PROCEEDINGS
OF THE
28th ANNUAL MEETING
FERTILIZER INDUSTRY
ROUND TABLE
1978

October 31, November 1 and 2, 1978

Sheraton-Biltmore Hotel
Atlanta, Georgia

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Tuesday, October 31, 1978

Morning Session
Rodger C. Smith, Chairman

Harold D. Blenkhorn, Moderator

OPENING REMARKS- CHAIRMAN SMITH: Ladies and Gentlemen.

Welcome to the twenty-eighth Fertilizer Industry Round Table. Yes, this is the twenty-eighth. People occasionally ask why the name "Round Table". The answer is quite simple - the first meeting was around a Round Table with about 30 persons concerned about analysis control, granulation technology which at that time was new and other areas of endeavor not differing greatly from the subject matter of this meeting.

The Round Table was initiated as a forum for those working in fertilizer technology and actual production. The strength of the Round Table has been and continues to be that it is a forum and source of pertinent, useful information for primarily production management and operating personnel from North America and several other countries. Indeed, we welcome the presence and participation each year of those of you from overseas. As you have noted, we are fortunate this year in having several speakers from other countries.

In recent weeks I have met with technical and production staffs of fertilizer manufacturers in several European countries. Let me assure you that fertilizer technology is alive and well in Europe, although their fertilizer industry has been somewhat depressed during the past few years.

It is a challenge to all of us in United States and in other countries to vitalize the search for ways to economically manufacture plant nutrients in forms and composition that produce large, nutritious crops, that minimize transportation and handling costs and that do not, in fact, detract from the environment. And let me quickly add that for this service the fertilizer industry deserves a satisfactory profit. Herein lies part of the difficulty of assuring new technical developments, which starts with adequate public and private funding of agronomic and technology research.

It should be said, however, that the fertilizer industry and consumers worldwide are fortunate to have the National Fertilizer Development center and the International Fertilizer Development Center at Muscle Shoals. While I was Chairman of the T.F.I. Government Liaison Committee in recent years, two joint industry-public agency groups were formed, called The Phosphate Workshop and The Granulation Workshop which are actively pursuing answers to problems critical to progress of these two important sectors of the United States fertilizer industry. We need to find other ways to keep the investigative process active and productive. As a forum for fertilizer technology, your Round Table helps to communicate and to generate new ideas which are a very important asset for any industry.

Your Board of Directors have again put together what many have been free to acknowledge is an excellent program. Your Board is to be commended for the fine spirit in which they accomplish this task annually. I express my appreciation to the Board, to each of the speakers on this 1978 Round Table and to the moderators.

I shall now call on Joe S. Drewry, Jr., of our Board of Directors, to introduce our first Speaker. (Applause).

Introduction
The Hon. Thomas T. Irvin

Joe S. Drewry

Thank you, Rodger. Ladies and Gentlemen, welcome to Winnersville. Those of you that saw that game last night know what I am talking about. Our professional hockey team is leading the National Hockey League, our basketball team won, the University of Georgia won over the weekend, Georgia Tech won, and last night the Falcons won. What a weekend, and we're off to a good start. Our welcoming speaker is also a member of that team.

It is a real privelege for me to introduce to you my good friend Thomas T. Irvin, Georgia Commissioner of Agriculture.

A native of Hall County and the son of a tenant farmer. Commissioner of Agriculture Tommy Irvin was reared on farms of northeast Georgia. Today, he and Mrs. Irvin live on a farm in Habersham County. They are the parents of five children.

Commissioner Irvin lost his father in an accident when he was a teenager. As the eldest of five children, he entered business for himself to help support the family, and by the time he was 25 years old, he was generally recognized as one of northeast Georgia's most successful young businessmen.

A past president of the Georgia School Boards Association, Mr. Irvin was elected to his first public office as a member of the Habersham County Board of Education in March 1956 and served continuously until his resignation at the end of 1975. In November of 1956, he was elected State Representative from Habersham County and served four terms, including service on the House Agricultural, Education and Appropriations Committees, as chairman of the Industrial Relations Committee and chairman of the Governor's Conference on Education. In 1967, he served as Assistant Administration Floor Leader in the House and later was named Executive Secretary to the Governor.

Appointed Georgia Commissioner of Agriculture in January 1969, in November of the following year, he was elected by nearly a four to one majority to a full four-year term in this office and was unopposed in his bid for a second full term in 1974. Several weeks ago Commissioner Irvin was elected to another four-year term.

Achievements in his home state have not only brought him prestige and recognition in Georgia; also on the national scene as well. He has served as president of the 16 state Soutern Commissioners of Agriculture organization and as an influential member of the National Commissioners Association. His voice is respected in the legislative halls of Washington as in his native state. He serves as chairman of the important Plant Industry Committee for the National Association of State Departments of Agriculture; on a National Task Force for Land Use Planning Research and as a trustee of the Livestock Merchandising Institute.

He is a member of Alpha Gamma Rho, an honorary member of Alpha Zeta national agricultural fraternity and a member of the University of Georgia chapter of Aghon, agricultural honorary society.

Tommy Irvin is recognized as one of Georgia's most active state officials. He has visited, and continues to visit, virtually every community in the state to insure that he remains personally familiar with the problems and progress of Georgia agriculture as well as consumer needs. (Applause).

Welcome To Georgia

Thomas T. Irvin

Thank you very much, Joe, for that over-introduction, but I am mighty greatful for it, and let me say that it is indeed a pleasure that you afforded me the opportunity to welcome you back to Atlanta. As you have already been told, I'm a country boy, raised on a tenant farm, and I guess most of you know what that is. I thought maybe I might mention a few little things that happened back earlier in life. If it had not been for the feed industry and the fertilizer industry back when I was a young lad, I doubt very seriously if most of we country folk here in Georgia would have anything to wear. I remember my first day at school. Now I believe I've got this correct. If I don't, well, somebody can correct me. My mother sent me off to school in a brand new shirt made out of a used guano sack. Now, did that throw you? And I believe the name on that guano sack was VC and the analysis was 9-3-3. And I want to tell you, I had a brand new pencil, and I believe it had Royster right across the front of it, too. I want to make sure we get in both brands. Maybe during the year I added a couple others. Seeing a couple, maybe more than two, of lovely ladies here, reminds me of a beautiful young girl we had in our community. Of course, her folks were poor folks, too, much like my parents, but her mother was a good seamstress too, and I remember how this girl likedto really dress up. She used to really like to catch everybody's eye. Her mother made her one real beautiful outfit and it was really an eyecatcher. She made the blouse out of a flour sack and the skirt out of a meal sack, and when she put that outfit on and wore it dowtown, you'd see her coming down the street and right across the front of that flour sack blouse it would say "self rising". As she'd walk on by, that meal sack skirt, and I want to assure you, now, as much as my shirt, we had trouble with that old red devil eye soap that we'd make out in the back yard, getting all of the letters and the figures out of the used sacks. But this meal sack skirt, as she would walk by, you could read right around the bottom. It said "get your grinding done here". Now, we like to talk about those things but it is really a lot of our history in the South and throughout America and I think that we can look back and be justly proud of what we have been able to accomplish over these last decades. You, who have visited Atlanta many times, you know the progress that we have made here. You know the progress we have made in modern agriculture and I like to brag about the progress we have made here in the South just in the span of my lifetime and where we have come from and where we are going.

You people in the fertilizer industry, helping to work with our professional people at our universities and new modern techniques of agriculture, have really brought us a long way. I'm not going to bore you with the statistics of agriculture here in Georgia and throughout the Sun Belt because all of you, I am sure, are just as familiar with this as I am. But it leads me to really believe that the future of food supply, of supplying food for an ever expanding world populace, that the activity that is going to happen in the next few years is going to happen right here in this region of America. We know we have the greatest reserve of land that you will find anywhere in the world, that is suitable for food production, so even though I look back on times that have happened in the last two years in our state due to the lack of rain at the proper time, and the set-backs that we have had and the fact that a lot of people in agriculture are pessimistic, I like to be optimistic about what I think our future has. I believe that you are going to help make all of these projections come true, so I wish you every success in your visits here. We want you to come back often. We want you to keep full confidence in the future of the greatest industry of all, — agriculture, here in this region of the world.

As you have already been told, I am one of the few Commissioners of Agriculture in America that is elected. In most of the states, you know, they are appointed by the Governor. We work very hard here, in this region of the country, to get involved in market development, development of markets for our commodities worldwide and we think there's a great potential and we think there's a great future. This is one of the things that I put at the top of my so-called "platform" for election, which I just won a few weeks ago for another four years.

We appreciate the cooperation we have with our chemical industry, our plant food industry and our regulatory programs. You work very close with our regulatory agencies, but I like to say that I'd like to see the time come when government can become less involved in regulatory work and let you, the people who do the manufacturing and supply of our products, become active in trying to do more of the work yourself. As a matter of fact, I would like to see less government rather then more government. I would like to see the Federal government get less involved in trying to call all the shots in our industry. Quite often in our meetings at the national level, we find ourselves at odds with certain Federal agencies. They try to encroach upon the authorities of local government and the authority in which we have to work close with you. As a matter of fact, we find ourselves many times interceding on your behalf. We expect to continue to keep that fired up. Let us keep our government as close to the people as possible, and let us keep the government as much out of our business as possible. Let us hope that your trade associations will become more responsible in the future, will become more involved in trying to educate the public that there ain't nothing free. If you're going to have more involvement of government in your business, someone's going to have to pay the tab. So, as you open your conference here, let me wish you a very productive meeting and invite you back to Georgia at your earliest convenience. Thank you. (Applause).

DIRECTOR DREWERY: Thank you Commissioner Irvin for that excellent kind message. Please remain with us as long as your time will permit.

CHAIRMAN SMITH: Thank you Joe and Tom.

It is now my privelege to introduce our keynote speaker, Mr. Frank Wooten. It is always a pleasure to be with Frank, a leader, good administrator and a real gentlemen. Frank is a native of North Carolina, source of many leaders in this industry, and a graduate of North Carolina State University. For several years he was employed by Armour Agricultural Chemical Company, including Vice President, Marketing. During the past 13 years he has been with Kaiser Agricultural Chemical Company, where he is Vice President and General Mgr. Frank was recently Chairman of the Board of Directors, The Fertilizer Institute, in which capacity he did an outstanding job. Frank, we welcome you to the 28th Round Table Meeting. (Applause).

Keynote Speaker

Frank L. Wooten

Thank you Rodger.Gentlemen, it is unusual for me to be asked to deliver a keynote address, and I want to tell you at the very beginning that it is not my intent to delve into the many areas of technology. It is not my intent to try to inspire you to any greater things in your position, but it is my intent, hopefully, to give you a little food for thought and a little reason to believe that it is time to act, and it is time to act by you.

In July of 1876 the body of General George Armstrong Custer was found near the crest of a small hill close by a then-unknown stream called the Little Bighorn. They found him reclining against the carcass of his horse, naked, with only one small wound in his chest, unscalped, but quite dead. He was surrounded by the remains of his unfortunate command.

Custer came to that particular hill on that particular afternoon as a result of ignorance . . . arrogance . . . bad judgment . . . and negligence.

Custer's small band faced the largest assembly of Indians that had ever come together on the Plains. But he was *ignorant* of their number because he totally disregarded the word of his scouts who told him they were going up against an Indian force larger than any of them had ever seen before.

In his *arrogance*, Custer felt that, under his brilliant command, his men were more than a match for anything or anyone.

Poor Judgment led him to divide his already small force into three separate units.

And *negligence* caused him to fail to establish any communications link between them.

Naked and dead in the summer sun on a lonely hill in Montana— the victim of ignorance . . . arrogance . . . bad judgment . . . and negligence. Ladies and gentlemen, there is a lesson here for all of us, but I'm afraid we haven't learned much in the intervening one hundred-odd years.

Business and industry in this country has been, and is, guilty of ignorance, arrogance, bad judgment, and negligence.

Labor in this country has been, and is, guilty of ignorance, arrogance, bad judgment, and negligence.

Education in this country has been, and is, guilty of ignorance, arrogance, bad judgment, and negligence.

Government in this Country has been, and is, guilty of ignorance, arrogance, bad judgment, and negligence.

We are on our way to a national version of "the Little Bighorn."

Our national leaders attract attention to their jousts with windmills like three-martini lunches, snail darters, and human rights in Chile, while the real problems are gnawing our legs off up to our knees.

The real problems . . . the problems which, if we do not solve them very soon, will undermine our entire way of life . . . the real problems are:

(1) inflation,
(2) unemployment, and
(3) energy.

I am not suggesting that tax loopholes where they exist, or environmental concerns, or human rights in other countries aren't important considerations. They are. But in terms of the problems this country faces, here and now, they pale into insignificance.

Business has left, is leaving, or is staying away from, our cities. Restrictive union rules discourage or prevent many youngsters from getting training or employment in skilled areas. Unrealistic minimum wage laws deny youth the vital experience of at least holding a job.

We cannot allow these things to continue.

Government make-work projects aren't the answer. The answer is jobs of substance that build pride and provide at least a glimmer of opportunity and hope.

Inflation, unemployment, energy— these are the critical problems facing our country today. There is only one way to solve them. The only way to solve these problems is for the groups who have the most to lose if they are not solved to come together and work like hell on the solutions . . . now!

The groups I have in mind are labor, business, and the nation's political system.

We all have a common interest at stake.

Inflation robs us all. Unemployment robs us all. Lack of energy development robs us all.

You'll notice that I haven't put government in this equation. Government has an important role to play, but the directions and the real solutions have to come from the people who have something to lose— who stand to be hurt if solutions aren't found. Government and politicians don't have anything to lose. You may recall that government did all right during the Great Depression. It was the people who suffered.

For too long, government has been unresponsive to the real needs of the people. We've failed to recognize that like all our institutions, government must change too.

We need to make our elected representatives more representative. More interested in solving problems than in reelection.

We can find those sorts of people if we make some changes to allow elected representatives to concentrate on the business of government rather than on the business of vote-getting. Changes like limiting the presidency to one six-year term; increasing the term for members of the House of Representatives to four years and limiting them to three terms; limiting senators to two six-year terms.

There is only one way we can pull ourselves out of this trouble— and that is to do it ourselves.

Government is not the answer. We are the answer. None of the things that must happen will happen— unless we make it so.

I believe we can make it so— if we will accept the responsibility and work together.

How, you say, does this pertain to us?

(a) Our 2.8 million farms constitute 20% of all private business in this nation.
(b) Farmers this year will have spent about $85 billion on production expenses and $40 billion on family living.
(c) Farmers operate over 4 million tractors and about 3 million trucks.
(d) They maintain assets of approximately $600 billion and pay interest on over $90 billion in loans.
(e) The production-processing and distribution of food and fiber account for 1/5 of the gross national product and provide jobs for 15 million people.

Why should the average american be interested in agriculture?

(a) Agriculture has produced a surplus to the U.S. trade balance every year since 1960.
(b) The fiscal year for trade balance is October 1 - September 30
    (1) In 1977-78 October through July total exports have been $107.6 billion with ag products $22.6 billion on the way to

an apparent record 26-27 billion. To date there is a $40.9 billion unfavorable balance in total but a $10.9 billion favorable ag balance.

Why not go back to 1950 (The good old days)?

(a) In 1950 the U.S. consumed 1.0 million tons of N and 4.1 million tons of total plant food nutrients. In 1977 we consumed 10.6 million tons of N and 22.1 million tons total nutrients.

(b) In 1950 we harvested 81.8 million acres of corn and in 1978 67.8 million acres. In 1950 81.8 million acres. We harvested 3.0 billion bushels or 37.6 bushels per acre. While in 1978 we will harvest 6.8 billion bushels or average 100.7 bushels per acre.

(c) In 1950 we exported 4% corn, 37% wheat and 9% soybeans. In 1977-78 30% corn, 55% wheat and 41% soybeans.

Now — Today— we have approximately 3 million tons of nitrogen production capacity shut down. By January we estimate some 37% of our nitrogen production will be produced from $2+ gas. In 1978 we will import more nitrogen than we export for the second consecutive year with a strong possibility of further import growth if price pressures continue.

Speakers that follow will cover supply demand on NPK. But I would like to state that if all the plants losing money on feedstick costs were to close, we would not have enough capacity domestically to produce food much above the 1950 level. I believe in the free enterprise system. I believe in free world trade but let me leave you with this thought—

There are vast differences in social and economic levels among people of many countries and governments differ dramatically. History records such statements from some government leaders that they eventually will control the world without firing a shot.

Imagine if you will a U.S. nitrogen business providing about 1/2 the need from U.S. production, 1/2 from imports for crop production. January 1, 1978 cables to U.S. nitrogen importers that 0 nitrogen available for indefenite period. We become in one year a major food importer.

Yes— Rachael Carson — there may be a silent spring — but for a different reason. (Applause).

CHAIRMAN SMITH: Thank you Frank. Your contribution is very informative and much appreciated.

Now let us commence our first session for which Director Harold Blenkhorn will be moderator. Harold is a Nova Scotian who graduated from McDonald College following which he was employed in soil fertility by the Canada Department of Agriculture. For the past 18 years he has been with Genstar where he is Manager Technical Service. During several of those years he has - been a very active Director of the Round Table - Harold. (Applause).

MODERATOR BLENKHORN: Thank you, Rodger. It's a pleasure for this Northerner to be in this great city of Atlanta. As Rodger told you, I was born in Nova Scotia which means I am up there amongst the New Englanders, and if I chose to, I would call myself a Yankee, but I am somewhat familiar with historic events that shaped, or rather re-shaped, this city of Atlanta so when I'm down in these parts, any claim I might have to calling myself a "damn Yankee" I simply won't choose to do so. A "damn Yankee" or whatever else you call them down here.

As is the custom in the opening session of the Round Table, we devote the first part to a review of raw materials supply. We are fortunate in having with us today a line-up of speakers who are well-qualified to discuss the status of raw materials on both a national and an international scale. One thing I neglected to tell them was that we are hungry for good news. Give us something to smile about when we go away from here. Anyhow, I haven't much control over that. They have to call it as they see it. We will review raw materials in the time-honored sequence, covering nitrogen first. This will be covered by Gene Graves of Agrico. Mr. Graves holds a Bachelor of Science and a Masters Degree in Business Administration from the University of Chicago. He has a background in the petroleum industry, joined Agrico in 1970 as Manager of Economics. He was appointed to his present position, Vice President — Planning and Economics — in 1975. It is with pleasure that I introduce Mr. Graves. (Applause)

Nitrogen Outlook

E. B. Graves

Much has been written about the nitrogen situation not only in the U.S. but throughout the rest of the world. This is particularly true during the last year or so in view of the relatively large level of surplus that we find ourselves with at this time.

In fact, the October 9th issue of "Business Week" would suggest that we hang a black wreath on the nitrogen industry.

I don't think anyone here this morning believes that it is quite as bad as that article, and several others that I have seen, suggests. However, these surpluses should not have been a surprise, if we had really done our homework several years ago.

In assessing the nitrogen outlook, I want to review briefly the factors that led to the present situation. Let me begin by summarizing for you what I consider the four distinct periods associated with the current nitrogen outlook.

Slide No. 1
Four Periods of Nitrogen Outlook

FOUR NITROGEN PERIODS

- Euphoria
- Me Too-ism
- Realization
- Opportunity

I call these four periods: Euphoria, Me Too-Ism, Realization, and Opportunity. Euphoria was the state of mind during 1973-74. It seemed that regardless of who prepared it, the outlook just couldn't be better in terms of pricing, supply/demand, etc.

This was then followed by a period of Me Too-Ism, resulting in rapid construction as companies began to implement what they saw as a rather rosey road ahead.

The Realization of what we have done to this industry was masked by the gas curtailment during the 1976-77 fertilizer year. However, it began to soak in last fall. That leads us to the period beginning in 1979, which I have chosen to call the period of Opportunity.

Let's now go into a little more detail on these various periods.

Slide No. 2

During the 1973-74 period, the supply/demand outlook generally showed a period wherein the domestic demand for nitrogen was growing anywhere from 4-8%, depending on who made the forecast.

Supply, on the other hand, was generally considered to be restricted primarily because of the lack of natural gas, coupled with such things as construction lag time and the inability to line up adequate import materials necessary to meet the projected short fall.

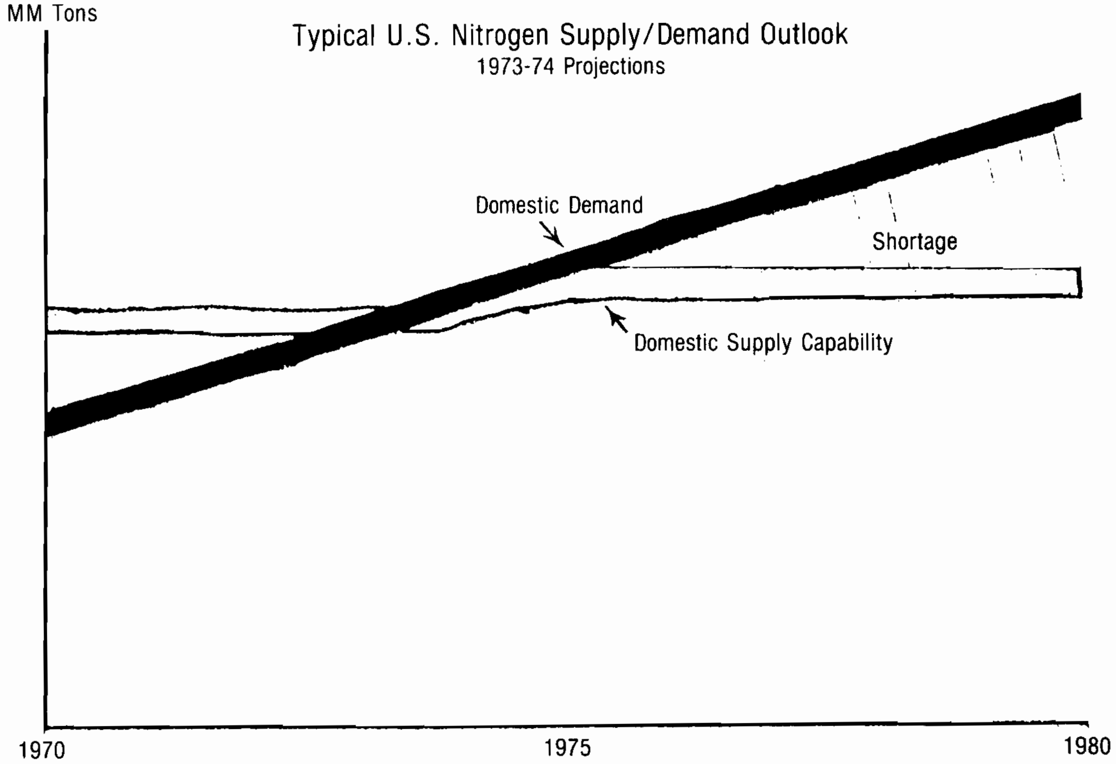
Many of you here this morning may remember reading articles which highlighted such comments as "If you think we had supply problems in 1974, just wait until next year."

This kind of outlook was not without some foundation. After all, the world price for ammonia was up to levels of $300-$400 per ton and it seemed highly unlikely that these would drop appreciably over any foreseeable period.

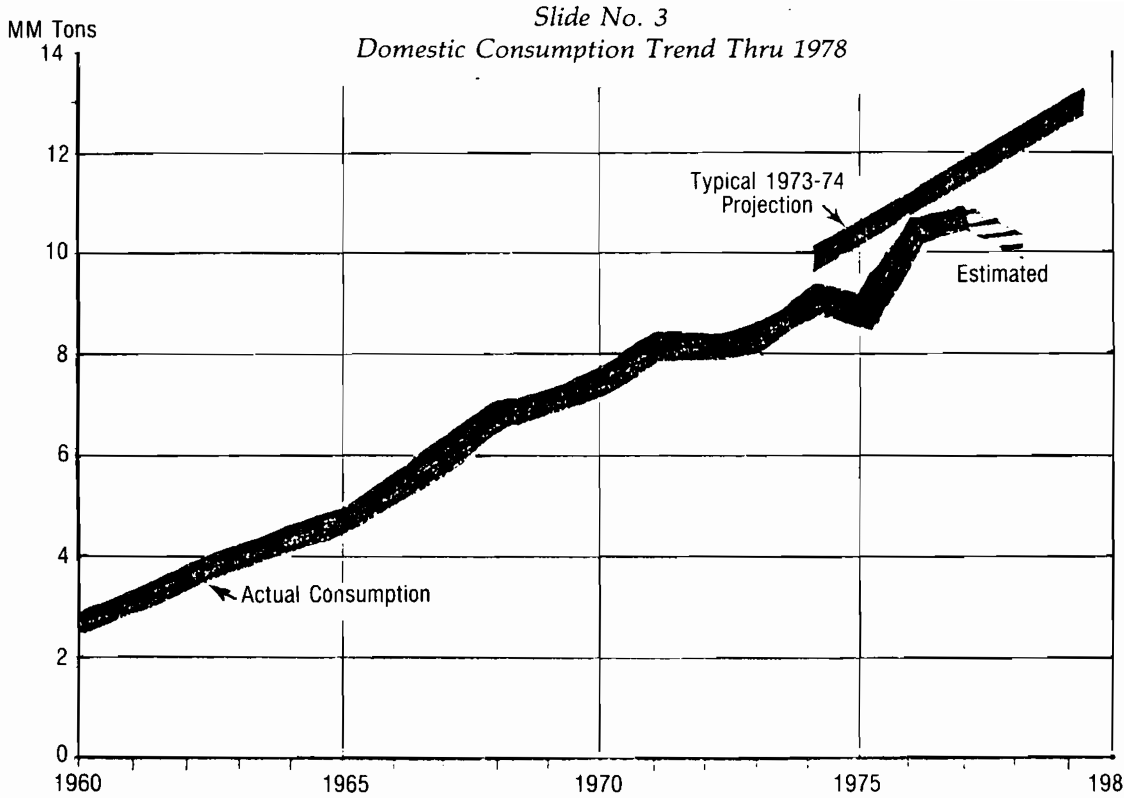
Obviously, no one really thought they would stay there indefinitely; but on the other hand, no one anticipated that they would drop to the levels that we are now experiencing. Thus, as board room after board room reviewed these supply/demand outlooks, in true "Me Too-ism" fashion the dye was cast for the situation that we find ourselves in today.

Market researchers were not totally without support from outside sources. I can recall reading numerous articles during the shortage period which basically said no one really knew what the domestic demand for nitrogen really was, but it certainly had to be far above anything that could possible have been produced during this time period.

Slide No. 2
Typical Nitrogen Supply/Demand Outlook—1974



Slide No. 3
Domestic Consumption Trend Thru 1978



Slide No. 3

As this slide indicates, consumption did not grow as fast as most people were predicting back in 1973-74.

Although nitrogen consumption hit a record high of 10.6 million tons during 1977, this did not begin to approach the level that many people were anticipating 3-4 years earlier. In fact, some people felt that, as early as 1974, demand for nitrogen was actually 10.5-11 million tons.

You will also notice that we actually had a dip during 1975. This was hardly anything that was anticipated just a year or so earlier.

Slide No. 4

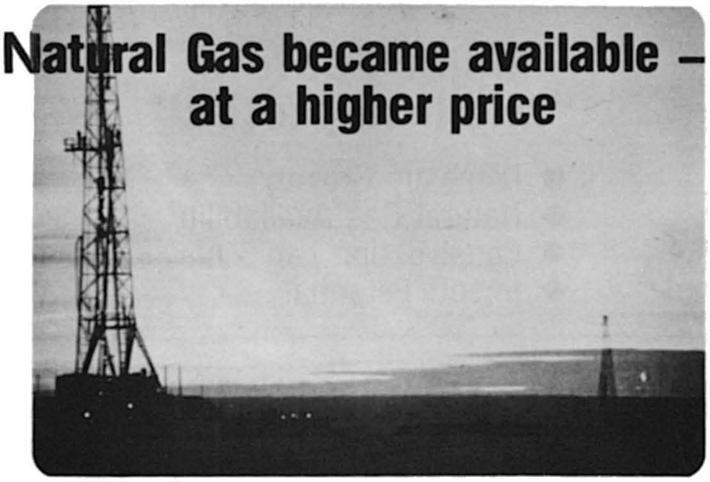
Contrary to what most people were predicting during the height of the industry crisis of late 1973 and early 1974, natural gas did become available for use as a feedstock to produce ammonia.

This gas was primarily located in the large producing areas, Louisiana and Oklahoma, and thus was available at intra-state prices as opposed to the federally controlled interstate prices. Nevertheless, it did become available in a quantity that no one could have predicted earlier.

