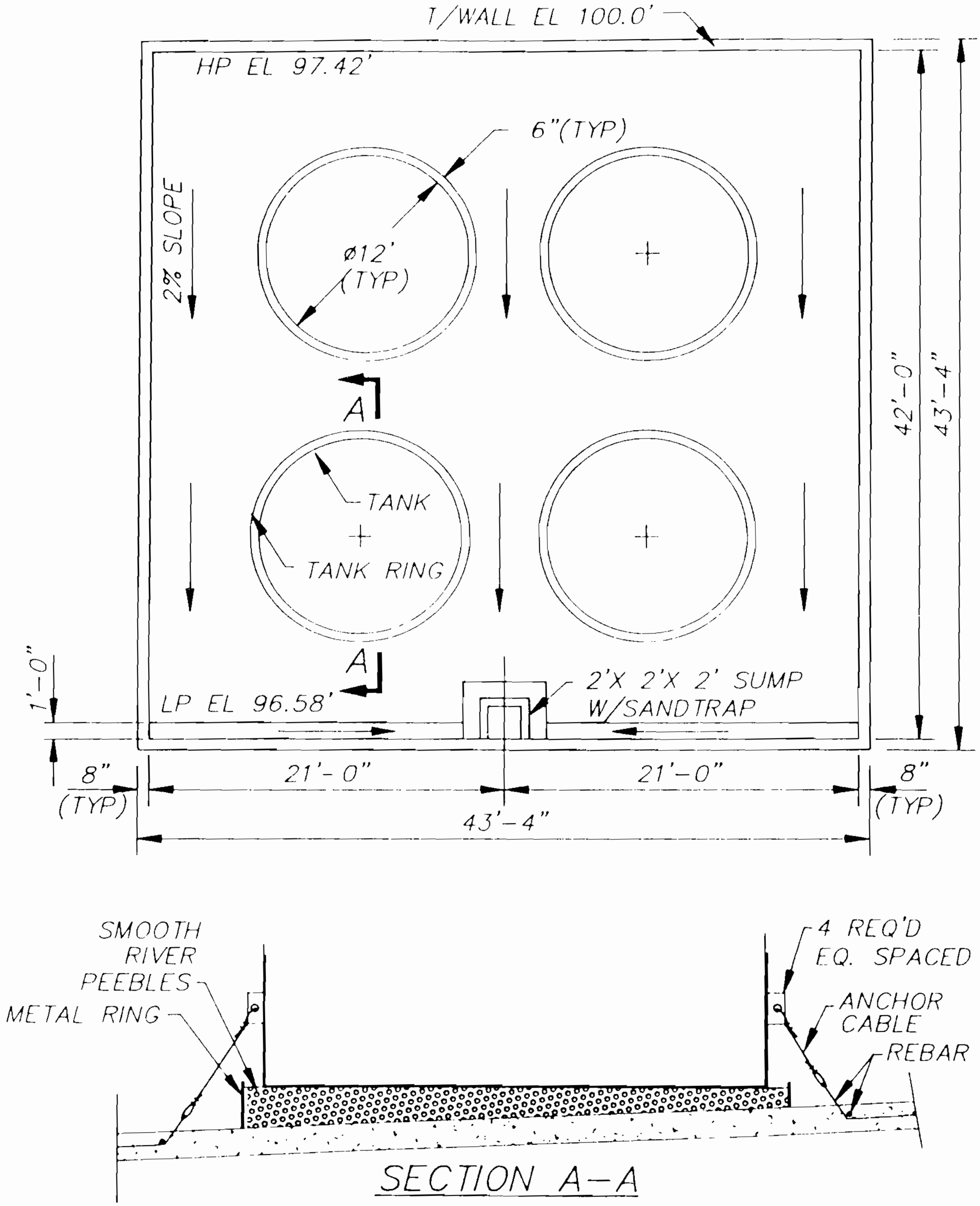


Figure 8. Typical secondary containment

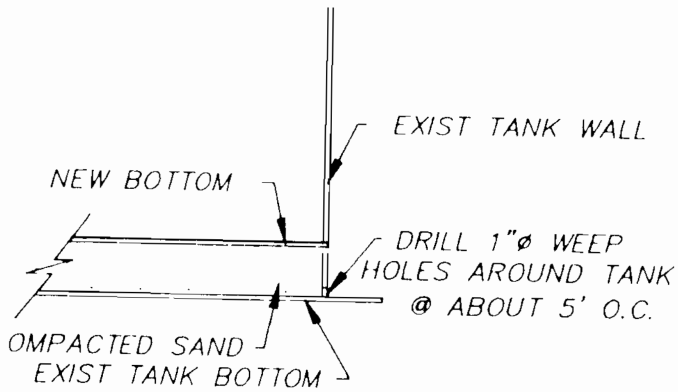


Figure 9. False tank bottom

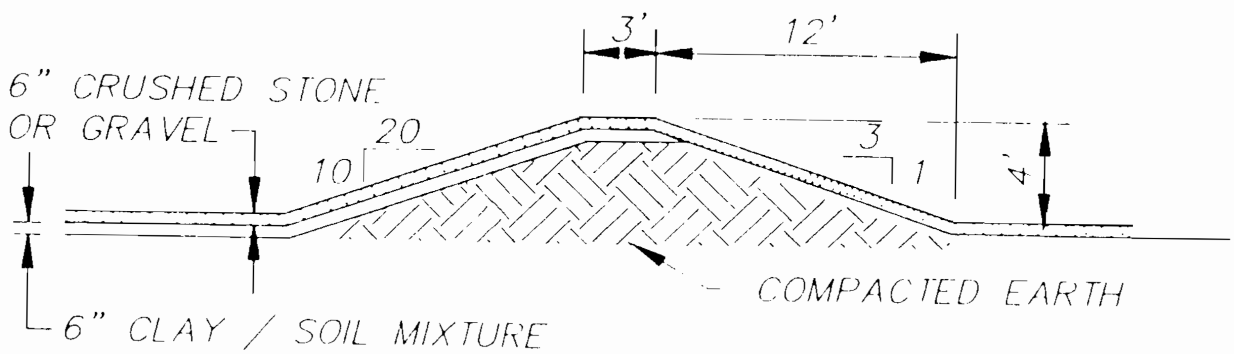


Figure 10. Clay-lined earthen dike

Regulatory View of Quality Control in Blending & Liquid Fertilizer Plants

Dale Dubberly
Florida Department of Agriculture & Consumer Services

I am pleased to participate in todays Fertilizer Industry Roundtable Discussions as a representative of the Florida Department of Agriculture and Consumer Services.

In the past, the most important responsibility of the Fertilizer program has been to maintain a balance between the farmer and the fertilizer manufacturer. while this role is still necessary in some situations, in a broader sense I see the Department and the fertilizer industry providing key elements relating to the beneficial use of fertilizer in Florida Agriculture. Programs such as the one this week allow the regulator and supplier to meet with those in the areas of research and education to learn more about fertilizers.

The primary purpose of the Florida Fertilizer Law is to assure farmers and the consuming public that the fertilizer product manufactured and/or offered for sale meets the plant food guarantees on the label. We are highly interested in improving our inspectional program for the benefit of the consumer and industry.

How many of you are producers, distributors, dealers or commercial applicators of fertilizers or otherwise engaged in the fertilizer industry?

Since our Department regulates these activities, I guess that puts me in a position where I can be somewhat dictatorial as to how you conduct the affairs of your businesses. In one manner of speaking, you might say that to some extent you work for me, doesn't it.

Another question... How many of you are taxpayers? That's what I was afraid of you're the people who pay my salary so that means that I work for you. That puts the shoe on the other foot doesn't it.

I guess what it really comes down to is that all of us really work for your customers... The purchaser of your products.

Further, if we want to stay in business, we need to keep the best interests of that purchaser in mind... And there is no question in my mind that all of us do have that customer's best interests in mind.

The next item that I will discuss is requirements of Chapter *576 Florida Commercial Fertilizer Law* and our view of Quality Control in Blending Plants and some elements that are very important.

(1) Deconing
(2) Sampling
(3) Quality

(l). Deconing - 576.055 The Department may adopt by rule procedures and methods which would require each in-state manufacturer of commercial fertilizer to incorporate specified procedures designed to avoid coning during the loading of bulk mixed fertilizer into transport vehicles to reduce separation and segregation of fertilizer components intended for delivery to a purchaser.

(2) FERTILIZER SAMPLING FACILITIES

In an effort to insure a degree of uniformity of fertilizer sampling facilities at blending plants.

We would like to recommend the following guidelines when constructing fertilizer sampling rooms. Although sampling facilities will vary from plant to plant, these guidelines will provide a basis for standards for facilities.

The standards for fertilizer sampling facilities are:

1. The room should have a minimum of 8 feet by 8 feet inside measurements and a height of not less than 7 feet.

2. It must be a sealed room with a tight floor to keep dust out.

3. It must be built adjacent to the belt discharge so that fertilizer can be sampled through a window centered in the room so that the sample can be drawn with either hand.

4. The floor should be approximately 3 feet lower than the belt discharge to eliminate excess stooping.

5. The door should be the standard width and height (min. 30" x 78").

6. The room should be equipped with a fan, lights, airline, waterline, table, electric outlet, and a small electric heater to aid in keeping equipment clean and dry.

7. The door is to have a padlock, with the Specialist having one key and the fertilizer plant office the other key.

8. The sample room should be equipped with intercom if it is more than 1OO feet from the shipping office.

9. Stairs to the room are to be a minimum of 36 inches wide, with handrails on both sides.

1O. Stairs should be no steeper than a 30 degree angle and have a riser height of not more than 7 1/2". Steps should be a minimum of 1O" wide and to be made of slatted metal to prevent slipping.

11. All structural supports around the sample room must be maintained by the manufacturer. The facilities must be safe for the Specialist to climb stairs and be in the room at all times.

(2). Sampling - The term "suitably equipped plant" means a manufacturing facility located within Florida which meets the requirements for and has been found acceptable by the department for plant sampling as follows:

1. Requirements for Plant Sampling Facilities:

a. Room to have a minimum of 8 feet by 8 feet inside measurements and a height of not less than 7 feet.

2. Conditions for discontinuing plant sampling. It will be the prerogative and duty of the department to discontinue this method of plant sampling at any establishment which displays an unwillingness to cooperate or when the following conditions prevail:

a. Failure of management to maintain sampling facilities in good order.

b. Alteration in belt sampling facilities which would make safe, effective and representative sampling impossible.

c. Development of excessive dust or gas conditions in the area of sampling station.

d. Failure of management to supply inspector appropriate lot information on individual loads.

e. Deliberate interruptions in the manufacturing of a bulk lot. This does not contemplate interruptions caused by equipment breakdown.

f. Failure of manufacturer to honor mutually determined time for manufacturing and sampling of special request lots of fertilizer.

g. Any similar conditions that would hamper or discourage the taking of official samples by the department.

h. The involuntary discontinuation of plant sampling at any establishment will be predicated on a thorough investigation made by the department, after written notice and opportunity for a hearing.

2. SAMPLING TOOLS - The following shall be the official sampling tools for taking samples of mixed fertilizer and fertilizer material in Florida:

a. Modified Belt Discharge Cup. (Opening 7/8" x 10", capacity approximately six pints). To be used in taking official samples of a mixed fertilizer or a fertilizer material from a belt or hopper discharge at in-state establishments which have been found acceptable for such sampling by the department.

b. Modified Belt Sampler. (Opening 1" x 7", curved base, capacity approximately six pints). To be used in taking official samples of a mixed fertilizer or a fertilizer material from top of belt at in-state establishments which have been found acceptable for such sampling by the department.

3. (b). Dry Bulk Mixed Fertilizer or Dry Bulk Fertilizer Materials Sampled from a Belt, Belt Discharge or Hopper Discharge at Suitably Equipped Plant.

1. official samples shall be taken with a modified belt discharge cup or a modified belt sampler. The official sample size shall be according to the following schedule:

LOT SIZE IN TONS	NO. OF CORES
Less than 1 thru 2	5
Greater than 2 thru 3	6
Greater than 3 thru 5	7
Greater than 5 thru 7	8
Greater than 7 thru 9	9
Greater than 9 thru 11	10
Greater than 11 thru 15	11
Greater than 15 thru 19	12
Greater than 19 thru 25	13
Greater than 25 thru 32	14
Greater than 32	15

2. This method will be utilized at suitably equipped plants for sampling bulk mixed fertilizer from belt, or belt discharge or hopper discharge.

3. These samples are to be taken by passing the cup perpendicularly through the belt, belt discharge or hopper discharge stream, cutting it completely a predetermined number of batches at intervals as necessary to obtain the required number of cores for the tonnage to be represented by the sample.

4. If the sample consists of more than one gallon, it will be mixed and divided by using the following equipment and procedure:

a. Equipment consists of a Jones or Archer type riffle and four pans to catch the sample from the riffle. Only standard pans as furnished by the Department for use with the specific Jones or Archer type riffle are to be used. All equipment is to be checked for cleanliness. The riffle must be seated level and not tilted.

b. The sample accumulated in the container is transferred to one or two pans as required for passing through the riffle. Any pan should be no more than 2/3 full or less than 1/3 full for preliminary riffling. The surface of the sample in each pan must be level before continuing.

i. Mixing Operation Before Dividing Sample - The pan containing the sample is held in both hands, as level as possible, and the pan tilted lengthwise onto the riffle as near the center as possible so that the lower top edge of the pan makes uniform and continuous contact with the entire surface of the riffle. The pan is further tilted and the material allowed to flow onto the riffle in a continuous stream with as uniform a rate of flow as possible, but not fast enough to flood the riffle. If two pans have been used to contain the sample, the same procedure is repeated with the second pan so the entire sample is accumulated in the two pans used to catch the sample from the riffle. This procedure is repeated at least two more times using the entire sample each time.

ii. Sample Dividing Operation - At this point, the entire sample is accumulated in two pans which should be removed from beneath the riffle, the surface of the sample in each pan leveled, and each passed through the riffle according to the procedure as indicated above. Both pans are removed from under the riffle; and one discarded. If the contents of the remaining Pan is one gallon or less, it is placed in sample container, sealed and forwarded to the Fertilizer Laboratory. If more than one gallon, the contents are passed back through the riffle under the procedure as previously stated. Both pans are removed from under the riffle; and one discarded. If the contents of the remaining pan amounts to one gallon or less, it is placed in sample container, sealed and forwarded to the Fertilizer Laboratory. This is repeated as necessary to secure a sample of one gallon or less. At no point in this entire procedure is anything except the entire contents of a pan which has caught the material from the riffle to be used.

PLANT DESIGN AND EQUIPMENT

A well designed plant is necessary to insure that:

1. Materials are not mixed or contaminated during receiving or in storage.

2. Materials remain in good physical condition during storage.

3. Materials are accurately weighted and well mixed during blending.

4. Mixtures do not separate during bulk load out or bagging operations.

When all of these objectives are attained, the blended product will meet the quality standards required by state regulatory officials.

A quality bulk blended, solid fertilizer is a uniform product made by mechanically mixing, in suitable equipment, two or more granular materials having known nutrient contents and which are closely matched in particle size.

Over 40 percent of all solid fertilizer sold in the U.S. is bulk blended. Therefore, the producer and/or seller of the materials used in blends and the operators of blend plants share a large responsibility for producing good blends.

Producers have the responsibility for providing blending plants with properly sized materials *of known nutrient content.* If the nutrient content of a given shipment is more than one percentage point below the value generally accepted as typical for the product, the blender should be informed by the time the material in question is received.

The blender has the responsibility for not only having good, well- maintained blending equipment, but good procedures for operating it and for determining if the materials he receives are suitable for blending.

The purpose of this manual is to describe:

1. *High quality blends* and the type of fertilizer materials needed to produce them.
2. *Acceptable blending plant equipment.*
3. *Procedures* for determining if a given material is suitable for use in good quality blends.
4. *Desirable blending plant operating practices* including personnel training, housekeeping, sampling, analyses training, scheduling, inventory control and treatment of customers and control officials.

The maintenance of good quality control practices in the bulk fertilizer blending plant deserves constant attention. The blender is liable for what he ships and, therefore, must do everything he can to prevent the possibilities of customers filing poor performance claims. Also, state deficiencies and/or fines must be kept at a minimum.

More and more frequently, blenders receive materials of varying analysis. Therefore, the blenders should give constant attention to the chemical analysis of each individual car or lot of material received. He also needs to be aware of the particle size of his purchased materials to be sure that he can blend them without severe segregation problems.

The first step in making a quality blend is to select materials with known chemical analysis and which are closely matched in particle size. Stated another way, the quality of a blend depends on nutrient content and particle size even though blending equipment and operating procedures are perfect!

1. *Chemical Analysis (Nutrient Content)*

The blending plant formulator of operator must know the nutrient content of each material used if he is to make blends containing the expected amounts of nutrients. When the nutrient content of a material is below the expected value by more than about one percentage point, blends containing that material may not meet the guarantee.

1. *Particle Size*

One of the major reasons for off-grade blends is segregation, which means the blended fertilizer is no longer uniform, or that smaller particles have separated from the larger ones and have collected in a different place. This important condition applies to both fillers and nutrient materials.

In order to determine whether segregation is going to take place, we need to have information about the particle size distribution of the materials to be used. Screen test are used to determine particle size.

3. *SGN - UI*

SGN was developed by the Canadian Fertilizer Institute (CFI). It is totally voluntary. CFI has developed two measures to describe the average particle size and particle size distribution of blending materials. The are the size guide number (SGN) and the uniformity index (UI).

SGN — What Is It?

SGN stands for Size Guide Number, SGN is the calculated diameter of the "average particle," expressed in millimeters to the second decimal and then multiplied by 100. More precisely, SGN is that particle size which divides the mass of all particles in two equal halves, one having all the larger size particles and the other half having all smaller size particles.

UI — What Is It?

UI stands for Uniformity Index. UI is the ratio of particle sizes, "fines" to "coarse" in the product, expressed in percentage. More precisely, UI is the ratio, times 100, of the two extreme sizes in the range of particles retained at the 95% level and at the 10% level.

A uniformity index of 100 would mean that all the particles have the same size (perfectly uniform).

How to Use SGN and UI — The Empirical Approach

The blender operator often develops a "rule of thumb" which works well in the particular plant, although not necessarily so elsewhere. After a certain amount of experimentation, it becomes fairly easy to set limits on the SGNs and UIs of materials mixed together. This empirical approach may take the form, for instance, of a rule "average plus or minus so much percent". In the case the blender operator calculates the average of the SGNs of the materials used together and establishes the "acceptable" range. A similar calculation is performed for the UIs of these same materials. If all materials used fall within the limits of the "acceptable" ranges, the formulation will be calculated with the standard overages. Otherwise, formulation overages will• be raised to offset the risk of deficiency caused by increased segregation.

	Mat. 1	*Mat. 2*	*Mat. 3*	*Mat. 4*	*Average*	*Acc. Range*
SGN	230	225	215	190	215.0	193.5–236.5
UI	44	44	40	36	41.0	36.0–45.1

In this example, material 4 falls out of both "acceptable" ranges. Therefore, higher overages will be required in formulation. (The proportion of material 4 in the formula may influence the amount of required overage). Alternatively, the blender operator will need another source of material 4 with SGN and UI values closer to the values of the other three materials.

Most blend plants make use of the belt type elevator with centrifugal discharge. They provided the highest capacities for the investment. Belt elevators require a smaller casing than do chain type elevators, so less space is required and installation is easier.

Capacities range from 30 tons per hour up to several hundred tons per hour. The elevator type and size must be selected carefully to accommodate the rate at which it is fed. Elevators which are slug-fed, as when supplied by a shovel loader, may require a feeder device at the inlet to prevent choking. Sometimes a restrictive gate is all that is needed.

The elevator casings may be built of many different materials. Wood, fiberglass reinforced plastics, mild steel and stainless steel are all widely used. Boot sections are the most critical and stainless steel of the 300 series is an excellent choice for this part. Intermediate casing sections and the head section may be fabricated of mild steel. A minimum thickness of 10-gauge is recommended for good service life.

7. Hoppers

Hoppers are very simple and relatively inexpensive. For that reason, little thought is given to their design or location; however, a poorly situated hopper can cause separation (segregation) of the most carefully prepared blend. Hoppers that receive blended product, either for bulk loadout or for bagging, must be designed and located properly.

Hoppers can be either cylindrical with cone bottoms or rectangular with pyramidal bottoms. In both cases, several design criteria must be met. These include:

Cone bottoms must be steep enough to permit easy, uniform exit flow.

Pyramid bottoms must have sides that are sloped steeply enough so that valley angles are at 50° or more to the horizontal.

8. Equipment for Quality Assurance

The following discussion will deal with the items of equipment needed by the blending plant to sample and evaluate the quality of the product or the raw materials.

1. Sampling probe, either the Missouri "D" tube manufactured by Boyt Tool & Die, Inc., Des Moines, Iowa; or the Fertilizer Trier, 36-1/2" long, Catalog Number 1-0599, that is sold by Seedboro Equipment Company, Chicago, Illinois.

2. A Sampling Cup made to dimensions as shown in Section I, Figure l. This is to be used to take samples at the discharge from horizontal conveyors or the ends of chutes.

3. A set of 8" diameter, 2" high test sieves. They can be obtained from the w. s. Tyler Company. The Tyler standard mesh sizes to purchase are: 6, 8, 10, 14 and 20 mesh. A bottom pan and a top cover are also needed.

4. A triple beam balance. These are obtainable from a laboratory supply house. It is used to weigh the portions of the material after it has been separated into size fractions by screening.

5. Sample Reducing Equipment. Before passing through the test sieves, it may be desired to reduce the size of the sample. This must be done very carefully to avoid bias. A simple method is to roll and quarter the sample. In this case, a rolling cloth and a Oplasterers trowel are needed. A better method is to use a riffle. (See Section I, "Sampling"). Riffles are also available from most scientific supply house catalogs.

How Important Is Sulphur In Increasing Farm Production?

Zane Blevins
Allied-Signal, Inc.

There are many references to sulfur in the Bible. Sulfur is mentioned in six books of the Old Testament and in two books of the New Testament in terms of "Brimstone" and usually associated with fire. You and I know brimstone as Sulfur. The Ancients associated Sulfur with disaster and devastation. There was good reason for this because where there were natural deposits, no vegetation or crops would grow and it was easy to get the sulfur to burn.

Sulfur is the 13th most abundant element in the earth's mantle. It is one of the few elements that exists in natural native single element form. (1)

Sulfur is one of the most important chemical raw materials used in fertilizer manufacturing and industrial complexes around the world. Ironically, of the 60 million tons of sulfur used in the world annually, about 60% of it is used for the purpose of making Phosphate Fertilizer. Yet, the sulfur never becomes a part of the fertilizer.

It is estimated that less than 4 million tons of sulfur are used intentionally as a plant nutrient in agriculture throughout the world. Agricultural plants require around one pound of sulfur for each ten pounds of nitrogen within the plant to satisfy a balanced need in the production of amino acids and thus proteins.

Appendix 1 In the U.S. the annual use of nitrogen is around 10 million tons of nutrient N. In order to balance the N used as fertilizer it would require about 1 million tons of sulfur as nutrient S. Actually, there are less than 500,000 tons of nutrient S used in the U.S. that are applied intentionally as a plant nutrient.Why is this? It's related to the traditional historical fertilizers used in the past. From the early beginnings of fertilizer use in the U.S., until the 1960's and 70's, most fertilizers contained at least 10 percent sulfur as incidental ingredient. This, together with other sulfur additions to the soil from atmospheri c depositions, prevented any awareness of a need for plant food sulfur, which was indeed a non-need.

Appendix 2 During the late 1970's and 80's, fertilizer production changed dramatically to high-analysis grades. These were refined to squeeze out fillers and incidental ingredients such as sulfur. At the same time, atmospheric additions of sulfur to the soil and environment were being addressed and eliminated by reducing SO_2 emissions from stack gases. We saw the trend of the amount of sulfur in fertilizers going down dramatically. This started in 1950, and by 1970, there wasn't enough sulfur in fertilizer to balance the nitrogen being used in the U.S. at a 1 to 10 ratio.

Appendix 3 Another trend is evident, also, in the number of states reporting sulfur deficiencies. Data from The Sulphur Institute indicates that by 1962, sulfur deficiencies were reported in 13 states.

Appendix 4 By 1986, this number had grown to 36 states. Allied-Signal has had an on going program called "Test for S" since 1982.

Appendix 5 This program offers an incentive for fertilizer dealers to take soil tests for sulfur. It is quite obvious that we need to emphasize the importance of adequate sulfur in fertilizer to growers. Higher crop yields and more intensive agriculture have now made it imperative that growers become aware of all the nutrients necessary to produce crops at profitable yields.

Sulfur, like nitrogen, is a plentiful element in our environment. But growing plants cannot assimilate these elements as they occur most naturally. For plant root uptake, sulfur must be in the sulfate (S04) form. It so happens that most (usually more than 90 percent) of the sulfur in the soil is tied up in the organic matter — complex organic compounds that require microbial and enzyme breakdown to release the sulfate ($S0_4$) form for plant uptake. This is not bad, because organic matter acts as a storehouse for many nutrient elements needed by the plant. It does signal, however, that sulfur requires special management to assure that adequate supplies are available to the plant when needed. Not only does organic matter act as a nutrient store house, but it also affects soil tilth, water-holding capacity, and in general, reflects the fertility level of a given soil.

CARBON/NITROGEN/SULFUR RATIO

Appendix 6 Literature indicates that a close relationship exists between Organic Carbon (C), total Nitrogen (N) and total Sulfur(S) in agricultural surface soils around the world. Essentially, this tells us that the makeup of organic matter stays fairly constant with a mean C/N/S ratio of 130/10/1.3.

It makes sense for a farming operation to treat the land as the most important production tool to be used for growing crops in abundance and at a profit. We know that a limited supply of sulfur will certainly change the ratio for balancing the production of organic matter. It also makes sense to evaluate sulfur as a most important nutrient which needs as much attention as nitrogen, even though it is usually needed only in 1/10th the volume of nitrogen.

It has often been said in agronomic circles that soil microbes eat at the first table. I think everyone will agree that if you turn under lots of stubble, the subsequent crop will look stunted unless additional nitrogen and sulfur are applied to overcome the tie-up of these nutrients in the decomposition process.

I am including this slide of a rooster crowing at sunrise because I think he represents the characteristics we associate with the farmer...up at dawn and about the day's work.

There is a certain air of independence with which we can identify a close relationship with the good earth. There has been a hue and cry recently which suggests that there needs to be a return to so-called "nature or natural pratices" in farming which are non-damaging to the environment. The American farmer was practicing "sustainable agriculture" long before it was a popular theme and a catch phrase for environmentalists.

Today, the American farmer produces enough food for himself and 120 other people. It is a record that has never before been equalled by man. At the same time, he has been able to leave the land in better condition than if left to the ravages of nature or in its natural state. A few years ago, it was thought that replenishing or rebuilding the organic matter in the soil was impossible. But, proven methods involving residue management and conservation tillage have demonstrated that soil organic matter can be sustained and even increased by proper management.

Today, with appropriate scientific evidence at his fingertips, the farmer can truly produce an abundance of food for a hungry world and enhance the environment at the same time.

Appendix 6 As we look again at the makeup of organic matter, the importance of sulfur is clearly evident— in maintaining the desired level of organic matter, and, at the same time, providing the crop with adequate sulfur in the sulfate form which is readily available to plant roots. If the nitrogen and sulfur in the organic matter have to be recycled by the soil microbes, we say that the carbon has been "burned off" much as wheat stubble is sometimes burned to give clean seedbed.

If enough sulfur and nitrogen is available, microbes will process the plant residue into life-teeming organic matter and over time, the soil will become mellow and more productive. Greater water and nutrient holding capacity will be the result, with little or no loss of excess nutrients to the environment.

How then should sulfur fertilization be managed to increase farm production?

Special attention should be given to having adequate sulfur in the young seedling root zone in early spring when the soil is cold and no ($S0_4$) sulfur is being mineralized from the organic matter.

Tissue Tests should be used at crop's peak nutrient requirement to check N/S ratio, which should not be higher than 16:1 in the plant.

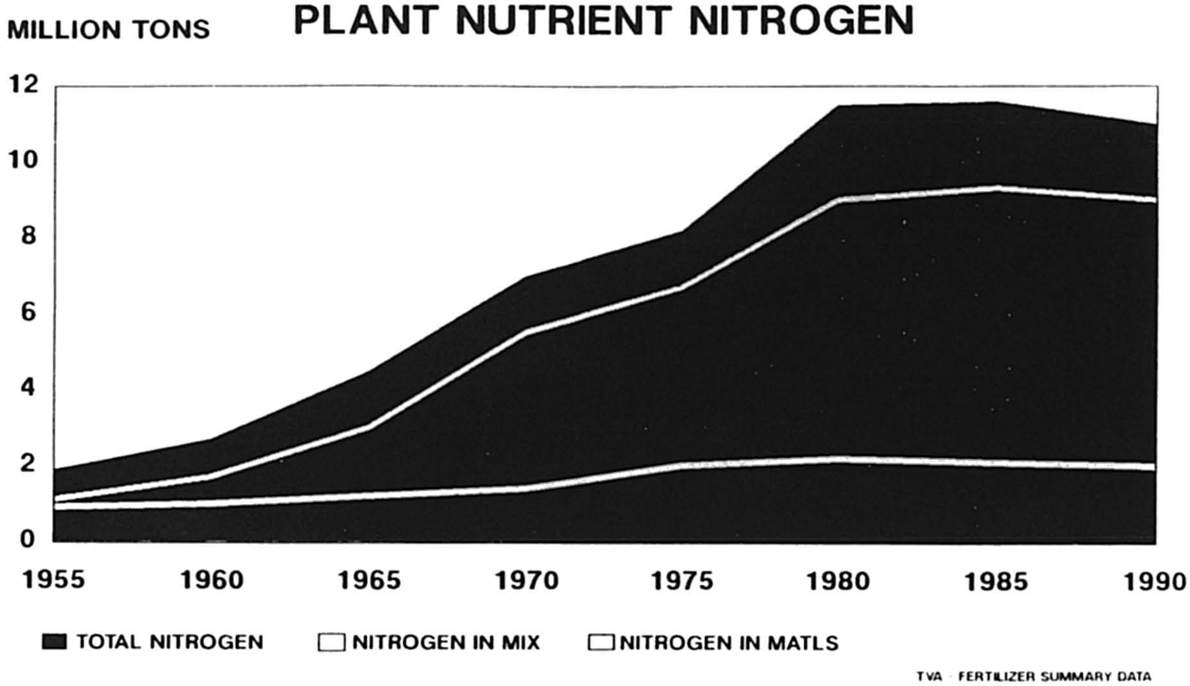
The carbon in plant residue can be converted to fertility enhancing organic matter by proper attention to nitrogen and sulfur balance...10:1

Sulfur has come from the "brimstone" of biblical times to the "bedrock" of today's agriculture. The fourth major nutrient in providing food and fiber for an exploding population on planet Earth.

(1) *Sulfur In Agriculture*, M.A. Tabatabai, Editor Number 27, Agronomy Series, American Society of Agronomy - 1986

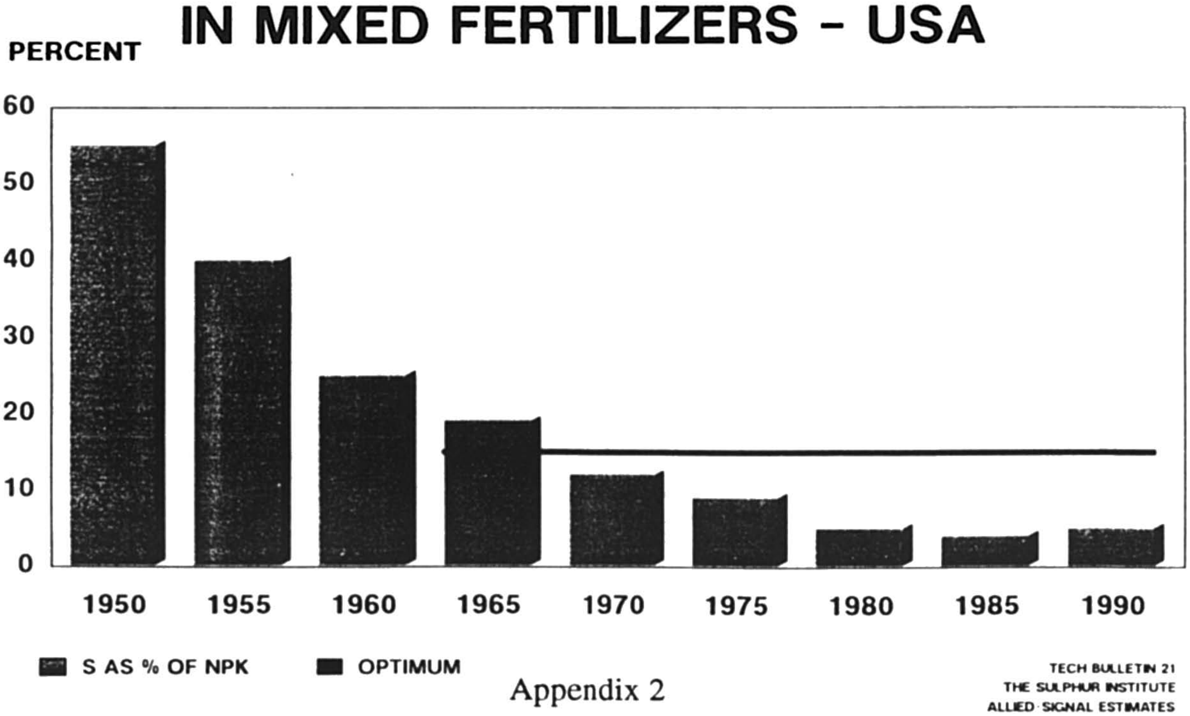
NITROGEN USE - USA

PLANT NUTRIENT NITROGEN



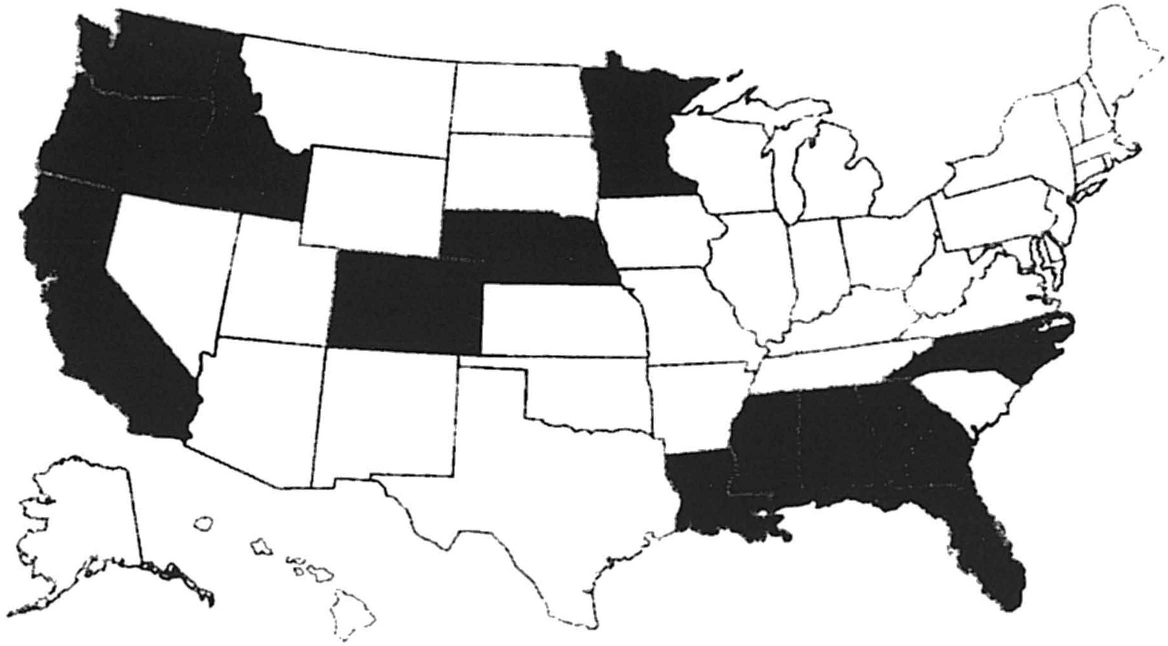
Appendix 1

TREND - SULFUR CONTENT IN MIXED FERTILIZERS - USA



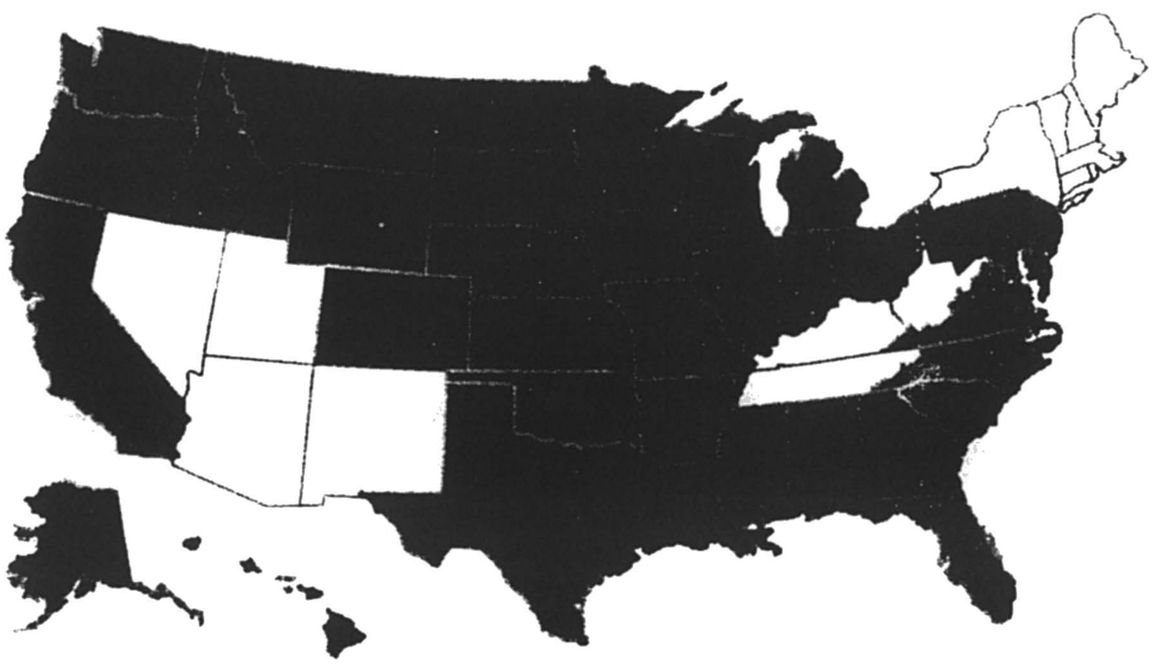
Appendix 2

1962: 13 SULFUR-DEFICIENT STATES



Appendix 3

1986: 36 SULFUR-DEFICIENT STATES



Appendix 4

1991: 48 SULFUR-DEFICIENT STATES

Appendix 5

ORGANIC MATTER

CARBON/NITROGEN/SULFUR

Sulfur in Agriculture - M.A. Tabatabai
Editor - #27 Agronomy Series
American Society of Agronomy - 1986

Appendix 6

Video Presentation

Billie Adams
Alliance Fertilizer

Modern Materials Handling and Production Facilities at Petersburg AGRA Terminal.

New Look at Drying and Cooling Technology

Robert E. Robinson
Heyl & Patterson, Inc.

We will discuss the process and mechanical design and process evaluation of direct heat rotary dryers and coolers as utilized in the fertilizer industry. Special attention All be given to the design of lifting, feed, and special flights for processing granular fertilizers and the effects of various flight configurations and loadings on dryer and cooler performance. There is a constant effort in the industry to improve performance.

PROCESS DESIGN VERSUS ANALYSIS

Process design of rotary dryers and coolers is somewhat different from analysis in an operating plant environment.

In design, the required performance is used to make sizing calculations and mass and heat balances are made, allowing a reasonable factor of safety for possible variations in the design conditions. A size is determined and certain limiting parameters are checked. Since the design is done under uncertainties, it is probabilistic. Conservative values and procedures are used to ensure that the design meet the performance warranty. Certain norms are used to check that the expected performance is within the limits established by previous experience These norms include the overall volumetric heat transfer coefficient, the number of heat transfer units, the specific evaporation, and the mean or exit gas velocity which largely determines the amount of fine particle entrainment in the exhaust gas stream.

In analysis, on the other hand, variables are carefully measured and calculations are made to determine the value of those same parameters. The results are studied to determine possible causes of difficulties and opportunities for improvement.

MECHANICAL DESIGN AND ANALYSIS

Following the process study, mechanical design or analysis is performed. Various components of the system are designed or chosen and appropriate structural and mechanical calculations are made. Experience is again an important factor in making evaluations. In analysis, the maintenance history is important. Any part or component which has required unusually frequent replacement or has otherwise been troublesome should be studied for adequacy. Improvements can often be achieved fairly easily when ordering spare parts.

DESIGN OF FLIGHTS

Flight design is an area which deserves careful and detailed attention because they importantly affect performance.

DESCRIPTION AND FUNCTION OF FLIGHTS

Within the context of this paper, flights may be defined as metallic appendages resembling fins or very short wings attached to and protruding inward from the inner surface of a rotating cylindrical shell having its axis horizontal or nearly horizontal. Their function is to cause and direct the motion of loose solids materials held and being processed within the rotating shell, including forward, axial propulsion and the lifting and showering of material downward through a moving stream of drying or cooling gas mixture.

Design considerations are dictated by physical properties of individual materials particles, properties of the mass of particles which we call bulk handling properties, and machine requirements. These considerations involve process, mechanical, and structural design.

In addition to facilitating heat and mass transfer, flights in rotary granular fertilizer dryers play an important role in the forming, shaping, compacting and hardening of granules.