It also goes without saying that price levels of the new intrastate gas were far above anything conceived of during the 1973-74 period.

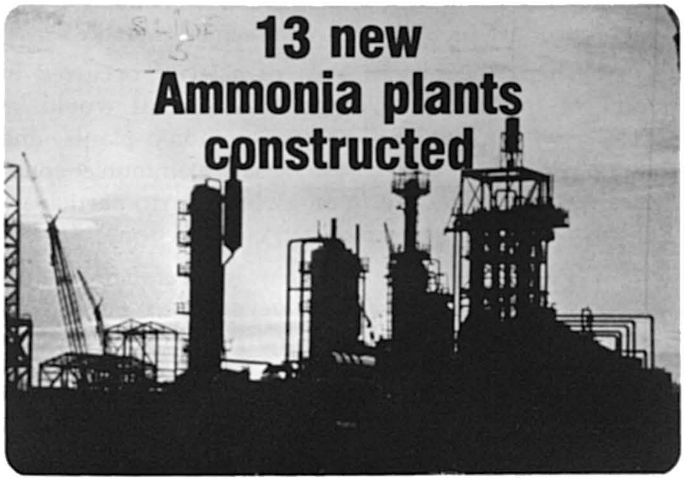
In view of the availability of the natural gas, plus the desire on the part of many companies to be at the

Slide No. 4
Natural Gas Availability



Natural Gas became available –
at a higher price

Slide No. 5
New Ammonia Plant Construction

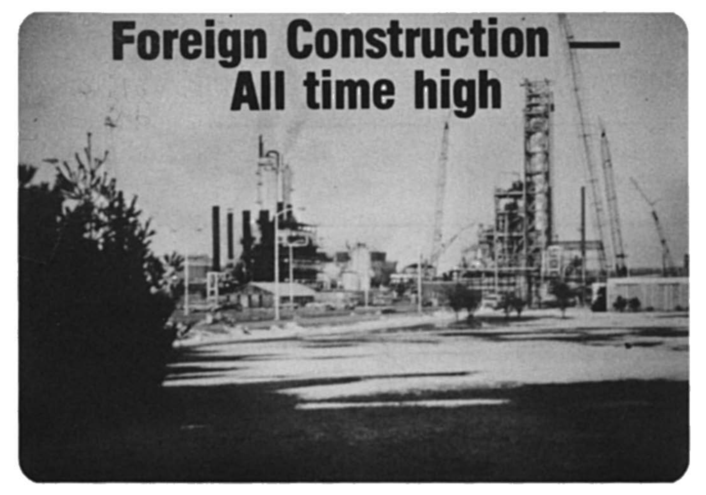


13 new
Ammonia plants
constructed

forefront of any new plant construction, we had a total of 13 new ammonia plants constructed within a two-year period. This was much faster than anyone could possibly have anticipated. These 13 new ammonia plants increased our total supply capability by about 5 million tons of ammonia.

Despite the fact that the cost of constructing plants such as these tripled and even quadrupled from levels of only about 3-4 years earlier, plants were nevertheless being constructed at record rates.

Slide No. 6
Foreign Construction



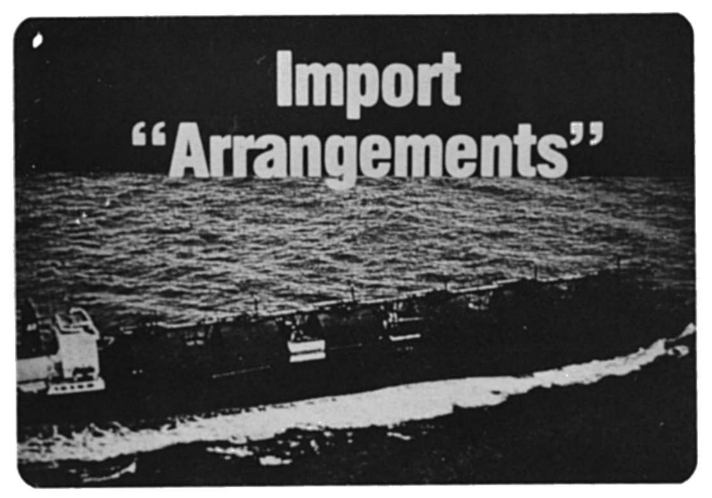
Along with the domestic construction, foreign plants were also being constructed at record rates. New plants were being announced on what seemed like a daily basis.

Gas availability throughout the rest of the world is obviously quite scattered. And, in some cases, gas was actually not being used and, therefore, production of a useful product such as ammonia seemed to make sense.

Perhaps the biggest area of activity occurred in some of the most unlikely places — that would be Russia, with about 30 - 40 new ammonia plants, and China with 13. In both cases, we saw Communist countries turn to Western technology in order to participate in this rapid growth of nitrogen construction.

We also saw countries such as India embark upon a major construction effort. However, their major construction is not yet complete and they still represent a major import country. Red China, of course, is also still importing substantial quantities, and most people expect them to continue to import at relatively large levels for some time to come.

Slide No. 7
Import Arrangements



As a result of the previous estimate of the shortage of nitrogen within the U.S., and the unavailability of natural gas in order to construct new facilities, some companies embarked upon barter arrangements in order to bring in large quantities of nitrogen into the U.S. This was based on exchange of both ammonia and urea for phosphate materials which have been major export items of the U.S.

In dealing with foreign countries, there seems to be a long time element in arriving at the final negotiations. therefore, we have only begun to see some of the nitrogen materials coming into this country as a direct result of the negotiations that have been going on for the past 4-5 years. Thus, we found that new supply can be made available very quickly, given the right set of circumstances.

Looking back, what really happened to the market research that was done during the 1973-74 period?

Slide No. 8
Major Factors Misinterpreted

Major Factors
"Mis-Interpreted"

- Domestic Growth
- Natural Gas Availability
- Construction Lag Time
- Import Potential

Basically, we misinterpreted virtually every key item relating to the nitrogen situation. First, we overestimated domestic growth. The old adage that the cure for high prices are high prices is probably valid in this situation.

There was just no way that farmers could continue paying the price that subsequently became the prevailing price during the shortage period and still make money, unless the price of commodities remained at very, very high levels.

Obviously, commodities, by their very nature, do vary on a year-to-year basis. This variance can be attributed to the crop production and availability of grain in key areas of the world. For example, Russia. You will recall that back in 1972-73, they had a rather significant drop in grain production and, therefore, chose to import large quantities of grain rather than slaughter their cattle as they had done in a similar situation earlier.

This, of course, brought about the substantial increase in grain prices and resulted in the U.S. farmer attempting to grow grains fence row to fence row.

We also misinterpreted the natural gas availability. As the prices went up, ways were found to conserve natural gas. People who were using it to heat homes, turned down their thermostats, thus using less. This should not have been a surprise, since natural gas was substantially underpriced relative to its market value. This, of course, was caused by the regulation of all natural gas involved in interstate traffic by the FPC.

The industry also completely understated the construction lag time. At one time we were telling each other that it would take a minimum of 3-4 years in order to construct plants in the U.S., primarily because of the lack of shop time.

We also thought that foreign plants could take as long as 4-5 years. This again proved erroneous since, with the expectation of high profits, people were willing to make deals with shops that provided the incentive to complete the compressors and other long lead time items in record time.

We also completely misinterpreted the import potential, for construction of foreign plants moved ahead much quicker than anybody anticipated. This provided a significant import potential into this country. This, of course, was also directly related to the fact that natural gas costs in the U.S. *are* substantially above those anticipated 4-5 years ago.

Back in 1973-74, a projection of natural gas of $1 an MCF by 1978 was probably considered on the high side. Therefore, it seemed unlikely that, at that time, import materials could compete with domestically produced ammonia despite the fact that they would have significantly lower costs of gas.

However, in retrospect, we now see natural gas at $2.00 at the wellhead and, based on projections used in the recently passed energy bill, it will be going up from there.

Thus, the total difference between the two and perhaps even three and four dollar gas that we may be seeing in a relatively short time period does provide enough of a margin such that import material can compete with domestic production.

That, then, provides some of the background which leads us into the third period, the one I call period of "Realization."

Slide 9

As this slide indicates, our total supply capability far exceed our demand and this ignores the question of imports. Unlike the earlier growth demand projections that ranged from 4-8% per year and in some cases perhaps higher, we are now looking at a demand for nitrogen that is growing at a much lower rate, perhaps more on the order of 2-3% per year.

In fact, during 1977-78, the year just completed, most projections of nitrogen consumption anticipated that it would be down. Friday, we should find out, since that is the date that the U.S.D.A. releases its first preliminary estimate.

I anticipate some recovery of this during the next fertilizer year, but see little change until the early 80's when the increasing demand for American grains will eliminate the set-a-sides and thus create additional demands on the U.S. farmer.

Industrial demands are also not growing rapidly as anticipated earlier. I anticipate these will be growing perhaps no more than 5-6% per year and generally will follow the general economic conditions of the U.S. In view of the rather shakey outlook for the next several years, primarily because of inflation, I would have to say that the outlook between now and 1980 would certainly not be anything above 5% per year.

Obvously, this surplus in the industry's ability to supply nitrogen to the U.S. market puts considerable pressure on domestic nitrogen producers.

The big question confronting the industry is: What is the likely outcome, recognizing that we have a large surplus, increasing costs, and are facing a world surplus. You will recall that the last time we had a large surplus, we also had the lowest production cost. This is no longer true; thus the big pressure is on the domestic outlook.

Let's first look at the industry cost profile.

Slide 10

As shown on this slide, the net result of an analysis of the production cost of the ammonia plants likely to supply the central U.S. indicates a significant variance in costs. These costs were based not only on where the plants are located, but also recognized that some plants would receive credits for upgrading of both UAN and urea.

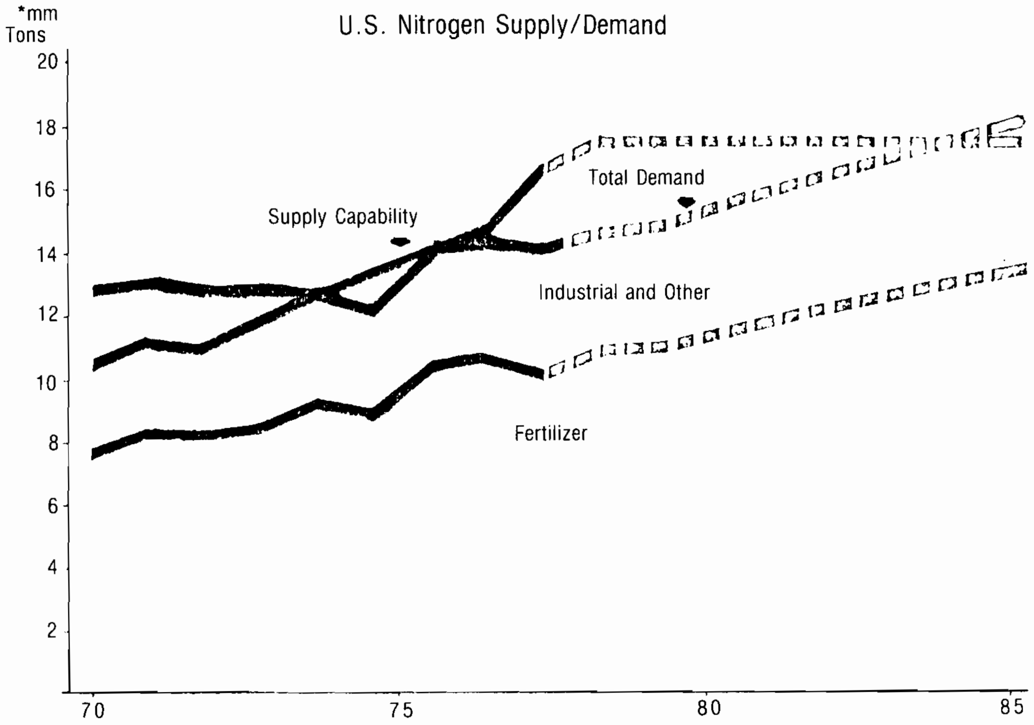
Several companies still have long-term, low-cost contracts and, therefore, have a very low delivered cost. On the other hand, some companies not only have high gas costs, but also high electricity costs as well.

Under classic laws of economics, the price is generally set at the marginal producer cost level. However, because of the large inventory level, I believe that the price will actually be slightly below this marginal cost and, on that basis, as much as 1/3 of the industry would be operating below their cost if they continued to operate.

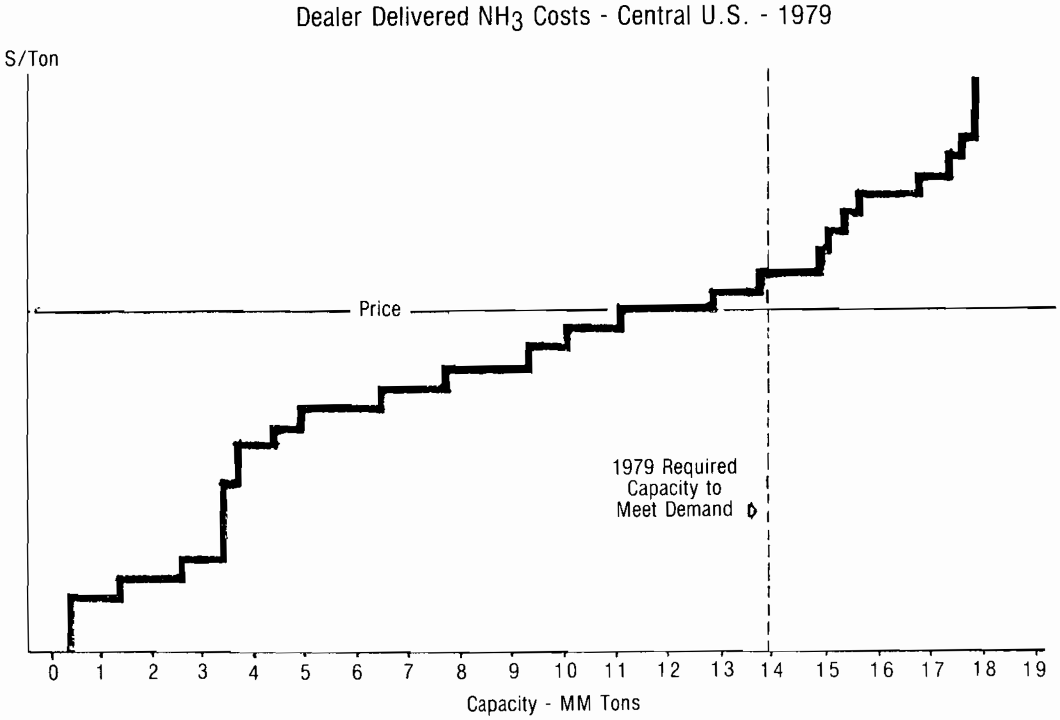
This suggests that many more plants will close, recognizing not only the current cost levels, but also future escalations of both natural gas and electricity.

That now leads me to the fourth period that I mentioned at the beginning, and that is the period of "Opportunity."

Slide No. 9
Current Nitrogen Supply/Demand Outlook



Slide No. 10
Ammonia Delivered Cost Profile



Slide 11

Looking first at this past year, we anticipated a total demand for ammonia of about 18.9 million tons.

However, our capability to produce, after recognizing the shutdowns that have already occurred, probably is more like 22.6 million tons. And further reducing this by an operating factor due to gas curtailment, down time, etc., would lower the total supply capability to 20.6 million tons.

This would leave us with a net surplus of 1.7 million tons, without recognizing any imports. However, we imported the equivalent of about 2.3 million tons of ammonia in the form of urea, UAN, and ammonia itself. Thus, we had a total surplus of 4 million tons. Obviously, the net impact was a substantially lower operating rate than the 91% shown here.

Looking forward to 1979, I see domestic curtailments increasing, which at the same time imports will be increasing.

By 1981 I anticipate that a total of nearly 6 million tons of capacity will be permanently closed. By that time, we will be net importers of a rather significant quantity of nitrogen in the form of ammonia, urea, and UAN. By 1983, we should be importing about 25% of our total ammonia requirements. I anticipate that imports will remain as a major factor in our domestic supply from now on.

It is highly unlikely that these imports will be at the extremely low price levels that we currently see. But rather, as these foreign countries increase their exports and they begin to recognize both our dependence on imports plus our increasing natural gas prices, they will be in a position to export ammonia to this country at ever higher prices.

What then is ahead for the U.S.?

Slide 12

First, it is highly unlikely that we will see any additional ammonia plants being built in the U.S. based on natural gas. There are several reasons for this. One, the cost of domestic natural gas is likely to remain significantly above those of some lesser developed countries. Second, the cost of building these facilities is very high and approaching the $100-plus million level for any plant that might now be undertaken.

Thus the combination of the increasing gas costs and high investment would mean that the margin necessary to encourage funding for new plants of this scale would appear to be so high as to virtually make it prohibitive since, at that point, we would probably see some reactivation of older plants, despite the fact that natural gas might be available for only a portion of the year.

Slide 13

It is also highly unlikely that we will see any coal based ammonia plants in the U.S. primarily, again, because of the high cost level.

Virtually every economic study run on coal based ammonia would seem to indicate that the daylight is just ahead. However, as we get to that point we find that coal prices have increased, and so has the capital necessary to build this plant.

Therefore, I believe it is highly unlikely that we will see any significant construction of new coal based ammonia, at least for the next decade, unless, of course, they are subsidized by the federal government. Rather, we will see imports increasing to meet demands.

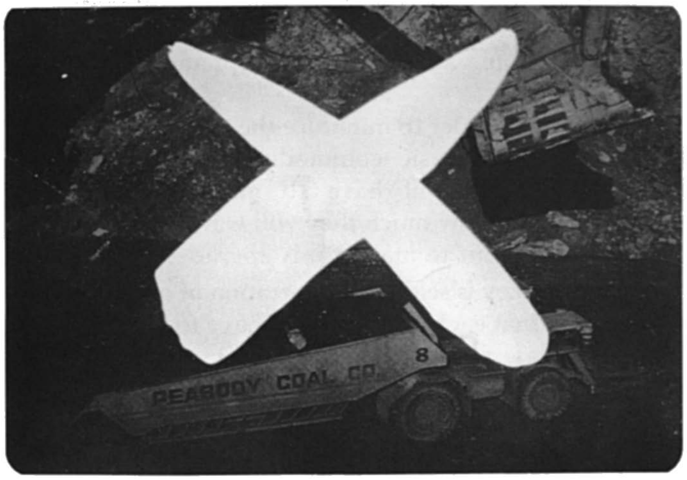
What then are the keys for the future of nitrogen in the U.S.?

Slide No. 11
Ammonia Balance
Ammonia Equivalent Supply/Demand
(MM Tons)

	1978	1979	1980	1981	1983
Demand	18.9	19.3	19.7	20.4	22.1
Supply					
Base	23.6	23.6	23.6	23.6	23.6
Shut Down	1.0	3.0	5.5	5.9	5.9
	22.6	20.6	18.1	17.7	17.7
Production @ 91%	20.6	18.7	16.5	16.1	16.1
Surplus/(Shortage)	1.7	(0.6)	(3.2)	(4.3)	(6.0)
Imports	2.3	2.9	3.6	5.1	5.5
Net Supply/(Shortage)	4.0	2.3	0.4	0.8	(0.5)

Slide No. 12
No More Construction in the U.S.

Slide No. 13
Coal Base Unlikely



Slide No. 14
Keys

Keys

- **Energy Conservation**
- **Improve Efficiency/Productivity**
- **Upgrade**
- **Selective Import**
- **Minimize Distribution Cost**

Foremost, the key to nitrogen profitability is energy conservation. As natural gas prices increase over time, and increase they surely will, the key will be to do whatever is necessary in order to minimize the amount of energy used. There appear to be numerous ways to reduce energy. For example, hydrogen recovery can reduce the consumption of natural gas by 2%, which, although not much, could mean $1-2 per ton.

Other changes will almost assuredly occur. Keep in mind that many of the ammonia plants were basically designed when natural gas prices of 50¢ per million BTU were considered high. Some changes in technology are already incorporated in the latest plants, thus making them more efficient.

The second key is to improve efficiency and/or productivity. Actually, you could argue that this should be put in the same category as energy conservation; however, I believe that there is a difference. Efficiency and/or productivity relate more to onstream time.

It also refers to de-bottle-necking wherever necessary in order to maximize the amount of production that can be produced from a given plant. As we already know, similar plants can produce at significantly different levels, primarily due to the way they are run.

The third key is upgrading. Less than one third of all the ammonia produced in this country is used as ammonia, and only about 40% of all the nitrogen used by the American farmer is actually used in the form of ammonia. The rest is used in such products as urea, UAN, ammonium nitrate, ammoniated phosphates and the like.

Therefore, in order to minimize the exposure to the fluctuations of the basic commodity, ammonia, individual companies will have to make their own assessments about how much they will want to upgrade and where they want to market this upgraded product.

The fourth key is selected importation of ammonia. By this I mean that each producer will have to determine what his costs are and compare these against the cost of importing material, recognizing that in many cases it will mean a complete shutdown and that there are some on-going costs even though a plant is shutdown.

Therefore, in order to make this decision, it will require a relatively firm commitment on the part of an offshore company and/or whoever makes the arrangement for the imports, since it is highly unlikely that a domestic company would be willing to forego a known quantity of domestic production for an unknown quantity of imports, despite the fact that the imports might be significantly lower cost.

The fifth and final key is to minimize distribution costs. Obviously, the seasonability of fertilizer distribution in the U.S. will become even more costly in the future. The fact that we utilize as much as 30% of our total fertilizer in a given month, whereas production actually occurs more on a uniform basis, requires that a significant portion of fertilizer be stored.

To the extent that we can level out some of the demands by applying in the fall, when there is more time, will certainly go a long way toward minimizing the total cost, which has to eventually be passed on to the American farmer.

Then, too, we also need to determine a more efficient way of moving the product all the way to the farmer by leveling out, to some extent, the shipments from the producer to the dealer itself. I recognize that this is rather a tough assignment, since the industry has been working on this one for probably the past half-century and still have not been successful.

Thus, in summary, I think that the nitrogen picture currently is one that will cause many board rooms to reassess their commitment to the industry. On the other hand, it also affords unique opportunities for those who are willing to take the time and effort necessary to assess what is happening, so that they are in a position to take advantage of the nitrogen situation when the supply/demand outlook finally rebounds — and rebound it will; it's just a question of when.

Thank you. (Applause)

DIRECTOR BLENKHORN: Does anybody have a question for Mr. Graves before we proceed with the next speaker? I don't know if you heard that or not. Mr. Graves said he had a question. He wondered when Frank Wooten was going to run for President. (Applause)

Thank you Bob.

MODERATOR BLENKHORN: Proceeding to the phosphate picture, we have a speaker all the way from Paris to deal with that subject, Mr. Pierre Louis of ISMA. The paper is jointly written by Mr. K. F. Isherwood, Secretary of Fertilizer for ISMA and Mr. Louis, who is here to give the paper. Mr. Louis is a graduate in agriculture from Gembloux University in Belgium. He has had experience in various agricultural centers in the Far East and Africa, joined ISMA in 1970, holds the position of Secretary of Raw Materials and External Relations. ISMA, as you may know, is an organization that has been around for a long time. ISMA stands for the International Superphosphate Manufacturers

Association. I mentioned to Mr. Louis last night, "Does that title still hold true"? And I said this very softly because Frank Achorn may have overhead me, and I said that superphosphate is a bit archaic, that's one of Frank's pet subjects, and anybody, there will be qualifications I understand on the structure of ISMA and possible changes in the terminology of the organization. Mr. Pierre Louis of ISMA. (Applause)

The Medium Term Outlook For Phosphate

P. L. Louis — K. F. Isherwood

Presented By P. L. Louis

MR. CHAIRMAN: It is indeed an honour for the ISMA Secretariat to be invited to address this meeting on the subject of the outlook for phosphate.

Further to your request, I shall very briefly introduce ISMA for the participants who are not familiar with this organization.

ISMA, formerly called the International Superphosphate Manufacturers Association, now named the International Phosphate Industry Association, but still ISMA Ltd is essentially a World Association of phosphate fertilizer and phosphate rock producers, although its membership includes also producers of sulphur, ammonia, potash, engineering companies, govermental bodies like T.V.A., I.F.D.C., the Bureau of Mines, trade associations, etc. ISMA has at present over 350 members in 64 countries.

The surveys I shall present here are conducted by the Secretariat, under the supervision of specialized committees and working parties (and I should stress that most of the information is directly provided by the producers). As indicated, in the ISMA Secretarist, my colleague Keith Isherwood, co-author of this paper, is responsible for the fertilizer aspects while I am responsible for the raw materials.

Now I shall deal with the first aspect in the outlook for phosphate: the supply and demand balance for phosphoric acid.

Each year the Economics Committee of ISMA carries out a survey among ISMA members in order to determine the likely increase in wet process phosphoric acid production capacity during the three following years. Similarly, three-year forecasts of the consumption of the different kinds of phosphate fertilizers are requested. From this information, a forecast of phosphoric acid demand can be calculated. Matching the supply potential with the demand estimate gives a supply/demand forecast for phosphoric acid.

The results of the survey carried out in February/March 1978, reported move fully at the ISMA Annual Conference at Cannes in June 1978, were as follows:

TABLE 1.PHOSPHORIC ACID BALANCES 1000 tonnes P205.

REGION	Potential supply minus demand	
	1975/76 1976	1980/81 1981
WEST EUROPE	+ 1 135	+ 356
NORTH AMERICA	+ 2 443	+ 2 750 R
LATIN AMERICA	- 719	- 1 508
N.W. AFRICA	+ 309	+ 1 329
AFRICA except NORTH	- 72	+ 281
NEAR EAST	- 299	+ 100
SOUTH ASIA	- 235	- 490
S.E. ASIA	- 57	- 267
WESTERN WORLD	+ 2 505	+ 2 551
EAST EUROPE	- 58	- 583 R
SOCIALIST ASIA (Imported fertilisers)	- 5	- 112
WORLD TOTAL	+ 2 442	+ 1 856

R = revised

In Western Europe the surplus falls as domestic consumption increases; there are virtually no increases in production capacity for fertilizer use. In North America there was some further increase in capacity in 1976/77 but the major reported increase thereafter is an Occidental project, presumably intended for the supply of acid to the U.S.S.R. A substantial increase in the quantity available for export from N.W. Africa is anticipated and it is calculated that the Near East will change from a deficit to a surplus situation — but see below. The import requirements of Latin America, South Asia, the developing countries of S.E. Asia are expected to increase substantially. The East European figure takes account of the shipment of 0.7 million tonnes P205 from Occidental to the U.S.S.R. Elsewhere deficits in Czechoslovakia, East Germany and Poland are offset by anticipated surpluses in Rumania and Yougoslavia.

These figures indicate a continued comfortable surplus of phosphoric acid production capacity and the likelihood is that this will turn out to be the case. However, surplus is only 9% of projected phosphoric acid consumption. If a higher-than-anticipated demand and a lower-than-anticipated supply occur simultaneously, the balance could be changed. The purpose of this paper is to examine some of the uncertainties.

Phosphate Fertilizer and phosphoric acid demand.

World phosphate fertilizer consumption is anticipated to increase as follows:

TABLE 2 PHOSPHATE FERTILISER CONSUMPTION 1000 tonnes P205

R E G I O N	1973/74 1973	1976/77 1976	1980/81 1980 Forecast*
WEST EUROPE	6 020	5 371	5 776 *(+ 1.8% p.a.)*
EAST EUROPE	6 374	7 967	10 889 *(+ 8.1% p.a.)*
NORTH AMERICA	5 095	5 626	6 019 *(+ 1.7% p.a.)*
LATIN AMERICA	1 469	1 975	3 127 *(+12.2% p.a.)*
OCEANIA	1 700	1 138	1 359 *(+ 4.5% p.a.)*
N. AFRICA/NEAR EAST	629	1 054	1 540 *(+ 9.9% p.a.)*
AFRICA except NORTH	512	582	733 *(+ 4.6% p.a.)*
SOUTH ASIA	677	849	1 505 *(+ 15.4% p.a.)*
S.E. ASIA	1 345	1 255	1 555 *(+ 5.5% p.a.)*
SOCIALIST ASIA	1 363	1 523	2 223 *(+ 9.9% p.a.)*
W O R L D	25 184	27 339	34 726 *(+ 6.2% p.a.)*

* The percentage relates to the compound annual rates of increase between 1976/77 and 1980/81.