The ultimate objectives are efficient performance of all functions with minimal capital and operating cost and maximum service life.

FEED FLIGHTS

Feed flights are usually provided at the feed end of rotating shells to move material away from the feed end dam and to distribute and deliver that material to the lifter flights. These flights are primarily conveying flights. They often are required to move damp sticky material. For low capacity requirements and dense materials, there is usually no problem in providing sufficient conveying capacity, but this should always be checked. There are a number of design constraints and when handling high capacities or light, fluffy materials where a lot of back spillage off the edges of the flights may occur, it can be a very challenging task to provide a suitable feed flight design.

Attached to the inner surface of the rotating cylindrical shell, these feed flights are similar in behavior to an Archimedes screw. The flight rotational speed is fixed by the shell speed and therefore is constrained by shell speed requirements in the drying or cooling section of the shell which set material retention time, economical shell horsepower, etc. Because of space limitations on flight height and spacing, these flights frequently suffer from spillage over the top edge with free flowing loose bulk solids, which can seriously reduce actual capacity. Stickiness of feed material can also be a problem. Sticky materials usually tend to stick most readily in inside corners, where material can bridge across two adjoining plane surfaces. For sticky conditions, it is usual to try to limit the number of corners by minimizing the number of flights as much as possible and to provide straight flight edges without bent lips to minimize both surface area and additional corners for sticking. If too many feed flights are used and the spaces between them are too small, those spaces may quickly fill completely with sticky material, necessitating excessive shut-downs for cleaning.

Wherever possible, some excess feed flight capacity is desirable to handle surges and moderate overloads without spillage over the feed end material retention dam. This dam should be made as high as reasonably possible to limit such spillage.

The ideal feed flight shape should present a smooth continuous surface to the material being conveyed with sufficient height to limit back-spillage and steep enough to dependably convey the material forward. The exact geometry is clearly dependent on material flow properties, but a wared (twisted) helicoid shape with constant pitch seems to be theoretically best. The axial length of the feed flight section is usually about one-half of the shell diameter, and the pitch, which is the forward displacement of the feed flight in one complete 360 degree revolution, is usually equal to one diameter. Continuously warped plate surfaces are difficult and expensive to produce, requiring plastic deformation of flat plate blanks to form sections which can then be fitted and welded in place. Flat segments can be laid out, cut, and then formed in a press brake with a pair of bends to approximate a wared helicoid flight section with one piece consisting of three adjoining planes. On large flights it is necessary to break the flight down into smaller sections.

LIFTER FLIGHTS

Following the feed flight section, most of the dryer or cooler shell is fitted with lifter flights. As with feed flights, the design is mainly dictated by materials properties, which may change down the length of the shell as material is dryed or cooled. Near the feed end moist material may be sticky and "open" straight radial blade flights may be provided to minimize sticking and material build-up. These flights are not full lifters but will lift and tumble the bed to some extent, helping particle surfaces to partially dry. With very sticky feeds, a bare section of shell may be left between the end of the feed flight section and the start of the first ring of lifters. This eliminates the corners where feed flights would intersect lifters at an angle, and allows additional surface drying to take place before lifting begins.

In the first part of the shell following the feed flight section, perhaps about 30% to 40% of the total shell length, it is often wise to provide "open" or a mix of "full" and "open" lifter flights to minimize material sticking and build-up. "Open" flights can be straight bladed with no lips or bent flights with 45 degree lips. The theory is simply that it is better to sacrifice performance in order to keep the unit running longer than it is to be shut down too often for cleaning, and that if the material is very sticky, it will dry slowly anyway.

For the remainder of the active lifter section full lifter flights with wide lips suitable for extending the showering across the full cross-section are used. Here, particles are nearly dry on the surface and sticking is usually less of a problem. Rings of flights are staggered to form closed pockets of falling material so that gases must contact material.

PERCENT VOLUMETRIC LOADING

An established standard norm for volumetric loading which is very useful as a starting point is ten percent. This is the volume of material held in the shell divided by the active shell volume, expressed as a decimal fraction, or, if multiplied by 100, as a percentage. Material in the bed should cover the lifter flights so that they will be fully loaded. If the flights are not fully loaded, normal showering over the full cross-section will not occur, heat will be lost, and efficiency will be reduced. If the shell is loaded too heavily, some material will advance by kiln action over the tops of the lifters, shortening the average retention time and causing material to be insufficiently dryed.

OPERATIONS AT SIGNIFICANTLY REDUCED RATES

If a dryer or cooler is fitted with high capacity lifting flights and then must be operated at a significantly reduced rate, some means of adequately loading the flights is needed to obtain adequate distribution of the showering curtain of material to avoid an empty zone on the lifting side. One possible method is to change the shell speed by using a variable speed drive, a two speed motor, or a change in ratio of a belt drive, roller chain drive, gear and pinion drive, or speed reducer. The resulting lower shell speed can increase the volumetric loading in the shell and once again properly load the flights.

INCREASING THE CAPACITY OF EXISTING LIFTER FLIGHTS

The capacity of existing lifter flights can be increased by extending the lips, sometimes at a different angle, so that more material will be lifted and so that the showering will be continued over the full cross-section area of the shell. Care must be taken that sufficient clearance between adjacent flights is maintained to permit complete and timely emptying. Should such modifications be temporary, the extensions can be made to lap over the existing lips and attached with bolts for easy removal. The effect on shell power required should always be checked before making this kind of modification.

BED TURN-OVER

It is usually desirable to lift and shower the entire bed approximately once per shell revolution where gas-to-solids or solids-to-gas heat transfer is the limiting process mechanism, but this is not always possible. In portions of the shell these mechanisms may not be limiting and the need for additional retention time for internal moisture migration inside granules may indicate heavier volumetric loading in those zones, with correspondingly less showering per pound of material. Excessive showering will increase power consumption and degradation of particles, generating more fines.

DISCHARGE BUCKETS FOR TOP DISCHARGE UNITS:

The most common type of discharge is a bottom gravity discharge into a breeching in which the material spills from the rotating shell. It is possible to use a set of lifting discharge buckets or flights to drop material into a discharge hopper near the top inside of the shell and to remove it with a chute. Such buckets must be capable of lifting and discharging the full product volume into the area occupied by the top of the hopper.

RARE SHELL SECTION AT DISCHARGE END TO REDUCE FINES ENTRAINMENT IN EXHAUST GAS STREAM:

When entrainment of fine material particles into the exhaust gas stream is a concern, gas velocity is kept low by using a large shell diameter and a large discharge breeching. By omitting lifter flights for the last few feet of shell length, more fines are given an opportunity to settle at the bottom of the shell and drop out without being caught in the upward turning exhaust gasses in the discharge breeching. A considerably oversized discharge breeching is also helpful.

STRUCTURAL CONSIDERATIONS

Since all flights are in rubbing and sliding contact with solids materials, they are subject to abrasive wear. In structural design, a net material thickness plus a wear and sometimes a corrosion allowance are therefore needed. For flights up to about 6" or 7" high, reinforcing gussets or braces behind the flights are usually not necessary hut for larger or heavily loaded flights the use of gussets or braces is advisable to protect against strains introduced by cyclical flexing under load which may cause fatigue failure in welds at the junction of flight to shell. A minimum of two gussets or two braces for each lifter flight is recommended. It is recommended that all flights be installed with continuous welds or that spaces between skip welds be sealed with continuous seal welds on both sides.

PRACTICALITY

The flow of loose bulk solids is sometimes unpredictable and some properties of solids materials will change from day to day in a plant. It is therefore necessary to design solids handling equipment in a conservative manner, making allowances for the worst expected conditions. Shells and flights should be designed to handle a modestly greater volumetric capacity than the exact design requirement and any design configuration likely to impede material flow should be avoided.

SHELL SPEED

Shell rotational speed should be considered along with a number of other design values with which it interacts. These include flight design, loading, shell slope, desired retention time, mechanical wear and tear on the equipment, power consumption, vibration, critical speed, and the ability of the flights to empty fully in the time allocated.

A widely used rule of thumb for shell speed has been to relate the rotational speed to the peripheral speed, using linear peripheral speeds of between 75 and 125 ft/min.

Critical speed is defined as that speed at which the centripetal acceleration at the shell surface equals the acceleration of gravity. Standard gravitational acceleration is 32.17 ft/sec/sec. At the critical speed, material would theoretically stick to the shell and not fall. Mixers, revolving screens, and tumbling mills usually do not exceed about 70 percent of critical speed, and as a practical matter, dryers and coolers usually operate at much lower speeds.

Economic considerations will favor using lower speeds for less equipment wear and lower power consumption.

As pointed out in the section on feed flights, feed flight capacity is related to shell rotational speed, and can be increased by a shell speed increase, but at the expense of reduced total material retention time.

EFFECTS OF FLIGHT DESIGN ON PERFORMANCE

The most obvious immediate effects of flight design are on material handling: feeding, conveying, lifting, showering, mixing, power consumption, average overall forward, axial velocity, and therefore overall retention time, and the percentage of time showering in the gas stream versus time in the bed and on the flights.

Any design feature provided to accommodate a special materials handling requirement such as dealing with a sticky material is very likely to involve a compromise with ideal design for lifting and showering performance. Recognizing that such compromises are necessary, the designer can still exercise some choices in flight configurations. Attention to both greater design considerations and to small details are very important.

INDICATORS OF POOR DRYER OR COOLER PERFORMANCE

The most obvious indicators of poor performance are high product moisture for a dryer and high product temperature for a cooler. In parallel flow dryers, a close approach of material discharge temperature to exit gas temperature is a sign of good heat transfer, but the material discharge temperature should be no higher than is necessary. Overheating the material consumes excess heat. Similarly, exit gas carries heat to the atmosphere as stack losses, so the temperature and quantity of exit gas should not be greatly excessive. A large difference in material discharge and exit gas temperatures suggests poor heat transfer or an excess quantity of drying gas mixture. An exit gas damper provides a means of controlling exit gas volume. The exhaust gas temperature should be kept well above the dew point to avoid condensation of moisture on duct walls.

The logic is similar for coolers. If a sample bucket-full of granular material initially seems to be cool but immediately displays a temperature rise, it is possible that the granules are cooled at their surfaces, but not throughout. If so, the temperature rise is caused by heat redistributing from the centers to the surfaces of granules, indicating the need for longer retention time and more complete cooling.

SUGGESTED PROCEDURES FOR MAKING IMPROVEMENTS

No single set of rules will cover every case but a few guide lines should be helpful. Always try to correctly identify the problem or problems. The easy, inexpensive, and reversible corrections should be tried first, such as opening a gas flow damper or raising or lowering a temperature set-point. Sometimes a speed change is easy, for example by changing a sheave diameter on an exhaust fan "V" belt drive. Often in life we are told to beware of quick and easy solutions, but here such simple trials are a means to learn the true situation before spending large sums of money.

Only one thing should be changed at a time so that the effect of each change can be observed before proceeding to another change. Results should be recorded carefully.

The ideal conditions for comparisons WOULD be for everything to be exactly the same except for the particular items under study but this is rarely possible. When such direct comparisons cannot be made, it is customary to reduce absolute rates to coefficients for comparison. This is acceptable methodology, but it should always be remembered that data drawn from dissimilar units may contain the effects of other unnoticed differences, and therefore should be used cautiously.

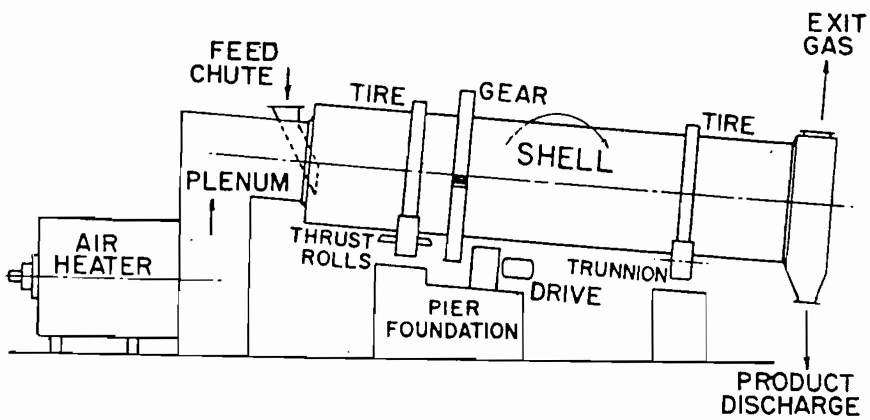


FIG. 1

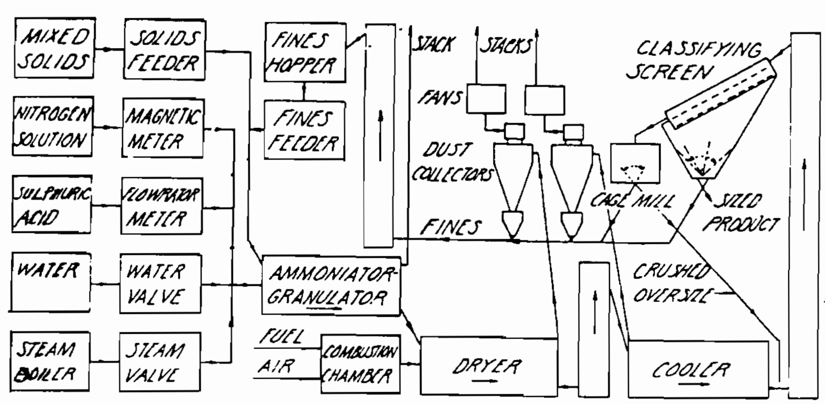


FIG. 2 SIMPLIFIED FLOW DIAGRAM - NPK GRANULAR

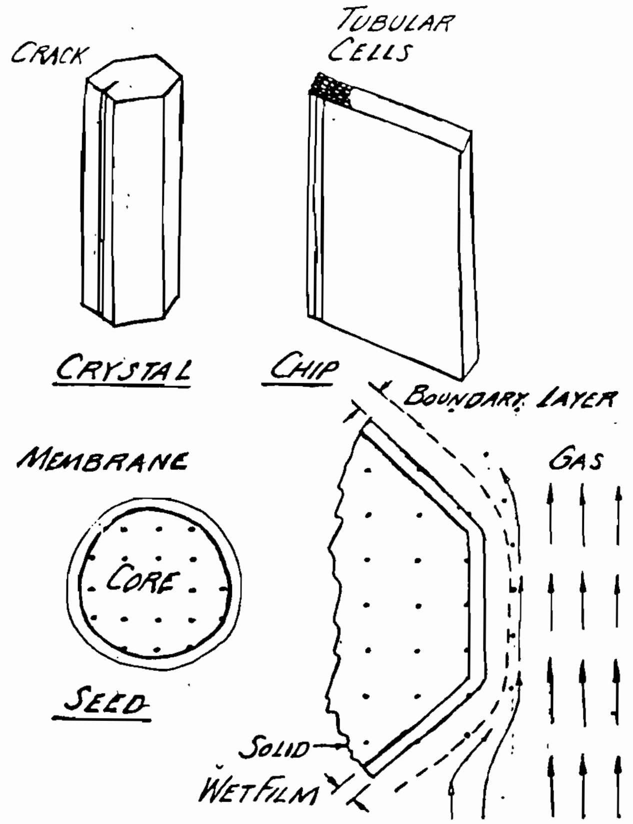
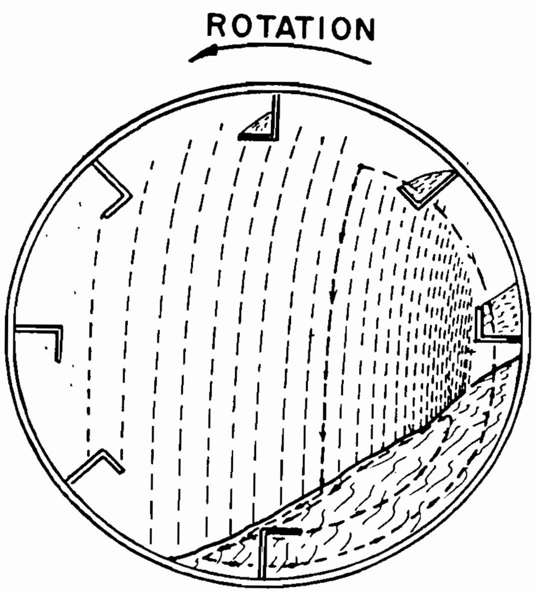
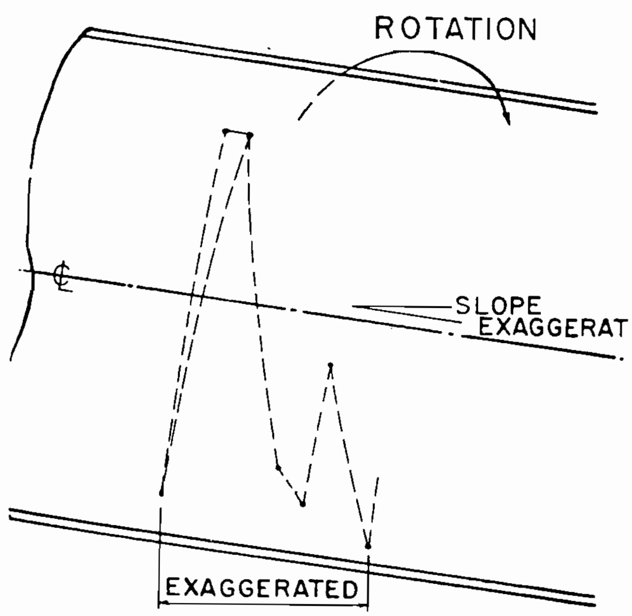


FIG.3 PARTICLES; BOUNDARY LAYER



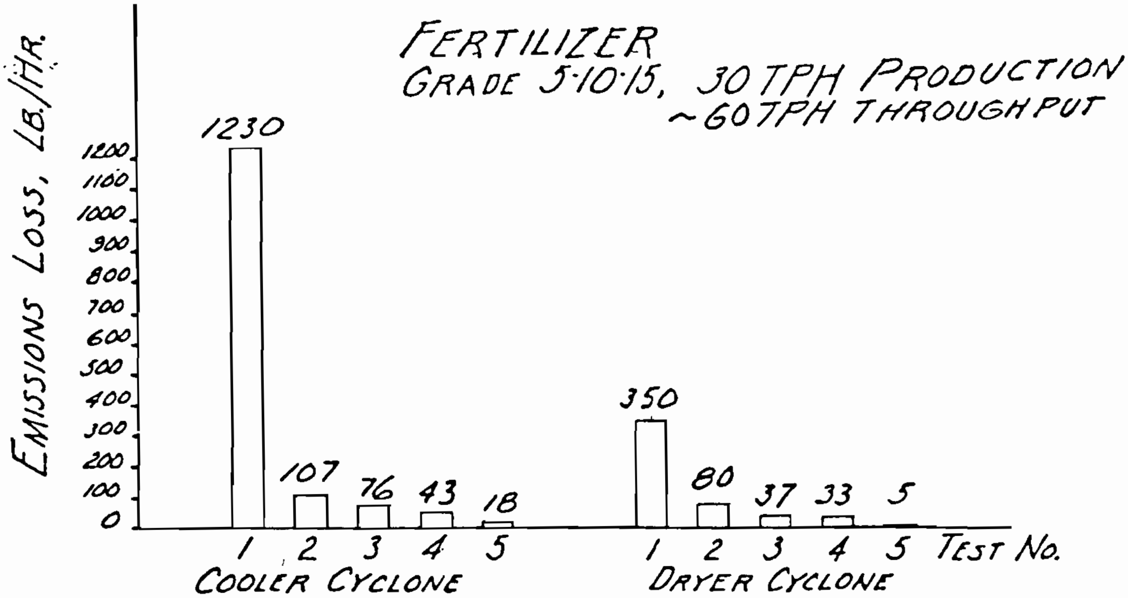
Cross Section Of Shell Showing A Typical Random Average Partical Path For About 20 Seconds

FIG. 4



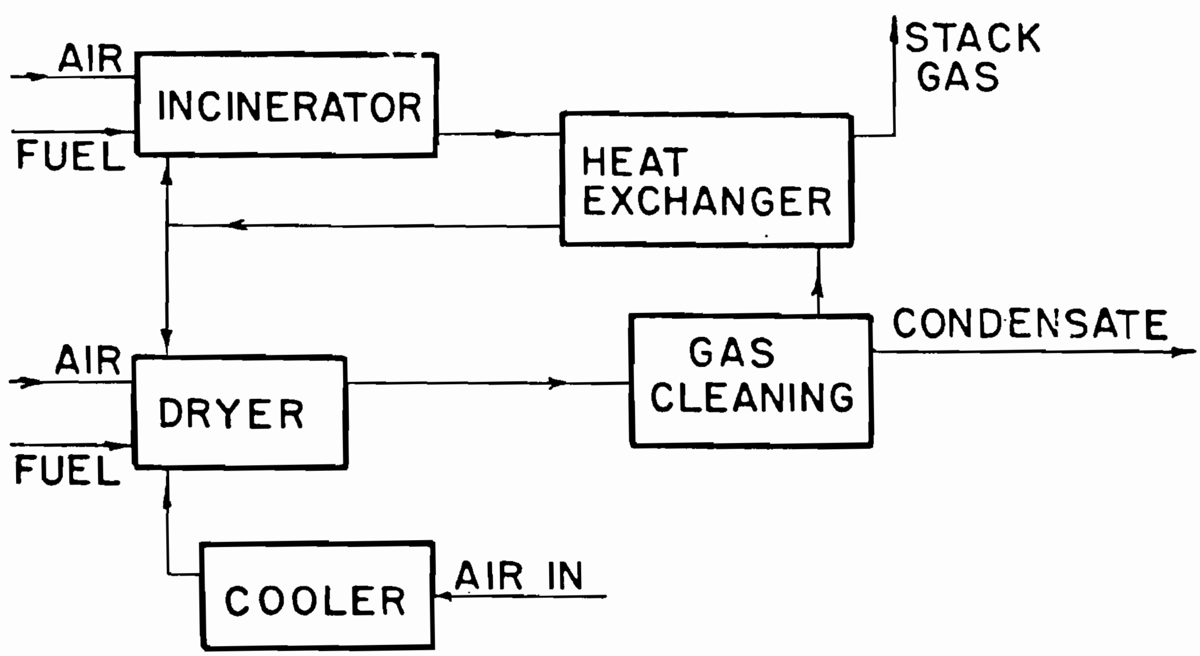
Longitudinal Section Of Shell Showing A Typical Random Average Particle Path For About 20 Seconds

FIG. 5



EMISSIONS REDUCTION BY AIR SYSTEM & CYCLONE MODIFICATIONS

FIG. 6



INTEGRATED EMISSION CONTROL AND ENERGY CONSERVING PROCESS SYSTEM

FIG. 7

DRYER DATA FOR PERFORMANCE ANALYSIS

1	Effective Shell L/D	[$ft.ft^{-1}$]	________
2	Shell Diameter	[ft]	________
3	Shell Effective Length	[ft]	________
4	Shell Axial Slope	[$ft.ft^{-1}$]	________
5	Shell Rotational Speed	[$rev.min^{-1}$]	________
6	Shell Effective Volume	[ft^{3}]	________
7	Material Feed Rate	[$lb.hr^{-1}$]	________
8	Mtl. Feed Bulk Density	[$lb.ft^{-3}$]	________
9	Mtl. Discharge Rate	[$lb.hr^{-1}$]	________
10	Mtl.Disch. Bulk Density	[$lb.ft^{-3}$]	________
11	Average Bulk Density	[$lb.ft^{-3}$]	________
12	Evaporation	[$lb.hr^{-1}$]	________
13	Dust Entrained & Removed	[$lb.hr^{-1}$]	________
14	Unit Feed Mtl. Moisture	[$lb.lb^{-1}$]	________
15	Unit Disch.Mtl.Moisture	[$lb.lb^{-1}$]	________
16	Mtl. Retention Time	[min]	________
17	Average Mtl. Throughput	[$lb.hr^{-1}$]	________
18	Average Material Hold-Up	[lb]	________
19	Av. Volume of Hold-Up	[ft^{3}]	________
20	Unit Volumetric Loading	[$ft^{3}.ft^{-3}$]	________
21	Material Inlet Temp.	[degF]	________
22	Material Dischg. Temp.	[degF]	________
23	Drying Gas Inlet Temp.	[degF]	________
24	Drying Gas Exit Temp.	[degF]	________

25	Log. Mean Temp. Diff.	[degF]	________
26	Heat Transfer Units		________
27	Heat to Mtl. Dry Basis	$[btu.hr^{-1}]$	________
28	Heat to Melt Ice	$[btu.hr^{-1}]$	________
29	Sensible Heat to Water	$[btu.hr^{-1}]$	________
30	Latent Heat of Vaporiz.	$[btu.hr^{-1}]$	________
31	Superheat to Water Vapor	$[btu.hr^{-1}]$	________
32	Heat to Product Moisture	$[btu.hr^{-1}]$	________
33	Heat Conv. & Radiat.Loss	$[btu.hr^{-1}]$	________
34	Total Heat Transferred	$[btu.hr^{-1}]$	________
35	Drying Gas Mixture Req'd.	$[lb.hr^{-1}]$	________
36	Dryer Net Heat Input	$[btu.hr^{-1}]$	________
37	Stack Heat Loss	$[btu.hr^{-1}]$	________
38	Dryer Only Thermal Eff.	[%]	________
39	Dryer Exit Gas Volume	[ACFM]	________
40	Dryer Exit Gas Velocity	$[ft.min^{-1}]$	________
41	Burner & Air Heater Eff.	[%]	________
42	Gross System Heat Input	$[btu.hr^{-1}]$	________
43	Gross System Thermal Eff.	[%]	________
44	O.A. Vol. Ht. Trans.Coef.	$[btu.degF^{-1}.ft^{-3}.hr^{-1}]$	________

COOLER DATA FOR PERFORMANCE ANALYSIS

1	Effective Shell L/D	[$ft.ft^{-1}$]	______
2	Shell Diameter	[ft]	______
3	Shell Effective Length	[ft]	______
4	Shell Axial Slope	[$ft.ft^{-1}$]	______
5	Shell Rotational Speed	[$rev.min^{-1}$]	______
6	Shell Effective Volume	[ft^3]	______
7	Material Feed Rate	[$lb.hr^{-1}$]	______
8	Mtl. Feed Bulk Density	[$lb.ft^{-3}$]	______
9	Mtl. Discharge Rate	[$lb.hr^{-1}$]	______
10	Mtl. Disch. Bulk Density	[$lb.ft^{-3}$]	______
11	Average Bulk Density	[$lb.ft^{-3}$]	______
12	Evaporation	[$lb.hr^{-1}$]	______
13	Dust Entrained & Removed	[$lb.hr^{-1}$]	______
14	Unit Feed Mtl. Moisture	[$lb.lb^{-1}$]	______
15	Unit Disch.Mtl.Moisture	[$lb.lb^{-1}$]	______
16	Mtl. Retention Time	[min]	______
17	Average Mtl. Throughput	[$lb.hr^{-1}$]	______
18	Average Material Hold-Up	[lb]	______
19	Av. Volume of Hold-Up	[ft^3]	______
20	Unit Volumetric Loading	[$ft^3.ft^{-3}$]	______
21	Material Inlet Temp.	[degF]	______
22	Material Dischg. Temp.	[degF]	______
23	Cooling Gas Inlet Temp.	[degF]	______
24	Cooling Gas Exit Temp.	[degF]	______

25	Log. Mean Temp. Diff.	[degF]	____
26	Heat Transfer Units		____
27	Heat fr. Mtl. Dry Basis	[$btu.hr^{-1}$]	____
28	Sensible Heat fr. Water	[$btu.hr^{-1}$]	____
29	Latent Heat of Vaporiz.	[$btu.hr^{-1}$]	____
30	Superheat to Water Vapor	[$btu.hr^{-1}$]	____
31	Heat fr.Product Moisture	[$btu.hr^{-1}$]	____
32	Heat Conv. & Radiat.Loss	[$btu.hr^{-1}$]	____
33	Total Heat Transferred	[$btu.hr^{-1}$]	____
34	Cooling Gas Mixture Reqd.	[$lb.hr^{-1}$]	____
35	Cooler Thermal Eff.	[%]	____
36	Cooler Exit Gas Volume	[ACFM]	____
37	Cooler Exit Gas Velocity	[$ft.min^{-1}$]	____
38	O.A. Vol. Ht. Trans.Coef.	[$btu.degF^{-1}.ft^{-3}.hr^{-1}$]	____

Fertilizer Production Facilities of the Twenty-First Century

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Presented By:
David E. Nichols
Tennessee Valley Authority

This is a summary of TVA's conceptual evaluation of the coproduction of fertilizer and electricity compared to the available fossil power generating options for new base-load capacity. TVA and the Electric Power Research Institute (EPRI) are co-funding a study to more clearly define the marketing, technical, and economic aspects of the coproduction concept. This study will be completed in June 1992. The information in the present paper is conceptual and will be more clearly defined at the conclusion of the TVA-EPRI study.

Technical

Competing Technologies

The competing fossil technologies to Integrated Gasification Combined Cycle (IGCC) for base-load capacity are considered to be pulverized coal (PC) combustion with flue gas desulfurization (FGD) and combined cycle/combustion turbine. Other new coal-based power generating technologies include the fluidized-bed combustion (FBC) plants, both atmospheric and pressurized. From an overall technical, economic, and environmental perspective, atmospheric FBC is equivalent to PC. Pressurized FBC has not been commercially demonstrated and at this time is not considered a "competing technology" for new fossil generating capacity. In the United States, IGCC has been commercially demonstrated at Southern California Edison's Cool Water plant during a five-year test program sponsored by a consortium led by EPRI. A lOO-MW Texaco gasification system and a conventional 2OOO°F combustion turbine (CT) were used in this facility. DOW has operated a l6O-Mw IGCC plant since 1987 on subbituminous coal in Louisiana. The DOW gasification process is used to fuel existing CTs. Shell operated a 3O-Mw-equivalent gasification demonstration project near Houston, Texas, from 1887 to 1991 and gasified IS different feedstocks. In Europe a consortium of Dutch utilities is building a 25O-MW IGCC plant using the Shell gasification process and a conventional CT. The heat rate of that project is approximately 8300 Btu/kWh on a high heat value basis. Newly developed IGCC designs using higher temperature (23OO°F) CTs a high degree of steam integration show heat rates of about 8000 Btu/kWh.

Coproduction Process Description

The coproduction concept is based on the use of commercial coal gasification and related process units to produce electricity and fertilizers concurrently. The combined cycle (CC) unit to produce electricity is sized for the full gasification synthesis gas output. The production of fertilizers can be bypassed during periods of peak power demand.

Coproduction of fertilizers requires the integration of the following additional process units with IGCC:

- Ammonia Unit: Hydrogen separation or enhancement and catalytic gas-phase reaction of H2 and nitrogen, from the air separation unit, to produce ammonia.

- Urea Unit: Two stage reaction of ammonia and carbon dioxide, from acid gas removal, to produce urea.

Market

General

The coproduction concept utilizes coal gasification to optimize revenues from the sale of the primary coproducts. Several by-products including sulfur or sulfuric acid, vitrified slag, and argon also provide revenue.

Coproducts

Electricity: TVA has projected the need for new peak capacity in 1997 and new base-load capacity in 2004. This projection is based on the medium load forecast of 2.5% increase annually in peak load demand and a 2.3% increase in total power generation. The load forecasts primarily track the predicted national and regional economic activity.

Fertilizer: Urea consumption in the United States is about 9 million tons per year (MTPY) and urea consumption in the 17 states served by the river systems accessible from west Tennessee or west Kentucky, proposed sites for such a facility, is estimated to be 2.8 MTPY. The coproduction demonstration facility will produce about 0.3 MTPY of urea. The United States is a net importer of nitrogen fertilizers and imports are expected to continue to grow due to the lack of economic incentives to build new ammonia/urea plants in the United States. In addition, the existing ammonia/urea plants are old, generally smaller than the newer plants, and use low-cost natural gas. The Coproduction Demonstration Project can either provide new capacity to replace future imports or replace existing capacity as old plants are retired.

By-products

Sulfur/Sulfuric Acid: Over 4O MTPY of sulfuric acid and 12 MTPY of elemental sulfur (used to produce the acid) are consumed in the United States. Since the coproduction demonstration facility will produce about 0.1 MTPY of acid, or about 0.03 MTPY of elemental sulfur, the emphasis of the market analysis will be to determine the market locations with the highest net revenue to the project. Transportation costs are a primary factor. The key to coproduct and by-products marketing is the impact on existing capacity market share and future new capacity market share. In Table 2 the existing capacity and future new capacity market share are summarized.

Environmental Evaluation

Gaseous Emissions

General: The SO_2 and NOx emissions from IGCC are significantly less than those from PC with conventional SO_2 and NOx control technology. In gasification the coal's sulfur and nitrogen are converted to reduced forms of sulfur. The reduced sulfur is more concentrated in the synthesis gas without the N_2 diluent in the air, and H_2S can be more easily recovered as a by-product compared with SO_2 from PC's flue gas. The reduced nitrogen compounds (NH_3 and HCN) are more easily removed than NOx and are decomposed in wastewater treatment (NH and HCN). In addition, the higher efficiency of IGCC, compared to PC, will also reduce CO_2 emissions, and IGCC/F will further reduce CO_2 emissions at the site by the production of urea.

Sulfur Dioxide (SO_2): Conventional SO_2 control for PC is through FGD. Typical FGD using wet absorption removes 90 to 95% of the SO_2 in the flue gas. Conventional reduced sulfur removal from IGCC's synthesis gas is by acid gas removal (AGR), and the total reduced sulfur (TRS) removal for high-sulfur coal has typically been 95 to 98% for power generation applications.

The expected IGCC and IGCC/F SO_2 emissions are shown in Table 3 to be less than 0.06 lb SO_2 per MBtu (greater than 99% overall sulfur removal). FGD at 95% 502 removal would have an SO_2 emission of 0.3 lb 502 per MBtu for a 3.5% sulfur coal as compared with the New Source Performance Standard (NSPS) of 1.2 lb SO_2 per MBtu. The ammonia catalyst used for fertilizer production can be poisoned by reduced sulfur compounds, one of several trace compounds in the coal-derived synthesis gas. Therefore, the total reduced sulfur in the synthesis gas must be below 2 ppmv from the AGR unit and reduced to less than 0.1 ppmv before entering the ammonia synthesis loop to avoid poisoning the ammonia catalyst.

A gasification plant used for ammonia production in Japan by Ube Industries meets this stringent level of sulfur removal. The commercially available physical absorption AGR process at this plant removes sulfur gases to below 1 ppmv from coal—derived synthesis gas.

Nitrogen Oxides: Typical uncontrolled NOx emissions from PC range from 0.6 to 1.0 lb NOx per MBtu. For the NSPS NOx standard of 0.5 to 0.6 lb NOx per MBtu, low-NOx burners are required with good control of both air and coal to each burner in the register. Additional NOx control can be achieved by selective catalytic or noncatalytic reduction (SCR and SNCR). For SCR/SNCR, ammonia or an ammonia-type compound (e.g., urea), is injected into the flue gas and used to catalytically/noncatalytically reduce the NOx to elemental N2. The SCR could reduce NOx to approximately 0.1 and 0.2 lb NOx per MBtu for controlled and uncontrolled combustion, respectively. Although, SCR has shown 80 to 90% NOx reduction, it has not been commercially demonstrated on high- sulfur coals.

In conventional CTs, NOx emissions are controlled to about 0.1 lb NOx per MBtu. The use of water/steam (wet) and/or nitrogen (dry) injection into the synthesis gas provides a diluent (heat sink) to reduce thermal NO_x emissions. The diluent reduces the heating value of the synthesis gas from about 280-300 Btu/standard cubic feet (SCF) to 130-150 Btu/SCF. In the IGCC plant at Cool Water, NO_x emissions were less than 0.08 lb per MBtu using a water saturated fuel gas in a conventional CT (200O°F operating temperature). The as-fired, saturated synthesis gas at Cool Water had a heating value of about 180 Btu/SCF. General Electric has demonstrated a NOx emission level of 0.14 lb/MBtu at their first high-temperature (23OO°F) CT installation using natural gas and wet NOx combustion control. The NOx emissions for IGCC and IGCC/F are expected to be 0.1 lb/MBtu.

Liquid Effluents

The primary liquid effluent from conventional PC power plants is the cooling tower blowdown. Since only one-third of IGCC's power is produced by the steam turbine, the amount of IGCC heat rejection (and cooling tower blowdown) is about one-half that of heat rejection in the PC plant.

IGCC produces a wastewater stream which contains ammonia, sulfides, cyanides, BOD, and COD, in addition to the normal power plant's general wastewater (demineralizer regenerant, boiler blowdown, etc.). All U.S. gasification projects have demonstrated the use of commercially available process units to treat the process wastewater to meet National Pollutant Discharge Elimination System (NPDES) effluent limits or to recycle the process wastewater.

Slag and Sulfur By-products

The ash and sulfur contents of coal produce potential solid wastes. The ash in bituminous coals ranges from 8 to 20%, with a typical content of about 12% ash, or about 10 lb ash per MBtu. Typical PC (dry bottom) furnaces have a 80/20% flyash/bottom ash split. Although, most U.S. PC plants can sell some of their bottom ash and all the slag from cyclone furnaces, most of their flyash requires landfill disposal. Entrained-bed gasification, produces a vitrified, granular ash (slag) due to the high temperatures and reducing atmosphere in the gasifier. The trace metals are encapsulated in the resulting slag from the gasifier. Recent tests have shown that gasification's slag is nonleachable and classified as nonhazardous under the Resource Conservation and Recovery Act (RCRA). The bulk of the gasification slag is considered a marketable by-product.

The sulfur content in bituminous coals ranges from 1.0 to 5.0%, and typically contains of about 3.5% sulfur for high-sulfur coals (5.6 lb SO_2 per MBtu with 97.5% of the coal sulfur evolved as SO_2). For high—sulfur, bituminous coals (2.0 to 5.0%), FGD solid waste from conventional PC combustion ranges from 8 to 22 lb solid waste per MBtu. For FBC, with a much higher stoichiometry (2.5), there would be a significant increase in FGD waste. IGCC, used for coproduction of ammonia, uses an oxygen-blown gasification process and produces elemental sulfur as a by-products. The current U.S. market for elemental sulfur is about 11 MTPY, and the Coproduction Demonstration Project would produce about 0.03 MTPY of elemental sulfur. Sulfur is transported by truck, rail, barge, and ocean transport and can be transported long distances for sale as a market-competitive by-product.

A comparison of the environmental impact of the competing technologies is shown in Table 3. IGCC and IGCC/F produce the lowest environmental impact of the coal-based technologies.

Fuel Prices

The impact of escalation on fuel prices is the key to the economics of the coproduction concept. Since nitrogen fertilizers are based on a natural gas feedstock, there could be a real escalation in fertilizer prices while electricity prices (based on coal) remain relatively stable. In addition, the revenue requirements for natural gas-based fertilizers in 1990 are also based on the use of fully depreciated plants and old, low—cost natural gas contracts. Any new fertilizer plant built in the late 19OOs or beyond will require depreciation (financing) of the new investment and a higher priced natural gas feedstock. An evaluation of energy price projections by DOE showed the following real escalation for coal and natural gas:

Time Period	Real Fuel Price Escalation, % Natural Gas	Coal
1990—2000	5.9	1.1
1990—2010	4.5	1.1
1990—2020	3.7	1.1
1990—2030	3.1	1.0

TVA's mid-1991 forecast of delivered coal and natural gas prices from 1991 to 2000 shows over a 6% real escalation for natural gas while coal is estimated to increase at less than 1%. Even to 2010, natural gas still shows a 5.5% real escalation, while coal shows about a 1% real escalation.

In 1990 EPRI (P-6821) summarized six natural gas forecasts and seven energy modeling results. One key component of the modeling results is the poor correlation between natural gas prices and supply. A 70-percent increase in natural gas price provides only a 10-percent increase in natural gas supply.

Based on all forecasts, the present low delivered price of natural gas to the TVA region, about $2.00 per MBtu, will increase to at least $3.50 per MBtu by 2000 and to $5.50 per MBtu by 2010 in constant 1990 dollars.

Competing Technologies

General: The economics optimized IGCC and IGCC/F will be evaluated against the available generic power-generating technologies available for new (future) capacity:

- Conventional PC technology
- Combined cycle
- Conventional IGCC

PC technology will incorporate flue gas desulfurization (FGD) and low NO_x burners. Selective catalytic reduction (SCR) is not incorporated into PC/FGD; however, SCR would be required for PC to achieve the same NO_x emission as IGCC.

Conventional Technologies: The first year revenue requirements for these competing technologies are shown in Table 4 and are based on EPRI's 1989 Technical Assessment Guide (TAG). The TAG provides a comparative basis for power generating technologies on a conceptual basis. The average annual heat rate is used for this comparison, which includes start-up and partial load inefficiencies. Load factor is an important variable in evaluating economics. The "equivalent availability" (EA) from the TAG is the maximum load factor a technology could have and the TAG's FA is used as the load factor for the economic evaluation in Table 4. The actual load factor for a specific plant is primarily dependent on its dispatch priority in an electric utility's power system. Generally, plants are dispatched to generate power in sequential order, based on their lowest incremental operating costs (fuel and variable O&M). The order of dispatch (and order of highest actual load factor) will be IGCC, PC, and CC.

The economics from EPRI's TAG show a 500 MW PC/FGD unit with lower revenue requirements than a 400 MW IGCC unit. However, IGCC has a significantly lower incremental operating costs due to a lower heat rate and a sulfur by-product credit. Therefore, IGCC would have a higher load factor than PC/FGD. A 70% instead of a 80.6% load factor as shown in Table 4 for PC/FGD would increase the revenue requirements by 4.6 m/kWh, from 50.3 to 54.9 m/kWh. In actual operation, a larger PC/FGD unit would then have higher revenue requirements than a smaller IGCC unit because of the lower actual load factor for PC/FGD.