As regards the different products, the expected pattern is as follows:

TABLE 3

CONSUMPTION OF THE DIFFERENT TYPES OF PHOSPHATE FERTILISERS.
(World excluding Socialist Asia)

% of total P205 consumption

P R O D U C T	1975/76 %	1980/81 %
Basic slag	2.6	1.9
Ground rock	4.9	4.2
Single superphosphate	19.3	14.7
Concentrated supers.	14.6	16.6
Ammonium phosphates	20.3	24.6
NPK Compounds	29.1	29.2
PK Compounds	4.8	4.4
Others	4.4	4.4
T O T A L	100.0	100.0

These figures relate to products for direct application in agriculture. It can be seen that the major increases are all in products which contain a high proportion of phosphoric acid. Substantial increases are expected in the cases of ammonium phosphate, NPK compounds and triple superphosphate. The consumption of basic slag continues to decline, owing to decreased supplies, but the decline is now more gradual. The decline in the proportion accounted for by ground rock phosphate hides an increase in absolute quantities. In the case of single superphosphate, although there is a continuing decrease in West Europe and North America, there is a substantial recovery in Oceania. These figures exclude Socialist Asia where it is believed that ground rock phosphate and single superphosphate predominate and where a substantial increase in consumption is expected. In the rest of the world it is estimated that the increase in phosphate fertilizer consumption will be in the form of products derived largely or entirely from phosphoric acid.

On a global basis (Figure 1) the 1980/81 forecast of 34.7 million tonnes P205 represents a continuation of the growth experienced since 1974/75, following the setback of that year.

The major uncertainties in future demand can be reduced to the irregular growth pattern of four countries, Brazil, India, the United States and the U.S.S.R. (Figure 2)

In the United States the rate of increase of phosphate fertilizer consumption appeared to be levelling off in 1973/74. Then there was a precipitous decline in 1974/75 followed by a complete recovery in 1975/76 and then an anticipated fall in 1977/78. 1978/79 is expected to be a good recovery year, unless the feed grain set-asides are higher than the anticipated 15 to 20%. It is very difficult to predict the development in the U.S.A. until these grain surpluses are lowered.

The pattern in India has been one of ups and downs around an increasing trend. It can be seen that the Indian forecast assumes that there will not be another down during the period of question. The Fertilizer Association of India predicts that growth will continue on a quadratic trend but at least one expert is less certain (G. M. Desai, Fertilizer News, July 1978).

Consumption in Brazil has followed a series of curves, albeit of a different shape. The forecast we have used assumes no set-back. However, if the prices of the relevant commodities were to fall, or fertilizer prices to rise - possibly as a result of import quotas - consumption could be affected.

In the U.S.S.R., consumption has tended to progress in a series of steps of alternately faster and slower growth. Consumption has depended largely on the supplies available from domestic production. What quantities of phosphoric acid and phosphoric acid — based fertilizers will this country, with its enormous potential demand, eventually import, from different sources, and when ?

There is also an enormous potential for growth in China. To date it has been possible to omit this country from the phosphoric acid balance since its demand has been determined largely by domestic supplies of phosphate fertilizers. However, today her trade policies are changing and imports of phosphate fertilizers have increased substantially. We have allowed for a substantial increase in Chinese imports (see table 1) but this could prove to be an under-estimate.

Also, although there have been substantial increases in recent years in a few developing countries, such as Turkey, India, Pakistan and Brazil, the increases in a host of other developing countries have been negligible. These countries represent a considerable potential for increased consumption.

Extrapolation of a long-term series of P205 consumption, using the best - fitting curve, indicates our 1980/81 forecast of 34.7 million tonnes P205 to be on the high side but we believe it to be achievable.

Phosphoric acid supply.

The estimated "production potential" of the different regions of the Western World is estimated to be as follows:

TABLE 4 POTENTIAL PRODUCTION OF PHOSPHORIC ACID FOR FERTILISERS

1000 tonnes P205

	1977/78	1980/81	CHANGE
WEST EUROPE	3 553	3 568	+ 15
NORTH AMERICA	7 998	8 522	+ 524
LATIN AMERICA	678	1 103	+ 425
N.W. AFRICA	947	1 570	+ 623
AFRICA exc.NORTH	751	808	+ 57
NEAR EAST	381	1 152	+ 771
SOUTH ASIA	428	557	+ 128
SOUTH EAST ASIA	864	885	+ 21
WESTERN WORLD	15 600	18 165	+ 2 565
EAST EUROPE	4 012	5 741	+ 1 729
WORLD TOTAL	19 612	23 906	+ 4 294
(Excluding Oceania)			

The increase between these two years is negligible for West Europe, South-Africa and South-East Asia. The increase in North America is largely accounted for by the expansion of Occidental's facilities. In Latin America, the increase is mostly in Brazil, occuring towards the end of the period. There is a steady expansion of the capacities of N.W. Africa. The increase in India is less than might be expected in view of the anticipated increase in demand.

The largest anticipated increase in the Western World is in the Near East region, i.e. Iran, Iraq, Jordan, Israel, Syria and Turkey. Even when most of the increased capacity was being constructed in industrially developed areas, there was a tendency for the total forecasted capacity to be reduced, for any given year, with each successive survey. this was partly but not entirely due to a reaction to market conditions. The near East region is a relatively new producing region and, for unavoidable physical reasons, it may not be possible to meet the target date of operation in certain cases.

In the following table, the total consumption of phosphoric acid (fertilizer and technical use) is compared with total capacity

TABLE 5 RATES OF WET PROCESS PHOSPHORIC ACID CAPACITY UTILISATION

1000 tonnes P205

Y E A R	TOTAL CAPACITY	FERTILISER USE	TECHNICAL USE	TOTAL USE AS % OF CAPACITY
1973/74	17 825	12 812	1 300	79.2 %
1974/75	21 071	12 503	1 191	65.0 %
1975/76	23 424	14 180	1 335	66.2 %
1976/77	25 720	15 939	1 398	67.4 %
1980/81	32 736	21 910	1 691	72.1 %

It can be seen that even in 1973/74, when plants were presumably producing almost as much as they could, on a global basis they were operating at less than 80% of capacity, according to ISMA figures. The rate of utilization of capacity is now increasing and, in view of the likely delays in the effective production dates of some projected new plants, the figure could be higher than indicated, by 1980/81.

In some cases, a declining availability of grades of rock for which plants were designed may affect their operating rates. This factor has not yet been taken into account in our supply/demand calculations.

Phosphate rock supply (table 6 - figure 3)

Each year the Raw Materials Committee of ISMA carries out a survey among ISMA members in order to determine the likely development of phosphate rock production potential for the 5 following years. The results of the 4th survey, conducted early this year, are used as a basis for this paper.

With the exception of the U.S.S.R. and Socialist Asia, the information was supplied by the producers. For the U.S.A., in view of the legal problems involved, the estimates were supplied by the Bureau of Mines, after consultation with the producers.

Table 6
on page 16

Main results

Compared with the production of 1974, which is considered to be close to the potential, the world increase in potential production in 1982 should be 63 million tonnes, or an increase of 58%. For the western world, the increase should be 51 million tonnes or a 62% growth. More than half of this increase will come from 2 regions: the first is North America which increases by 55% compared to 1974, to reach 62.7 million metric tonnes (estimate of early 1978). This accounts for 35% of world growth. The second region is North West Africa (Algeria, Morocco, Sahara and Tunisia) which increases by 50% to reach 39.4 million tonnes, i.e. 21% of world growth.

Other regions increase also in a remarkable manner, more particularly the Near East with + 8.6 million tonnes to reach 12.3 million tonnes and Latin America

Table 6 PHOSPHATE ROCK

('000 tonnes product)

	ACTUAL PRODUCTION				FORECASTED SUPPLY POTENTIAL				
	1974	1975	1976	1977	1978	1979	1980	1981	1982
West Europe	105.0	105.1	110.3	115.1	86	103	310	340	350
East Europe	22500.0	24150.0	24200.0	24200.0^{E}	24600^{E}	25400^{E}	27000^{E}	28400^{E}	29500^{E}
North America	40458.3	44301.4	44670.8	47256.0	51600	54200	56200	56200	62700
Latin America	673.8	820.9	796.9	1024.0	1690	2540	3190	3340	4440
N.W. Africa	26318.6	20417.2	19580.1	21927.2	28200	31300	34430	36850	39400
Near East	3698.5	3471.0	3501.7	4019.6	5880	7820	10770	11500	12300
Africa S & W	5926.1	5042.5	5739.6	7274.1	8217	8543	8773	8918	9043
South Asia	331.9	326.2	552.0	635.4	885	960	1035	1110	1110^{E}
S.E. Asia	-	-	-	-	-	-	-	-	-
Socialist Asia	4600.0^{E}	5250.0^{E}	5700.0^{E}	6100.0^{E}	6800^{E}	7500^{E}	8200^{E}	8800^{E}	9500^{E}
Oceania	4614.7	3571.0	2453.1	3261.9	4680	4675	3900	3900	3900
TOTAL	109226.2	107455.3	107304.4	115813.3	132638	143041	153808	159358	172243

jumping from 0.7 million tonnes in 1974 to 4.4 million tonnes in 1982. This increase is of course almost entirely due to Brazil.

U.S.S.R.

The U.S.S.R. has a very ambitious programme for the development of fertilizer production and consumption.

On the other hand, the U.S.S.R. has made several contracts to ensure a supply of finished or semi-finished products and, on a longer term basis, the import of large quantitites of Moroccan phosphate rock. The U.S.S.R. has also reduced its exports of phosphate rock, especially to Western Europe. This might be due to rather disappointing results regarding phosphate rock production and the relevant logistics problems.

Our forecasts are based on the hypothesis that around 1982, the exports of Soviet phosphate rock could amount to about 3 million tonnes (compared to 4.2 million in 1977) and that the imports of processed phosphate could reach 700 000 tonnes P_2O_5.

Significant imports of phosphate rock should not occur during the period under consideration.

Socialist Asia

For this region, which includes the producing countries of China, North Korea and Vietnam, we do not have the information necessary for a sound assessment of the present production and consumption of phosphate rock and phosphate fertilizers.

China is of course the most important country and it seems now that considerable efforts are being made there to develop the use of phosphate. It would be very interesting to know if China is intending to create modern complexes likely to be supplied with imported phosphate rock (apart from the present imports from Viet-Nam and North Korea). As far as we know, there are no such projects and the development of phosphate use will be related to the development of the resources of the country and to the importation of processed phosphate.

Viet-Nam is apparently exporting a substantial tonnage of phosphate rock to China, an estimated 1 million tonnes annually. It is difficult to forsee the future of this trade and we consider that a limited amount of exports to Eastern Europe or the Western world could take place in the future. Nevertheless, for our forecast, we have assumed that the phosphate rock production will satisfy the demand and that the imports and exports of rock will remain limited in tonnage.

Major changes in the phosphate rock scene

A few changes, already apparent in the phosphate rock scene, are likely to further increase the uncertainty in the forecasts of phosphate rock production potential.

Present producing areas

With few exceptions, the expansion of the production potential, and in some cases even the maintenance of the present capacity, implies the development of less attractive mining sites.

The new mining conditions can be less attractive for different reasons:

— the measures for the protection of the environment are becoming a major constraint to phosphate rock production;

— the ore to be mined sometimes contains certain impurities which make the beneficiation and/or the processing of the ore more complicated.

But, in more general terms, the P_2O_5 content of the rock is often lower, as most of the deposits have been "high graded" and one has to use deeper and lower grade phosphate beds.

This general decline in phosphate rock grades can be seen from the results of the 4th phosphate rock survey. Figures 4 and 5 show the increasing importance of the category 66-68% BPL and that most of the anticipated increase in the production potential concerns the category 68% BPL and less, a phosphate considered as "low grade" a few years ago.

That mining conditions are less favorable is certainly not a factor encouraging the investment in new capacities, especially when the cost of capital is so high. It is then not surprising to see, with each new survey, that some of the projects have been abandoned or delayed, for various reasons, not only as a reaction to market conditions.

New producers

A series of new producers are appearing on the phosphate rock scene. For the period considered in our servey, i.e. up to 1982, these new producers will not supply an important part of the world production, although the new mines in Brazil account already for 78% of the anticipated increase in Latin America. But, in the longer term, a larger number of countries will produce phosphate. Taking account of the projects being implemented or just being considered, one can mention: Brazil, Peru, Colombia, Mexico, Norway, Finland, Yugoslavia, Greece, Turkey, Iraq, Iran, Saudi Arabia, Egypt, Niger, Upper Volta, Mali, Zambia, Pakistan, Sri Landa, Indonesia, (Australia) and the list is certainly not complete. Of course, several of these projects will probably not be implemented, at least in the near future, and the importance of these projects varies considerably. Nevertheless, it is interesting to note the number of these possible projects and their spread all over the world. It is also very interesting to analyse the reasons for the projects.

Amongst the reasons often quoted are:

— to reduce the impact of fluctuations in the international prices for fertilizers and fertilizer raw materials;

— to save foreign currencies;

— to develop a part of the country and to promote the development of some mining and chemical industry;

— to fight unemployment, etc.

So, for certain projects, the true financial profitability, the yard-stick of conventional private companies, is only a secondary aspect. They should then be considered in a completely different context.

In general terms, one can see a number of development which could result from these projects:

— more rock from diversified sources will be made available to the world.

— research work on beneficiation and use of new types of rock will be developed. This may eventually prove advantageous for the entire world.

— certain developing countries may be encouraged to promote more effectively the use of phosphate fertilizers if they are partly produced from local ressources.

— However, these projects also add to the uncertainty when forecasting the world phosphate rock producing potenial. Mine projects in new producing areas are more liable to delays than the more conventional expansions of existing mining operations. Moreover, certain of these new projects will be heavily dependent on governmental financial assistance, either directly at the production stage or indirectly by subsidizing the fertilizer if the local fertilizer manufacturers have to use the local rock. In this case, any change in the financial support may affect significantly the production of phosphate rock and perhaps also the local consumption of phosphate fertilizer.

Phosphate rock supply and demand balance

On the basis of our forecasts of phosphate rock supply potential and of phosphate fertilizer demand and demand for non-fertiliser use, we have calculated the balance for 1980/81 and 1982/83.

Figure 6 shows that there should be a substantial surplus of about 16% on a world basis in 1982. However, with each new survey, the surplus is becoming smaller, as shown in figure 7 which compares the surpluses forcasted each year since 1975. In considering these decreasing surpluses, it should be born in mind that it takes 7 years or more to develop a new mine in Florida and at least as long in most developing countries.

CONCLUSION

The results of the 1978 ISMA surveys indicate that it is probable that there will be more than sufficient phosphate rock and phosphoric acid capacity, on a global basis, to satisfy the demand at least up to 1981.

There will certainly be no justification for a repetition of the panic buying which occurred in 1973/74. However, there are several uncertainties and the situation needs to be monitored carefully.

Note: Figures No. 1 thru No. 7
on pages 18 and 19.

Figure 1

PHOSPHATE FERTILISER CONSUMPTION

1000 Tonnes P_2O_5.

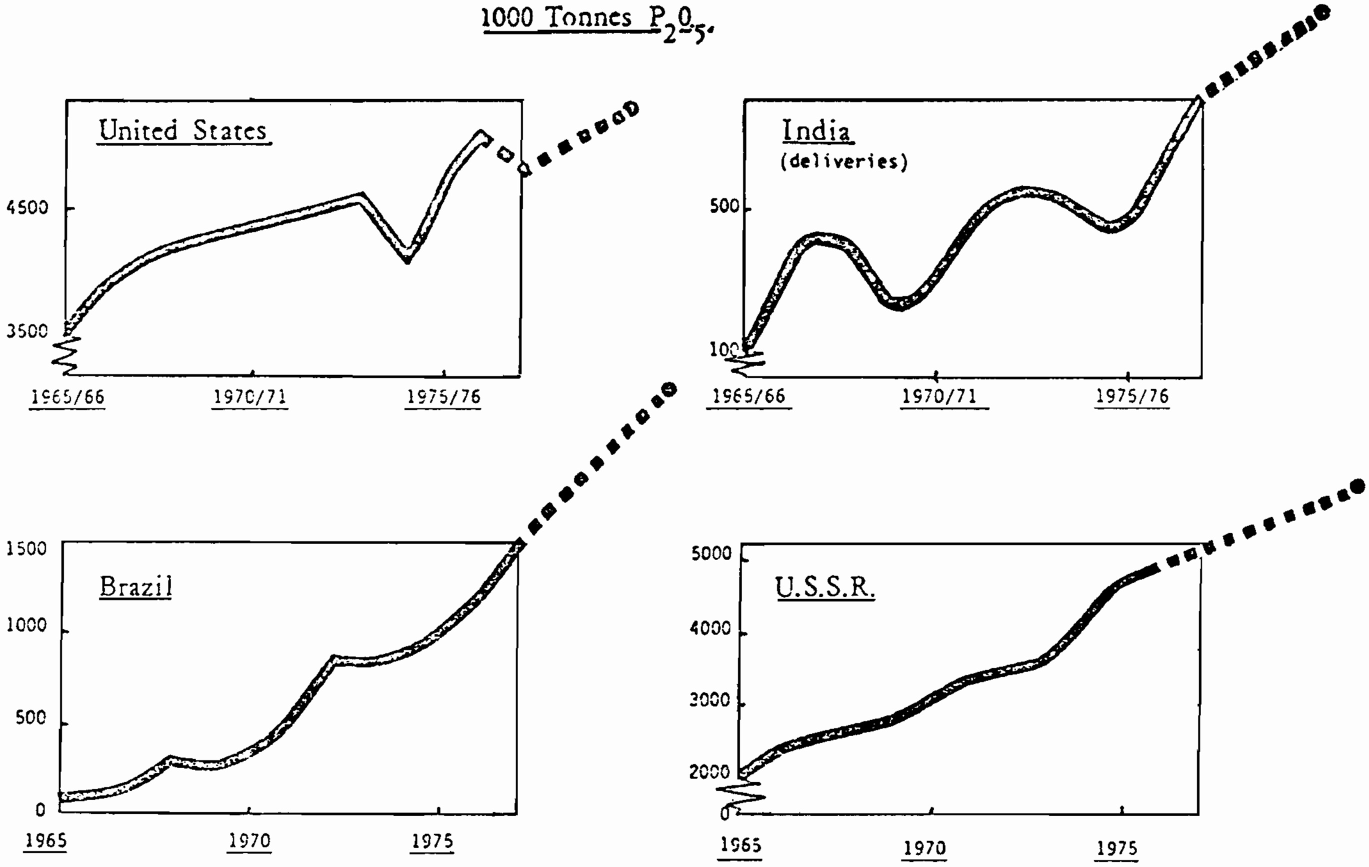


Figure 2

WORLD PHOSPHATE FERTILISER CONSUMPTION

1000 Tonnes P_2O_5

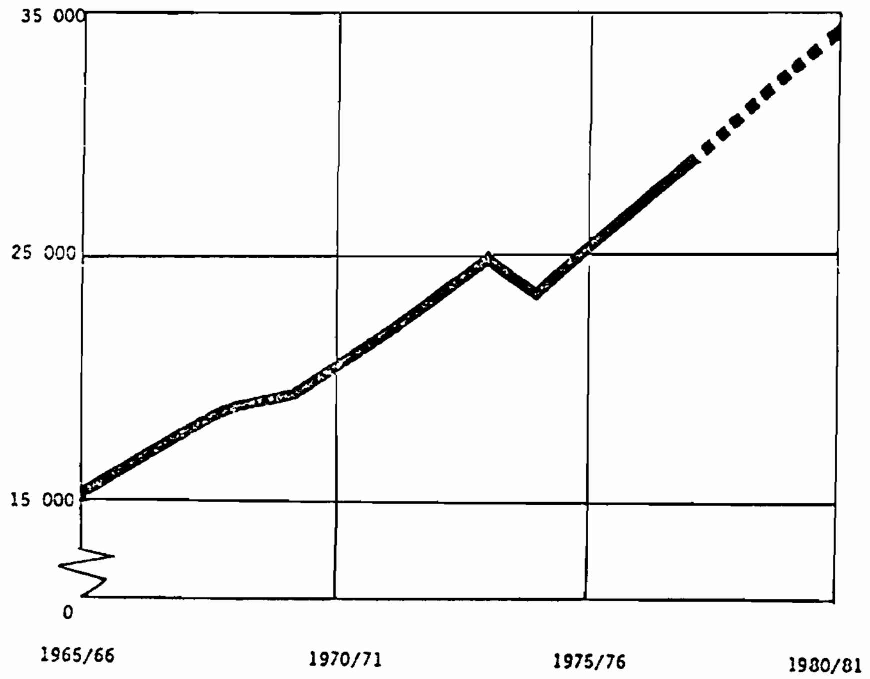


Figure 3

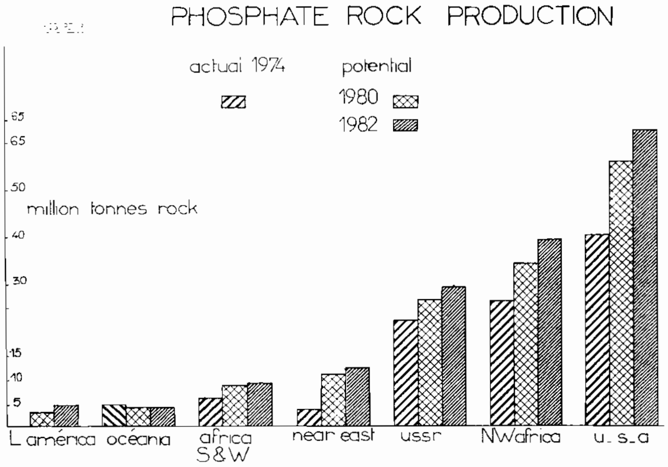


Figure 4

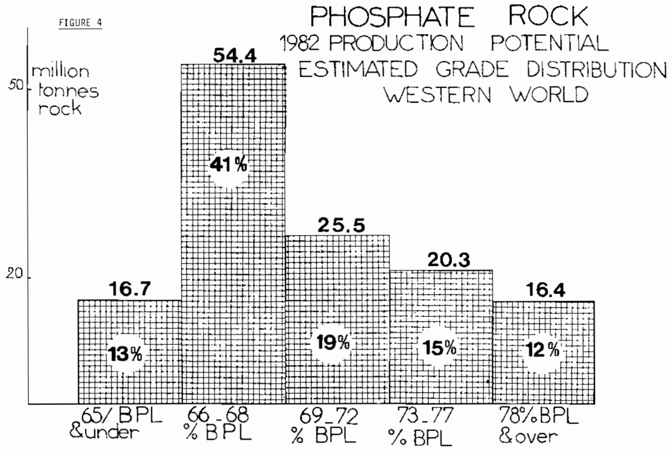


Figure 5

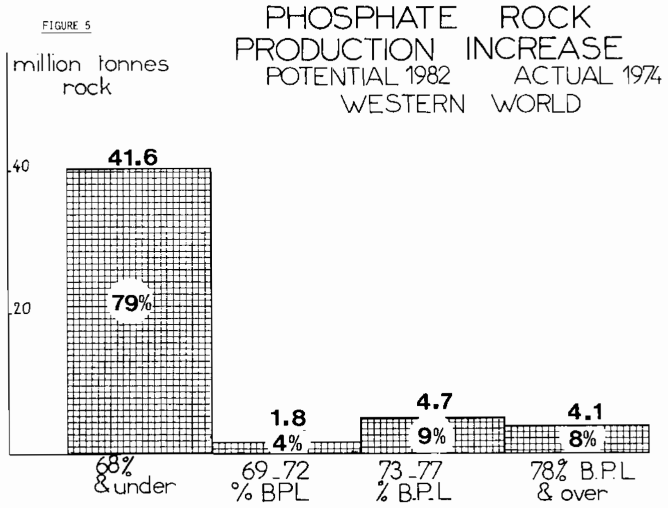


Figure 6

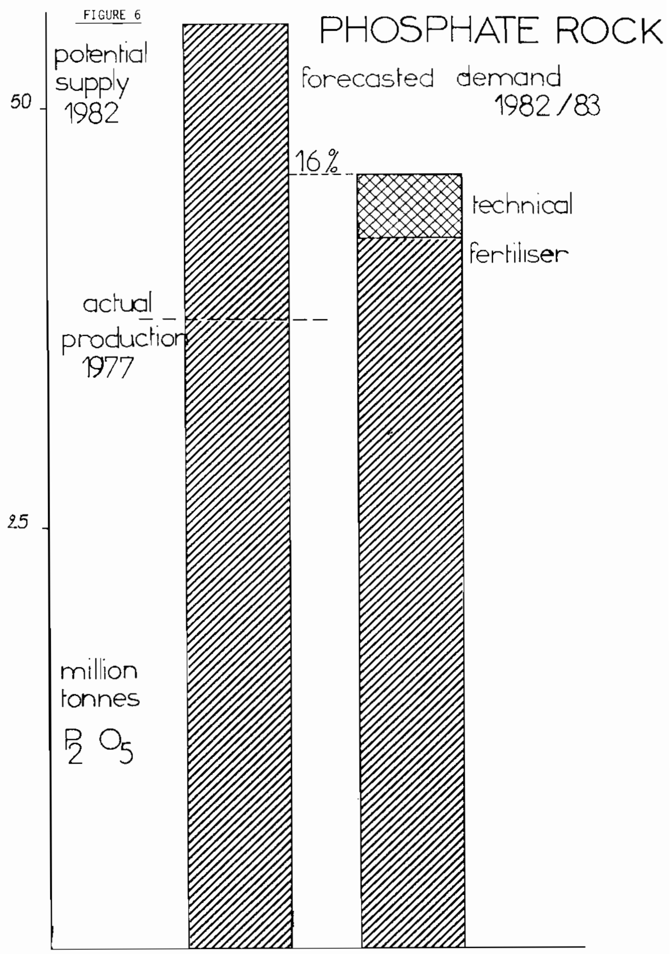
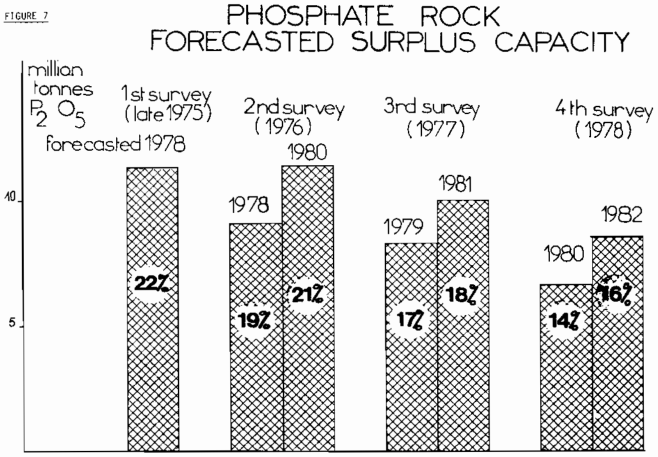


Figure 7



MODERATOR BLENKHORN: Any questions of Mr. Louis before we proceed to the next speaker?

QUESTIONS FROM THE AUDIENCE: In examining new phosphoric acid capacities, what is your opinion about the percentage of new hemihydrate processes versus the old dihydrate processes. Have you looked at that question?

PIERRE LOUIS: Well, we haven't been considering that so much these days. Our way of working is, of course, to establish a list of phosphoric acid plants with the namely capacity. Then, with the help of the members of our country and with all members in the countries, we just estimate what can be really produced from these plants, whether it be hemihydrate or dihydrate process. They can estimate what effective production will be. This is, of course, nothing but an estimate.

MODERATOR BLENKHORN: Thank you, Pierre.

You need not apologize for your accent. It came through loud and clear and it was very interesting to everyone. (Applause).

We proceed now to Potash, and to cover this subject, we have Rolf Holzkaemper, the Vice Preisent of Marketing for Potash Corporation of Saskatchewan Sales Ltd. Mr. Holzkaemper was born and educated in Germany. He has extensive experience in the international marketing of potash, starting out in Europe and moving to New York in 1964 as Vice President, Marketing for Potash Chemical Corporation. In 1968 he moved to Canada as Managing Director of the Potash Company of Canada, a subsidiary of Alwinsal. Following the sale of Alwinsal to Potash Corporation of Saskatchewan, Mr. Holzkaemper joined P.S.C. as Vice President, Marketing, the position that he now holds. He is a Director and Vice Chairman of CANPOTEX, the export arm of the potash industry. He is the Director of the Potassium Phosphate Institute and of the Canadian and American Fertilizer Institutes. Mr. Rolf Holzkaemper. (Applause).

Potash Supply/Demand Outlook

E. H. Holzkaemper

It is a pleasure to be with you this morning and to share with you some thoughts on potash supply and demand. The potash industry, in particular the North American industry, is undergoing some dramatic changes which will have a considerable effect on U.S. buyers. My projection deals with supply and demand to 1985/86.

Throughout the presentation, the data is presented in short tons K_2O. In the various tables, I have used the term "productive capability" to describe the historical actual production or the projected output. Certain assumptions were made in respect to the operating rate in relation to the announced nameplate capacity. The "demand" projections should not be confused with consumption. The term demand used throughout the presentation is synonymous with shipping demand, ie. deliveries from basic producers.

All of the statistics presented are based on data published by the Potash/Phosphate Institute, United Nations, independent consultants and, of course, PCS's own Market Research Department.

In order to see the North American situation in proper perspective, I would like first of all to review briefly worldwide supply and demand.

Table 1 presents the world supply/demand balance by region, reflecting trade between regions.

1976/77 is the last fertilizer year for which complete data is available. Actual production totals 27 million tons. Twenty seven and a half million tons (27,500,000) were consumed and inventories were drawn down by 500,000 tons K_2O. Productive capability was probably 1.5 to 1.7 million tons higher. During that year, the West European production was reduced to adjust downward the high level of inventories. As is apparent, East Europe and North America are the two net exporting areas in the world. East Europe, more specifically Russia, is the biggest potash producer and consumer in the world.

Looking towards 1980/81, you will observe that total productive capability and demand are projected to increase to 33 million and 34 million tons respectively, reflecting an increase in production and demand equal to 5.3% per year. West Europe has resumed normal production levels and we are forecasting that the Cleveland mine in the U.K. will be operating at a reasonable rate. The East Block countries have surged ahead in production. At the same time, the demand in the Comecom countries has equally jumped to 13 million tons. North American consumption will be 8,250,000 for a positive balance of 1,750,000.

As worldwide inventories were very high at the end of 1976/77, no immediate product shortage can be construed from the above projections. A great deal will depend, however, on the capability of the Eastern Block to physically export their surplus production. I am of the opinion that, for this and other reasons, we will see a narrowing of the supply/demand gap in the very near future and I project shortages in specific grades and/or locations to take place during the 1979 calendar year.

Looking forward to 1985/86, with production output expected to increase at a conservative 3.5-4% per year, we are projecting world-wide production to reach 37½ million tons whereas demand, expected to grow at 5% per year, will have soared to 42 million tons.

Our forecast is made on the assumption that Europe, the East Block and the United States will produce at maximum capabilities as are presently in operation or announced. For Canada, we have assumed production at maximum levels of the properties presently in operation, including expansions that have been indicated. We are not assuming additional production from mines which have not been announced or for which financial commitments have not been made to date.

Our projection forecast for the Mid East includes the coming on stream of the Jordanian project expected to be operating at 720,000 tons K_2O.

Slide 2 is a graphic illustration of the table you have just seen.

Let us now turn to North America. You will recall the unusual and unfavorable circumstances which affected our 1977/78 season; the unfavorable weather conditions that prevailed last fall, the severe winter and the wet spring which delayed and compressed the selling season and, of course, the negative attitude taken by many farmers as a result of the low farm commodity prices. We were all fortunate indeed that things had turned around to some degree when planting time finally came around. The continuing demand through May and the strong retail activity in June bailed us out of an unfortunate situation. Since then, we as potash producers have seen the movement of product from the mines into the market. We should not be disappointed that the first quarter shipping data is a little off from a year ago. We must bear in mind that we enjoyed unusually heavy movement from the mines last June and I believe that dealer inventories in the field were filled at the start of the fall season.

Slide 3 shows the current and anticipated domestic disappearance from U.S. and Canadian mines. In addition, imports have been projected as we see them develop over the next number of years. Over the nine-year period 1977/78 to 1985/86, the total available production reaches 9½ million tons K_2O. This represents a 3½% average annual growth.

We assume that American potash producers will produce at the limit of their capacity and that they will market their potash primarily in the United States, though no doubt sizeable tonnage will continue to be exported into those lucrative offshore markets where Carsbad enjoys freight advantages.

We further assume that imports from overseas will continue to increase. We are doubtful, however, whether or not the hugh volumes of Russian potash that have been talked about for a number of years will ever materialize. Russia will likely start delivering potash next year under the arrangement with Occidental, but at least for another year, the major importer of Muriate of Potash will be Israel.

You will find the projection of imports from overseas to be quite conservative. Indeed, there exists a margin of error, but in our view an extra 100,000 tons imported from offshore will not change the picture. At PCS we foresee that imports will level out at around the million ton product mark. Some of the reasons behind our thinking are related to logistics. In particular, we are mindful of the distribution system that needs to be set up by the importers if they wish to serve the market on a continuous basis with large volumes.

In 1977/78, domestic disappearance dropped marginally by 53,000 tons after allowing for imports. The present outlook for potash sales in North America in the 1978/79 season remains excellent. I take into consideration the huge corn crop that is currently being harvested at about 7% above last season and the drop in corn prices that has taken place over the last few months. I recognized the disappointing cotton crop and the drought conditions that plague the South East. I am equally aware that the government-sponsored set-aside programs will likely affect fertilizer deliveries to some degree. All in all, while I am reducing some earlier predictions, I remain nonetheless optimistic that total shipments of potash in North America from basic producers will increase by just over 10%. The positive farmer attitude is one important aspect. Another aspect equally important to me is the tight rail car situation which will stay with us for a long time. I am confident that many buyers will take potash as fast as the producers can deliver. This assumes and includes heavy movement in June after the spring season.

From the slide, you will note that my projections beyond 1978/79 for domestic demand are dropping to a conservative 2.8% which I believe to be realistic. As stated, I project imports to level out at 600,000 tons of K_2O or one million product tons, largely for logistical reasons.

The next slide (4) shows potash supply and demand for U.S. producers. I project that U.S. companies can reach and maintain production at about 2.5 million short tons K_2O, including Sulphates. The U.S. producers will increasingly emphasize supplying first the domestic market and at the expense of offshore sales.

Every rail freight increase intensifies somewhat the competitive advantage for New Mexican producers over the Canadian mines in most of the domestic market, and we expect a sizeable rail freight increase this season. At the same time, stable market conditions are another factor that will make it attractive for the Carlsbad producers to increase sales at home.

New Mexico also has a significant freight advantage in certain offshore countries; for example, Central America and Brazil. I am of the opinion that these markets will be maintained; however, overall exports from the United States will decline.

Slide 5 is a graph of the projected supply/demand for U.S. potash, illustrating what I have just said.

In my projections, year-end inventories will drop to 250,000 tons K_2O. Given the number of mines involved as well as the different products, this is in fact an inventory rate below the desirable working level. I am suggesting that U.S. producers will sell all the potash they can produce, with more destined to the home market, provided transportation can be provided by the Santa Fe Railway.

Slide 6 is a table showing you the Canadian production and demand picture. I had expected production in Canada to go down in 1978/79, but I now believe that it will remain at the 6.8-6.9 million ton level. It assumes that all mines are operating at maximum capacities and that no unforeseen production stoppages occur. You may be aware that PCS had temporarily shut down its Lanigan Division in order to undertake a major refurbishment and to begin work on an expansion. We expect to bring Lanigan back into production before the year-end.

In 1979/80, production is expected to reach 7.2 million tons and thereafter quickly grow to 7.5 and 8 million tons by 1981/82. In my view, 8 million tons K_2O represents the Saskatchewan sustainable production rate after debottlenecking and the expansions presently underway at PCS. Beginning 1982, I project production to become available in New Brunswick and I expect this production may reach 600,000 tons as early as 1984/85.

Domestic demand is expected to grow at about 4% annually from 1977/78 to 1986 and this will bring about shifts in the pattern of distribution. On the one hand, Canadian producers must accept the inevitability of imports as well as fluctuations in the delivery pattern that can result from a temporary shift in emphasis on exports by U.S. producers. In any case, Canadian potash will penetrate deeper into the U.S. markets. This requires new and expanded distribution systems and a new and fresh approach to change the traditional seasonal movement.

Overseas exports from Canada increased last year by 50%. I expect a 13-14% growth this year with a 10% increase thereafter through to 1985/86.

Of Canada's major export markets, sales to Japan remain steady whereas India and Brazil continue to grow at above-average rates. A major new development has taken place in China, where Canpotex, the Canadian export association, which markets 85% of potash exported overseas from Canada, has recently sold 300,000 metric tons of Muriate. There are indications that the Chinese may wish to enter into a long-term potash supply agreement with Canada. If this should happen, I would assure that it would be for more or less one-half million tons product per annum.

In future years, more and more of the potash requirements of overseas countries will be supplied by either Russia or Canada.

I would like to draw your attention to the last column on the slide, which indicates the producer-held inventories by year. In 1977/78, inventories in producers' hands increased marginally by about 30,000 tons. The huge pick-up in demand in 1978/79, without a parallel increase in output, is expected to bring down potash inventories in Canada as of June 30, 1979 to 800,000 tons. An 800,000 ton inventory, spread among ten producing mines, plus the Canpotex stocks at Vancouver, and further subdivided into the various potash grades, simply means that Canadian producers will likely sell this year as much potash as they can deliver. In fact, it is not impossible that shortages for specific grades may ultimately develop, particularly in Coarse grade. From 1979/80 forward, we will have a shortfall expected to become rather severe.

Slide 7 is a graphic illustration of the table you have just seen. Please note the widening gap between production and demand. Unless new, not yet authorized, potash production capacity is brought on stream rapidly, demand for Canadian potash will outstrip available supply, possibly beginning as early as 1979, right through the mid-80's. The anticipated shortfall could reach in excess of 2.5 million tons of K_2O by 1985/86 on an annual basis.

Slide 8 is a summary table of the combined U.S. and Canadian production versus demand. I draw your attention to the inventory position as of June 30, 1978 at 1,642,000 tons K_2O. The estimated increase in demand from customers in North America and overseas will draw down these inventories by nearly a million product tons by June, 1979. At that time, inventories will be at their lowest level since 1973/74. We must bear in mind, however, that over-all production has significantly increased and an inventory level of 11-12% is, in my view, unsatisfactory and insufficient. Do not be misled by the reported higher level of inventories versus a year ago. Since February 1978, when inventories to producer hands reached a high of nearly two million tons K_2O, there has been a steady drawdown to 1,225,000 at the end of September; nearly 800,000 tons. This drawdown will become more visible over the next three months. From June, 1980 onward, North American potash supply and demand will face an actual net supply gap unless tonnage presently earmarked for export overseas is directed to the U.S. (Slide 9).

Potash producers in Canada and the United States will have to work very closely with customers in order to assure product availability when needed. I wish to stress the need for domestic potash buyers to advise their suppliers early of their anticipated requirements, including requirments by grade and to enter into written commitments early. I am sure that all producers in the U.S. and Canada will give preferred supply to our North American customers. You cannot afford, however, to place your orders at the last minute and expect a producer to turn down an export order that may come up in the meantime.

I would like to address briefly the question of distribution. Rail car shortages have been a recurring problem each spring for potash producers and users. The situation will get worse and it will get worse to an alarming degree. At PCS we have experienced insufficient car supply since February and do not expect any improvement this season. Other producers report similar experiences.

One reason behind this prediction is the growing volume of commodities that have to be moved by the American and Canadian railroads. As in the United States, Canada has just completed a record grain year, including a total of 15,240,000 metric tons of grain exports.

In Western Canada, the capability of the railroads to physically haul the ever-increasing tonnages of grains, potash, coal, sulphur and other bulk commodities will very shortly reach a limit unless new distribution patterns and methods are developed.

I do not have to elaborate on the rail situation in the U.S., and the demand for hopper cars to haul grain.

At the same time, you have to cope with the problem of abandonment of branch rail lines.

At PCS, we are of the view that a new look needs to be taken at distribution. A new way has to be found to level the increased shipments from the mines and to decrease dramatically the turn-around time of rail cars. With this in mind, we have retained the services of a well-known group of consultants to undertake for us a major distribution study which will concern itself with all aspects of distribution: seasonal freight rates, unit trains, truck/train combinations, field warehouses, vessel shipments via the lakes and via west coast ports.

Regardless of the outcome of our study, and regardless of the goodwill and dedication by potash producers to invest time and money in improved distribution facilities, it can be said frankly that a close co-operation between potash producer and buyer is necessary in order to achieve the mutual goal. Intermediate warehouse facilities are costly and will be an inadequate substitute for getting the potash to the dealer in season. In my view, it is important that either indoor or outdoor potash storage be added at the point of final distribution. There will have to be sufficient economic incentives to provide such additional storage. We are trying to work with the railroads and with our customers in an effort to develop a program which will make it worthwhile for customers to take equal delivery of potash year-round.

Such a program can only work if and when the customer has an assurance that product purchased in the off-season will not decrease in value as the year progresses. In other words, price stability is a very important factor in this context.

I would be remiss if I failed to comment, however briefly, on the price you can be expected to pay for potash.

It is my personal view that the narrowing of the supply and demand balance will obviously result in stabilizing the potash price. I do not expect "fire sales" for potash to recur. Many potash buyers are rapidly becoming more concerned about guarantee of supply than about prices. There is a need for the price of potash to increase to the point where the increased costs of production incurred over the last four or five years be adequately reflected in the selling price. In 1977/78, the average potash price was about $1.00 higher than during the previous year. Once the adjustment has taken place, potash prices can remain stable and hopefully further increases will again reflect only cost increases in production. I would hope that potash producers will not take undue advantage of the developmenting product shortage and peg price increases to the rate of inflation which we expect to be considerably higher than the increase in production cost. While potash prices have to catch up, I believe that potash will remain the lowest priced of the three major plant nutrients. Also, Canadian potash producers are aware of the competitive situation that exists. We intend to protect our main markets, the U.S. and Canada, both with respect to price and tonnage.

A brief comment on the role of Canada as a major supplier of potash to the world and to our North American farmers now and in the future.

Slide 10 graphically shows our estimate of the Canadian share in world potash markets. Canadian shipments reached 22% in 1976/77 and are gradually increasing to 24% in 1980/81 and to 26% by 1985/86; a very steady growth. This slide had been prepared several months ago. Since then we have made some changes in our forecast which were reflected in Slide 1 but are not reflected here. These changes are minor and on the whole the slide is correct.

Canada provided approximately 73% of all potash supplied in North America in 1976/77. Due to imports and increasing deliveries from U.S. mines, the Canadian share in North America will drop temporarily. By 1985/86 it is expected to be back to the 73-75% level.

The Canadian share in world markets other than North America is growing by varying degrees, tied in with changes in transportation costs which are going to influence the Canadian position. However, all this will depend in whether Canada can produce the tonnages required by the market.

As noted earlier, it is my view that the production capability of Saskatchewan in 1979/80 is 7.2 million tons K_2O. With some luck, we may be able to increase that production to 7.5 million in 1980. I assume that the current expansions underway at PCS's Cory, Rocanville and Lanigan Division will be completed at that time. The three expansions will add one million product tons capacity to the present Canadian production.

PCS has completed an Engineering Feasibility Study for a Phase II expansion of the Rocanville Division. We are going to our Board this week and if approved, the added capacity can become available during the 1981/82 season. We have additional expansions for Cory and Lanigan under review, but no funds have been committed to date. We also recognize that at least one new major plant will have to be brought into production in Canada for the mid-80's.

At your meeting a year ago, the potash speaker spent some considerable time discussing the involvement of government and the rate of royalties and taxes assessed on Canadian potash producers.

The controversy between the Canadian federal and provincial governments over the ownership of and authority to impose taxes on natural resources has not been resolved. There are indications that the federal government may be willing to discuss with the Provinces the right to levy taxes on natural resources, notwithstanding two recent decisions by the Supreme Court of Canada to the contary. The matter will be discussed at a forthcoming meeting of First Ministers.

As you have heard, the Government of Premier Blakeney was returned in the October 18th elections with an overwhelming majority. Control and taxation of natural resources was a major issue during the campaign and Premier Blakeney will stress his case in Ottawa following the clear mandate he has received from the voters.

It is my belief that the provincial government and the potash producers can arrive at a settlement of their taxation dispute in the early spring of 1979 at the latest.

In conclusion, we in the fertilizer industry, and especially in potash, can look quite positively for continued growth in the future.

Potash will be in tight supply, beginning next year. Proper planning and co-operation between buyer and seller can help Canadian potash producers to fill the gap.

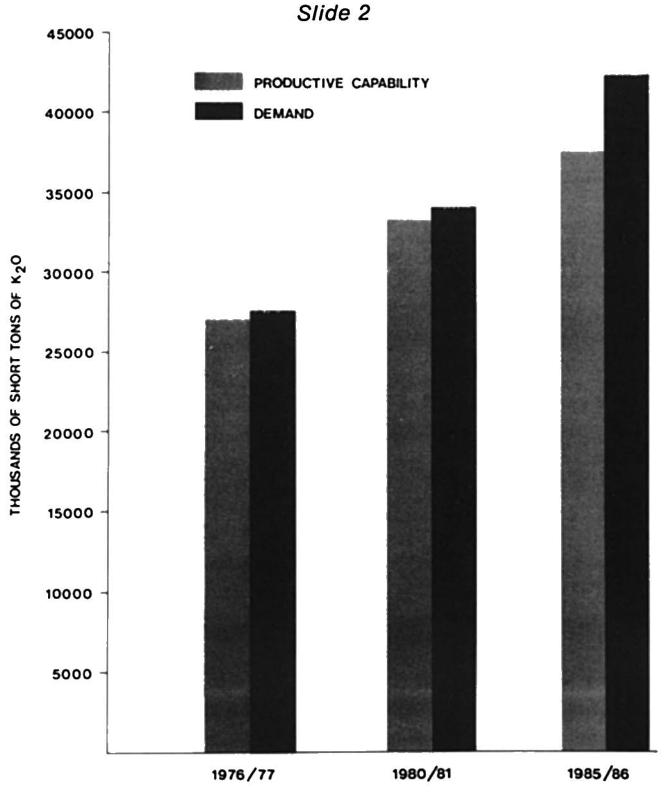
Slide 1

WORLD SUPPLY-DEMAND BALANCE

in Thousands of Short Tons K_2O

	1976/77			1980/81			1985/86		
	Productive Capability	Demand	Balance	Productive Capability	Demand	Balance	Productive Capability	Demand	Balanc
West Europe	6,680	5,830	850	6,687	6,850	(163)	7,236	7,790	(554)
Africa	330	380	(50)	-	560	(560)	-	890	(890)
Oceania	-	280	(280)	-	320	(320)	-	390	(390)
Asia) Middle East)	790	2,150	(1360)	711	3,000	(2289)	1,602	4,720	(3118)
East Europe	12,620	10,520	2,100	15,870	13,240	2,630	17,500	16,120	1,380
Latin America	-	1,420	(1420)	-	1,810	(1810)	-	2,880	(2880)
North America	10,125	6,986	3,139	10,000	8,250	1,750	11,100	9,470	1,630
TOTAL	30,545	27,566	2979	33,268	34,030	(762)	37,438	42,260	(4822)

Slide 2



WORLD SUPPLY/DEMAND BALANCE

Slide 3

NORTH AMERICAN POTASH DISAPPEARANCE

Thousands Short Tons K_20

YEAR	SUPPLY EX CANADA	SUPPLY EX U.S.A.	NORTH AMERICAN MINES SUPPLY	OVERSEAS IMPORTS	TOTAL AVAILABLE
1973/74	4,370	1,818	6,188	87	6,274
1974/75	3,907	1,572	5,479	113	5,592
1975/76	4,060	1,506	5,566	126	5,692
1976/77	5,071	1,734	6,805	195	7,000
1977/78	5,194	1,483	6,677	270	6,947
1978/79	5,420	1,880	7,300	380	7,680
1979/80	5,675	1,825	7,500	450	7,950
1980/81	5,850	1,800	7,650	600	8,250
1981/82	6,080	1,800	7,880	600	8,480
1982/83	6,315	1,800	8,115	600	8,715
1983/84	6,560	1,800	8,360	600	8,960
1984/85	6,810	1,800	8,610	600	9,210
1985/86	7,070	1,800	8,870	600	9,470

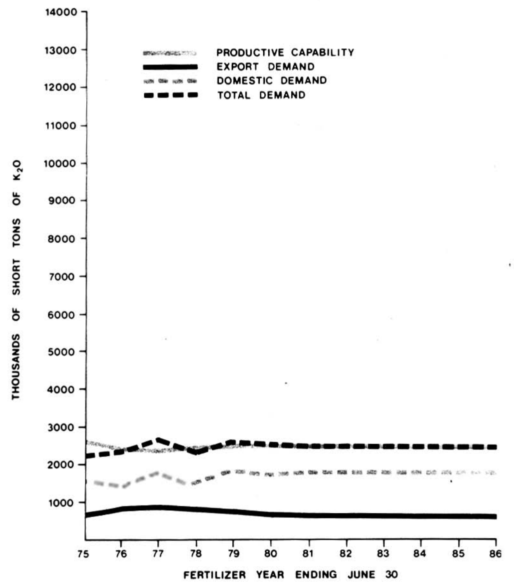
Slide 4

U.S. POTASH PRODUCERS SUPPLY AND DEMAND BALANCE

(Thousands Short Tons K_2O)

YEAR	PRODUCTIVE CAPABILITY	DOMESTIC DEMAND	EXPORT DEMAND	TOTAL DEMAND	ENDING INVENTORY
1974/75	2,613	1,572	717	2,289	473
1975/76	2,447	1,506	881	2,387	532
1976/77	2,413	1,734	901	2,635	310
1977/78	2,485	1,483	841	2,324	480
1978/79	2,500	1,880	800	2,680	300
1979/80	2,500	1,825	725	2,550	250
1980/81	2,500	1,800	700	2,500	250
1981/82	2,500	1,800	700	2,500	250
1982/83	2,500	1,800	700	2,500	250
1983/84	2,500	1,800	700	2,500	250
1984/85	2,500	1,800	700	2,500	250
1985/86	2,500	1,800	700	2,500	250

Slide 5



U.S. POTASH SUPPLY / DEMAND

Slide 6

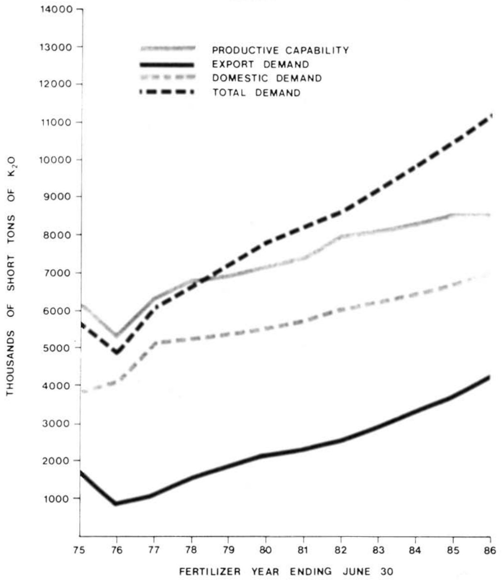
CANADIAN POTASH PRODUCERS SUPPLY AND DEMAND BALANCE

(Thousands Short Tons K_2O)

YEAR	PRODUCTIVE CAPABILITY	DOMESTIC DEMAND	EXPORT DEMAND	TOTAL DEMAND	ENDING INVENTORY
1974/75	6,198	3,907	1,746	5,653	668
1975/76	5,337	4,060	887	4,947	1,058
1976/77	6,234	5,071	1,080	6,151	1,142
1977/78	6,842	5,194	1,619	6,813	1,171
1978/79	6,900	5,420	1,850	7,270	801
1979/80	7,200	5,675	2,075	7,750	251
1980/81	7,500	5,850	2,350	8,200	(449)
1981/82	8,000	6,080	2,600	8,680	(680)
1982/83*	8,200	6,315	3,000	9,315	(1,115)
1983/84*	8,400	6,560	3,400	9,960	(1,560)
1984/85*	8,600	6,810	3,800	10,610	(2,010)
1985/86*	8,600	7,070	4,200	11,270	(2,670)

* Includes production from New Brunswick beginning in 1982/83

Slide 7



CANADIAN POTASH SUPPLY / DEMAND

Slide 8

SLIDE 8
Oct/78

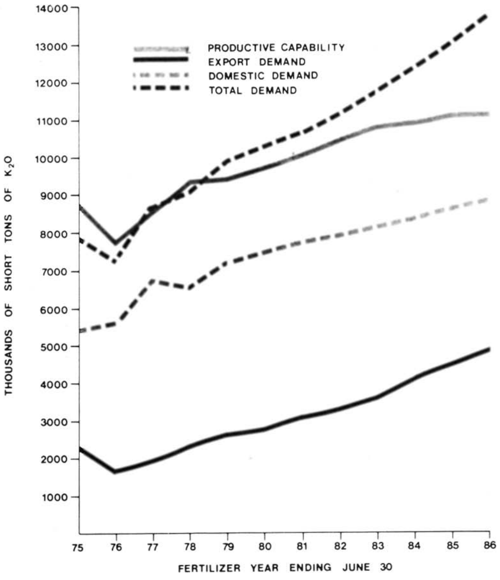
NORTH AMERICAN POTASH PRODUCERS SUPPLY & DEMAND

(Thousands Short Tons K_2O)

YEAR	PRODUCTIVE CAPACITY	DOMESTIC DEMAND	EXPORT DEMAND	TOTAL DEMAND	ENDING INVENTORY
1974/75	8,811	5,479	2,463	7,942	1,141
1975/76	7,784	5,566	1,768	7,334	1,590
1976/77	8,647	6,805	1,981	8,786	1,452
1977/78	9,327	6,677	2,460	9,137	1,642
1978/79	9,400	7,300	2,650	9,950	1,092
1979/80	9,700	7,500	2,800	10,300	492
1980/81	10,000	7,650	3,050	10,700	(208)
1981/82*	10,500	7,880	3,300	11,180	(680)
1982/83*	10,700	8,115	3,700	11,815	(1,115)
1983/84*	10,900	8,360	4,100	12,460	(1,560)
1984/85*	11,100	8,610	4,500	13,110	(2,010)
1985/86*	11,100	8,870	4,900	13,770	(2,670)

* Includes New Brunswick

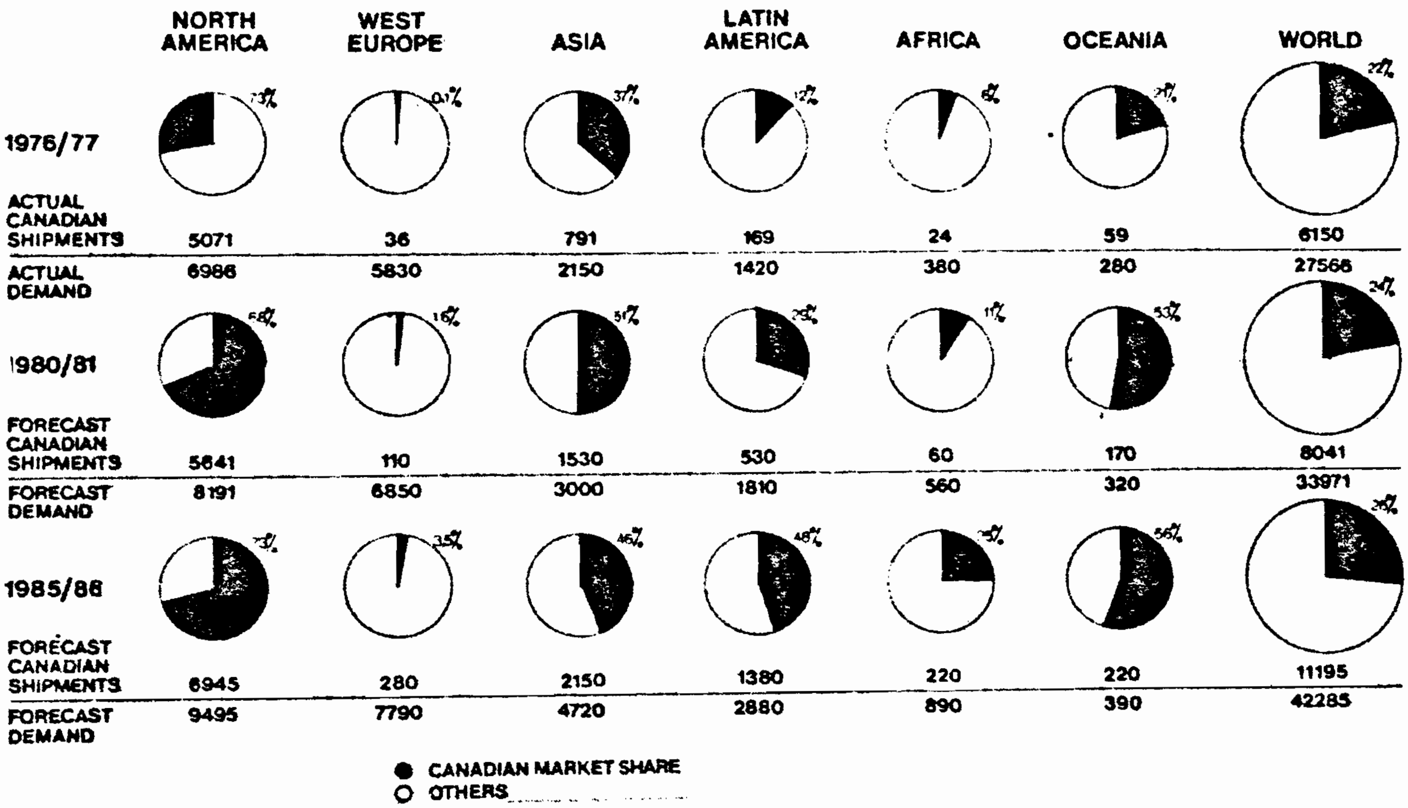
Slide 9



NORTH AMERICAN POTASH SUPPLY / DEMAND

CANADIAN MARKET SHARE

(THOUSANDS OF SHORT TONS OF K_2O)



MODERATOR BLENKHORN: Any questions for Mr. Holzkaemper?