The first year revenue requirement (FYRR) for CC looks economical for an electric utility compared to the other technologies with natural gas at $2.50 per MBtu. However, all plant specific capital costs are combined when a plant is brought into service and only the incremental operating cost determines whether a plant is dispatched. Even at today's low natural gas prices, CC would only provide intermediate loads, with about a 30-50% load factor. A 50% load factor, as compared to the 90.5% load factor as shown in Table 4, would increase the CC FYRR by almost 8 m/kWh. For the late 199Os, with higher real natural gas prices, CC FYRR will be even less economical and will be dispatched even less frequently due to a higher incremental operating cost.

IGCC Technologies: The TAG data for the CC and IGCC technologies is based on early design projections for the new high temperature (23OO°F) combustion turbines, now commercially available from General Electric (GE). The TAG data has proven to be very conservative. Actual GE data shows a significant increase in power output and some reduction in heat rate. The optimization of IGCC has also produced further heat rate reductions as the gasification process vendors have begun to do detail IGCC design to utilize steam effectively.

The assumed evolution of IGCC economics is also shown in Table 4 and consists of three IGCC cases.

- TAG IGCC (400 MW)
- 500 MW IGCC (based on TAG Scale—up factors for a larger plant)
- Optimized 500 MW IGCC

The scale-up to 500 MW is based on a single module IGCC size of 250 MW, compared to about 210 MW as originally used in the TAG. The TAG has a capital cost adjustment method for unit costs ($/kW). The TAG capital cost adjustment method is consistent with the TAG's O&M costs for 400 MW and 800 MW IGCC. This 500 MW IGCC first—year revenue requirement of 50.3 can now be compared with the PC cost of 50.3.

Optimized IGCC is based on the following improvements:

- CT combustors designed for medium—Btu gas (MBG), instead of natural gas combustors
- Further advances in CT operating temperature to 235O° F

The IGCC heat rate will range from 8000 to 9000 Btu/kWh, depending on the type of coal (wet or dry) feed, type of heat recovery, type of bituminous coal, and the degree of process and steam integration. The optimized IGCC will have the same CC, gasification-related process units, and most of the balance of plant units as the TAG IGCC.

Table 4 compares the revenue requirements for the three IGCC cases. IGCC design, economics, and performance has been, and will continue to be, evolutionary through incremental steps. What is shown does not involve technology breakthroughs. PC, on the other hand, is considered to be mature except for higher steam pressures and temperatures.

The results of the joint TVA-EPRI coproduction study will be used to update the comparison shown in Table 4.

IGCC Coproduction Technology: The IGCC/F coproduction economics are based on a nominal 5OO-MW plant with about one-third of the synthesis gas being used for fertilizer production. TVA preliminary estimates for the capital cost of the ammonia and urea units to produce a nominal 2000 tons per day (TPD) of urea are about 21% of the optimized IGCC capital cost. The same ratio was also used to adjust the fixed and variable O&M costs. The sulfur credit does not change for coproduction but the CC unit heat rate is 9500 Btu/kWh due to operation at 67% load. For IGCC/F operation with 20% of the synthesis gas for fertilizer production (80% of CC load), the heat rate would be about 9000 Btu/kWh.

TVA is using two methods for economic evaluation of the coproduction concept, based on the total and the base electric generating capacity of the plant. The total electric capacity is 500 MW without fertilizer production. The base electric capacity is about two-thirds of plant capacity for electricity (335 MW) with fertilizer production from the remaining 33% of the plant capacity (165 MW equivalent). All of the costs for IGCC/F are allocated against the base electric output with the fertilizer units in operation in this analysis. The fertilizer by-product credit is also applied against the base electric output. The base electric method results in a very high revenue requirement because the costs are only allocated to 335 MW. Correspondingly, the fertilizer credit is higher for the same reason.

The fertilizer credit is given for a new 2OOO-TPD urea plant and TVA's estimated natural gas prices in 2000 ($3.5O/MBtu) and 2010 ($5.5O/MBtu), all prices in 1990 dollars. Urea revenue using the $3.50 (2000) and $s.so (2010) per MBtu values are $170.00 and $200.00 per ton of urea, respectively, for new plants. The 1990 wholesale market price of urea in the TVA region is about $150 per ton with natural gas prices of about $2.00 per MBtu.

Real escalation in natural gas-based fertilizer prices will result in potentially higher urea prices and a corresponding reduction in electricity annual revenue requirement of about 10% compared with PC in the year 2000. By the year 2010, the potential reduction in electricity's annual revenue requirement should be up to 20 to 30%. The levelized revenue requirements for IGCC/F should be less than the present average wholesale electricity rates of TVA and many other utilities.

Overall Schedule

The sequence of activities from development of the coproduction concept to commercial operation of the Coproduction Demonstration Project is shown in Figure 2. There are four major activities in the development of the coproduction concept:

- TVA-EPRI IGCC/F Coproduction Study. This began in January 1991 and will be concluded by June 1992,
- DOE Clean Coal Technology (CCT) v Proposal. The program opportunity notice is to be issued in March 1992.
- Site Selection, Environmental, and Permitting. This will require an Environmental Impact Statement which will be completed before site work begins in 1995.
- Coproduction Demonstration Project. Construction will be completed by October 1998. After a 3 year demonstration program, the facility will be used as a commercial unit in the TVA system.

Conclusions

The conceptual evaluation of coproduction shows the following:

- Process units for the IGCC/F are commercially available.
- Future demand and market projections of electricity and nitrogen fertilizers in the TVA region support new capacity.
- Conceptual economics indicate fertilizer with a higher value than electricity, as natural gas prices show real escalation.
- IGCC/F offers lowest SO_2 and NOx emissions and solid waste disposal requirements than any other coal-based capacity option.

TheTVA-EPRI study will provide the preliminary market, technical, environmental, and economic basis for the coproduction of electricity and fertilizers. At the conclusion of this study and pending continued favorable economics, TVA plans to proceed with detailed process engineering and capital and O&M cost estimates for project authorization.

TABLE 1

Coal Conversion

Coal Component	Coal Combustion (Full Oxidation)	Coal Gasification (Partial Oxidation)
Carbon (C)	Carbon Dioxide (CO_2)	Carbon Monoxide (CO)
Hydrogen (H_2)	Water (H_2O)	Hydrogen (H_2)
Sulfur (S)	Sulfur Dioxide (SO_2)	Hydrogen Sulfide (H_2S)
Nitrogen (N_2)	Nitrogen Oxides (NO_x)	Nitrogen (N_2)

TABLE 2

Coproduct and Byproduct Market Share

Product	Coproduction Demonstration Project Capacity	Existing Market Capacity	Projected Additional Capacity by 2000
Electricity, MW	250	24,600 (TVA)	4,700 (TVA)
Fertilizer, MTPY[a] (Urea)	0.3	9.0 (U.S.) 2.8 (TVA market area)	1.0 (U.S.) 0.3 (TVA market area)
Sulfur, MTPY[a]	0.03	12 (U.S.)	NA
Sulfuric acid, MTPY[a]	0.1	40 (U.S.)	NA

[a] Million tons per year.

TABLE 3

Environmental Comparison of Competing Technologies

Power Plant	PC/FGD	PC/FGD/SCR	IGCC	IGCC/F
Heat Rate, Btu/kWh	9,850	10,000	8,500	9,500
SO_2 Emissions				
lb/MBtu	0.60	0.30	0.15	0.06
lb/MWh	5.8	2.9	1.3	0.6
NO_x Emissions				
lb/MBtu	0.5	0.1	0.1	0.1
lb/MWh	4.9	1.0	0.8	0.9
Solid Waste				
lb/MBtu	24.4	25.0	10.4	10.4
lb/MWh	240.0	250.0	88.0	99.0

TABLE 4

Economic Comparison[a] of Power Generating Technologies

Technology	Conventional Technologies PC/FGD[b]	Conventional Technologies CC[b]	IGCC Technologies IGCC[b]	IGCC Technologies Adjusted IGCC[b]	IGCC Technologies Optimized IGCC
Size, MW	500	210	400	500	500
Load factor, %	80.6	90.5	85.7	85.7	85.7
Heat rate, Btu/kWh (average annual)	9,830	7,740	9,220	9,220	8,500
First-year revenue requirements, m/kWh	50.3	31.7	52.7	50.3	47.7
Incremental operating cost, (dispatch priority), m/kWh	20.0	23.1	16.4	16.2	15.2

[a] Based on coal and natural gas prices of $1.50 and $2.50 per MBtu, respectively.
[b] From EPRI TAG - 12/88.

TABLE 5

Economic Comparisons[a] of Coproduction of Electricity and Fertilizer

Technology	Optimized IGCC	Optimized IGCC/F
Size, MW		
Electric (base)	500	335
Fertilizer (MW equivalent)	0	165
Total	500	500
Heat rate, Btu/kWh	8,500	9,500
Subtotal revenue requirement, m/kWh	NA	84.7
Subtotal incremental operating cost, (dispatch priority) m/kWh	NA	25.1
Fertilizer credit, m/kWh		
At $3.50/MBtu[b] ($170/ton urea)	NA	39.4
At $5.50/MBtu[b] ($200/ton urea)	NA	49.7
First-year revenue requirement		
At $3.50/MBtu[b] ($170/ton urea)	NA	45.3
At $5.50/MBtu[b] ($200/ton urea)	NA	35.0
Total incremental operating cost, m/kWh		
At $3.50/MBtu[b]	NA	-14.3
at $5.50/MBtu[b]	NA	-24.6

[a] EPRI's TAG (12/88) and TVA adjustments.
[b] Natural gas feedstock.

Tuesday October 22, 1991

Session IV
Moderator:

Richard F. McFarlin

Impact On The Phosphate Industry Of Public Concern Over Radon

Gordon D. Nifong
Florida Institute of Phosphate Research

I'd like to begin this discussion by rephrasing my title to the form of a question: "Is there an impact on the phosphate industry created by public concern over radon, and, I would add, other forms of natural radiation?" I think about everyone in the industry would answer "Yes!" I'd like to share with you some thoughts in four areas: (l) What are some of the impacts on the industry from public concern over radiation? (2) Why is the public so especially concerned about radiation? (3) What are some of the facts about radiation in Florida and its effects on our citizens? (4) What can industry do to clarify the issues?

We can begin by realizing that concern over radiation, including radon, fuels public involvement in even the establishment of any new mine, processing facility, or just about any new industry activity. Witness the controversy that has surrounded the establishment of an integrated operation proposed for Desoto County in the '90's. Public concern impacts the obtaining, and certainly the ease of obtaining, of mine extensions in the phosphate region. It influences set-backs that will be required for further mining, thus often removing significant amounts of mineral ore from further consideration. It plays a role in people's fear of groundwater contamination, recently forcing one company to bring into a community a water tank truck, and another company to pay for extension of city water into a rural area.

Concerns of the public impact land reclamation. Right now Hillsborough County is considering a radiation standard for reclaimed land that would limit radium level of reclaimed surface land (top six feet) to no more than 3 picoCuries per gram (pCi/g) over pre-mined conditions, with a cap of 5 pCi/g, unless the land before mining exceeded that. The majority of reclaimed phosphate land exceeds 5 pCi/g! This type of standard can be met, but at substantial added cost. Meanwhile there is a constant threat in the background for the industry to operate so as to not elevate soil radiation levels at all. These concerns also limit the future of reclaimed lands for higher profit uses. The U. S. Environmental Protection Agency (EPA) and Manasota-88 have come out strongly that home construction on reclaimed phosphate lands should not be permitted, because of an added indoor radon risk. In their defense, our studies have shown that homes on reclaimed land do have added radon, perhaps 50%, over near-by homes on unmined land. The state is attacking this problem by developing a radon entry-resistant building code, one that would allow you to build anywhere, with minimal entry of radon from the soil. Next we have some persons who suggest we prohibit any growing of food crops, or even the grazing of cattle, on reclaimed lands, especially clay areas. These persons forget that dietary intake of radionuclides contributes an extremely low portion (about 1%) of total human exposure to natural radiation, even under worst-case conditions.

Finally there is the issue of phosphogypsum. Thanks partly to public concern, you're in trouble if you store it, and you're in trouble if you try to use it. If you stack it, there is the possibility that some radionuclides may leach into near-by shallow groundwater. Chemical plants are now looking at putting impervious liners under any new stack. Eventually they may have to cap any decommissioned stacks. The public is concerned over radon gas emanation from stacks, even though crusting of the surface of old stacks and the presence of moisture and pond water at active stacks greatly inhibit radon release. In fact, in a study done recently for the Institute, we found that ambient radon levels on top of, and around the perimeter of, two typical stacks were no higher than levels found in some residential areas of Bartow. However, both were higher than levels generally found elsewhere in the state. Because of crusting, moisture, and dust particle size, dispersion of particulate material seems to present no problem. When the public does not like the looks of a stack in their "backyard," however, they can find many reasons why it should not be there.

This brings us to the issue of using phosphogypsum. We have about 600 million tons of this by-product stored on the ground in Florida today, and are adding about 30 million tons per year. Over the past decade a major part of Institute research has gone toward trying to find economically viable and environmentally sound uses for the material. We have looked at its use in road construction, as a soil additive, its conversion back to sulfur for industry reuse, and its incorporation into selected building products. For most of this time the EPA has chosen not to regulate phosphogypsum as a hazardous waste under the Resource Conservation and Recovery Act. In the Spring of 1990, partly due to prodding from the public, the agency prohibited off-site use of phosphogypsum under the National Emission Standards for Hazardous Air Pollutants. Waivers have been granted for agricultural uses, but just about everything else, including research, has been on hold for over a year and a half. The issue is still not settled. Hopefully, soon EPA will reach a final decision and permit research and at least allow its use on a case-by-case basis. But in the meantime the industry is sitting on a vast quantity of a by-product resource that it can't use.

Turning to the second point, people are concerned about radiation because of their perceived risk of what it presents to them, their family, or even their property, and because it's an unknown to most of them. The perception of risk to most citizens is different from what is means to a professional risk analyst. There is no doubt we as a society are a nation of risk takers - a third of us smoke tobacco, a third of us drink perhaps too much, and, despite knowing quite well how it is transmitted, somewhere over a million Americans now carry the AIDS virus. But we are not a nation of risk accepters. Two years ago we almost wiped out our apple industry in a scare over Alar, even though an earlier federal study had shown you would have to eat 28,000 pounds of apples every day for 70 years to receive a toxic dose. The risk analyst defines risk as a combination of hazard (magnitude of the consequences of an unwanted event), and the probability of that event ever occurring. Air travel is considered low risk; even though the consequences of an accident are grave, the probability of its happening are extremely small. The public's perception of risk, however, is based on hazard, but in conjunction with an "outrage" factor rather than probability. Some factors determining outrage are: voluntary or coerced, natural or man-made, familiar versus exotic, who gets any benefits, controlled by the taker or by someone else, dreaded result or not, plus others. These two definitions of risk produce very different rankings of risks; outrage created through fear of the exotic pushes radiation near the top of the chart. Unfortunately, most people worry too little about the big hazards and too much about the little hazards. They worry about the one death in a million caused by adding chlorine to drinking water, but forget that chlorine is added to water to prevent thousands and thousands of deaths yearly from cholera and typhus epidemics. More to our point today, they become excited over possible radiation from a gypsum stack, while forgetting that famine is one of the three leading causes of death in the world. If you are concerned over the public's reactions to risk, you face a challenge: you should be spending your time raising the level of outrage over real hazards, but instead you're probably forced to spend most of your time trying to reduce outrage over trivial hazards. The health risks of radiation, i. e. cancer, are not trivial, but they are far lower than what most people think they are, and they are not as high as many everyday risks most people accept as a part of life. A prudent person will seek to maintain his exposure to radiation to a level as low as reasonably achieveable, but not at the expense of ignoring all else. Getting back to radiation, two of the nation's top radon researchers, Nero at Lawrence Berkeley Labs and Cohen at the University of Pittsburgh, have found no increase in lung cancer in areas where radon is elevated; in fact they have found a slight negative correlation. They conclude the risks have been exaggerated.

Therefore, let's look at a few facts about radon, other environmental radiation, and risks from radiation exposure. First, radiation from natural background accounts for about 80% of total dose to the average American. At least half of this is due to indoor radon, but cosmic and terrestrial radiations are significant. Man-made sources, mostly medical, account for 20%. While phosphate lands are elevated in soil radium and the release of radon to the atmosphere, phosphate lands account for some 0.04% of radon emitted to the atmosphere each year over the U. S. Undisturbed soil, the tilling of soil, and miscellaneous sources account for 99.96%. Does this presence of phosphate make Florida a hotbed of radiation? Not really. In a state-wide study of indoor radon in over 6,000 homes completed four years ago, the average level found was just under 1 picoCurie per liter of air (pCi/l). Only about three and a third percent of homes were found to contain radon in excess of the EPA guideline of 4 pCi/l, above which some concern may be warranted. In 17 other states, surveyed by EPA, roughly 25% of homes have shown elevated levels. The Florida study found elevated radon levels in homes from Tallahassee to Homestead, in 18 counties. Work done by HRS in the last several years, involving several hundred thousand samples, has shown that radon can be found virtually anywhere in Florida. This is the reason the state has gone the route of a radon-resistant building code for future construction. Does building a home on reclaimed phosphate land in central Florida increase radon over a similar home built on adjacent but unmined land? Yes, in past years by about 50%; hence, again, the reason for a building code.

How does Florida compare with the other 49 states in terms of outdoor, or ambient, radon? Over the past year or so the EPA has been conducting a study of outdoor radon in every state. In a recent report of their findings, EPA put Florida in 38th place.

The public's concern over radon is driven largely by EPA's projection that radon and its decay products cause some 5 to 20 thousand lung cancer deaths yearly in the U. S.; that it is second only to smoking as a cause of that disease. They base this on an extrapolation of mortality from far higher doses to uranium miners during the 40's and 50's, down to the low levels experienced today by most citizens. I have no doubt that exposure to high levels of radon contributes to lung cancer, but I question the significance of the levels most home dwellers experience. There simply is no correlation state-by-state, or within states, between levels of radon and incidence of lung cancer. High radon states, such as Missouri, Iowa, and North Dakota, have lower than average lung cancer. In Florida, if low levels of radon are significant in lung cancer, and if phosphate seriously elevates radon levels, we should see an excess of cancer in those counties where phosphate is mined or processed. Let me read you the ranking of several Florida counties for death by cancer of the trachea, bronchi and lungs, as reported by the Florida Department of Health and Rehabilitative Services, Public Health Statistics Section, for 1989:

1. Franklin
14. Manatee
23. Pinellas
30. DeSoto
36. Polk
40. Hardee
48. Hamilton
52. Hillsborough
54. Duval

Now, let's return to phosphogypsum for a moment. It contains an elevated level of radium, typically about 25 to 30 pCi/g, compared with the 1 to 2 pCi/g found in non-mineralized soils. But before that really alarms us, let's compare for a minute the radioactivity of phosphogypsum with that of some consumer items readily accepted by most people. Are you wearing a watch with a luminous dial? Then you are wearing something with a radiation content equivalent to 200 pounds of phosphogypsum. Any fluorescent lights in your home? Each starter is worth a 100 pounds. Then we can really look at risk versus benefit - do you have any smoke detectors in your home? Each one contains radioactive material equal to a half ton of phosphogypsum.

Is radon emanating from phosphogypsum stacks? Yes, but not as much as its radium content would suggest. Because of crusting and moisture, the emanation rate is about half that of most soils. I believe every stack tested so far in Florida meets the EPA limitation of 20 picoCuries per square meter per second. Our studies show that radon emission from a stack is from mainly the first few feet of top or sides; so the radon emission of a six-foot stack and that of a 200-foot stack won't be much different except for area. Is there an increase in direct gamma radiation from gypsum? Most definitely, about six or seven times background, but only if you are standing on the stack when you take the reading.

What are some of the things that can be done to alleviate the public's concern over radiation from the phosphate industry? First, always remembering that you are talking to peoples's emotions and hence their feeling of outrage rather than true hazard, do talk to them. Tell them when there is a hazard, but also tell them when there is no problem. Discuss risks in lay terms; point out risks that are trivial and those that are real. Second, talk to the news media when asked. Never say "No comment." Try to find out the reporter's level of knowledge about the issue, and keep you discussion at his level. One sure way to get an erroneous story is for a newsperson to write about something he doesn't understand. If you don't know the answer to a question, admit it, but either find an answer or refer the reporter to someone else who will have an answer. And finally, be ready to talk to the politicians and the regulators.

In summation, we need to try to get across to the public that there is a difference between trivial risk and real risk; that there's a difference between a needless risk and one whose benefits outweigh any danger involved; and that radiation is not an exotic risk. Most radiation exposure occurs naturally, but risks therefrom are better understood than those from just about any other hazard to mankind. We do not live in a risk-free world. People must understand that zero risk is not attainable, but that an acceptable level of risk, as balanced against benefits, is attainable.

Phosphogypsum Use Reduction

Whit Yelverton
The Fertilizer Institute

I have been asked to speak today concerning the use restriction on Phosphogypsum. Normally, I begin my talks by describing the Fertilizer Institutes and what we do. However, in this case, I believe most everyone here knows something about TFI. You probably also know that Karl Johnson on our staff is the real expert on Phosphogypsum. Hopefully, if I leave you questions unanswered, we can pass them on to Karl.