QUESTIONS FROM THE AUDIENCE: Can you tell us the approximately total potash reserves in Canada?

ROLF HOLZKAEMPER: I'm sorry, I can't honestly tell you at the moment. At the present production levels I would say it is in the vicinity of 200 years, so I don't think we have to worry about that as far as our boys are concerned. (Applause).

MODERATOR BLENKHORN: Thank you Rolf for coming so far to give that excellent presentation. (Applause).

We move on now to what we feel is a logical extension of the subjects that we have just heard dealt with here, and that is to take a look at the prospects for the end use of our product in the future. Now, if you're going to get down to the grass roots of anything, there's no better person to do it than an old forage specialist. When I say old, I mean that in quotation marks. To speak on the subject of NPK Utilization, we have Dr. Bob Wagner, President of the Potash/Phosphate Institute. Dr. Wagner has a long background of teaching, research and extension. He is a native of Kansas, educated at Kansas State and the University of Wisconsin. He has been variously employed as a forage specialist in Kansas, at the U.S.D.A. Research Station in Beltsville, Maryland, has been Chairman of the Department of Agronomy at the University of Maryland, Director of Extension Service — State of Maryland, served as Regional Director and Vice President of the old Potash Institute and was elected, about three years ago I believe, President of the Potash/Phosphate Institute. He is a Fellow of the American Society of Agronomy, an honor that is not lightly bestowed. Dr. Bob Wagner. (Applause).

NPK Utilization

Dr. R. E. Wagner

If we can believe even the more conservative projections for fertilizer use, this country will consume more NPK in the next 15 to 20 years than it has used in all previous history. That says several things.

The first thing it says to me is that agriculture will require sizable quantities to keep farmers in business and sufficiently strong to produce food needs. It says that we in the fertilizer industry are in a relatively young business with a potentially exciting future. It says we are in big business, getting bigger all the time. It says demand should be great enough to cause new N plants to be built and new phosphate and potash mines to be developed.

However, the day is past when it *"just happens"* that actual consumption equals what is projected. From now on it must be *made* to happen. Remember, projections do not sell fertilizer, and they do not assure farmers that they will have the kind of advice on fertilizer use that is in their best interests.

Past experience shows that projections always are easier to articulate than to attain. Worldwide phosphate use was *projected* to rise 8 to 9% yearly over the past 10 years, but *demand* actually rose 6 to 6.5%.

Nevertheless, the past record of prognosticators has not been bad except for some short-term situations. Corporations that have used them as the basis for their plans usually have fared well.

I share the concern of many that projections will not serve so well in the future *unless* the industry is willing to invest more in market development based on agronomic research and education.

New Constraints To Further Increased Fertilizer Use

Why do I and others have concerns for the reliability of today's projections for tommorrow's consumption? What's different now from what it has been in the past? I'll mention some key points of difference.

1—Fertilizer economies in some heavy using areas are maturing. Heavy use areas are in developed nations, which now use about three-fourths of the world's fertilizer tonnage and are forecast to be using two-thirds of the total 20 years from now. Although total tonnage increase during that time will be greatest in developed countries, consumption is forecast to increase 2.5 fold compared to a 4.5 fold jump in developing nations.

Growth stops when full maturity is reached. We are not at that point yet anywhere in the world although Japan is coming close. We are at the point in several areas, though, where crops do not respond as dramatically as they once did to applied nutrients. Where this is happening, the case for increased fertilizer consumption is less convincing. Simply maintaining current tonnage presents a challenge to research and education.

2—Maturity in fertilizer use in a few areas is causing an unfortunate focus and preoccupation with over-fertilization. We hear more and more about it in America . . . in western Europe . . . other nations.

This can prove to be very detrimental because such talk too often generalizes and distorts the total picture. Such talk puts fertilizer recommendations and use in the negative posture of a savings syndrome. It raises questions on how little the farmer can get by with rather than how much he should use to assure best possible plant growth that will maximize his profits.

Years of heavy fertilization can build up some soils. In 1967 the soils tested in Michigan showed 59% or less in P. By 1977 the figure had dropped to 31%, indicating buildup in some soils. However, in Iowa 80% averaged medium or low P in 1964-7 versis 78% in 1968-73. In Missouri the figures were 68% in 1964 and 70% in 1976; in Kansas 67% in 1968 and 71% in 1977.

Where there has been buildup, indeed, we must say so. To do otherwise would be to deny scientific fact. But we must be sure it truly is over fertilization and not under production. Low yields or under production in most parts of the world is far more common than over fertilization. Many soils test low to medium in both phosphorus and potassium in most of the U.S. and the world.

3—Crop yields have plateaued. The skyrocketing yield levels of the 1950's and 60's topped out about 10 years ago. For example, average corn yield in the U.S. in 1950 was 38 bushels and hit 86 bushels in 1969. While the record of 97 bushels came in 1972, there has not been a substantial increase since. A new record yield of 100 bushels is predicted for 1978. The average yield for the past five years, including 1978's indicated record, is 87 bushels, the same as the average for the 1969-73 five-year period.

Obviously, if yields do not move upward, one of the strong points for increased fertilizer use has been removed. Undoubtedly, the future will see greater recognition of the need for fertilization to improve crop quality, a need that can be additional to requirements for yield. Also, more states are expected to follow Illinois lead in adopting a soil buildup plus maintenance fertility program.

4—Research support is eroding. A recent study made by the institute of a five-state area, Kansas, Nebraska, Oklahoma, Missouri, and Iowa, revealed that ten years ago soil fertility research funds were only 3% of the total state and federal support for agricultural research, which was $40,781,555. Since then that low level support has further eroded to 2%. Between 1968 and 1976 total state and federal research dollars for agriculture doubled to $81,240,599, but soil fertility funding increased only 33%— from $1,225,405 to $1,625,389— well below the inflation rate and, therefore, a loss of support.

Most important, soil fertility research lost nearly one-third of the scientist years assigned to it. Effectiveness of some of the best remaining researchers has been hampered by greatly reduced operating funds.

Federal funding actually dropped by 7.4% during this period. Recent USDA projections indicate an even further decline through 1981.

Pollution abatement, food safety and other issues of the environment and pressures for social programs are in priority position. The resulting regulatory overkill is rampant in today's society and does need researching— but not in the name of nor at the expense of soil fertility research.

5—A high yield focus still is missing in much research. Without it, there is a high risk that results will duplicate what already has been done. Maximum yield research is the best assurance that new knowledge will be generated. Top producers are hungry for information from research conducted at their yield levels or above. Such research is not valuable exclusively to top farmers. It also adds to the bank of information already available for the average or below average farmer. The goal is to move production systems to higher levels whether a farmer is average or above or below.

The total package of production practices must be considered. Only in this way will there be the breakthroughs leading researchers are looking for and that will take crop yields to new heights.

6—The supply and reserve situation of NPK is considered by some to be a deterrent to growth in the industry. Energy requirements for nitrogen production are of concern. Reserves of phosphate are finite and those in the U.S. have been variously estimated to be adequate for 50 to 100 years. However, technology can make what is waste today into marketable product in the years ahead. Geologists indicate there should theoretically be additional resources which are three times as large as presently identifiable resources. Potash presents no problems in terms of reserves. Canada alone has enough to supply the world's needs at present consumption levels for the next 2,000-3,000 years.

7—Locomotive and rail car shortages likely will become increasingly severe. Keen competition from the coal and grain industries has accentuated the problem. Large capital expenditures will be required in the years ahead for the purchase of cars and for repair and maintenance of track.

8—Fertilizers as polluters is a theme that some will constantly try to feature. Dr. R. L. Cook of Michigan State said it well. "The practices we perform to grow our top yields do the best job in conserving and building our soils." This is especially important in reference to 208 implications.

These constraints raise a number of questions about the future of the fertilizer industry. Not if it will survive, because obviously it will. The questions are how much vigor and how much growth will be there?

One thing is certain. There will be great need for plant nutrients to produce food for increasing numbers of people around the world. There will be great need for plant nutrients to build and maintain yield levels that are profitable enough to provide incentives for farmers to produce that food.

The biggest question of all still remains. How much of the need will be translated into actual use? It is not difficult to prove the need. Selling the need to the ultimate user in the face of the kinds of constraints we have talked about is the real challenge of the future for the industry.

Market Development Can Make A Difference

As we've already said, projections do not sell fertilizer. An aggressive sales program and special customer services of an individual company certainly can increase sales for that particular company, but they do not necessarily expand the total market for a product on a long-term basis.

It is interesting and somewhat disturbing that some key people in industry question if anything can be done— if market development through agronomics can make a difference. If such fatalism were the prevailing thinking of the industry, we would be very hard pressed to meet even the relatively conservative projections that Dr. John Douglas presented at the third World Fertilizer Conference in San Francisco this past September. He said that the NPK growth rate would be 2.5% annually through 1990. This compares to 8.0% in the 1960's and 4.5% so far in the 1970's. He predicted only a 1.8% growth rate for P, 2.5% for K, and 3.0% for N. The prediction was upsetting to many in the industry. It has stimulated a lot of talk and thought. Of course, we need to bear in mind always that the tonnage base is getting bigger and a 3% increase in 1990 is the equivalent of an 8% increase in 1960.

If the industry takes the position that nothing can be done— and does nothing— I would say John's predictions are too high. On the other hand, I believe just as strongly that actual consumption figures can be moved above the projected increases.

It will take a vigorous effort by the industry in market development. The fertilizer industry, as a whole, never has been real serious about market development compared to other industries. Not long ago a major pharmaceutical concern reported that it spent 16% of its gross on market development. How many fertilizer companies approach that? Many invest $100 to $200 million in a plant or a mine. Some do put a great deal of effort into product development, but not on product utilization. The fertilizer industry is fortunate its product is essential and not merely a luxury item.

One could argue that until now a strong market development effort wasn't needed in the fertilizer industry. The requirements for essential plant nutrients were so obvious and crop responses so dramatic that fertilizer sold itself. Actually, for many years this was true to a great extent in the case of nitrogen and to a lesser degree with phosphorus. However, potassium in developing fertilizer economies nearly always has been the stepchild element of the "Big 3" and always has needed a market promotion and development program.

The potash industry recognized that many years ago— 43 to be exact. To do something about it, they founded the American Potash Institute; later the Potash Institute; and now the Potash & Phosphate Institute.

It was founded in 1935 with a charge to help get fertilizer used on a basis that is scientifically sound and profitable to the farmer. Clearly this meant working closely with universities as well as the industry and giving support to their research and education programs.

It is of interest to examine the pattern of potash consumption in the United States from the early days of the Institute to now. In 1935 consumption was 307,000 tons K_2O. In 1977 it was 5,833,000 tons.

Obviously, the Institute and university colleagues cannot take total credit for what happened. But there are those who will argue that the influence was significant.

Phosphate did not have a market development institute working in its behalf until July 1, 1977, when several producers joined potash producers in support of the Potash & Phosphate Institute. The phosphate industry recognizes the time has come when the market for their product needs to be strengthened.

In 1935, the first year of the American Potash Institute, phosphate consumption in the United States held a substantial 597,000 to 307,000 ton lead over potash. The gap narrowed through the years but was not finally closed until 1974 when potash caught up. Consumption of the two remained essentially the same for 3 years; then in 1977 potash pulled ahead. A strong research program on phosphate will be needed to moderate a widening gap in that direction.

High Yield Research The Base For Market Development

A renewed emphasis on support to university high yield research in soil fertility is central to the Institute's present and future program. Such research is one of the greatest needs of both the industry and agriculture. The level considered high or maximum will, of course, vary greatly with climate, soil type, etc. Man can adjust climate very little; plants cannot be made fully "climate proof"; and it is costly to alter problem soils enough for profitable production. In many parts of the world irrigation is the most effective means of modifying the environment. The point is to be sure that the goal is to maximize yield for any given set of conditions by optimizing the use of the controllable inputs, of which fertilizer is primary.

In fertility experiments if there is no response at a level that best judgment suggests is less than maximum yield for that given soil type and climate, then something else is limiting and the original objective of studying response to fertilizer cannot be achieved. Too often the conclusion is that fertilizer will not increase yield, when, in fact, that was not even being studied because something else got in the way.

Striving for top yields sets up a highly charged system of interactions among nutrients in the soil and in the plant. There is much missing information on components of high yields and interactions among those components and what barriers to higher production might be set up by them. Top farmers wonder why they can't move to still higher yields. When they can't, they get impatient or uncomfortable as they realize how little is known about what they already are doing.

Obviously, high yield means more use of plant nutrients in proper balance. But, it does not mean *excess* or *careless* usage. It means more into the plant and less into the environment. More use of nutrients can be justified only to the extent that it helps the plant make better use of other inputs and its total environment for best possible growth expression of the plant.

Fertilizer can account for at least 30-40% of yield even though it may represent only 15-20% of total production costs of most crops. That is a key point. Equally important is to recognize that fertilizers alone do not guarantee profitable yields; however, on most soils it is impossible to obtain high yields without the addition of some nutrients.

It is a matter of upgrading the total production system. The goal should be to build soil productivity, not just fertility. This takes in the total picture, including production of more residues through higher yields, proper use of residues by incorporating in the soil or leaving on the surface, chiseling or subsoiling to break a pan and/or to deepen the productive soil surface layer over the years in some soils, proper control of pests, water management through drainage and/or irrigation, as well as more adequate levels of all nutrients for high yields. The future will demand that increasing emphasis be given to water and energy use efficiency in production practices. High yields will be called upon to help get it accomplished.

High Yield Research The Base For Farmer Profits

At the Extension Workers Breakfast during the American Society of Agronomy meetings in December 1977, Mr. Richard Rominger, farmer and director of the California Department of Food and Agriculture, said, "The ability to produce higher yields has kept farmers in business over the years."

In a recent issue of the Wall Street Journal this statement was made, "Farmers say higher yields are the only way they can make money. Extra cash from extra bushels provides the edge over fixed production costs that keeps successful growers in business while other flounder."

The same article quoted Arnold Paulsen, Iowa State University economist, "More broadly, those extra bushels represent national economic development. If we get more soybeans out of each resource unit, we've got a choice between using more soybeans or using newly freed resources to meet other needs."

Research at yesterday's yield levels are not adequate for the high yields our economy now demands for the farmer to cover his costs and still realize a profit. Let me emphasize that point with this example. The average 1975-78 corn yield in the U.S. was 91 bushels per acre. According to USDA, the 1978 cost of producing corn in the Lake States and Corn Belt was projected to be $248.92 per acre. The average farmer (91 bushels per acre) would be losing money unless he got about $2.75 for his corn. If he did move his yields to 125 bushels, he could cover those costs with $2.00 corn. Pushing to 150 bushels would put the break-even point at $1.70 corn. For those who are leading the way and get 200 bushels per acre, $1.25 corn will cover the above costs; and if they can get $2.00 for their corn, they would net somewhere between $100 and $125 per acre depending on extra fertilizer and harvesting costs.

It is abundantly clear that average yields are unprofitable and that there is a compelling need for average farmers to upgrade their production systems. Low yields can drive farmers out of business today quicker than at any time in the past. Costs have risen much faster than yields in recent years. Whether yields are low or high, fixed costs are about the same and payment becomes due at the same time. While the farmers' total worth has increased rapidly, so has their indebtedness.

Dr. Allan Bandel of Maryland says, "It is obvious that poor fertilization practices eventually catch up with the farmer. On good land, he can live initially in a "fool's paradise" by exploiting his residual soil fertility. But this practice is like always withdrawing money from the bank and never putting any back. Eventually, the account will be overdrawn. From then on, declining yields and declining profits are certain unless a good sound fertilization program is reinstated and followed faithfully."

Illinois farmer, Mr. Herman Warsaw, heeds what Dr. Bandel says. A graph of his yields in the past 7 years looks like a graph of fertilizer sales or prices— lots of peaks and valleys. But the big point is that at no time during that 7-year period did his yields drop below 200 bushels per acre even though he experienced two dry years.

Also a significant point is that he had the full package of practices in place— including a good fertilizer program— to take full advantage of the good years when they came. Such a year was in 1975 when he produced 338 bushels per acre.

A young Michigan farmer bettered that mark in 1977 with a new world record yield of 352 bushels per acre. It was helped by irrigation and a good fertilizer program.

We in the institute believe that staying close to these kinds of pioneering efforts and challenging researchers to get information helpful to the trail-blazers is an effective way to expand fertilizer markets.

A Resaearch Uplife Needed

The kind of research that made American agriculture the envy of the world had its day. We must move on.

Research of the kind that helps modern top farmers is limited. Components of maximum yields for any given situation are not well defined. Balance and interaction of nutrients— major, secondary, and micro— at high levels need special attention. Soil tests are not well correlated with high yield levels. More analyses are needed to determine the economic consequences to farmers adopting new research findings. What crop quality changes— good or bad— occur in high yield circumstances? How effective are high yields in improving water and energy use efficiency?

We need a research uplift. With maximum yields as a goal nearly everything that is studied becomes new— nutrient balance in the soil and in the plant; interactions of nutrient elements; water relationships and management; tillage practices; crop quality; fertilizer economics; soil test correlations; fertility in relationship to environmental influence and energy requirements; etc. Without maximum yields, experimentation is at high risk of redoing what was done 10 or 20 years ago or, at best, of falling short of getting the answers needed for agriculture five, ten, or more years down the road. The farmer who already gets 150 bushels and is searching for ways to go to 200 bushels, is not turned on by research with 100 or 125-bushel corn.

While the industry's primary interest is in applied research, there also is recognition that longer-term basic studies are vital for building market strength on a continuing basis. Perhaps the greatest inefficiency in all agriculture is the use of solar energy by plants in their growth processes. Use seldom exceeds 2% of what is available to plants, and often it is less than 1%. Breakthroughs to developing more photosynthetically efficient crops in converting solar energy and carbon dioxide fixation will come only through basic research. This is a big field that involves complicated biological mechanisms. The role of different levels of nutrients, including micro-nutrients, interacting in these systems needs study.

Water will be an increasingly scarce item in the future. As someone said, H and O in a 2:1 ratio are our most important nutrients. Altering plants to more efficiently utilize water when it is available, as well as to better withstand periods of deficiency, will get the attention of researchers. Significant progress will be made in developing resistance to environmental stresses only if researched in depth. Insects, diseases, weeds, and nematodes are biological systems that compete with crop plants, commonly causing losses of 25-35%. A recent study showed pests get 33% of U.S. crop production— 13% lost to insects, 12% lost to diseases, and 8% lost to weeds. These sytems need basic researching to remove barriers to food production.

Research is not knowing, but being willing to find out. Scientists who spell out challenging yield goals in their research projects reflect their willingness and eagerness to find out. They don't believe that working with high-profit yields is non-scientific. They are willing to apply practical economics to scientific responses. They deserve more support from the industry.

An excellent example of what could be done and have considerable impact is the cooperative industry-Land Grant university program in soil fertility research now under discussion. If the talks are successful— and we are very hopeful they will be— the program will get its start in the five-state area of Kansas, Nebraska, Oklahoma, Missouri, and Iowa. A science based industry supported effort, as envisioned, can be a great boost to deserving researchers.

From key researchers will come the results needed to form a scientific base for future meaningful market programs in the industry. Working against greater odds than we have known in the past, we must have fresh research information if the fertilizer industry is to experience a sustained and vigorous growth. The vigor or growth will be in proportion to the amount of support the industry is willing to give to developing its markets through research and education. Strong agronomic and agro-economic programs sell fertilizer — and build long-term market growth.

All fertilizer programs from the most unsophisticated to the most sophisticated must be based squarely on scientific truth. There is no other way to create programs that build markets— not for just a season, but for decades.

DIRECTOR BLENKHORN: Thank you, Bob. We're doing pretty well with our time budget. Any questions for Dr. Wagner? I think he covered his subject so throughly that there aren't any questions necessary.

Well, that ends the program for this morning. I would like to thank the four speakers for the excellent presentation and effort that they put into their presentations. We heard a lot of words of wisdom and some excellent graphic art displays and this, I think, reflected the serious way that these speakers regarded their task, and I think they did an excellent job, and I think they should have a round of applause (Applause).

That concludes the morning program, and we meet here again at 1:30. (Applause).

Tuesday, October 31, 1978

Afternoon Session
Moderator Douglas Caine

MODERATOR CAINE: We are now ready to start our afternoon session. This morning you heard papers and presentations on the future — of the way things are going to be. This afternoon will be devoted to people that will be speaking on topics telling you things like the way they really are today. Our first speaker, Glenn Feagin, is a native Georgian. He was born in Atlanta and raised in Americus, Georgia. He graduated from the Georgia Institute of Technology in 1949 as a Chemical Engineer. He has been with the International Minerals and Chemicals Corporation since that date. During his service with IMC, he has held jobs which run the full gamut. He has been a production trainee, a sulfuric acid plant foreman, a plant manager, and a zone production manager, and he is now the Manager of Fertilizer Technology for the Rainbow Division and lives here in Atlanta. Like many of us, Glenn wears several hats. In addition to his technical responsibilities, he is quite heavily involved with employee safety and training. At this time, Glenn would like to share with you a program that IMC has effectively used in accident prevention. Mr. Glenn Feagin. (Applause).

Safety In Plants — Film
Glenn Feagin

Do you realize that in just 3 short months, the fertilizer "season" will have started? What a busy time! Trucks rolling in and out of the plant, the phone ringing off of the wall, everyone wants his order *at once!*

Got to have extra help to keep it moving — get them hired — get them to work — come on, move it.

Hold it, wait a minute! Have you thought about what's going to happen if one of those new employees gets hurt, or even worse, gets killed? Hadn't you better plan on familiarizing them with plant operations and plant safety rules before you let them start to work?

I would like to share with you the slide/tape program IMC Rainbow uses for this purpose. This program was professionally recorded to make it as interesting as possible. However, you could make one yourself with only a camera and a tape recorder.

To stay within my allotted time, it was necessary to delete the sections dealing with electrical safety, maintenance, fire protection and first aid.

Now, let's watch "SIMPLE AS 3-2-ONE".

Script of Slide Presentation.

Rainbow Safety Film.

Slide No. 1
ROCKET ON PAD

Slide No. 2
ROCKET BLAST

Slide No. 3
ROCKET RISING

Slide No. 4
GROUND CONTROL

Slide No. 5
CLOUD-COVERED EARTH
AS SEEN FROM SPACESHIP

Slide No. 6
EARTH FROM SPACE

Slide No. 7
ASTRONAUT ON SPACE WALK

Slide No. 8
APPROACHING MOON

Slide No. 9
MOON LANDER GOING DOWN TO MOON.
HALF-EARTH ON HORIZON

Slide No. 10
MOON LANDER APPROACHING
MOON SURFACE

Slide No. 11
ASTRONAUT CLIMBING DOWN
LADDER TO MOON SURFACE
SFX: "The Eagle has landed . . ."

Slide No. 12
ASTRONAUT BOTH FEET ON MOON
MUSIC: Climax, Transition to new and gentler theme.

Slide No. 13
ASTRONAUT ON MOON
LOOKING UP AT LADDER
NARR: Men on the moon. Men . . . on the job . . . prepared! Ready for almost anything. they had to be! Nobody had ever been on the moon before.

Slide No. 14
ASTRONAUT PLANTING
U.S. FLAG ON MOON

Slide No. 15
ASTRONAUT WALKING INTO
DISTANT DESOLATION OF MOON
VOICE: Kind of eerie . . . unfriendly place. Dangerous, too. I don't think I'd care to go there.

Slide No. 16
EXTERIOR OF RAINBOW PLANT
NARR: How's this?
VOICE: A Rainbow plant? Suits me fine. And it's a lot safer. Give me good old solid earth every time.

Slide No. 17
IMC MAN IN PLANT
EXTERIOR FOREGROUND.
LOOKING BACK OVER
SHOULDER AT CAMERA
NARR: Bet THAT'S what John Glenn said.
VOICE: The astronaut? Didn't he . . .?
NARR: Made two trips into orbit. then he slipped in his bathtub at home.

Slide No. 18
SAME. MAN FACING CAMERA.
VOICE: I remember. He hurt his back. And THAT
NARR: Un-huh! . . . ended his job in space.
VOICE: You're trying to tell me something?

Slide No. 19
SAME. MAN LOOKING UPWARD AT
TYPE OVERHEAD: **"SAFETY"**
NARR: About SAFETY.
VOICE: Safety? What about it?
MUSIC: TITLE THEME QUIETLY BUILDING

Slide No. 20
TITLE FRAME: "SIMPLE AS 3, 2, ONE"
ON SPACE THERMATICS
NARR: It's as simple as 3, 2, one!
MUSIC: Full to cover.

Slide No. 21
SAME BG. CHANGE TYPE TO:
"PRODUCED BY IMC RAINBOW"

Slide No. 22
MAN ABOUT TO ENTER PLANT;
TURNS FOR APPROVAL TOWARD CAMERA
VOICE: OK if I blast off to work?
NARR: When you're ready—

Slide No. 23
SPLIT SCREEN MAN AND ASTRONAUT
IN COMPLETE SPACE OUTFIT
VOICE: I'm not wearing a space suit.
NARR: We don't ask you to. But working around a fertilizer plant requires some special protection.
VOICE: Like what?
NARR: Let's start from the bottom up. With footware.

Slide No. 24
FEET OF WORKER IN BOOTS
VOICE: How are these?
NARR: Perfect! We require safety-toed work boots to protect your feet. In fact, we provide them to all full-time personnel.

Slide No. 25
MCU. IMC-ISSUE PANTS
VOICE: Like these pants?
NARR: A tightly-woven fabric— of cotton or cotton blend— protects your skin from dust and liquids . . . doesn't melt like synthetics when exposed to fire.

Slide No. 26
MCU. MAN IN UNIFORM SHIRT
VOICE: Same for the shirt, right? Like this.
NARR: It's for your protection!

Slide No. 27
C.U. HANDS

Slide No. 28
GLOVES

VOICE: Do I need gloves?
NARR: For outside work on wintry days perhaps. And when working with liquid chemicals you ALWAYS wear gloves. We provide them to you.

Slide No. 29
FACE WITH GOGGLES

Slide No. 30
MAN FACING CAMERA WEARING
BOTH GOGGLES AND DUST MASK

NARR: And we provide clear safety goggles to protect your eyes. And safety prescription glasses if you require them. (Where dust levels are high, we provide a protective face mask to filter the air you breathe.)
VOICE: Next thing I know, you'll have me wearing an oxygen mask . . . a complete life-support system.

Slide No. 31
SAME. SPLIT FRAME WITH GAS MASK

NARR: That's right. We have gas masks — "just in case."
VOICE: For protection.
NARR: For protection! That's why you always wear . . .

Slide No. 32
CU. HANDS HOLDING HARDHAT

. . . THIS in and around the plant.
VOICE: A hard hat! Looks uncomfortable.
NARR: It isn't . . . not really.

Slide No. 33
VCU. HANDS ADJUSTING HAT SIZE

It has an adjustable band that allows you to fit it to your head.