Phosphogypsum is a large-volume and unavoidable by-product of phosphoric acid manufacture. It is most commonly disposed of in large "stacks" or in the mines from which the phosphate ore was taken. Phosphogypsum contains primarily calcium and sulfur, and is slightly radioactive.

Thousands of farmers use Phosphogypsum as a soil amendment and mineral source. Approximately 400,000 tons per year are used by farmers, a lot of that going on peanuts. There are other limited uses as well, including construction and sulfur recovery. Unfortunately, all of these uses constitute only a small fraction of the Phosphogypsum being produced. Research into other beneficial re-uses of this by-product has been actively persued over the years.

The prohibition on these uses of Phosphogypsum came as somewhat of a surprise. The EPA issued rules in December, 1989 which regulate radon emissions from Phosphogypsum stacks. As a caveat, EPA, citing concerns over the possible human health and environmental effects of the radon in Phosphogypsum, issued "work-practice Rules" which required that Phosphogypsum be disposed of in a stack or mine cavity. This action, of course, eliminated all other uses, including land application, construction, etc. Researchers were also prohibited from obtaining any samples to use in experiments.

TFI immediately petitioned the EPA, asking the agency to reconsider its ruling. We also asked for a stay of the work practice rule.

In April of 1990, EPA granted a waiver of compliance until October 1, 1990. They also asked for public comment on four possible options regarding the work practice rule.

The first option proposed was no change. This was of course unacceptable, since we considered the work practice rule to be unwarranted and unsubstantiated anyway.

The second option suggested that a threshold radium content be developed, which would effectively determine whether Phosphogypsum is acceptable for land application. Since there is no data available to indicate that any particular radium content in Phosphogypsum makes it unsafe for land application, this option is impractical.

The third option was to permit research use only. Again, with no evidence that the product is unsafe, why should there be any limits?

The fourth, and final option presented was to allow full use, but regulated or controlled on a case-by-case basis. In rejecting this fourth option, TFI called upon EPA to reopen a full consideration of whether any ban or restriction was called for.

EPA initiated data-gathering, saying that they would make a final decision prior to the expiration of the compliance waiver in October, 1990. The University of Georgia was contracted to conduct research on uptake and leaching from test plots. Delivery of the data has been delayed.

In October, 1990 the waiver expired, and EPA had not made a decision. TFI petitioned for a one-year extension; EPA extended the waiver until June, 1991. In June, still with no decision, EPA granted another extension until October 1, 1991.

Of course, during this period of proposals, waivers, delays, and indecision, everyone, from farmers to distributors to manufacturers, has suffered. Farmers, who were unsure of getting our product, faced the prospects of paying three times as much for alternative material. Distributors were unable to reassure farmers, alienating some of their best customers; they also faced the prospect of financial losses from taking inventory which they could not ship. Producers were stung by not having an answer for everyone else; they also faced the prospect of having to find alternative disposal for the product. Even TFI felt the effects, having to pay enormous sums to attorneys and consultants who were playing the EPA game on our behalf.

No additional waiver of compiance was issued past October 1, 1991. Presumably, a complete ban on Phosphogypsum use is now in effect. EPA has promised to reach a decision during November of this year. Recent rumors heard from EPA seem to indicate that they will ultimately allow most or all uses, within a fully regulated structure of use permits, licenses, applications, etc. Whether this makes land-use uneconomical or just inconvenient will depend on the exact nature of the final ruling.

The two-year episode I have just described will not have a happy ending. EPA will not fully release its hold on agricultural use of Phosphogypsum, and the public's view of our industry and its products will not fully regain its previous stature.

This is a very clear demonstration of the EPA philosophy of "regulate first and justify later". The agency stumbled into its opportunity to regulate Phosphogypsum; it had no indications that agricultural or other uses posed any risk to human health or to the environment. However, the opportunity for extending its reach further into U.S. commerce was irresistible, and the agency has persisted despite the lack of justification and despite the objections of industry.

EPA's stated mission includes protection of the environment, and promotion of beneficial re-use of necessary waste or by-product materials. EPA has chosen, again and again, however, to build new regulatory empires and to extend its reach into private business rather than to follow its basic mission.

The result of EPA's current methods of operation has been restraint of commerce, loss of revenues and employment, and a rising hysterical fear of chemicals and manufacturing industries among the American public. Our task and continuing occupation today is to turn the tide on this regulatory intimidation.

Agricultural Use of Reclaimed Phosphatic Waste Clays

J. A. Stricker
Florida Cooperative Extension Service

Characteristics of Phosphatic Clay

Phosphatic clay is a by-product of phosphate mining operations. Phosphate ore is a matrix of sand, clay and phosphate. Clay is washed from the ore matrix in the beneficiation process and pumped to large settling areas at about 2% solids. The clay, often called slimes, is allowed to settle while the water is decanted and reused. Phosphatic clay consists mostly of clay particles less than 2 microns in size, however, about half, by weight, are less than .2 microns (Hawkins, 1973). Phosphate minerals, mainly apatite make up the average size fractions while clay minerals, mainly montmorillonite, make up the finer fractions. Composition of phosphatic clay includes 50 - 60% clay, 30 - 40% quartz and 2 - 5% heavy minerals and miscellaneous.

Until the mid 1980's it was believed that clay settling areas, once filled, would become waste lands because of the difficulty of drying the clay. It was generally believed that a clay settling area would take 30 or more years to dry naturally to the point of supporting conventional farm equipment. In the early 1980's Agrico Chemical Co. introduced the use of high flotation tractors with rotary ditching plows to drain the clay surface and speed reclamation. Use of the tractors and plows, coupled with a ditch around the interior rim of the settling area dike, hastened the reclamation process. Agrico Chemical also introduced the use of alfalfa, a deep rooted perennial legume, to further hasten the drying process. In this way reclamation time has been reduced to as little as three to five years (Presnell 1987).

Phosphatic clay as a soil is unique in Florida where natural soils are typically sandy or organic in nature. The clay has many desirable characteristics, including high water holding capacity, which greatly reduces the need for supplemental irrigation. One of the most important characteristics from a soil management perspective is the clays shrinking/swelling nature. This results in large clods breaking into smaller pieces through the process of wetting and drying. Referred to locally as "mellowing", the clay swells when wet and shrinks as it dries creating fracture lines on the surface of clods. The clods then break along these fracture lines. With repeated wetting/drying cycles smaller and smaller clay structures result.

A major disadvantage is that the clay cannot be worked when wet. The wet-sticky nature of the clay can limit field access during wet periods and limit maintenance and harvest operations during critical periods for some crops. Strategies are being explored by the Mined Lands Research/Demonstration Project to minimize these problems.

Phosphatic clay is also naturally fertile (Table l) with high levels of phosphorus, calcium, magnesium and potassium. Adequate amounts of the minor elements are also present. Soil pH varies from 7 to 8 which is slightly higher than optimum for most crops. Mild manganese deficiency symptoms have been observed in some crops, however, no yield response has been documented as a result of foliar applications of manganese.

Table 1. Fertility comparison between a typical Florida sand soil and phosphatic clay.

Soil	pH	Ca	Mg	K	P	Zn	Mn
		ppm					
Sand*	4.8	63	10	67	166	1	.3
Phosphatic Clay**	7.2	5923	2569	332	586	5.6	6.3

* Mehlich I extractant
** Melich III extractant

Although phosphatic clay as a soil is unique to Florida there are similar soils in other areas of the world. The polder soils of Holland and clay soils of the Po river valley in Italy have been described as similar. In this country alluvial soils called "gumbo" are found in many river flood plains. Agriculture is well developed on these soils and there is reason to believe that given time and adequate investment a well developed agriculture will evolve on the phosphatic clay soils of Florida.

Mined Lands Agricultural Research/Demonstration Project

In the early 1980's then County Commissioner Ernie Caldwell recognized that Phosphate mining in Polk County would be winding down over the next 20 years. In July, 1983 Caldwell raised the issue of what could the University of Florida, Institute of Food and Agricultural Sciences (IFAS) do to help find productive uses for reclaimed phosphate land with the Polk County Extension Advisory Council. From this beginning the idea of establishing a research and education program directed to growing high value agricultural crops on reclaimed land was developed.

In October, 1985 the Florida Institute of Phosphate Research funded the Mined Lands Project. The Project is a cooperative effort involving the Polk County Board of County Commissioners, University of Florida-IFAS, Polk Soil and Water Conservation District, Florida Institute of Phosphate Research and the Phosphate Industry. This cooperative effort is unique and capitalizes on the strengths of each organization.

The project is now entering it's seventh year of operation and has Identified and addressed a number of problems related to production of high value crops on phosphatic clay. Some of the main problems are discussed in this paper including: The need to build drainage systems on the surface of clay settling areas, the issue of elevated levels of radionuclides in phosphatic clay and potential crops for phosphatic clay.

Size of the Resource in Florida

After land is mined for phosphate, three land forms remain: overburden, sand tailings and phosphatic clay. Overburden is the material from the soil surface down to the top of the ore body which is cast aside in the mining process. Sand tailings is quartz sand separated from the ore in the beneficiation process. Phosphatic clay is colloidal material (-150 mesh) separated by hydrocyclone from the phosphate feed in the beneficiation process. Phosphatic clay is pumped to settling ponds at 1 1/2 to 2% solids.

By mid-1990 230,000 acres of land had been mined for phosphate in Florida. Most of the mined land is located in Polk County where reserves are expected to be depleted in the next 10 to 15 years. Roughly 60% of the land area after mining is covered with phosphatic clay. Presently there is about 140,000 acres of clay with approximately 2000 acres being added each year. The remaining 40% of the land area is made up of overburden, sand tailings, sand tailings capped with overburden and a small acreage of sand/clay mix. As of October, 1991 only 6,349 acres of phosphatic clay has been reclaimed or roughly 4.5% of the total (Sherwood and Albin, personal communication). Reclamation of phosphatic clay is expected to increase dramatically in the near future.

To help put the size of the mined land resource in perspective, The area presently covered by mined land in Florida is larger than five Counties. The counties of Pinellas, Seminole, Bradford, Gilchrist and Union each have a land area less than 230,000 acres.

Radionuclide Issue

Phosphatic clays have been found to have higher levels of radionuclides than native Florida soils. Radionuclides are elements with atomic weight greater than 80 and fall into three distinct decay series: Uranium (U), Thorium (Th) and Actinium (Ac). Each series starts with an element having a long half life. The U decay series is of greatest concern. $Radium^{226}$ (Ra), $Lead^{210}$ (Pb) and $Polonium^{210}$ (Po) belong to the U decay series whose parent U^{238} has a half life of 4.5×10^9 years.

$Radium^{226}$ levels in phosphatic clay have been measured at .574 Bq/g compared to .03 Bq/g for undisturbed mineral soil(dry weight) (Stricker et al. 1991). Research has shown, however, that a certain concentration of a radionuclide in soil, does not indicate that plants grown in that soil will have an equal amount in their tissues. Plants accumulate radionuclides depending on many factors including, soil type, species of plant and specific plant tissue such as leaf, stem or fruit (Peterson 1983; Guidry et al. 1986; Guidry et al. 1990).

A number of studies of radionuclides in crops grown on reclaimed phosphatic clay has shown that generally crops grown on phosphatic clay exhibit higher concentrations of radionuclides than crops grown on natural soils. The levels were found to vary significantly with the individual crop and the part harvested for food (Hanlon 1991). In general, concentration of Ra^{226}, Pb^{210} and Po^{210} were lowest in grain or fruit compared with vegetative portions. $Radium^{226}$ content in corn, sunflower and grain sorghum was about 8% that found in their leaves and stems (Mislevy et al. 1991).

Vegetables grown on phosphatic clays often, but not always, contain higher levels of radionuclides than vegetables grown on undisturbed mineral soils (Shibles and Riddle 1991). Lowest concentrations were found in the fruit and the highest found in older leaves. Cabbage wrapper leaves (outer leaves removed before food preparation) contained higher concentrations than cabbage heads. Little difference was found in radionuclide levels in cabbage heads grown on phosphatic clay compared to cabbage grown on undisturbed mineral soil. Vegetables grown for their edible leaves, such as turnip and collard greens, had higher levels than root crops such as carrots or turnip roots (Million et al. 1991; Shibles and Riddle 1991).

Two studies were conducted to evaluate the influence of forages grown on phosphatic clay on radionuclide concentrations in animal products. $Radium^{226}$ and Pb^{210} were found to be higher in milk from cows fed corn and alfalfa silage grown on phosphatic clay. These values were only slightly above the normal range reported for milk produced in the United States (Staples et al. 1991).

Steers fed forages grown on phosphatic clay or from unmined pasture showed increased Ra^{226} in bone samp!es compared with kidney and muscle samples. Levels of Ra^{226} in muscle samples were very low (Stricker et al. 1991).

Radionuclides that occur naturally in the environment pose little threat of causing cancer through the food chain. "The risk levels associated with radionuclides in foods (about 1 in 1,000,000/yr) are considered to be insignificant or de minimis" (Walsh 1991). Soils with elevated levels of radionuclides, such as phosphatic clay, can be used for the production of agronomic and vegetable crops without an appreciable increase in health risks to either animals or man. Choosing crops that produce fruits or grain rather than leafy vegetables will keep the health risks very low (Hanlon 1991).

Drainage Considerations

Clay settling areas typically cover a square mile and can range from a few feet to 60 feet or more in depth. As water is removed from the clay during reclamation the clay consolidates or shrinks in volume. The amount of consolidation appears to be in proportion to the depth of the clay so that deeper areas within the impoundment settle more than the shallower areas. This can be an advantage in settling areas where ridges were left in the bottom before filling. However, in many settling areas the bottom is relatively flat resulting in a flat poorly drained clay surface after reclamation. Since phosphatic clay is relatively impervious to water (saturated conductivity about .02 in/hr), surface drainage is needed for crops to survive periods of high rainfall.

As water is drained from the clay surface during reclamation the surface begins to dry and consolidate forming a "crust". Clay beneath the surface remains semi-fluid or plastic. Observation has shown that once the crust becomes 10 or more inches thick, the clay surface is able to support conventional farm equipment. If the crust is penetrated or removed, the plastic subsurface is exposed and will no longer support equipment until a new crust is formed.

The Florida Dept. of Natural Resources (DNR) regulates mining and reclamation. DNR's standards do not require drainage that is adequate for production of high value agricultural crops. In many cases drainage in addition to basic reclamation will be needed for successful production of high value crops.

On flat, poorly drained, settling areas "macrobeds" show promise from a drainage and crop production perspective (Figure 1). Macrobeds for clay settling areas are approximately 200 feet wide with a 1 to 1 1/2% slope. These macrobeds are similar to the polders widely used in the reclaimed areas of Holland to provide surface drainage of agricultural land. A similar drainage system is used to remove water from the agricultural land in the Po river valley of Italy (Shaw 1991).

Several methods of macrobed construction (Figure 1.) have been evaluated on a shallow clay area including: use of a small (Cat D3) bulldozer repeated moldboard plowing in one direction, use of a whirlwind terracer and construction with a motor grader. Construction with the bulldozer was time consuming and required a drying period between passes. The terracer was not an effective soil mover so its use has been discontinued. Repeated use of the moldboard plow was satisfactory although construction was not as rapid as with the motor grader under dry soil conditions. Several excellent quality macrobeds have been constructed with the plow and the motor grader but both of these machines require very dry soil conditions.

During construction of macrobeds with farm tractors or motor graders, there is always the hazard of getting mired when the crust is penetrated. Motor scrapers cannot be used for bed construction because the soft clay will not support heavy axle loads. Since conventional construction machinery can only be operated during dry periods, other methods and techniques for earth moving are being explored. One promising alternative is a cable powered earth moving system. Two winch and cable power units will be used, one on each side of the area to be worked. The units will draw a soil mover back and forth across the area. Mathis (1982) reported a "winch-dozer" system proved to be twice as effective as bulldozers for leveling strip mined land in Texas.

Two cable and winch power units (Figure 2.) are currently being designed and fabricated by the Agricultural Engineering Dept. at the University of Florida. Testing is expected to begin in early 1992. Design and fabrication of a reversible soilmover for macrobed construction, to be powered by the winch and cable units, (Figure 3.) is scheduled for later in 1992.

Although there are more than 140,000 acres of clay settling areas presently in Florida, more settling areas are being built each year. One way to help solve the drainage problem on reclaimed clay settling areas is to plan the drainage system during initial construction. If the drainage system is built into the bottom of the settling area during construction, the clay surface will take the shape of the bottom after reclamation (Figures 4. & 5.). This will eliminate the expense of building drainage into the clay surface and result in land with a higher value after mining and reclamation.

Potential Crops for Phosphatic Clay

Research by the Mined Lands Research/Demonstration project over the past 6 years has shown a wide variety of crops can be successfully grown on phosphatic clay. High value forages, vegetables, grain crops, turf grass, ornamental trees, biomass crops, legume seed and others have all been examined. Successfully growing a crop is only part of the picture, however. A market must exist or be developed for a crop and there must be reasonable expectation of profit from growing and selling the crop.

Marketing studies have been completed on a limited number of crops and others are planned.

Dr. Tim Taylor of the IFAS Food and Resource Economics Dept. recently (4/91) reported on a study comparing vegetable production on phosphatic clay with other production areas in Florida. Data from phosphatic clay was based on extrapolating from small plot work while costs and returns from commercial production areas is based mainly on interviews with growers. His findings were:

* *Single crop cucumbers on phosphatic clay were more profitable than cucumbers produced in Southwest Florida. Profitability would be even higher with cucumbers grown in a multiple cropping system.*
* *Single crop cabbage was marginal on phosphatic clay compared to production in the Hastings area. Use of plastic mulch and drip irrigation on clay was the major difference. Multiple crop ping cabbagewith cucumbers or squash would spread the costs and increase profitability of both crops.*
* *Single crop squash production on clay was less profitable than Dade County rockland. Once again the main difference was the cost of plastic mulch and drip tape.*

Rahmani and Degner (1990) completed a study of the market potential for feed grains and alfalfa in central Florida. A present market for 478,000 tons of alfalfa hay was identified within a 100 mile radius of Polk County. Virtually all of the alfalfa is shipped into Florida from other states and is selling for $120 or more per ton. Alfalfa grown on phosphatic clay in central Florida yields 6 - 8 tons per acre at an estimated cost of $50 or less per ton. With current yields, 60,000 to 80,000 acres could be utilized to supply this market from local sources.

Harvesting and storing alfalfa for hay presents serious problems in central Florida especially during the rainy season. Alfalfa is hygroscopic in nature and high humidity and frequent rains prevent alfalfa from getting dry and promotes mold growth. One solution is to harvest and store alfalfa as silage or haylage during the rainy season. Unfortunately, alfalfa silage or haylage will not likely bring the premium prices of hay. Another alternative is to artificially dry alfalfa but high fuel costs make the economics doubtful. Present efforts are focused on identifying sources of waste heat for drying alfalfa and other crops.

Alfalfa stand life is also a problem under Florida's conditions. Normally an alfalfa stand will last only two or three years. One alternative being explored is perennial peanut, a tropical forage legume. Perennial peanut is similar in appearance to alfalfa and has virtually the same feeding quality as alfalfa. Preliminary tests with perennial peanut have been encouraging. The plant thrives under hot humid conditions and has no known insect or disease problems. Perennial peanut does not produce seed and must be vegetatively propagated. Once established, it is believed a properly managed stand will last indefinitely. Harvest and storage problems will be similar to alfalfa, however.

Although specific marketing studies have not been completed, turf crops and ornamental trees are expected to have potential for profitable production on phosphatic clay. St Augustinegrass sod has been grown, the sod lifted and laid on natural sand soil along with sand grown St. Augustinegrass sod. No difference was found in the rooting ability of the clay vs sand grown sod. Cost of producing sod on clay is expected to be less than on sand because of lower irrigation requirements and lower fertility costs.

Live oak, laural oak, slash pine, southern magnolia, wax myrtle and red maple were all grown on phosphatic clay. Growth rate was judged to be equal to or greater than the same trees grown on sand. After initial establishment, non irrigated trees grew faster than irrigated trees. After three years, a sample of 30 trees were dug with a tree spade, transported more than 100 miles and transplanted in a sand soil. Only three of 30 trees died and the remaining 27 rooted normally. A second group of seven were transplanted one year later in Bartow. All trees survived and rooted in a deep sand soil. Although the present market for landscape trees is depressed, there should be future opportunities for profitable production on phosphatic clay because irrigation costs on clay will be minimal compared with irrigation costs on sand land.

Biomass/energy crops have performed exceptionally well on phosphatic clay. Total drv matter yield of some sugarcane varieties have averaged 25 tons per acre over the past 4 years. The biomass plots were established in 1986 and have been harvested annually with no sign of decline. Biomass crops can be utilized in alcohol or methane production or by direct burning to produce energy. There is presently no market for biomass crops in central Florida. However, new technology for conversion of cellulose and hemicellulose to alcohol is expected to improve the economics of alcohol production. Increased demand for alcohol as a result of the federal clean air act could provide future opportunities.