Slide No. 34
MCU. MAN WEARING HAT HAS
HAND ON TOP OF IT

VOICE: It kinda floats on top. One thing for sure, this beats a crack on the head.
NARR: You got it.

Slide No. 35
FULL FIGURE OF MAN
DRESSED FOR THE JOB

From head to toe, you're ready for work.
VOICE: I'm counting down. Three . . .
NARR: That's you, the physical you. That 3!
VOICE: And two . . .?

Slide No. 36
SAME. SHOW MORE OF THE PLANT

NARR: Two is the plant . . . a safe place to work when youknow what to do . . . what to expect. And that means doing everything by the BOOK. Do you have your copy?

Slide No. 37
XCU. SAFETY MANUAL IN POCKET

VOICE: This one? I read it as you told me.
NARR: Then you already know a lot about your job. We're at TWO and holding . . .

Slide No. 38
RAINBOW FACILITY

The outside of this IMC Rainbow facility . . .

Slide No. 39
SPARTANBURG FACILITY

. . . all Rainbow plants . . . tells you a lot about the company, IMC.

Slide No. 40
ANOTHER FACILITY

Slide No. 41
INTERIOR OF PLANT

When a plant is neat looking . . . when the surrounding area is free of litter . . . it's a safe bet that the inside is just as tidy and workers have the safety attitude.
VOICE: You want the plant to look good inside
NARR: We want to keep it SAFE inside.

Slide No. 43
MAN IN FOREGROUND OF
RAW MATERIALS BIN

NARR: How does it make the plant safer? Fertilizer raw materials and finished products are in the form of little prills . . . like little ball bearings Walking on it . . .

Slide No. 44
XCU PRILL FORMS OF PRODUCT
BETWEEN FINGERS OF HAND

VOICE: . . . is like walking on roller skates.
NARR: You can imagine what driving on it is like!

Slide No. 45
CU. FEET ON
FERTILIZER MATERIALS

VOICE: . . is like walking on roller skates.
NARR: You can imagine what driving on it is like!

Slide No. 46
FRONT END LOADER AT
STORAGE BIN

VOICE: Driving?
NARR: Sometime soon you could be driving a front end loader on this concrete alley.

Slide No. 47
LOADER SCOOPING UP PRODUCT

They make a job easier, . . . but they're tricky to handle.

Slide No. 48
LOADER HAS TURNED TO
CARRY MATERIALS AWAY

Driving on a fertilizer-covered surface — a wet, slick pavement — your vehicle can roll in all directions . . . out of control.

Slide No. 49
LOADER EN ROUTE PAST WALLS AND/
OR OTHER WORKERS

It could crash into machinery, a wall . . . or even worse, a man.

Slide No. 50
MAN WITH PUSH BROOM

VOICE: So we keep those floors swept?
NARR: Good housekeeping prevents accidents.

Slide No. 51
MS. MAN SWEEPING AGAINST
BG OF SEVERAL BINS

Sweeping helps conserve materials . . . keep them free of foreign materials . . .

Slide No. 52
MLS. SAME BG OF MANY MATERIALS

. .helps avoid waste in storage. In our busy season these bins are filled to capacity.

Slide No. 53
MS. LOW ANGLE SHOT OF MOUNTAIN
OF MATERIALS SPILLING TOWARD CAMERA

Piles of fertilizer can fall and they are a threat to you and your safety.

Slide No. 54
MAN WITH FOOT ON F.E.L.

VOICE: These front-end loaders . . . I can't wait 'til I get a chance to drive one.

Slide No. 55
MAN DRIVING INSIDE DRIVER'S SEAT

Slide No. 56
MAN IN SEAT FASTENING
SAFETY BELT

VOICE: I see they have a safety belt just like my car.

Slide No. 57
DOWN SHOT TO REVEAL TOP PROTECTION.
MAN LOOKING UP FROM BENEATH.

NARR: Buckle it up when you get in . . . and leave it buckled until you get out. (PAUSE) Look up . . . and you see it's equipped on top to protect you from falling objects.
VOICE: Boy! they mighty rugged looking machines.

Slide No. 58
F.E.L. IN ACTION

NARR: They're tough and they're heavy, but they work in tight places between mountains of materials.

Slide No. 59
F.E.L. BETWEEN SHEER
WALLS OF MATERIALS

VOICE: I can see that if I undercut a wall one of those mountains could cave in on me.

Slide No. 60
DRIVER'S PERSPECTIVE

NARR: It could, if you're not careful. Some of that material sets up in the bin . . . comes out in big hard chunks.

Slide No. 61
MCU. HAND HOLDING ROCK-SIZE
BOULDERS OF SET UP MATERIAL

VOICE: Watch out for falling rocks! Now I know why there's protection on top . . .

Slide No. 62
MAN REMEMBERING HARD HAT

NARR: . . . . and why you wear a hard hat!

Slide No. 63
MS. FORKLIFT. IDLE

VOICE: A forklift! You use them, too.
NARR: . . . and safely.

Slide No. 64
PILE OF UNORGANIZED
SMALL BAGS ON PALLET

Do you think you could move that top pellet of 50-pound bags?
VOICE: Right now? With a forklift Sure!
NARR: Not here, you won't. Not those bags. They're unbalanced.

Slide No. 65
MAN RESETTING BAGS
IN BALANCE ON PALLET

Around here . . . you get off the truck and rearrange those bags before you try moving them. That's the safe way. The Rainbow way.

Slide No. 66
DRIVER'S VIEW OF FORKLIFT ATTACKING BAGS

VOICE: I see. Then they'll stay put when I pick 'em up. (PAUSE) Front-end loaders! Forklifts.

Slide No. 67
MONTAGE OF TRAINING MATERIALS, TEST & CERTIFICATE

NARR: We will train you to operate our heavy equipment . . . test you . . . before you receive your IMC certificate. We'll train you, test you, certify you for all special jobs you may do around the plant.
VOICE: Including electrical?
NARR: Including electrical.

Slide No. 68
MS. ELECTRICALLY OPERATED EQUIPMENT

NARR: We use a lot of POWER inside these manufacturing plants. And it's often higher voltage than you find around your house.

Slide No. 69
220 & 440V OUTLETS

VOICE: 220?
NARR: Even 440 volts. So we take a lot of precautions.

Slide No. 70
MAZE OF ELECTRICAL CONDUIT

All heavy cables inside the plant are enclosed in conduit. All outside electrical lines are in conduit.

Slide No. 71
HEAVY DUTY SWITCHBOX

Switches are enclosed in boxes . . . heavy duty boxes.

Slide No. 72
OVERHEAD LIGHT WITH PROTECTIVE MESH

VOICE: What's that? Covers on your light bulbs?
NARR: You're seeing right. That's to protect them from accidental banging . . . and breakage.

Slide No. 73
CU. GROUNDED POWER OUTLET

VOICE: Every power outlet I see is a grounded outlet.
NARR: You're right again. All our extension cords are three-wire, so they're grounded.

Slide No. 74
VCU. GROUNDED MALE PLUG WITH PLIER ABOUT TO REMOVE GROUND PRONG

Never . . . never . . . clip off the third prong! It's there to protect you.

Slide No. 75
DAMPNESS WITHIN PLANT.

Around a fertilizer plant, it's usually damp — even when it's not raining. Grounding protects you from electrical shock or worse. We go one better.

Slide No. 76
GROUND-FAULT INTERRUPTER BEING ADDED TO HEAVY POWER SANDER

We use a ground fault interrupter to protect you. And by the way, when you need an extension cord, be sure the one you choose is larger than the cord on the tool you're going to use.

Slide No. 77
MCU. FACE OF MAN REACTING

VOICE: At IMC you sure are sticklers for safety!
NARR: There's a simple reason for our concern.
VOICE: What's that?
NARR: You! You're IMPORTANT to us.

Slide No. 78
CU. BENCH GRINDER WITH EYE SCREEN

That's why our grinders have protective eye shields.

Slide No. 79
MAN EXAMINING ACETYLENE TANKS, ETC.

VOICE: Acetylene tanks! You have a complete workshop.

Slide No. 80
MAN WELDING WITH MASK & GLOVES

NARR: And a safe one. Onece again, you'll receive proper instruction and equipment to do welding repair jobs right and safely.
NARR: The right equipment! We have it— even to show you presentations like this one. Right now, your trained operator is quickly changing slide trays. We will continue your safety tour of the plant and your job in just a moment.

Slide No. 81
CU. GUARD AROUND CHAIN DRIVE OF MACHINERY

VOICE: Protective guards around motors and chain drives.
NARR: If they ever need repair, be sure to replace those safety guards when you're finished. And while you're making those repairs . . .

Slide No. 82
LOCKOUT PADLOCK ON POWER BOX

. . . LOCKOUT the equipment so it cannot be turned on accidently. We LOCKOUT all hazardous

equipment— screw conveyors, mixers, elevators— when it is not being used.
VOICE: Be careful, right?

Slide No. 83
TOOLS IN NEAT LAYOUT

NARR: Right! And be sure to return your tools. There's a place for everything. Help us keep everything in its place. It helps us to find it fast . . . a socket wrench . . .

Slide No. 84
FIRST AID CABINET

. . . or first aid supplies.
VOICE: You've planned for everything!
NARR: We've tried! And we KEEP TRYING.

Slide No. 85
INSIDE OF CABINET

VOICE: I suppose I'll be receiving first-aid training?
NARR: That, too. And what to do in case of fire.

Slide No. 86
FIRE EXTINGUISHER

VOICE: I've noticed . . . fire extinguishers are EVERYWHERE.
NARR: They're strategically located throughout the plant. (We use the ABC 20-pound extinguisher suitable for all types of fires.
VOICE: Types of fires? I thought a fire is a fire. (I) guess I do have a lot to learn. And you'll teach me.
NARR: Sure will! Teach you to prevent accidents from happening. That's our most important job.

Slide No. 87
GUARD POSTS ABOUT GAS PUMP

That's why . . . we put protective guards about our gas pumps to prevent "accidental" collisions.

Slide No. 88
CONCRETE BARRIER ABOUT LIQUID FUEL TANKS

There are guard rails or concrete barriers around our fuel and liquid chemical tanks. For safety sake, we protect everything . . . but mostly YOU. We're careful around here.

Slide No. 89
MAN AND LADDER

. . . even when it comes to using ladders. We use wooden ladders to protect you from the possibility of electrical shock.

Slide No. 90
SAFETY FEET OF LADDER

And our wood ladders have special non-skid safety feet. Still, even the best equipment can be misused.

Slide No. 91
IMPROPER LADDER ANGLE AGAINST WALL

This angle is WRONG. Lean a ladder at the proper angle. There are safety rules.

Slide No. 92
PROPER ANGLE. MAN CLIMBING

The base of the ladder should be one fourth as far from the wall as the top of the ladder is from the floor. When you are standing erect, the rung in front of you should be at arm's reach.

Slide No. 93
CU. MAN REACTING

VOICE: You Rainbow guys really do care about safety . . . MY safety [PENSIVE]. Even how to use a ladder.

Slide No. 94
MAN WITHIN CAGED LADDER

I see most of your permanent ladders are CAGED.
NARR: Yes . . . and we have railings and protective walkways on all of our high places . . .

Slide No. 95
MAN ON HIGH WALKWAY STANDS NEAR GUARD RAIL

. . . even on the roofs of our buildings . . . wherever you have to work.

Slide No. 96
HIGH LEVEL VIEW PLANT FROM ACID TANKS

VOICE: Wow! What a view! Trucks . . . tanks . . . buildings . . . railroad cars . . . tracks!

Slide No. 97
GROUND LEVEL VIEW OF TRAIN PULLING INTO PLANT

NARR: You're looking at the lifeblood of the plant: raw materials coming in . . . finished product going out.

Slide No. 98
XCU. "DANGER" ON SULFURIC ACID TANKCARS. MAN IN BG CLIMBING STAIRS

We get tankcars filled with sulfuric acid — lots of them — to manufacture superphosphate.

Slide No. 99
MAN PUMPING OUT S ACID TANK

VOICE: sulfuric acid? That's dangerous!
NARR: That's why we wear the clothes we do: protective rubber raincoats and gloves, goggles AND a face mask.
VOICE: That's protection!

Slide No. 100
MLS. TANK CARS OF N
NARR: Just part of our safety precautions. We receive tank cars filled with ammonia and liquid nitrogen solutions.

Slide No. 101
MCU. MAN PUMPING N CAR.
WEARING GOGGLES & GLOVES
You'll be getting special training on what to wear and how to handle those products too . . . later on.

Slide No. 102
SAME. SUPER ART EFFECT OF "WATER"
WASHING DOWN FRAME
And if you should get exposed to ammonia and nitrogen solutions you need to wash off fast— real FAST. Water Remember, WATER. And plenty of it. WASH! It'll save your skin.

Slide No. 103
MS. OUTSIDE SHOWER
That's why we have showers all around you . . . just in case. And every shower has a special attachment to bathe the eyes.

Slide No. 104
MANY TANK CARS ON TWO TRACKS
VOICE: You've thought of everything.
NARR: It's OUR business. And YOURS too.
VOICE: Tanks . . . and pipes . . . Sulfuric acid . . . ammonia . . . liquid nitrogen solutions . . .
NARR: We don't want those tank cars rolling away, moving while they're being pumped out . . .
VOICE: . . . with me on top.

Slide No. 105
CU. WHEEL CHOCKS IN
PLACE BY ON TRACK
NARR: right. So we place chocks under the wheels to keep them from moving.

Slide No. 106
BLUE WARNING SIGN TO
LOCOMOTIVE ENGINEER
We put these blue warning signs on the track to alert the locomotive engineer to "stay clear" . . . "go no further." "The cars ahead are being worked on." Believe me, they obey that sign.

Slide No. 107
MCU. DE-RAILER ON TRACK
VOICE: What's that yellow thing on the track.
NARR: That "thing" is a DERAILER.
VOICE: Derailer?
NARR: Uh-huh. And it does exactly what it's supposed to. It will keep a dangerous car from running loose within the plant or into town where it might hurt a lot of people . . . untrained people.
VOICE: It makes the railcar jump the track.

Slide No. 108
P CAR BEING UNLOADED
NARR: And STOP! It's just another safety precaution. We have many of them . . . for unloading cars filled with phosphate rock from our mines in Florida . . .

Slide No. 109
K CAR BEING UNLOADED
. . . and potash from IMC's mines in New Mexico and Canada.
VOICE: This is some operation . . .

Slide No. 110
CONVEYOR DROPS MATERIALS
ONTO PILES IN BIN
NARR: We fill our bins with raw materials. In this plant we react phosphate rock with sulfuric acid to make superphosphate. The chemical reaction releases fluorine gas from the rock.
VOICE: Fluorine? Isn't that dangerous too?

Slide No. 111
HFS ACID SCRUBBER
NARR: Not the way we handle it. In those scrubbers we capture almost all the fluorine . . . keep it from escaping into the air.

Slide No. 112
TANK TRUCK BEING LOADED
WITH HFS ACID
And the fluorine is used by many cities — in their water supplies — to purify the water and protect children from tooth decay.

Slide No. 113
MAN. PLEASED FACIAL REACTION
VOICE: That's where it comes from . . . from HERE. What else do we make?
NARR: Mostly fertilizers . . . to help farmers grow food . . . more food for more people.

Slide No. 114
BLENDING OPERATION
Here we formulate different products for different crops.

Slide No. 115
BLENDING OPERATION
Here we formulate different products for different crops.

Slide No. 116
CU. FORMULATION
VOICE: Add a little salt . . . a touch of pepper . . . and cook until ready. Right?
NARR: That's it. Very close.

Slide No. 117
FORMULATION OF DIFFERENT
COLOR PRODUCTS IN HOPPER
Only our kitchen handles tons, not ounces. And the cooking process is almost entirely enclosed — out of sight.
VOICE: Safe!

Slide No. 118
SCRUBBERS NEAR AMMONIATION
NARR: And CLEAN. We remove OUR cooking odor from the air AND IMPURITIES. We've invested millions of dollars in scrubbers to keep the air about the plant CLEAN.

Slide No. 119
COOLING TOWER
Many thousands of dollars have been spent on water cooling towers and water filtration.

Slide No. 120
PRODUCT ON CONVEYOR BELT
We do our best to be both an employer and a good neighbor in the community.

Slide No. 121
CU. FACE OF MAN
VOICE: Whew! How am I goin to remember everything I have seen, everything I'm supposed to do?

Slide No. 122
FULL FIGURE OF MAN AT
ENTRANCE, PROPERLY DRESSED
NARR: You know what to wear on the job. That's 3!

Slide No. 123
LS. INTERIOR OF PLANT & BINS
VOICE: I've had a quick look inside and outside the plant. I know you're concerned about safety — MY safety.

Slide No. 124
CU. FACE. SERIOUS
NARR: That's right! We're at two and holding.
VOICE: When do I blast off? When do we get down to ONE?
NARR: YOU are the ONE. Everyday, every moment of every day, you are the ONE who makes to all go . . . and go SAFELY.

Slide No. 125
POSTER
You're the one who can make it safe for yourself . . .

Slide No. 126
ANOTHER
. . . and your fellow workers. We will train you . . .

Slide No. 127
ANOTHER
. . . and keep reminding you of the right way to do your job.

Slide No. 128
ANOTHER
Safety! It's all around you.

Slide No. 129
REPEAT SAFETY MANUAL
And it's in the book. But only YOU can make safety WORK.

Slide No. 130
CU. FACE OF MAN
You're the one. And safety is your job.

Slide No. 131
F.E.L. & MAN SWEEPING
NARR: You'll be working with loaders and brooms . . .

Slide No. 132
TANK CAR AND DANGER SIGN
. . . trucks and trains.

Slide No. 133
MAN ATOP RAIL CAR
You'll be handling the raw materials coming in . . .

Slide No. 134
THE MANUFACTURING PROCESS
. . . be a part of the manufacturing process . . .

Slide No. 135
LOADING OF BAGS
. . . contribute to the finished products that leave this plant.

Slide No. 136
BAGS ON CONVEYOR

Slide No. 137
BAGS ON FLATBED

Slide No. 138
TRAIN LEAVING PLANT
NARR: YOU are IMPORTANT to us!

Slide No. 139
HOPPER TRAILER UNDER
LOADER, BEING FILLED
NARR: You are important to us!
MUSIC: Full to cover.

Slide No. 140
TRUCK AT WEIGHING STATION

Slide No. 141
TRUCK PASSING IMC SIGN

Slide No. 142
TRUCK ON COUNTRY ROAD

Slide No. 143
SAME. MORE DISTANT.

Slide No. 144
INFINITE SPACE
NARR: We are your "ground control."

Slide No. 145
N.A.S.A. GROUND CONTROL
We'll be watching your progress . . . as much as possible.

Slide No. 146
ASTRONAUT IN SPACE
But we cannot monitor your thoughts. That's up to you.

Slide No. 147
SPACE VEHICLE
Keep thinking safety . . . at work and at home.

Slide No. 148
SAME. ADD RAINBOW LOGO
That's really your job with Rainbow. It's . . .

Slide No. 149
SAME. ADD "SIMPLE AS 3 . . . 2 . . . 1"
as simple as 3 . . .2 . . . ONE That one . . .
Music to conclusion.

Slide No. 150
SAME. REPLACE "1" WITH "YOU"
. . . is YOU. You make all systems GO.

Lots of applause.

MODERATOR CAINE: At this time we would welcome any questions for Mr. Feagin. any questions from the audience on this program? Well, thank you, Glenn, for sharing this very comprehensive safety film.I am sure it was very informative to all of us. (Applause)

MODERATOR CAINE: Our next speaker will be Mr. Kenneth Herron. Ken is a native of Chattanooga, Tennessee but received all of his formal education in Ohio. He is a graudate of Cleveland State University with a degree in Mechanical Engineering. Ken has been intimately connected with several facets of the vibration industry for many years. He has been with the W.S. Tyler Company since 1976, and during that relatively short period of time, has acquired considerable exposure to raw materials and finished products which are used in the fertilizer industry. Ken will now relate to us his experience with motor-driven vibrations on screens. Mr. Ken Herron. (Applause).

Rotary Electric Vibrators And Screening

Kenneth L. Herron

Good afternoon. I would like to thank the Fertilizer Round Table for the opportunity to speak about our experience with rotary electric vibrating motors and their portrayal in screening.

Let's begin by taking a look at a rotary electric vibrator. (Picture #1) This is not a complex device, just an electric motor with a shaft protruding from each end, with unbalanced weights attached. (Picture #2) Each end of the motor actually has two weights— one fixed and one adjustable. Various force levels can be achieved by adjusting the outer weight to its maximum unbalanced position. The force is transmitted to the screen sections thru the post assembly, as shown in (Picture #3). The speed of the motor can also be controlled by means of an AC variable speed controller. I mention the controller, as both factors, force and speed (frequency) play an important role in screening.

These rotary electric vibrators are used extensively on the Hum-mer screen, well known in the fertilizer industry. These vibrators are available on the market today in two types. The first is the fixed speed, 1800 RPM unit, (Picture #4), and the second is the variable speed, 0 to 3600 RPM.

The force output of these units varies slightly among manufactures. The fixed speed is typically around 1800#, and the variable speed around 2000#. One might ask what the difference is, application wise, between the two. The answer to this question leads us into screening theory.

SCREENING THEORY

Every material and separation has a practical optimum frequency and amplitude to achieve high efficient screening. Coarse materials require lower frequencies and high amplitudes or up and down movement. (Picture #5) This is where the fixed speed rotary electric vibrator is best suited. We typically recommend this type of unit for a scalping operation or a fines removal operation. There are, however, other factors to be considered and we use this as a simple "rule of thumb". Fine materials respond better to higher frequencies and less amplitude or up and down movement. Smaller particles require less force to achieve stratification. (Picture #6) Therefore, we can increase the number of times we "bounce" the particle upward thru higher frequency or speed. The adjustable force and frequency allows the ability to "tune" the screen sections to the material being processed. If screening conditions change a quick and easy adjustment can be made to again achieve 95% commercially perfect efficiency.

FORCE VS. SPEED

Let us look at a foce vs. speed graph of a typical variable speed rotary electric vibrator. (Figure #1) There are 10 weight adjustments on this motor and you will note when the speed is increased at each weight setting, the force also increases. We randomly picked 6 points on this graph and conducted the following laboratory tests to verify our previous statements.

The conditions for the tests conducted are as follows: (Figure #2)

TEST -1

We started at a high force output of 1570# (maximum possible 2000# and a high speed of 3380 RPM. The percentage of product recovered was 26.3. This would give us an efficiency of 31.5%. *Very* low.

TEST -2

The force was reduced to 1144# and the speed reduced to 2720 RPM. The percentage of product recovered was 41.9. The efficiency at this point would be 50.1% — higher than #1 but still very low.

TEST -3

The force was, again, reduced to 1008# and the speed set at 3040 RPM. The product recovered at these settings was 45.6%. The efficiency increased to 54.5%.

TEST -4

The force on this test was reduced to 617# and the speed set at 3600 RPM. The product recovered increased to 72.5%, the efficiency increased to 86.7%. This is starting to prove our initial theory, which stated low force and high frequency is required for fine screening.

TEST -5

The force was, again, reduced to 549# and the speed set at 3380 RPM. The project recovered was 75% and the efficiency jumped to 89.7%.

TEST -6

The force was dropped to 525# and the speed was reduced to 2050 RPM. Only 52.5% of the product was recovered. The efficiency dropped to 62.8%.

The high frequency and low force of Test No. 5 gave us the best efficiency of 89.7%. Comparing Test #5 and Test #6 we see a change in speed of 1330 RPM with the force remaining almost identical. The efficiency dropped 26.9% when the frequency was reduced. This proves the frequency, or the number of times the screen section moves up and down, plays an important role in fine screening.

There are also other favorable advantages in using this type of vibrator. The noise level on this type of unit is typically around 85 db(A) well within government regulations. The maintenance is very low as this type of unit only requires occasional lubrication. Another plus would be the use of rubber dust covers for superior dust control.

Thank you for your time and attention. (Applause).

Note: Tests, Pictures and Slides
Continued on page #42 thru #45

Test #1

Material D. A. P.

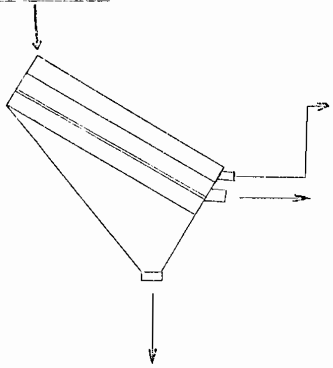
Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH

22 TONS PER HOUR



16.082 TONS PER HOUR - 73.1%

5.786 TONS PER HOUR - 26.3%

.132 TONS PER HOUR

.6%

Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 31.5%

Test #2

Material D. A. P.

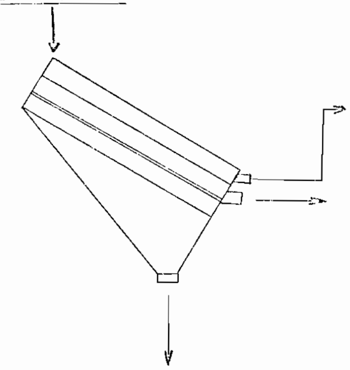
Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH

22 TONS PER HOUR



12.65 TONS PER HOUR - 57.5%

9.218 TONS PER HOUR - 41.9%

.132 TONS PER HOUR

.6%

Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 50.1%

Test #3

Material D. A. P.

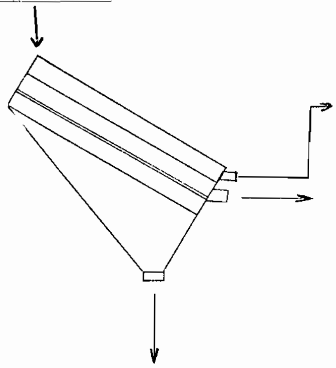
Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH

22 TONS PER HOUR



11.836 TONS PER HOUR - 53.8%

10.032 TONS PER HOUR - 45.6%

.132 TONS PER HOUR

.6%

Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 54.5%

Test #4

Material D. A. P.

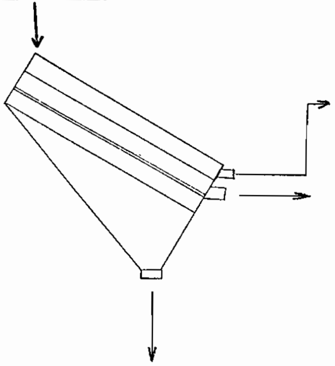
Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH

22 TONS PER HOUR



5.83 TONS PER HOUR - 26.5%

15.95 TONS PER HOUR - 72.5%

.396

1.8%

Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 86.7%

Test #5

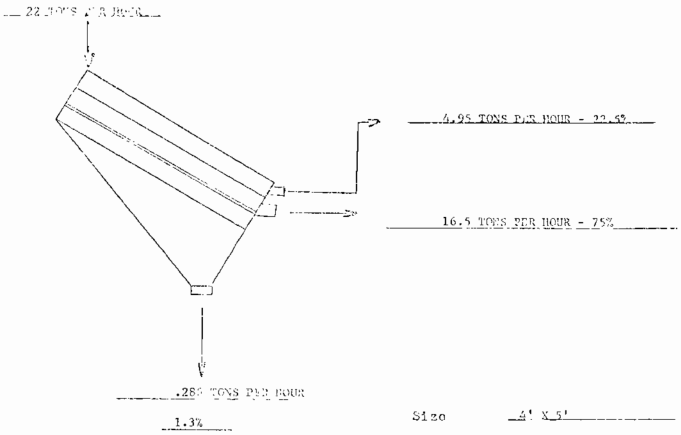
Material D. A. P.

Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH



Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 89.7%

Test #6

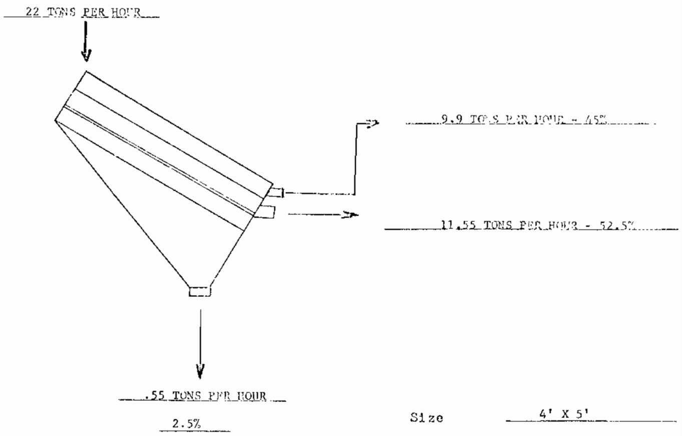
Material D. A. P.