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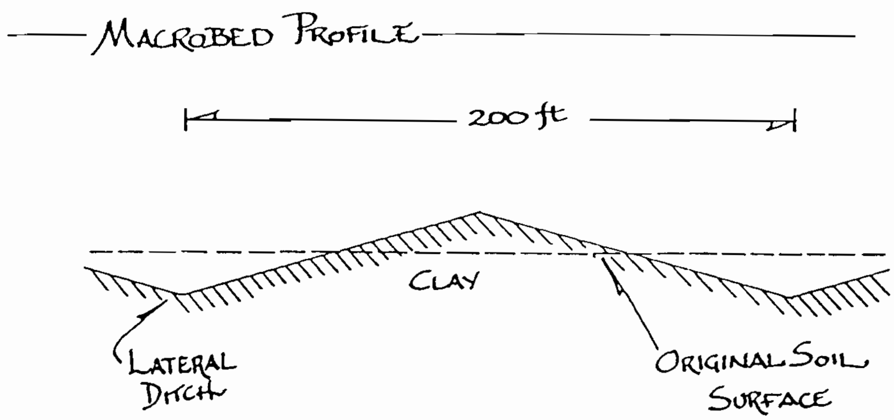

Figure 1. Cross section of a macrobed design used at the Mined Lands Research/Demonstration Project. (from Hanlon et al. 1991)

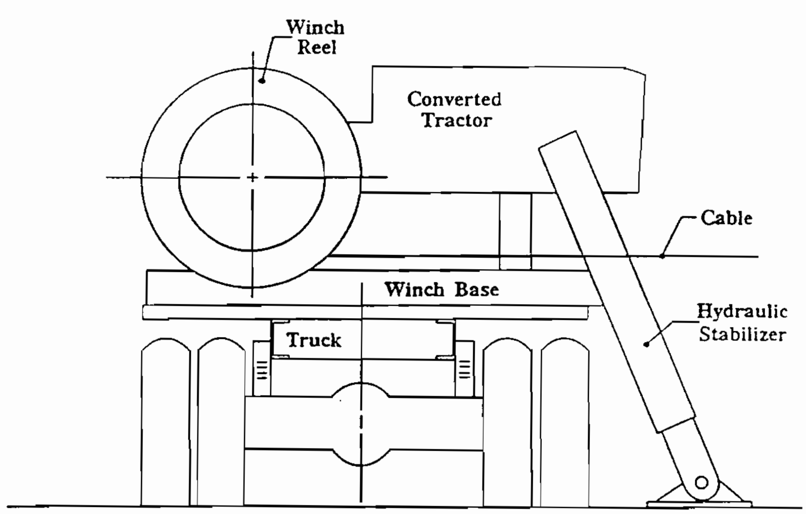

Figure 2. Truck mounted winch unit (Shaw 1991).

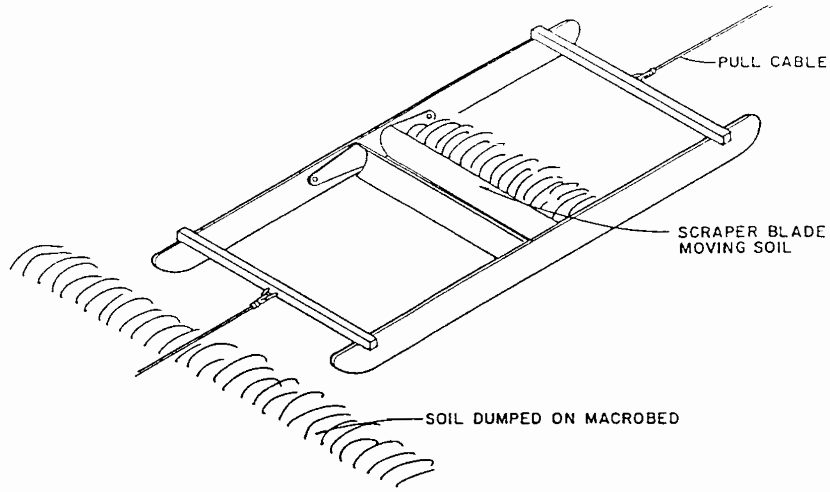

Figure 3. Reversible Soilmover for macrobed construction (Shaw 1991)

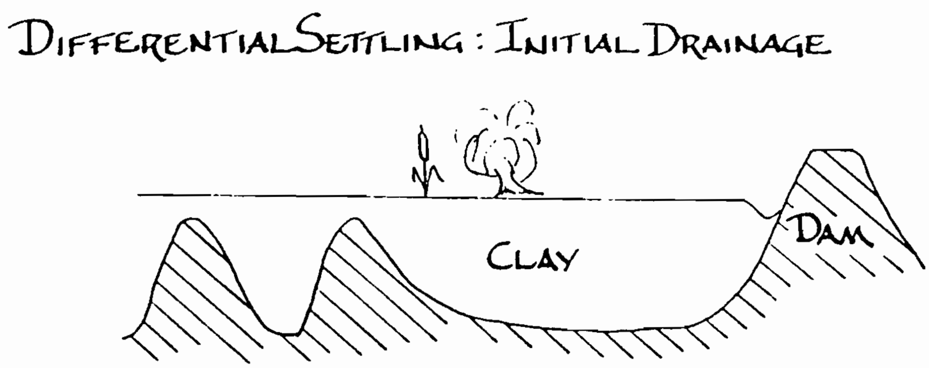

Figure 4. Cross section of a phosphatic clay settling area with contoured basin before reclamation. (from Hanlon et al. 1991)

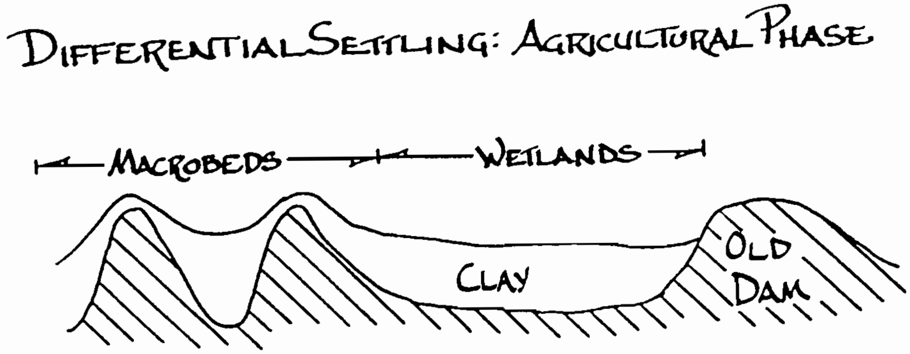

Figure 5. Cross section of a phosphatic clay settling area with contoured basin after reclamation and differential settling. (from Hanlon et al. 1991)

HRS Recovery System Update

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Monsanto Enviro-Chem Systems, Inc.

HRS Background

The Monsanto Enviro-Chem Heat Recovery System was invented a little over eight years ago. The Heat Recovery System has now been in commercial operation at two plants at Namhae in Korea for almost four years. Several more HRS units have started up since Namhae and many more are now on the drawing board and scheduled for start-up during the next couple of years. This paper will give the status of the Heat Recovery System and discuss the economics that are driving customers to make the capital investment for adding the Heat Recovery Systems to their plants.

The Heat Recovery System has been the subject of numerous technical papers. The flow scheme is as shown in (Figure l). The Heat Recovery System is basically an absorber that operates at about 400°F and uses a boiler to remove the heat as steam instead of acid coolers where the heat is wasted. The invention that made this development possible is this: by increasing acid concentration in the absorber by less than 1%, rather common stainless steel alloys become virtually corrosion resistant up to over 4OO°F. The Heat Recovery towers have proven to be very easy to operate. In fact, they are no more difficult to operate than a normal absorption tower.

Existing HRS Plants

Seven Heat Recovery Systems have been started up to date.

Falconbridge in Norway was a new 270 MTPD smelter plant and the HRS was started up in early 1988. This plant was designed to operate either with or without the HRS boiler. Currently, the plant is running without the boiler.

The two 600 MTPD Dongbu plants in Korea were converted to double absorption and started up in May 1990. They also continue to run well.

The 1000 MTPD new sulfur burning plant for Tessenderlo was started up in September 1990. The initial HRS boiler, not built by Enviro-Chem, was defective and the plant operated on acid coolers until September 1991 when HRS was put into service.

At Namhae, the two 1300 MTPD plants were converted to double absorption and started up with the Heat Recovery System in late 1987 and these plants continue to run well today.

Since Namhae has been running the longest, I would like to give you more details on its start-up and operation. As I reported at the British Sulphur Conference in November 1988, there were some minor problems with start-up at Namhae. One was that absorber acid concentration was allowed to drop to 93% for a few hours, resulting in significant corrosion on the acid circulating pump impeller. Other minor problems included excessive vibration at the diluter. This was solved by providing a stronger structural steel support. Some Teflon piping at the diluter collapsed and was replaced with stainless steel. The most serious problem was that about one liter of drip acid per shift was being obtained out of the duct leaving the interpass tower. This was greatly improved by replacing the two inch Intalox packing in the upper stage with one and one-half inch Intalox. The plant met all process guarantees with a wide margin to spare. The Namhae plant continues to run well today.

The first Heat Recovery System in the USA was installed to replace the original interpass absorption tower on IMCF's 2500 STPD plant at New Wales, Florida. It was put in service in June 1991. The start-up went well with only minor problems such as excessive vibration of the diluter. This was cured by modifying the water sparger. There were too many flow measurement instrument problems and Enviro-Chem is determined to have instrumentation in better shape on future start-ups. The plant was demonstrated seven days after start-up and all guarantees were met. Testing at the outlet of the Heat Recovery tower showed mist was .24 mg/ACF and SO_3 and vapor was .27 mg/ACF which is as good or better than a typical interpass absorber. (Photo 1.)

About one month after start-up, IMCF detected some drip acid in the duct exiting the HRS. Internal inspection showed poor irrigation in the lower stage from a pipe distributor. Some improvement was made by moving some of the orifices in the piping header farther away from the distributor.

A second inspection in late August showed that lower stage acid distribution had deteriorated even more. Further inspection showed corrosion on the orifices in the acid headers and on the acid feed holes in the pipe distributor. The excessive corrosion was found only in the high velocity areas.

A secondary problem found was pluggage of the upper stage acid distributor with a black organic material. IMCF engineers identified it as being cation resin which had been charred by the acid. IMCF uses the cation backflush water for dilution. Therefore, IMCF will install a filter to be sure that the resin does not get into the acid system.

With temporary repairs made, the plant was restarted. Mist testing after start-up showed excessive sulfuric vapor and SO_3 leaving the tower. Lowering the strength of the acid being circulated over both the lower and upper stage resulted in quite good operation. The lower acid strengths compensate for the poor acid distribution over the lower stage. IMCF is now running with a good stick test at the exit of the absorber and no drip acid in the duct after the tower or in the economisers.

Enviro-Chem is fabricating a new trough distributor for the lower stage. This new trough design eliminates high velocity acid feed points. At the same time, we will also replace the one and one half inch Intalox in the upper stage with one inch Super Intalox saddles. The increased packing effectiveness will help compensate for acid distribution problems. These design changes will be part of all future HRS plants including the seven currently in various project stages.

Extensive testing, including mist and SO_3 sampling, is planned at IMCF. More tests are being made to determine if any other improvements are needed. Tests will be made after the modifications to assure us that the mist and vapor leaving the Heat Recovery tower is no greater than that found in the standard double absorption plant.

For IMCF and all of the current HRS plants that are being designed, a lot of thought has been put into dealing with an HRS boiler leak when and if one ever occurs. The basic concept is to get the acid, water, and steam out of the boiler very quickly. We have designed these plants so that if an acid leak occurs, the plant is shut down and within a few minutes, the boiler water is blowed down until the boiler is dry, the steam pressure is vented to zero atmosphere which quickly cools the boiler from 4OO°F operating temperature to about 212°F and the acid is allowed to run back into the pump tank. More instrumentation has also been provided. Printed information for operators is available that will make it much easier for them to detect boiler leaks. The new Heat Recovery units are even safer than the ones that have run very well for the last four years in Korea. In fact, we now have over 15 years combined experience with full-scale HRS with no injuries or catastrophic failures. (Photo 2.)

Current HRS Projects

Monsanto Enviro-Chem has major projects underway that include Heat Recovery Systems for Seminole in Bartow, Agrico at South Pierce and Texasgulf in North Carolina.

The Seminole project will consist of three Heat Recovery Systems and a 41 MW ABB turbine generator. Basic engineering on this project is complete and the project was approved by the Seminole board on September 5. The first of the Heat Recovery Systems are scheduled to start-up in August 1992 and all three will be operating along with the turbine generator in October 1992. Economics of the project were enhanced by debottlenecking the three sulfuric acid plants to 2200 TPD, and by replacing one of the 30 pound back pressure turbines on the acid plant main compressor with a 150 pound back pressure to give the desired site steam balance. The power produced will meet the needs of both the chemical plant and the Hookers Prairie mine. The remainder will be sold under a long-term agreement with Florida Power Corporation. There are provisions for the future addition of a gas turbine.

The project at Agrico South Pierce will include the improved energy recovery on the two sulfuric acid plants by new low temperature economisers, superheaters and Enviro-Chem's Heat Recovery System. The sulfuric plants' capacity will be expanded from 2100 TPD to 2500 TPD. A new 36 MW G.E. turbine generator is also being installed. Power generated will be used in their chemical plant and Fort Green mine. Start-up is scheduled for September 1992. By design, the Agrico, Seminole and IMCF HRS boilers are all identical so, if desired, they can share spare parts. This could even include a spare tube bundle.

Texasgulf authorized us in August to proceed with installation of Heat Recovery Systems in their two largest plants, one running at 3250 TPD and the other at 3600 TPD. Changes in product mix at Texasgulf and the installation of a phosphoric acid purification unit left them short of steam for the existing turbo-generator. The installation of the two Heat Recovery Systems will load this turbo-generator up and increase power generation and power sales.

In the new 3200 TPD plant that Enviro-Chem is building for Agrico at Uncle Sam, the Heat Recovery tower is being built, but the boiler is not being installed at this time. During the initial years of operation, the Heat Recovery tower will operate as a normal IPA tower. When the excess electrical generating capacity in the area has been used up so that the electrical utilities will pay a reasonable price for power, Agrico will install the HRS boiler and add the generating capacity to produce additional power.

IRS Economics

How can customers justify spending the capital to install HRS and the related generating capacity? The answer is that in every project to date, HRS has been an enhancement that has provided additional benefits to the customer. The HRS installations at Namhae and Dongbu were part of a conversion to interpass absorption. Tessenderlo was part of a new sulfuric plant. IMCF installed HRS instead of replacing a leaking IPA tower. Seminole will receive additional sulfuric acid plant capacity. Agrico at South Pierce will have additional capacity, as well as additional high pressure steam recovery. Texasgulf has loaded up their existing turbo-generator. We recommend taking a broad look to see if an HRS project can be developed that provides you added power generation from HRS, but also additional benefits such as capacity or reduced emissions. (Photo 3.)

As sulfuric acid plants near the end of their useful life, it may not make sense to spend the added capital to add the Heat Recovery System. In this case, replacing the old plants with a new energy efficient plant is probably the better alternative. Economics can be particularly good if two or more old plants can be replaced with one large modern plant. This option can be made even more attractive with the installation of Enviro-Chem's new Monarch" plant. Monarch combines the Heat Recovery System with a wet gas design and gives the very maximum power output with lowest capital cost. A paper was given on the Monarch process at the British Sulphur Conference in Cancun in 1990 and is available from Enviro-Chem.

While considering a new HRS project, a look at the addition of a gas fired turbine may be appropriate. The exhaust heat from the gas turbine can be used to super heat the HRS steam which significantly increases power output. Enviro-Chem calls this process Super HRS and will be the subject of a paper given at the 1991 British Sulphur meeting in New Orleans in November.

The obvious question is how much advantage will HRS offer in the market place. The value of the power produced from HRS alone at $0.05 per KW will yield an $11 per ton reduction in the cost of producing P205. Super HRS (the installation of a gas turbine) can boost this profit from sale of power to $23 per ton of P_2O_5. More significantly, firm price power contracts are available which assure power producers of getting about $0.10 per KW in the years ahead. This would bring the cost reduction per ton of P_20_5 to $22 to $46. It may be hard to believe that prices for power will go up so significantly in the future. However, considering the projected cost for producing electricity, the new coal burning power plants with all of the pollution controls, $0.10 per KW is not out of line. Further, it is difficult to believe that natural gas will continue to be available at today's very attractive long-term contract prices.

Summary

Monsanto Enviro-Chem' s Heat Recovery System is the most state-of-the-art process design available to maximize energy recovery. It is proven. We are celebrating the fifth anniversary of our first installation. Since then, six more have been installed, and seven are in construction.

HRS on these 14 plants will have a total power output of 76 MW, or 5% of the potential power from all sulfuric acid plants worldwide. HRS projects underway in the U.S. will produce about 60 MW or 20% of the power potential of the domestic fertilizer industry. If an equitable agreement could be reached between all fertilizer producers and utilities to receive a reasonable return for power, an additional 240 MW of power would be made available. The economics are there. Short-term simple payback, significant cost reduction in producing P2O5. Plus, there is potential of even more power output by installing a Super HRS.

Enviro-Chem has put eight years of effort into making our patented HRS a viable product. As of today, HRS has a combined experience life of 15 years. It works. It has great value. But go beyond the economics and think about the future. Not only our future, but the future of our children.

HRS provides the cleanest form of energy possible from your plants. It produces power without emissions from power plant stacks. It conserves our fossil fuels. It reduces our dependence on oil. And it makes us good citizens . . . working in harmony with the environment. That is one of the best legacies we can leave for future generations.

The Monsanto Enviro-Chem Heat Recovery System can make your operation more energy efficient, self-reliant, and cost-competitive. The rewards will be invaluable.