Lbs./Cu.Ft. 56

Feed Rate 22 TONS PER HOUR

Separation 6 MESH

12 MESH



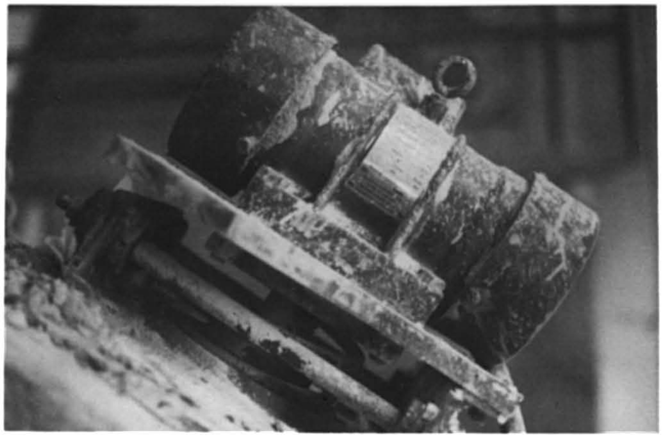
Size 4' X 5'

Machine HUM-MER

Screen Angle 33°

EFFICIENCY - 62.8%

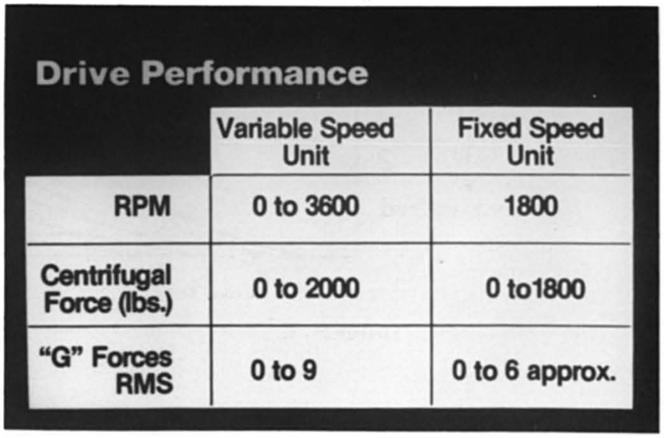
Picture #1



Picture #2

Picture #3

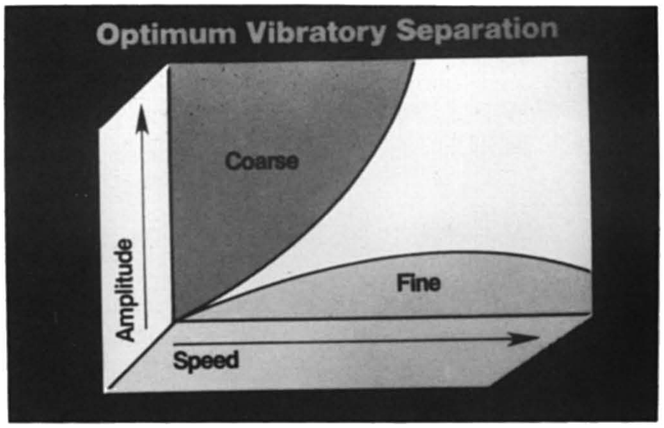
Picture #4



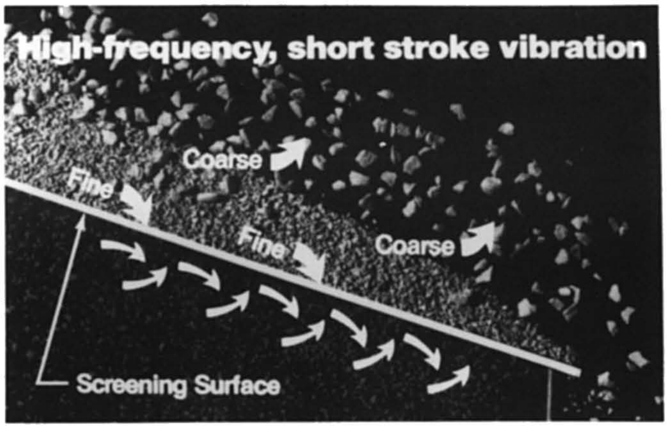
Drive Performance

	Variable Speed Unit	Fixed Speed Unit
RPM	0 to 3600	1800
Centrifugal Force (lbs.)	0 to 2000	0 to1800
"G" Forces RMS	0 to 9	0 to 6 approx.

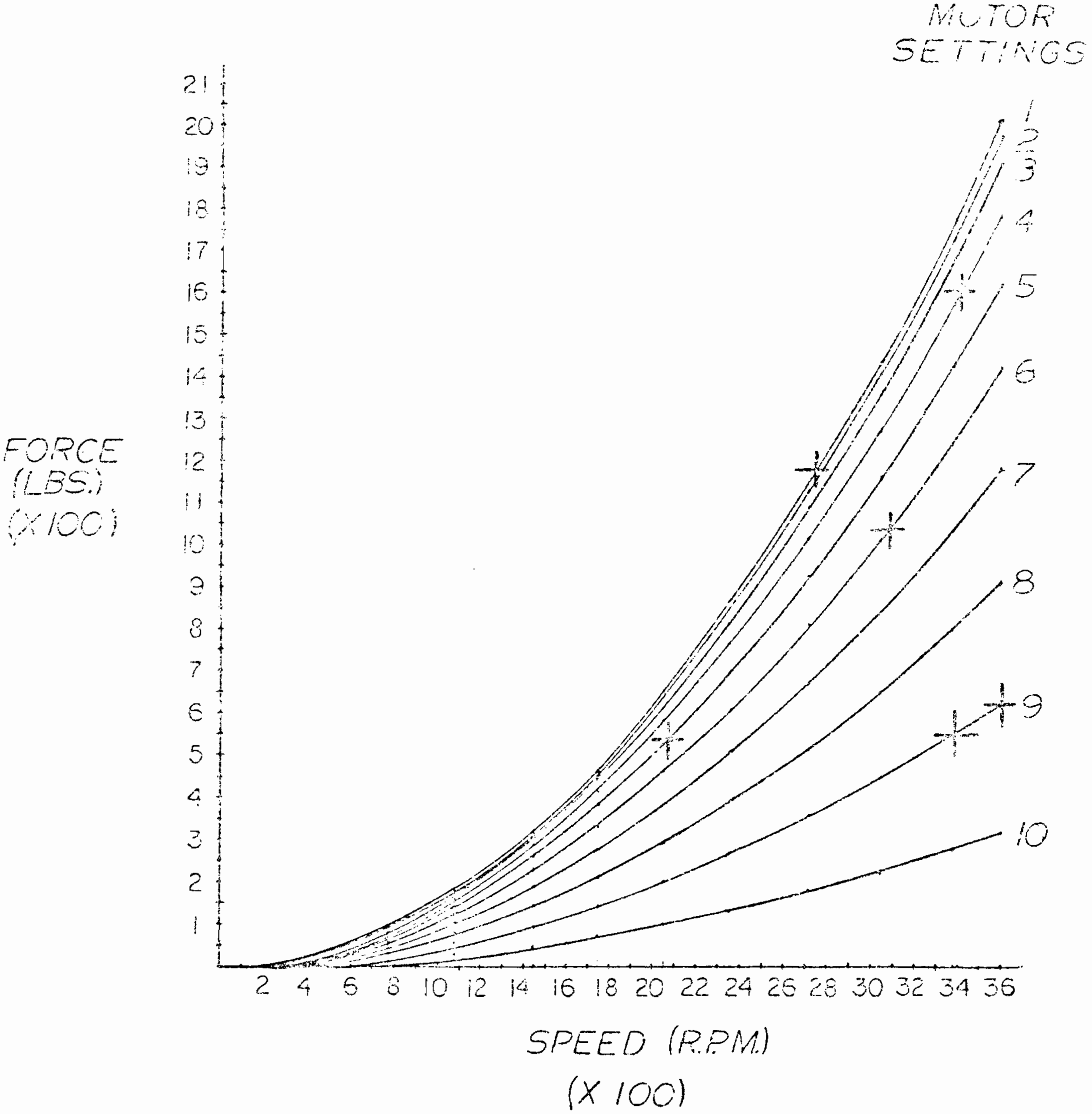
Picture #5



Picture #6



Motor Settings



MATERIAL = D.A.P.

WEIGHT = 56#/CU.FT.

SIEVE ANALYSIS OF FEED

U.S. NO.	GRAMS	PERCENT ON SIEVE
¼ OPG.	-	-
4M	1.5	1.0
5	1.6	1.0
6	15.1	9.9
7	40.9	26.7
8	36.4	23.8
10	33.8	22.1
12	16.8	11.0
14	5.2	3.4
16	1.0	.7
18	.2	.1
20	TRACE	-
PAN	.5	.3
	153.0	100%

SEPARATION 6 MESH - TOP SURFACE

12 MESH - BOTTOM SURFACE

AVAILABLE PRODUCT IN FEED - 83.6%

TYPE OF SCREEN = HUM-MER

SIZE = 4' WIDE X 5' LONG

ANGLE = 33°

FEED RATE = 22 TPH

MODERATOR CAINE: Thank you Ken for that excellent information on Rotary Electric Vibrators and Screening. Are there any questions for Ken?

QUESTION FROM THE AUDIENCE: Did you try any tests with screens at a different angle? I noticed you always used 33 degrees. Did you try another angle?

ANSWER: No, We just used a 33. The angle actually makes a difference in your opening. If you increase the angle, you have to go to a larger opening cloth to compensate for the extra degrees. The difference there would be just cloth and the opening used. We have used them from 30 to 36 degrees, and as far as the vibrator itself, have noticed no difference, as long as, of course, the right cloth spec. is in there.

Any other questions? Thank you. (Applause).

MODERATOR CAINE: Thank you, Ken, for illustrating how the proper operation of the vibrator can contribute to a good screening performance.

Our next speaker is Rick Rose of IMC. Rick has completed studies at Northwestern and Rutgers Universities. His curriculum has included work in business administration, in warehousing, materials handling and transportation analysis. Additional studies have been carried out at the College of DuPage and the University of Wisconsin. Rick has held management and executive positions in industry and with transportation carriers. He has conducted several seminars on the subject of hazardous materials. He is presently the hazardous materials manager for the International Minerals & Chemicals Corporation. Rick will talk to us today on hazardous materials marking. Mr. Rick Rose. (Applause)

Hazardous Materials Marketing Nurse Tanks - Anhydrous Ammonia

Rick Rose

Probably the most cxontroversial container in transportation is the nurse tank. Until 1975, when the Hazardous Materials Transportation Act, known as the "Transportation Safety Act of 1974," (Public Law 93-633) became effective, the nurse tank had an almost autonomous existence in transportation. The several states, each being sovereign, choose to, or not to, impose some type of regulation on this bastard piece of equipment.

Development and sophistication of hardware, which is an integral part of the distribution of product, advanced slowly. It did, however, create a need for some regulation because tanks were getting larger and due to anhydrous ammonia suppliers' locations, longer distances were being traveled on public highways.

The Department of Transportation (DOT) made no provision in its regulations for the transportation of hazardous materials (Title 49 Code of Federal regulations) for nurse tanks. Two of the United States, Arkansas and Nebraska, created regulations for their individual states. These regulations mandated marking and placarding the nurse tanks the same as required for cargo tanks (tank trucks) as provided in the DOT regulations. The states also required a "Slow-Moving-Vehicle" sign on the rear of the tank.

After much controversy between the Federal Government's regulators and the agricultural industry, the Department of Transportation declared nurse tanks used for the farm industry exempt under certain conditions. The nurse tank would be classed as, "A tool of agricultural husbandry," and would have to comply with the following edicts:

1. Operated by private carrier for agricultural purposes.
2. Minimum design pressure of 250 psi (pounds per square inch).
3. Painted white or aluminum.
4. Having 3,000 water gallon capacity or less.
5. Loaded to a filling density no greater than 56% (85% liquid).
6. Placard on front, rear and both sides with the DOT specification "Non-Flammable Gas" placard (for anhydrous ammonia).

7. Stenciled on both sides, the legend "Anhydrous Ammonia" in letters not less than 2 inches high.
8. "Slow-Moving-Vehicle" symbol on the rear of the tank (state law).
9. Securely mounted on a farm wagon.
10. Must travel no faster than 25 miles per hour on public highways.
11. Must travel on public highways only during daylight hours.

The DOT makes no mention of proper accompanying paperwork, which includes proper classification, hazard identity and placarding proof.

Certain problems become manifest due to the shape of the nurse tank and the products carried therein.

1. Because of the "bullet" shape of some tanks, it is not feasible to have the placard and slow-moving-vehicle emblem both visible on the rear of the tank. The DOT has not openly resolved this problem as it involves both Federal and State regulations.
2. Some nurse tanks have both "Anhydrous Ammonia" and "Nitrogen" stenciled on the sides. *ONLY* the product contained therein should have the identifying name visible and the other should be either covered or obliterated.

Although the DOT regulates interstate (crossing a state line) commerce, the National Transportation Safety Board (NTSB) has adopted the DOT regulations for enforcement purposes. Also, 44 of the 48 continental United States have adopted Title 49 CFR, in whole or part, as the state's regulations so non-compliance can be very costly.

There are an estimated 350,000 nurse tanks in active use in the United States. Each user, lessor or owner, should make every effort to comply with the regulations that are now in existence. Your government is presently pursuing nurse tank regulations to make them practical and still economically feasible. Your assistance by compliance and your expertise gained by experience, when provided to the regulators for consideration, can produce regulations that all can live by.

RICK ROSE: Do I have any questions from the floor? Well, Gentlemen, I thank you very much for inviting me. Good Afternoon. (Applause).

MODERATOR CAINE: Thank you Rick for a very informative presentation on hazardous materials marketing.

We will proceed with our panel which will be dealing with recent pipe cross experiences. This panel will be in charge of Hubert L. Balay of TVA. Bud is a Field Chemical Engineer in the Process and Product Improvement Section of the TVA National Fertilizer Development Center at Muscle Shoals, Alabama. He has been with TVA since 1966. Bud is a graduate of the University of Arkansas. Before joining TVA he worked for 14 years with Spencer Chemical Corp. in an ammonia plant and as a sales engineer. Bud has constructed and started numerous bulk blending, granulation, liquid and suspension fertilizer plants. He has worked on plant operating and field application problems with TVA and also with Spencer. At this time I present Bud Balay, and he, in turn will clue you in on his panel.

Panel Discussion
Recent Pipe Cross Experiences

Moderator: Hubert L. Balay

Panel: Harold Green, Donald J. Brunner
R. O. Britt, Albert P. Super

MODERATOR BALAY: Panel, come forward please. I had not seen Al Super today and I didn't know if he would be here since we did not put his name on the program. Al we decided that with a name like Super you did not need any extra billing in the fertilizer industry — Al Super, Smith Douglas. This is going to be an update on TVA's pipe cross reactor.

A number of people at the Round Table have put in pipe crosses, and we have had progress reports on the pipe cross the last two years. The gentlemen on the panel are people who have actually operated the pipe cross in their plants and have had operating experience. Some of them have presented data on the pipe cross before but they can now update their presentation with experiences they have had in the last two years.

We know of 15 pipe cross reactors that have been installed. There may be more than that. We know a number of people are planning to install these reactors, so there is a lot of interest. I believe you will find the information these gentlemen have very useful.

Harold Green will be our first speaker. Harold is Plant Manager for Gold Kist. He has been with Gold Kist for 33 years. He has been involved in all types of production. As we introduce the panel members, please note the expertise that they have, many kinds of operations that they have been in charge of, the kind of experience they have had. It is important that all of those gentlemen do have actual field experience.

Harold has managed various Gold Kist chemical and fertilizer plants and now is in charge of four fertilizer plants and one pesticide plant. I believe that only one of these has a pipe cross reactor. Is that true, Harold? Just one — Harold Green. (Applause).

Gold Kist
Pipe Cross Reactor
Panelist: Harold Green

Gold Kist Inc., an Atlanta based co-operative operates three granulation plants. Two in Georgia and one in North Alabama. The Alabama plant was selected for the installation of the pipe cross reactor because of the grades marketed in the trade area. Grades manufactured with the pipe cross are 13-13-13, our largest grade, and 8-24-24, and 7-14-21.

This plant is equipped with a 7′ x 14′ ammoniator, 8′ x 50′ drier and 8′ x 50′ cooler and two 4′ x 8′ double deck Hummer screens. Product is sized on +6—12 screen. Rate per hour is 18 to 30 tons, depending on analysis. Scrubbers are Duco fiberglass venturi, one for the ammoniator and one for the drier and cooler.

A 15′ wide 150′ long and 8′ deep pond stores the water used in the scrubbers. From this, pond water is pumped into the drier and cooler scrubber tank and overflow into the ammoniator scrubber tank. Water not used here in the process overflows back into the holding pond.

Water from the ammoniator scrubbers is pumped into the pipe cross to recover nitrogen lost in scrubbing operation. This scrubber water with a high solid content has caused some build-up in the reactor pipe and has to be cleaned occasionally. Approximately every 1,000 to 1,500 tons.

The panel board that operates the controls is housed in an enclosed cabinet and panels slide out for ease of service or adjustment. Due to the production of O-X-X grades and some low analysis grades we left the meters for production of those grades in-tact and built an enclosed room free of dust to house the Foxboro automatic control valves.

The controls are operated by a 5 H.P. air compressor equipped with calcium chloride packed moisture trap, used for this panel only to avoid contamination.

This has proven well worth the cost. Meters are kept free of dust and corrosion and can be serviced easily. Magnetic flow meters are used on sulfuric acid and phosphoric acid with current to air converters for operation of controlled valves.

Pneumatic D/P cell transmitters are used for water and NH3. All sulfuric acid is fed into pipe reactor, phos acid is metered into pipe and into ammoniator and is divided as need to promote good granulation. NH3 is also split with a portion in pipe and portion under bed in ammoniator. Either fresh or scrubber water can be used in the pipe. Roughly 2/3 of liquid are put in pipe and 1/3 in ammoniator. Metering equipment cost a little over $22,000.00.

P.V.C. pipe used for phosphoric acid and sulfuric acid proved to be unsatisfactory and has been replaced with 3/6 stainless steel.

Pipe is Hastelloy "C-276 schedule 40-6" I.D. 9 ft. long with a 90° L welded on discharge end and discharges about 1/3 down stream from the intake end and on top of rolling bed turning counter-clockwise. Liquid lines connected to reactor pipe are color coded red *NH3*, blue *phos acid*, black *sul. acid*. Scrubber water is neutral.

Open discharge end of ammoniator had to be enclosed to pull more air from the ammoniator. Air flow through ammoniator is 7,000 cfm which is not enough and doesn't pull enough steam out restricting the chemical drying somewhat. Air flow should be 10 to 12,000 c.f.m. for good drying.

We have storage for about 1,000 tons of phosphoric acid, one 100 ton fiberglass tank and 2-400 ton rubber lined tanks.

A new NH3 tank and unloading station was completed prior to start up. A 2" Corking pump is used to the process and Worthington vapor pump for unloading tank cars or trucks.

A lab was installed at a cost of approximately $4,500.00. An N.P.K. sample can be completed in about 6 hours. We run 2 each day.

Our pipe was put into operation last December. We ran over 22,000 tons with it through last spring. Cost of installation of pipe cross was approximately $60,000 not including N.H.3. installation. The only additional personnel added was the lab technician.

Formula cost saving on 13-13-13 is $5.00. Production rate on 13-13-13 is — 18 to 20 T.P.H. — with mole ratio of 1.1 and ph of 4 B.T.U. 493,000. Back pressure in the pipe runs from 60 to 80 lbs. Heat in the pipe runs 290° to 300°. Product goes into storage at ambient temperature. Experimental runs of low analysis such as 5-10-15 were successful, and are being run at 30 tons per hour.

Due to time allotted, I have not gone into formulations. I do have this information and if anyone is interested I will be glad to discuss it with you some time during the meeting. (Applause).

MODERATOR BALAY: Thank you, Harold, for that very useful information. Our next speaker will be Don Brunner. Don is Production Manager at the Missouri Farmers Association Plant in Palmyra, Missouri. Don has been in fertilizer production since 1947 and has been with MFA since 1968. MFA's Palmyra plant is a very important part of pipe cross reactor history since the first one was put in there. Don has given information on the pipe cross at the Round Table before, but he now has important update information for us. Don Brunner please. (Applause).

MFA's Recent Experiences With the TVA Pipe Cross Reactor

Panelist: Donald J. Brunner

At our Palmyra, Missouri plant a very serious blow-out occurred in our 6" Pipe Cross Reactor on the evening of April 13, at 21:10 hours. The PCR had been running approximately 3/4 to 1 hour before blow-out occurred. The crew informed me they had two or three minor blow-outs before the serious one. Though we have had some blow-outs before, this was by far the most serious. It broke the hanger loose on the discharge end of the PCR and either blew or broke the acid and ammonia lines off the feed end. The 6" PCR pipe itself was also badly deformed and had a split in it.

When we inspected this pipe after it had been removed, there was a little scale in the top part of the pipe about 2" wide and about 2" thick and perhaps about 3' long. It appeared the blow-out had cleaned out most of the pipe.

In order to find out the cause of this blow-out, TVA engineers were called in to assist us. I agree with the following reasons they came up with, along with a few I have added.

1) We were using a high rate of sulphuric acid (12 GPM) with a low rate of phosphoric acid (4 GPM).
2) We were letting the NH3 into the PCR too fast on start-up.
3) We were using 6 to 8 GPM of fresh water with the NH3. Should have been only 2 to 3 GPM.
4) We were not using scrubber water to control temperature.
5) We were probably getting sludge acid out of the bottom of the phosphoric storage tank.
6) The skin temperature of the PCR had been running in excess of 300° F. It should be kept between 240° and 280° F.

It is my opinion this occurance was not a chemical explosion, but rather a blockage in the pipe. When heat built up in the pipe it blew out the discharge end.

Immediately after this rupture, the 6" PCR was removed and a repaired 5" PCR was installed. The following changes were made. The formula was changed so there was more phosphoric acid to the PCR. The phosphoric was withdrawn from an outlet higher up from the bottom of the storage tank to reduce the sludge. The PCR was adjusted to a reduced mole ratio for a short time but was raised to .65 after about 15 minutes. The NH3 was added very slowly on starting the PCR.

We then finished this run of 12-12-12, a long run of 6-24-24, and a short run of 8-22-11. We have had no more ruptures, the operators are starting the PCR more carefully and they are using scrubber water instead of fresh water to control temperature. We have had times when the temperature of the PCR would drop very fast. When this has happened, we shut off the NH3 for a short period, then started back up and it ran OK. This rapid change in temperature tends to prove that erratic reaction in the PCR was causing the explosions.

A new 4" PCR was installed on May 15, 1978. We have provided an opening in this pipe for a safety release valve. We feel, for safety reasons, some type of release is needed on a Pipe Cross Reactor because the potential is there for a serious explosion. The problem will be to install a release valve or rupture disk which will work when it is needed. We are installing ours just ahead of the acid mixing area to avoid plugging of the valve.

The discharge of this safety valve will be into the ammoniator. A ruptured disk may be a better application, but the disk would probably have to be Hastalloy C and would be expensive. This disk would need to be mounted as close to the inside wall of the pipe as you could get it so that MAP crystals would not have it plugged off. I think the proper location of the safety valve is important if it is going to operate properly when it is needed. The reason we are using a spring loaded safety valve is because I thought the hot acids would erode out a rupture disk. The safety release valve with Hastalloy C has a delivery of 20 weeks. It has not yet been received.

We feel that 4" PCR is the better size for our formulation. We feel that the 6" PCR was too large. The 6" was difficult to start up and much harder to keep operating smoothly. We have not had any difficulty like this with the 4" PCR.

The rest of this paper will deal with changes that occur in a conventional TVA granulation plant when a Pipe Cross Reactor process is installed. Knowing that all TVA type granulation plants are not the same, nor do all companies formulate the same, I think my comments should be based on certain assumptions.

These assumptions being that when you install the PCR process you will do the following.

#1 Go from a low liquid and heat phase formulation to a high one.
#2 That you change your ammoniation rate from DAP to MAP.
#3 That the moisture content of your finished product does not need to be lower than 1.5%.

These three items will entirely eliminate the need for fossil fuels for drying product. Some of you may recall we removed a 30,000,000 BTU burner from our plant two years ago.

There are four major areas of change that I would like to mention.

#1 The elimination of the need for drying.

#2 Ammoniator granulator controls.
#3 Ammoniator granulator scrubbing system.
#4 Re-cycle rate.

At the time we installed our PCR, we were pulling approximately 17,000 CFM of air co-current thru our rotary dryer and 17,000 CFM counter current thru our rotary cooler. Our dryer size is 9′ x 60′ and the cooler 7′ x 60′. The problem we had with this arrangement was the ducts and cyclones at the exit of the dryer would plug with wet dust. In fact, when the weather was cold, water would run out of the cyclone. The moisture content of the material coming out of the ammoniator was about 2-1/2%. We decided we did not need all the air we were pulling, so we cut off one fan. This improved the problem but did not eliminate it entirely. We then decided we needed to convert this drum into a cooler instead of a dryer. We installed a small fan at the other end of the dryer and are now pulling about 3000 CFM counter current of the material and are discharging this air into the ammonia scrubber. The idea is to just pull enough air to pull the steam out of the dryer and keep dust from coming out the discharge of the dryer. We are finding out that this 3000 CFM air is not quite enough to do this. We are now in the process of moving this fan and improving the air flow.

The air and dust system on our rotary cooler worked satisfactorily but because of less water being evaporated from the dryer the whole system ran hotter. As a result the product going to storage was hotter. We chose to install a stationary cooler in the final product stream exit the final screening. We used one of the existing fans from the rotary cooler, which left one 100 HP fan pulling air thru each cooler. This lowered the temperature of our final product an average of 20° F.

#2—The changes that the PCR process makes in the ammonia granulator are the most important of all the items I have mentioned. Control of these changes can call for other changes throughout the plant. The key to a good operating plant is determined by the appearance of the product when it comes out of the ammoniator.

If the final product is too dry, too wet, not granulated or over granulated it must be controlled in the ammoniator granulator with a PCR process the same as before. The mole ratio is very important for good operation and product quality. You will be granulating with less moisture, therefore, the wetness of material must be chemical rather than water wet. As your materials exit the ammoniator they will probably be hotter than before but never more than 260° F. The consistency of this material can feel rather wet but must dry quickly when rolled in your hand. It can also be rather dry but must be granulated properly. As I have stated, these corrections are controlled with mole ratio and temperature. You can use water for granulating if the temperature of material stays above 210° F. Better metering and larger acid pumps will likely be necessary when you install a PCR.

#3—You will be emitting more water vapor as steam from your ammoniator. As a result you may need more air flow. Assuming you will be using more anhydrous ammonia, your ammonia loss with this air from the ammoniator will be greater. It may require improved scrubbing. We are presently packing ours with plastic rings to improve our NH3 recovery.

#4—Recycle rate: this item may be very crucial in some plants. In our case it was not, because the plant was designed for a larger amount of recycle. When we changed from DAP to MAP, the ammoniator rate actually used less recycle. Most plants will likely need more recycle, because I know that some operate as low as a 1 to 1 recycle ratio. A 3 to 1 ratio is needed for very high liquid phase formulas. This would mean, to increase the overall capacity of the plant or lower the production rate.

These changes did occur in our plant when we changed to the PCR process. I hope this paper will be of assistance to you, whether you are using a PCR or if you are thinking of installing one. Thank you for your attention. (Applause).

MODERATOR BALAY: We will have time for questions when we get through. I think maybe we are running a little ahead of time. Thank you very much for the useful information Don. If we do not talk about problems, we are not going to solve them. One thing we at TVA are doing is putting a rupture disk on the pipe. We are going to find out if that works. I believe it's a graphic disk. Anyway, it is very corrosive resistant material and not too expensive. We are coating it with teflon, so we hope the melt doesn't stick to it, but we will just have to try it and see. Another thing we have done is move the ammonia pipe — we had it near the top on our original pipes — to the center. We think the reaction was taking place too close to the shell. By moving the reactor to the center we expect to get less corrosion. We will let you know our results on this next year.