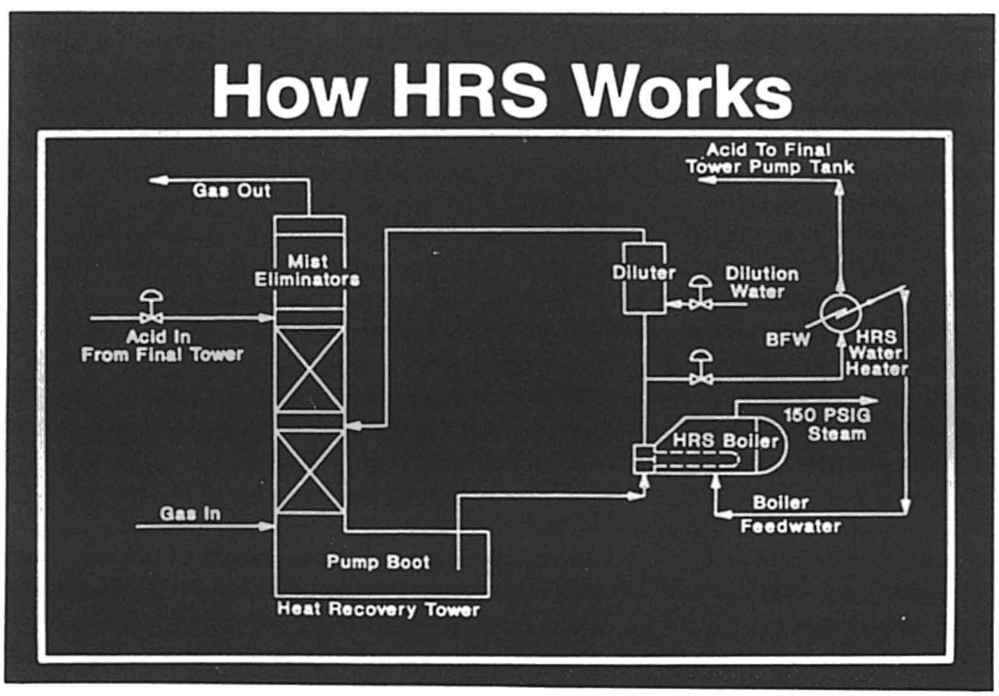


Figure 1 - HRS Simple Flow Diagram

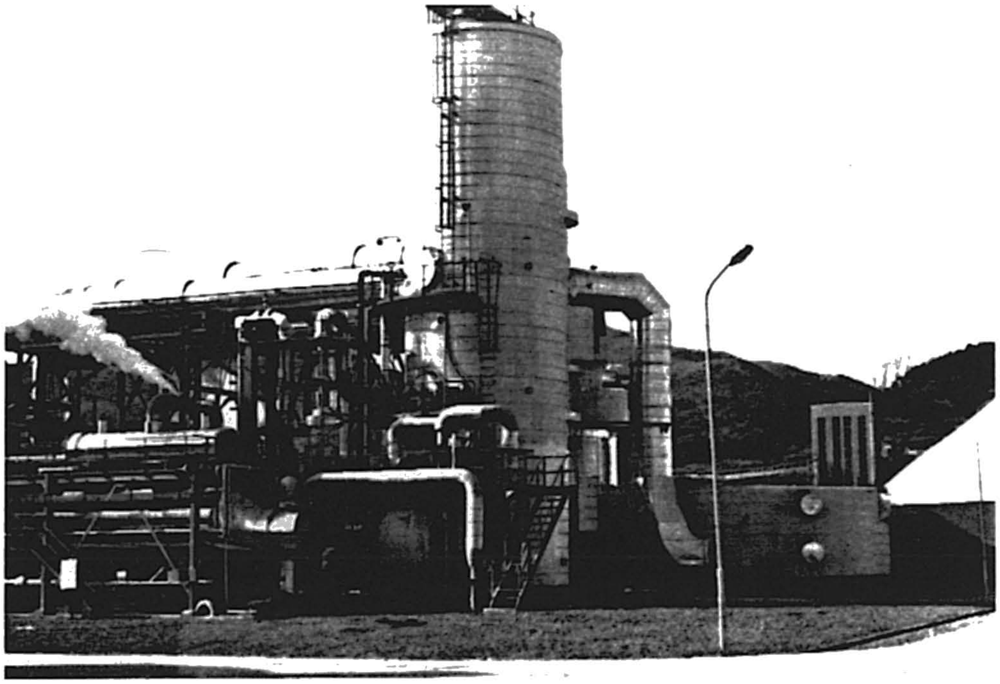


Photo of Namahe Heat Recovery System

Photo of IMCF Heat Recovery System

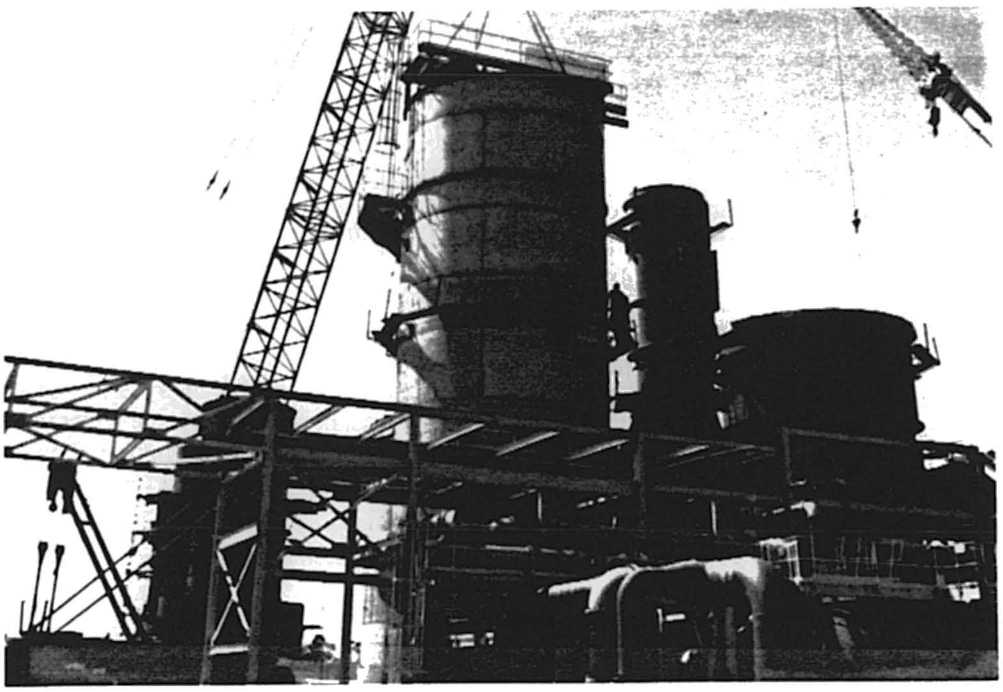


Photo of Agrico Heat Recovery Tower

The Theory, Design and Experience of Lamella Gravity Settlers in the Phosphate Industry

Sandra E. Wenk
Parkson Corporation

Abstract

Lamella Gravity Settlers (LGS) have been in use in the phosphate industry for 10-15 years, There are over 30 LGS units in operation in the United States, Mexico and South Africa.

An introduction and discussion of the basic theory of operation of the Lamella Gravity Settler (LGS) is included. The benefits of clarification using an LGS over conventional clarification techniques is examined.

Information on design criteria and performance parameters for the various phosphate applications is discussed along with an update on long-term maintenance and operating conditions.

Basic theory

The Lamella Gravity Settler (LGS) is an inclined plate, shallow depth sedimentation unit. As with any type gravity settler, the most significant aspect of its design is its available settling area. LGS units are designed on the basis of square feet of settling area, but using the inclined plate concept, the effective settling area becomes the area of each plate projected on a horizontal surface, multiplied by the number of plates (Fig. 1). Using a series of inclined parallel plates reduces the land area required. When compared to a conventional type clarifier, the LGS unit uses only 10% of the area, but provides the same total effective area.

(Figure 2.) shows a scale drawing of a conventional rake type clarifier and the equivalent LGS unit. The compactness produces other benefits than just the reduced space requirement. Cost savings of up to 40% are common when dealing with stainless alloys and rubber-lined steel for wetted parts.

Retrofitting existing plants with LGS units for additional clarification capacity can be performed by placing the LGS above ground to allow gravity flow of product or sludge.

(Figure 3.) is a cut-away drawing detailing the internals of construction of the LGS unit. The feed stream is introduced via the flash mix tank where a coagulant is introduced and is rapid mixed for approximately 10-15 seconds. It overflows into the flocculation chamber where a gentle mixing occurs using a picket fence type mixer for about 1-3 minutes. The flocculated stream is presented to the unit through a bottomless rectangular feed box. The feed flows onto the plates through side entry slots as it flows upward. The solids settle out on the plates while the effluent exits the plates through orifice holes. The holes are placed directly above the plates and are sized to induce a calculated pressure drop to ensure that the feed is hydraulically distributed equally among the plates. The solids slide down the plate into the sludge hopper. Further thickening of the sludge is done in the hopper due to compression in the quiescent zone made possible by feeding the plates from the sides rather than the bottom.

Initial pilot testing

Lamella Gravity Settlers have been installed in over 1800 sites in the U.S. In early 1973, Parkson Corporation discussed using an LGS as a phosphoric acid clarifier with USS Agri-Chemicals in Bartow, Florida. A small pilot unit was installed at the Fort Meade plant.

The plant had been experiencing increasing impurities in the phosphate rock. The production of phosphoric acid by the wet process produces a sludge by-product which contaminated the acid. The plant was using conventional acid clarifiers for the 30% P_2O_5, evaporating to 54% P_2O_5 and centrifuging prior to shipping. The heavy solids load caused problem with the clarifier rake assemblies. The centrifuges had increased maintenance costs and the removal efficiency was decreased. Shutdowns for maintenance and repairs became expensive The results from the pilot study were reported by Mr. Ralph York of U.S. Agri-Chemicals at the 1974 Central Florida Section AICHE meeting. (Table 1.) summarizes the results of the pilot test.

Applications

LGS units have been accepted by the phosphate industry for the acid clarification of 30%. 42% and 54% P_2O_5. (Table 2.) outlines the list of installations in the industry. A basic flow sheet for the phosphoric acid industry is illustrated by Figure 4. Data collection can be a sensitive issue with management, therefore a summary of units by acid strength is shown in (Table 3).

Actual operating results

Visits were made to plant sites to update the data available. Correlating the results shows that there is not a lot in common between plants, type of rock, how the units are used or in data collection. The phosphate rock is never the same twice and plants process it differently. Some plants report data on weight percent basis; others as volume percents. Figures 5 and 6 are typical flow diagrams for 40% P_2O_5 and 54% P_2O_5 respectively. Each has typical operating data as to influent, effluent and underflow solids and polymer doses. These results are very similar to the pilot test results (Table 1). A list of applications for the phosphate industry is shown in (Table 4).

Design improvements

Since the units were originally designed, a few modifications have occured with the plates, the effluent flumes and the hopper.

The plates are made from hand lay-up FRP (Hetron 197 or equal). They are suitable for the higher temperatures seen in the wet acid process and are chemically compatible. A new configuration with a center channel eliminated a possible 'nesting' problem. The original plates did not have the center beam, and were not notched on the bottom edges (see Fig. 7).

The effluent flume has to be changed to a slightly 'V' shaped bottom. This allows excellent viewing of the plates and easy access for cleaning.

The sludge hopper is totally bolted, which allows easy removal for cleaning.

Maintenance

The maintenance information available from plant personnel indicates the ease of operation and maintenance units are periodically washed on a general schedule to ensure proper working order. The plates need to be replaced approximately every three years due to the hot acid process. The rubber lining is replaced about every five years.

Table 1. U.S.S. Agr-chemicals.
Pilot test

40% Acid clarification			
Feed flow	Solids*, Weight%		
(GPM)	Feed	Products	Underflow
20	1.98	0.04	7.0
30	2.05	0.13	11.7
40	2.47	0.16	13.4
45	2.35	0.26	12.3
50	2.61	0.55	13.6
AVG all test data	2.52	0.33	12.4

*Average of test data at given flow

Table 2. Lamella Gravity Settler installations in the phosphoric acid industry

Company	No. units	Location
Beker Industries	1	Taft, Louisiana
Beker Industries	1	Conda, Idaho
C.F. Industries	2	Plant City, Florida
Esso Chemicals	1	Redwater, Alberta Canada
F.F.M.	1	Coatzacoalcos, Mexico
Farmland Industries	2	Bartow, Florida
FED-MIS	1	South Africa
Mississippi Chemical	3	Pascagoulis, Mississippi
Occidental Chemical	2	Lathorp, California
Occidental Chemical	2	White Springs, Florida
Simplot	1	Pocatello, Idaho
U.S.S. Agri-Chemicals	2	Bartow, Florida
U.S.S. Agri-Chemicals	3	Fort Meade, Florida
Seminole Fertilizer	6	Bartow, Florida
Western Co-op	1	Calgary, Alberta Canada
Mobil Mining & Minerals Co.	1	Pasadena, Texas

Table 3. Installations catagorized by acid strength

P_2O_5 Acid Strength	Number of Units
29-31%	5
40-42%	14
50-54%	6

Table 4. Proven application for Lamella Gravity Settlers in the phosphate industry

Application	Comment
1) 29-31% P_2O_5 Phosphoric Acid	Strong filtrate, hot
2) 29-31% P_2O_5 Phosphoric Acid *	Uranium recovery feed, cold
3) 40-42% P_2O_5 Phosphoric Acid	Interstage evaporator product
4) 46% P_2O_5 Phosphoric Acid *	Make-up acid to DAP, Blend of 30% & 54%
5) 50-54% P_2O_5 Phosphoric Acid	Final evaporator product, hot, unaged
6) 50-54%P_2O_5 Phosphoric Acid	Shipping acid, aged, reheated
7) Neutralized Plant Run-Off	Both single-stage and 'Doubleliming'
8) Calciner Rock Dust	Wet scrubber effluent
9) Phossy Water *	Electric furnace process
10) Mining Slimes*	Primary, secondary and mixture of both

*Proven on Pilot Test Basis

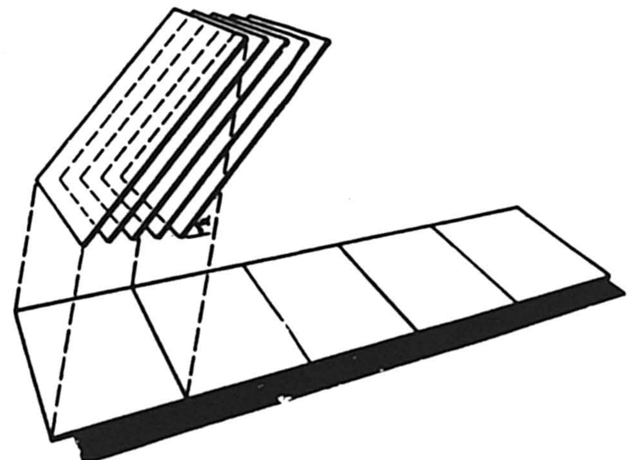


Fig. 1. Concept of projected settling area using inclined, parallel plates.

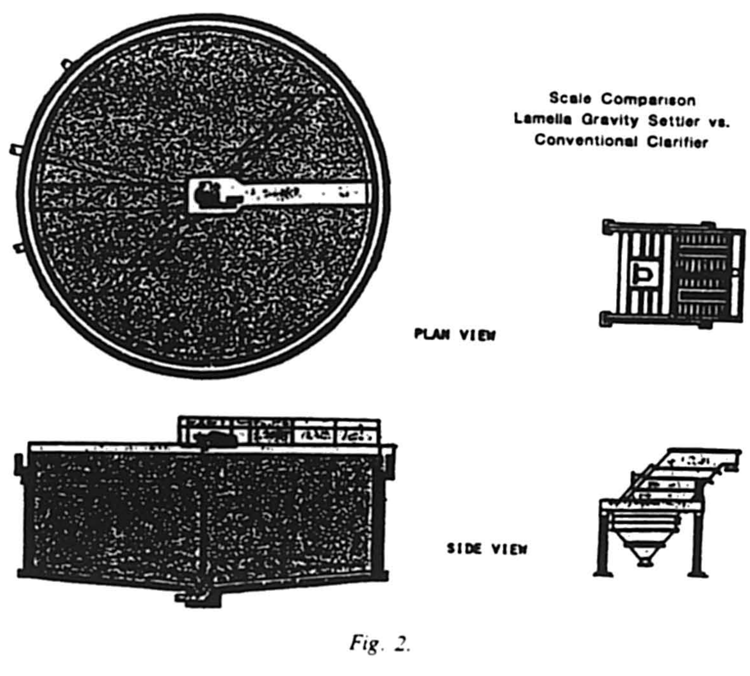


Fig. 2.

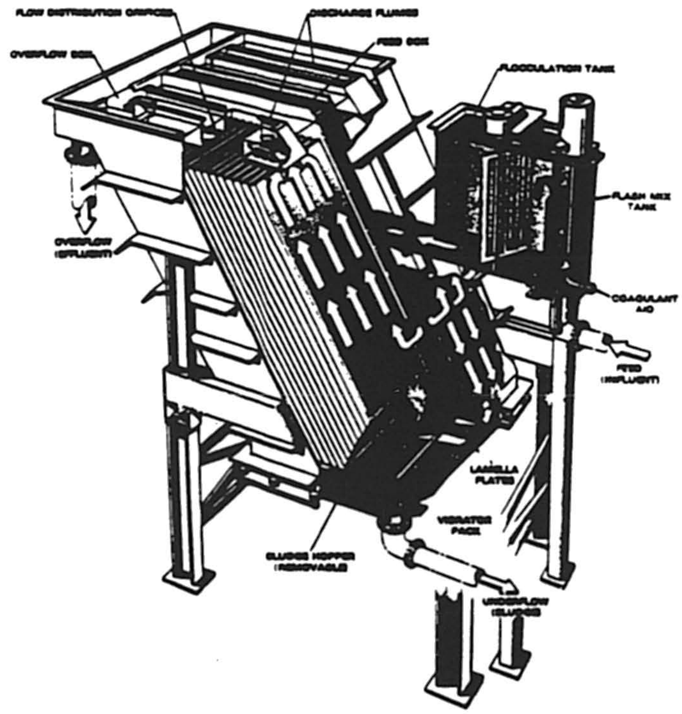
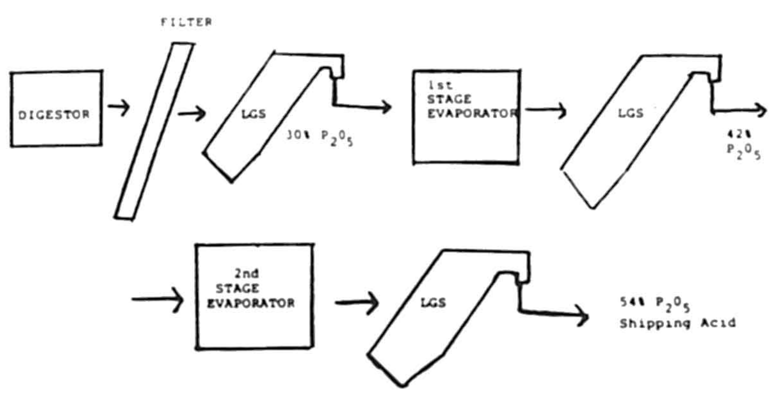


Fig. 3. Lamella Gravity Settler (LGS).



Phosphoric Acid Flow Diagram

Fig. 4. Phosphoric Acid flow diagram.

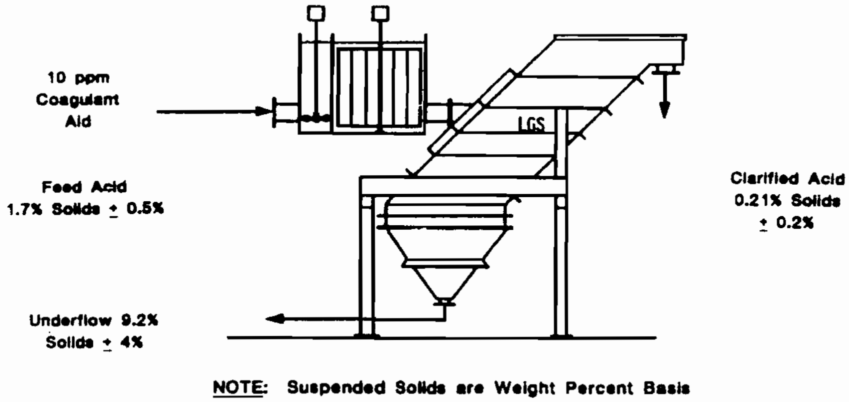


Fig. 5. Flow diagram – 40% P_2O_5 Phosphoric Acid 0.1 gpm/ft.^{2}.

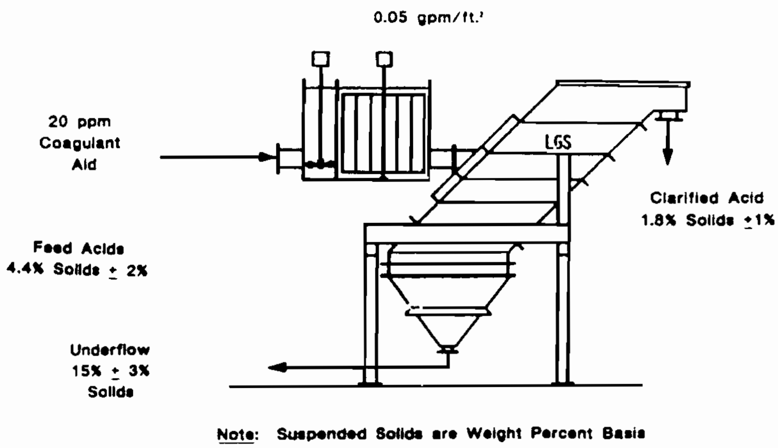


Fig. 6 Flow diagram – 54% P_2O_5 Phosphoric Acid (HOT).

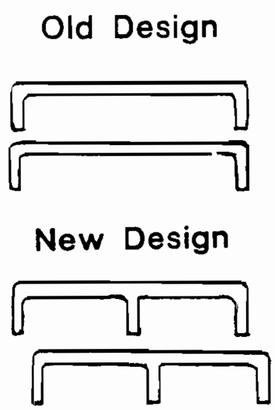


Fig. 7. Plate configuration.

Wednesday, October 23, 1991

Session V
Tour of Phosphate Facilities

Organized by:
David Leyshon

Tour of Phosphate Facilities

At approximately 8:00 A.M., the group left the hotel by buses and proceeded to the Phosphate Museum at Mulberry, Florida. Here museum director Gary Hacking gave the Round Table participants an interesting and informative talk on the history and contents of the museum and an archeological history of the phosphate fields.

Following this, the group, under the direction of Joe Shaw and Larry Peace of IMC toured the IMC facilities at the New Wales location and then visited an operating drag line of IMC's mining sites.

The Fertilizer Industry Round Table is most appreciative of the hospitality extended by Gary Hacking and the Phosphate Museum, by IMC, by Larry Peace, and by Joe Shaw, who we have learned with sadness has since passed away.

FINANCIAL STATEMENT

November 12, 1990 to October 20, 1991

Cash Balance November 12, 1990		$20,447.97
Income November 12 1990 to October 20, 1991		
Registration Fees - 1990 Meeting & Cocktail Party Receipts	7,981.72	
Sale of Proceedings	1,538.29	
Registration Fees - 1991 Meeting & Cocktail Party Receipts	16,490.00	
Total Receipts November 12, 1990 to October 20, 1991		$26,010.01
Total Funds Available November 12, 1990 to October 20, 1991		$46,457.98
Disbursements November 12, 1990 to October 20, 1991		
1990 Meeting Expenses (Incl. Cocktail Party)	8,117.70	
Misc. Expenses Incl. Postage, Stationery, etc.	138.39	
Directors Meetings	1,266.90	
1990 Proceedings, Incl. Postage, etc.	8,697.86	
1991 Meeting - Prel. Expenses	2,000.27	
Total Disbursements November 12, 1990 to October 20, 1991		$20,221.12
Cash Balance October 20, 1991		$26,236.86

Respectfully submitted,

Paul J. Prosser, Jr.
Secretary/Treasurer

Meeting Attendance: 177