Robert Britt, Operations Manager at Swift's East St. Louis Plant, is our next speaker. He has a B.S. in agricultural chemistry from the University of Missouri. He's been with Swift since 1949 and has been at the East St. Louis plant since 1966. In the time he was with Swift, he worked three years in research and development. He is especially qualified to talk about the pipe cross reactor. Robert Britt please. (Applause).

Pipe Cross Reactor Experiences Swift Agricultural and Chemicals Corp. East St. Louis, Illinois

Panelist R. O. Britt

We became interested in the TVA Pipe Cross Reactor in the Fall 1976 and made the installation during Summer 1977.

By going to the pipe cross reactor, we hoped to accomplish several objectives, most importantly:

(1) Reduce our ammonia losses.
(2) Reduce smog from granulator scrubber.
(3) Reduce drying costs.
(4) Use more scrubber water from our closed circuit scrubbing system.
(5) Improve product sizing.

Being sceptical of new developments, we installed the pipe cross reactor in such a manner that we could easily switch to our conventional injection system in case of mechanical or operating problems with the reactor. since installation, the reactor has been used for approximately 95% of our production. We have used it to produce approximately 40,000 tons of grades such as 6-24-24, 12-12-12, 8-32-16, 18-8-0, 10-10-10, 10-6-4, 5-10-10, and 6-10-4.

Because of the limitations of our other granulation equipment, such as a 7′ x 14′ granulator and 4′ x 15′ screening capacity, we have not used the reactor to its potential of handling extreme high liquid loading in formulations. We have kept our formulations more conventional with liquid usage in the range of 200 to 400 lbs. of phosphoric acid; 90 to 110 lbs. of anhydrous ammonia; and 50 to 250 lbs. of 60 baume sulfuric acid per ton. We cannot handle the necessary recycle nor steam emissions from high liquid levels and maintain our desired production rate of 20 tons per hour.

Our experiences with the reactor have been good. We can say that it definitely reduces ammonia losses and smog from the granulator scrubber; that it definitely is a granulation aid; and that we seldom have to clean our closed circuit scrubber system because scrubber water consumption runs as high as 800 gallons per hour. In addition, we find the granulation easier to control with less wet to dry cycling and faster to get onstream.

We have also found that several factors are important in the operation of the reactor to make it successful. Among these are:

(1) Reactor temperature. Too cool or too hot results in poor granulation. Need not know exact temperature, but most have a thermometer at some point on the reactor to indicate a change.
(2) Accurate metering and uniform, constant liquid flows are required. Reactor can plug if acid flow is interrupted.
(3) Water flow through reactor has great influence on reactor temperature and granulation. Complete loss of water through reactor can cause mixer buildup and even minor explosions.
(4) Mole ratio in formulation affects granulation. Must experiment until proper results obtained. .89 to 1.17 works best for us.
(5) Proportion of anhydrous and phosphoric acid through reactor and directly to granulator must be tried until best proportion is found.

I would summarize our experience with the pipe cross reactor by saying that although we have not been able to take advantage of its potential to reduce drying costs, we have proven its value in other ways to the smaller granulator operator who makes a wide range of grades. (Applause).

It's nice to know that even when you don't save money on drying costs, there are other advantages for the pipe cross.

Our next speaker is Al Super. He is Process Engineer, Smith Douglas Division of Borden Chemical. He is stationed in Norfolk, Virginia. He holds a B.S. degree in chemical engineering from Virginia Polytech Institute and State University. I didn't know what that S.U. stood for before Al— I have always wondered. Al super: They have added that since I was there.

MODERATOR BALAY: Al Super has been in the fertilizer industry for 3-1/2 years, all of this with Smith Douglas in Process Engineering and Formulation. Previous experience has been with the Hercules Phillip-Morris and Newpsort News Shipbuilding and Drydock Company, so he has a lot of engineering experience. Al Super assisted in the design and start-up of the pipe cross reactor at Smith Douglas, Streator, Illinois plant. He is here to give a report on the start-up and operations of that pipe cross. Al please.

Recent Pipe Cross Experience

Panelist: Albert P. Super

We started up our pipe-cross reactor at the Streator, Illinois plant in January, 1978.

We had two chief reasons for installing the PCR at Streator:

1. The limiting factor in the production rate was the dryer capacity. therefore, with the PCR, we expected to increase production rates because less drying would be required.
2. We wanted to reduce ammonium chloride fumes. This can be accomplished with the PCR because the sulfuric acid reacts in the PCR where there is no potash.

We installed a 6″D x 10′ 7-3/8″ Hastelloy C276 pipe in the granulator that is 13′D x 15′ long. The design conformed to the TVA recommendations.

Our Streator plant screens the material before the cooler so that we have hot recycle. This was different from the plants that were already using PCR's, but we did not anticipate trouble from this — nor have we experienced it.

Since the start-up, we have produced 10 different grades of fertilizer totaling over 60,000 tons without encountering any serious problems.

We have increased production rates by 5 TPH. The 6-24-24 is now run at 30 TPH — up from 25 TPH. The rate on other grades has been increased from 20 to 25 TPH. The production rate is now limited by screen and batching capacity.

We have no figures on fuel savings, but we know the dryer furnace is being operated with less fuel input then before because the gas valve is not opened as far.

There has also been improvement in the stack discharge from the ammoniator although it was not bad previously. We have an impingement scrubber with phosphoric acid followed by a venturi scrubber.

We use 40% P_2O_5 phosphoric acid which is ammoniated at a 1:1 N/P mol ratio. About 60%-70% of the phosphoric acid is fed into the PCR with the remainder being sprayed on the bed.

On October 23rd, we had the first plug-up of the pipe. The hose was blown off the phosphoric acid inlet connection, and a shock wave was created, but no damage was done. This plug-up occurred just after starting up and the cause is not known. The pipe was filled with solid material from the discharge end to within 20" of the inlet end. Laboratory analysis indicated this material to be ammonium sulfate. A rupture disc will be installed.

Previous to this plug-up, we had not removed the flange at the inlet of the PCR. Inspection showed no corrosion of the pipe, but some corrosion of welds at the inlet connections. The 316 SS scrubber water inlet pipe was corroded away while the 316 SS ammonia inlet pipe showed no corrosion. Since the scrubber water pipe has not been used, we assume it corroded because it was hotter than the ammonia pipe.

In summary, we are satisfied with the pipe-cross reactor and plan to install them at two other plants this year. (Applause).

MODERATOR BALAY: Thank you, Al, for that extremely useful information. I am especially pleased to hear that you plan to install two more pipe crosses. I think that, you will pardon the "pun", is the acid test.

I want to open the Panel to questions from the floor shortly, but I am going to reserve the first question for myself. I used to have a unit operations professor that would look squarely at me and say "It's better to ask a stupid question that to make a stupid mistake.

Panel Answering Questions From and to each Panelist and from the Audience

Panel Leader: Hubert L. Balay

QUESTION: Robert, did I understand you to say that you are not really saving a lot on drying with your pipe?

ROBERT BRITT: Well, Bud in reply to your question, we have not discounted the possibility that we will eliminate all drying; however, for the time being, considering the large volume of low analysis grades such as 6-10-4, the 5-10-10, the triple 10's and so forth and the large amounts of scrubber water that we do use to keep our closed circuit scrubber in operation, we feel the drying is necessary. I will say that we do not dry as much. In other words, we can operate at a lower temperature on our dryer than we did previously.

MODERATOR BALAY: Do you think the pipe cross assists you in having a closed system.

ROBERT BRITT: Definitely, because we can use much more scrubber water than we did previously right into the granulator. I feel that it's a definite aid in keeping our scrubber system in operation. That had always been a problem— keeping the scrubber water clean enough to circulate in the closed system. With the ability to use a larger volume of scrubber water and constantly add fresh makeup water to the scrubber, it's no longer a problem.

MODERATOR BALAY: I have another question. I would like for all four of you gentlemen to comment briefly; if you will. Are you satisfied with the products you are making? I think Don touched on that briefly. Is it better or worse or the same as it was before?

PANELIST BRUNNER: Well, we think it has improved the product. I am not really saying you can't make a good product without a pipe cross reactor, but it really does improve the product. I mentioned in my paper how some people think you have to have moisture down below one. Our moisture runs consistantly between one and a half and two. We see no problem in the quality and storage of that product with the moisture being that high. I think it has to do with the crystallization and the good comglomeration of the combination of sulphate and MAP crystals that you get with a pipe reactor.

PANELIST GREEN: All of our pellets are not exactly the same size, but we have improved on the size. We are getting much more uniform pellets now than we were and the storage contion is excellent. We bagged some after it had been manufactured two or three days. We bagged and stored 20 high for two months, and when we took the bags down and opened them up, we had no packing at all. Since the time we have been using the pipe cross reactor we have not had to regrind any fertilizer as we did previously. I would comment on the energy savings also. We are saving about 75% on natural gas; however, it is only fair to say that we are spending more on power due to the fact that we have cut our ratio down, so we are swapping some gas for some power, but I do not think the swap-off is even. I still think we are saving a considerable amount of energy.

AL SUPER: I cannot say that our product is any better. It looks about the same, however, we are just a little concerned with the amount of dust we are getting in our shipping operation. As far as energy savings, we do not have any quantitative figures, we just know that we are not using as much gas for the dryer, as we used to, because the gas valve openings are usually at a lower setting than previously.

ROBERT BRITT: I would say generally the product is a little better. The pipe cross reactor, of course is only one part of the entire system. It will not do the job alone. I feel that some of our other equipment is not consistent with the real good product and I am referring specifically to the screening ability. You still have to screen the product and recycle the fines.

DON BRUNNER: I just want to comment on fuel savings. Our figures would be a little outdated because we have not used the furnace for about three years. We use no fossil fuels at all. But I believe in our paper we presented last year we estimated, using one half propane and one half natural gas, the savings is about $2.00 a ton. That figure would probably be higher now. I talked in my paper about some of the difficulties it caused us in the dryer and air area. You know, one way to save that would be to have a furnace and with a little hot air it would save a lot of misery. We chose not to use any fossil fuels at all. We feel that there are other ways to overcome the use of any fuels in this area, and this is what we are striving for. We are making an effort to do it.

MODERATOR BALAY: Now I'm going to open up the panel for questions from the floor.

QUESTION FROM THE AUDIENCE: I want to know if they're making any 18-46?

MODERATOR BALAY: Is anyone on the panel making 18-46? No. How about from the floor? Anybody using a pipe cross to make 18-46? Nowhere I guess.

QUESTION FROM THE AUDIENCE: How about a blunger — a pug mill?

MODERATOR BALAY: Let me make a comment on that. We have tried it. We haven't been successful. I would say that use of the pipe cross in the blunger is the only complete failure we have had. The problem is not in the operation of the pipe cross itself, but in disengagement of the melt from the steam. The steam, in passing from the discharge of the pipe to the air vent, tends to entrain melt and deposit that melt on the inside of the blunger and the blunger builds up. At best we have been able to run only about eight hours before we have to shut down and clean out. We get pretty good granulation and good control with the pipe, but we haven't overcome the build-up problem. The way a blunger is designed, I don't believe we will be able to overcome this problem. The people that have pipe crosses in blungers have made statements that they like the pipe but may have to change to a rotary granulator to use it. We haven't given up, but we do have a lot of build-up problems that we haven't been able to solve.

The pipe also builds up on the end. With the TVA ammoniator granulator, you can stand at the front of the granulator and see the pipe building up. When build up gets too big, you can reach in and bang the pipe with a rod and the build-up will fall off. With a blunger, you can't see what's going on. I am sure this kind of build-up occurs and it probably continues to build up around the pipe and on the sides of the blunger until it begins to drag on the blades. This is just assumption since we can't see what's going on. I noticed one gentlemen here who has run a pipe cross in a blunger. We would like some comments from him if he would care to make any. I guess not. That's been my experience. We may solve the problem. So far, we haven't. Other questions?

QUESTION FROM THE AUDIENCE: Can you tell me what strength of P_2O_5 phosphoric acid is used to make triple 12 and triple 13?

DON BRUNNER: We use 54% because that's the strength of our acid. It comes out of Florida and you don't want to ship all that water out of there and that's the reason we use it. We have to add a considerable amount of water with this to hold the temperature down, so there's no reason why a lower strength cannot be used.

HAROLD GREEN: We buy all of our phosphoric acid and it's 54%, and this is the reason we use 54% also.

ROBERT BRITT: 54%.

AL SUPER: Forty percent is all we have used. We have made triple 12 with it.

MODERATOR BALAY: My experience is the same as that of the panel. 40% is as low as we have gone. We think there is a potential there of using a little lower strength acid, but we feel, too, that if we go too low we may have to do more drying and may defeat the purpose of having the pipe cross. Next question.

QUESTION FROM THE AUDIENCE: I don't believe you get anything for nothing in this world. If you save energy in drying, don't you have to put energy into the acid with which you are reacting your ammonia, and if that's so, aren't there more ways of reacting acids with ammonia other than pipe cross reactors?

MODERATOR BALAY: I'll try to answer this question. We were wasting a lot of chemical energy with the processes we were using before. We were reacting limited amounts of acid and ammonia in the bed and putting in water to help granulate. The chemical heat developed, evaporated only part of the water out of the fertilizer, leaving water which had to be removed by burning fossil fuels. The amount of acid and ammonia was limited because we couldn't get hot enough in the bed to dry the fertilizer. We had to keep the temperature down because of the reaction between sulfuric acid and potash led to fume problems, which caused all kinds of complications with neighbors. Some operators were reacting in a preneutralizer, but operation of a preneutralizer was difficult for small plants and the equipment was expensive. Also preneutralizer slurry contains more water than pipe cross melt. The chemical energy for drying was there all the time, we were just wasting it. We really don't get something for nothing. We are using more effectively what we already have. Frank Achorn, would you comment on that.

FRANK ACHORN: In the U.S. we ship 54% acid which I think very few other countries do. We use 54% acid in granulation plants in the region close to the use area or near an ammonia supply which does not exist in other countries. Pipe cross reactor or similar reactors are efficient means of utilizing chemical heat available in the material used in granulation plants. Others use the less efficient method of adding water to the preneutralizer and creating a slurry (20% H_2O) that can be pumped. We do not add much water to the pipe cross so we didn't make a slurry that could be pumped. The product from the pipe reactor is an essentially anhydrous melt. I think one thing that hasn't been brought out, and I'm sure Al would have if he had remembered it, is in using a preneutralizer one of the problems is obtaining good distribution of the slurry in the granulator. For this reason the pipe cross reactor is a good instrument to distribute ammonium phosphate slurries made from dilute acid (30 - 40% P_2O_5) across the bed in the granulator. So in effect you can control your recycle more effectively because of better distribution of slurry across the bed in the granulator.

MODERATOR BALAY: I still have visions, Frank, of our old semi-granulation plants where we didn't have a dryer and used chemical heat for drying by putting large quantities of acid and ammonia into the bed. For about a mile around the plant you couldn't see your hand in front of your face. We're really doing the same thing except we've taken the reaction out of the bed and are able to use more acid and ammonia to dry.

QUESTION FROM THE AUDIENCE: When you are using 54% acid, this is clarified and I can see the point when your plant is far away from your acid. Of course, in Europe, most of us are on integrated units where we produce our acid and our compounds on the same site. Is there any experience with a pipe reactor in which you are using acids of much lower strength and, therefore, with a much higher solids content; i.e., non-clarified acids and where the calcium sulfate solubility will be much higher.

AL SUPER: We use 40% phosphoric acid. This is a mixture of 30% acid made at the site and 53% acid shipped from Florida.

MODERATOR BALAY: Frank, talking about Europe, don't you think the quality of the rock being shipped to them is better than some we are getting. I am searching for an explanation. Possibly someone here, familiar with rock, could comment.

FROM THE AUDIENCE: The answer, sir, is hemihydrate, not dihydrate.

MODERATOR BALAY: Don, you have a comment?

DON BRUNNER: Well, in my paper, again, you know when we were looking for reasons we mentioned sludge acid, but we put a little indecision in there because we don't know how much effect that might have had on that particular explosion. We have a storage tank 28 x 30 in diameter. We do have a lot of sludge down in the bottom of it and at times there's enough sludge in this acid so it even looks gray. It doesn't particularly affect the operation or the running of the pipe cross. Of course, it will knock your grade down because you're pumping a lot of solids with the P_2O_5. But I believe you could use unclarified acid with no difficulty.

FRANK ACHORN: The one test that we conducted in his plant had 12% solids.

QUESTION FROM THE AUDIENCE: How much phosphoric acid per ton in pounds per ton?

MODERATOR BALAY: We have put in about 912 pounds of acid per ton of 6-24-24 at a P_2O_5 content of 53%.

DON BRUNNER: 806 in our highest formula.

ROBERT BRITT: 500 pounds maximum.

MODERATOR BALAY: Al?

AL SUPER: About 15 units P_2O_5 from acid.

MODERATOR BALAY: Okay, that answers your question?

QUESTION FROM AUDIENCE: How about ammonia loss? I would like you to comment on the amount of ammonia loss you're experiencing and, perhaps, how you cope with that in the scrubbing system.

DON BRUNNER: We overformulate ammonia a maximum of 1/2 unit and usually a 1/4 unit and we come close to the grade so we're losing 1/4 - 1/2 unit. Theoretically, we should be recovering that because it goes into our wet scrubber and we use a lot of scrubber water. Of course, we do not recover it all.

QUESTION FROM THE AUDIENCE: Doesn't the scrubber water become saturated with ammonia?

DON BRUNNER: No, because we add enough fresh make-up water to it. It's always on the alkaline side.

HAROLD GREEN: We overformulate between 1/4 and 1/2 unit on triple 13. We had some problems when we first began to operate the plant on analysis, on nitrogen. But we have made some changes during the summer and now our nitrogen loss has improved. Analysis about 3% under guaranted. Total nitrogen loss is unknown.

DON BRUNNER: Well, our ammonia loss is too high. Probably somewhat higher than Harold said. I don't believe that it's too high, though, if we can make our scrubber as efficient as it ought to be that it will be recovered. We will recover it with water, but we will probably need to use acids to hold the pH correct in the water.

QUESTION FROM JIM McARTHUR: You said you changed from a DAP to a MAP formulation. I would like to know what impact this had on formulation costs.

DON BRUNNER: I think that would be probably different in different areas. It would depend a lot on what your sulfuric cost was. I wanted to make a comment on that because we have been using available sulfuric acid and there is a lot of real cheap sulfuric acid if you know where it is. They are going to have to dispose of this acid someway, as a result it is available for cost of freight.

We are experimenting now by using the 60° sulfuric acid. So, that formula cost would be determined by what your sulfuric costs you and what kind of material you were using before this.

DOUGLAS CAINE: Thank you Bud and the members of the Panel for bringing us up-to-date on the recent pipe cross experiences. (Applause)

Our next speaker is guaranteed to get attention because he insists upon being introduced twice.

Karl T. Johnson is Vice President, Member Services of The Fertilizer Institute, Washington, D.C. His major responsibilities are in two important program areas, Environmental Regulations Affecting Manufacturing Plants and Product Quality. Before coming to TFI in 1975, Karl worked for the U.S. Environmental Protection Agency in its Office of Enforcement. During his duty he helped to implement the nation-wide industrial waste water permit system, so he may generate a lot of questions in respect to that. Karl is a graduate of Iowa State University with a B.S. in Chemical Engineering, and his work experience also includes positions with DuPont and the Atlantic Research Corporation. Karl will bring us up to date on a subject, which is becoming more and more an everyday experience with us, Toxic Substances and Hazardous Wastes.

Toxic Substances — Hazardous Wastes

Karl T. Johnson

The newspapers, trade journals and environmental news publications come to us each day with articles about toxic substances, toxic pollutants, hazardous substances, hazardous materials, hazardous wastes, hazardous air pollutants etc. It is easy to get lost in this sea of similar terms. But it can be critical to your business operation to know which specific term is meant. Different Federal Agencies have authority for regulating what may sound like the same thing, but the regulatory requirements affect entirely different phases of your business.

For example, hazardous materials are regulated by the Department of Transportation but hazardous substances are regulated by the Environmental Protection Agency (EPA) (under the Clean Water Act), by the Consumer Product Safety Commission (under the Federal Hazardous Substances Act) and the Occupational Safety and Health Administration.

Adding to the "toxic and hazardous" confusion is a Toxic Substances Control Act administered by EPA which does not even include the term "toxic substance" in its list of definitions. Toxic pollutants, however, are subject to control by EPA under the Clean Water Act. If they get into the air they are called hazardous air pollutants. If they are deposited on land they become hazardous wastes, under the Resource conservation and Recovery Act. The last category, by the way, is the main topic of my talk today. Before getting into the heart of my talk though, I wanted to make the point that in the world of "toxic and hazardous" it is extremely important to be specific.

A year ago I reported to this group about the Toxic Substance Control Act. At that time the first requirement for industry, that of reporting on production and import of existing chemical substances, was about to get under-way. Now, a year later after industry met its initial reporting deadline of May 1st, we are waiting for publication of that initial inventory. The latest estimate we have is that it will not be available before March 1979. Once that is published a special 210 day reporting will begin for processors to report any chemical substance they use which was overlooked in the initial inventory. It appears then, that by sometime in 1980 we will finally learn the identity of all "existing" chemical substances.

Before that however, anyone who intends to manufacture or import a new chemical substance, that is, one not on the initial inventory, must file a premanufacture notification. This requirement becomes effective thirty days after publication of the initial inventory.

The EPA is hard at work developing premanfacture notice and testing rules. They have estimated a January 1979 publication of final premanufacture notification regulations. Testing standards for oncogencity and other chronic effects is targeted for March 1979.

With that brief status of activities under the Toxic Substances Control Act let's turn now to Hazardous Waste Management. There is no doubt that fertilizer manufacturers will find it necessary to review and make individual assessment of regulations being developed under the Resource Conservation and Recovery Act (RCRA) of 1976. This Act was an amendment to the Solid Waste Disposal Act. The objectives of this act, signed into law two years ago this month, are to "promote the protection of health and the environment and to conserve valuable material and energy resources . ." The Congress not only set objectives but also statutorily established the Office of Solid Waste within the EPA to carry out the requirements of RCRA. With this law in place, the EPA was thus given a complete set of tools to carry out its mission of health and environmental protection.

RCRA expands the regulatory control of the EPA in three major areas:

1. It provides for and emphasizes state control of solid wastes based on Federal guidelines.

2. It provides for control of hazardous wastes through a Federal program of standards, permits and penalties. States may qualify to conduct the hazardous waste program in lieu of the Federal Program.

3. It provides Federal programs in research and development, technical and financial assistance and full-scale demonstration projects.

In assessing the impact of this Act it is necessary to look at some important definitions. First — the term "solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operation, except for solids or dissolved materials in domestic sewage and irrigation return flows, or industrial discharges subject to point source control under section 402 of the Clean Water Act (The National Pollutant Discharge Elimination System).

Adding to that all-encompassing definition is the term "hazardous waste" which means a solid waste, or combination of solid wastes, which because of its quantity, concentration or physical, chemical, or infectious characteristics may —

1. cause or significantly contribute to an increase in mortality or an increase in mortality or an increase in serious irreversible, or incapaciting reversible illness, or

2. pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

Since "disposal" is central to handling of wastes, we should look at its meaning which is the discharge, deposit, injection, dumping, spilling, leaking or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters.

Finally, two more which are important are "sanitary landfill" and "open dump." A sanitary landfill is a facility for disposal of solid waste which meets certain criteria to be published, which as a minimum require that there by no reasonable probability of adverse effects on health or the environment from the disposal of solid wastes at such a facility. An open dump is a solid waste disposal site which is not a sanitary landfill.

The last two definitions are important in that State plans for management of solid waste will cover sanitary landfills and open dumps are to be prohibited. Therefore, managers of fertilizer plants where land disposal of wastes is practiced should expect to have regulatory officials take a closer look at how the disposal is performed.

Of special interest to industry environmental affairs managers will be the regulations for Hazardous Waste Management which will be developed under subtitle C of RCRA. The regulations will include identification and listing of hazardous wastes; standards for generators; standards for transporters; standards for owners and operators of hazardous waste treatment, storage and disposal facilities; permits for treatment, storage and disposal; and notification requirements for those who handle a hazardous waste.

Time doesn't permit us to get into detail on all of these but I will highlight three which are very important.

First is the identification and listing of hazardous wastes. As I mentioned, all solid wstes will be subject to some degree of control. Once a solid waste is determined to be a hazardous waste however, then other, more stringent regulations governing your conduct come into play. Under draft regulations for Section 3001 of RCRA, now in circulation at EPA (dated September 12, 1978), the criteria and methods for identifying hazardous waste are prescribed. It also contains a listing of hazardous waste. Once the regulations are published, wastes can be determined to be hazardous in either of two ways — have certain characteristics identified in the criteria or to be on the list. The listing covers not only specific waste but also waste streams which are considered hazardous due to it characteristics, properties or potential hazard — regardless of whether it is in fact managed properly.

The characteristics currently selected to identify a hazardous waste are ignitability, reactivity, corrosiveness and toxicity. Infectious and radioactivity characteristics were considered earlier but will now be handled by listing sources of wastes having these characteristics. EPA is planning to seek information from which they can establish a radioactivity characteristic to use in judging any waste.

Briefly, the limits for each characteristic are as follows:

Ignitable Waste—

1. Flash point (liquid) less than 140°F. (60°C.) or liable to cause fire through friction or chemical change during handling.

2. a compressed gas as defined by DOT in 49CFR173.300.

3. an oxidizer as defined by DOT in 49CFR173.151.

Corrosive Waste—
1. Is aqueous with $pH \leqq 3 \geqq 12$
2. has corrosion rate greater than 0.250 inch per year on SAE 1020 steel at 130°F.

Reactive Waste—
1. Normally unstable-readily undergoes violent chemical change.
2. capable of detonation at normal temperature and pressure
3. capable of detonation but requires strong initiator.

Toxic Waste—

Extract of waste subjected to Toxic Extration Procedure (TEP) contains a substance covered by primary drinking water standards at a concentration 10 times the standard.

The current list of hazardous wastes and process generating waste is extensive. Examples of commonly found wastes listed as hazardous are cooling tower sludges and waste solvents. As you might suspect a large number of organic and inorganic chemical processes are listed as generating hazardous wastes. Near to our interests is phosphate rock mining for overburden, tailings and slimes and phosphoric acid for by-product gypsum.

The second regulation I would mention, and perhaps the most important initially, concerns notification.

Persons who generate, handle, transport or dispose of hazardous waste must notify the EPA of such within ninety days after the regulation for section 3001 is finally promulgated. Without such notification it will be illegal to perform any function with a hazardous waste.

The other regulation I would particularly note are those which contain the standards for owners and operators of hazardous waste treatment, storage and disposal facilities, in other words the persons subject to the notification I just mentioned. These rules are required by section 3004 of RCRA. The standards will establish uniform minimum requirements which apply nationwide. They embody rules for protecting all media from pollutants: air, land, surface water and groundwater. As currently drafted, they cover human health and environmental standards, general facility standards, storage standards, treatment and disposal standards and special waste standards.

It is under these regulations that you will find details on general aspects of facility operation, such as site selection, monitoring, training, security, recordkeeping/reporting and financial requirements. Also a feature of these regulations is the recognition by EPA that certain special wastes just do not fit into traditional waste management schemes. The Fertilizer Institute has been instrumental in getting the phosphate related waste, which EPA is planning to list as hazardous, into a special waste category. Through this approach it is intended that the general facility standards which would be totally in appropriate for these high volume wastes would not be applicable. Standards which recognize the available management practices coupled with degree of hazard involved would be tailored for these wastes.

Before closing I would mention the estimated schedule EPA has for issuing Hazardous Waste Management regulations. EPA has already missed the statutory deadline of April 21, 1978 due to the complexity of issues involved with these regulations. They are now targeting January 1979 for proposal of most of them. A public comment period until April is planned with final promulgation in January 1980.

With that timetable, it may seem that there is no imminent concern over these regulations. Nothing is further from the truth. I heartily recommend that you have your environmental control managers get into the details of these regulations now — as they are developing at EPA. It is *now* that the best opportunity exists for obtaining regulations which can be lived with in the future. (Applause).

MODERATOR CAINE: Thank you Karl for brining us up to date on what the Government is doing. It looks like we have a lot of reporting ahead of us. This will conclude our formal program for today.

A Question? Yes.

FROM THE AUDIENCE: This "Gyp" probably meets at least one or more of the hazardous wastes. What are we going to do? That is every fertilizer produced in the United States?

KARL JOHNSON: That's why we're worried about it. I would mention that the reason E.P.A. put it on the list as hazardous waste is because of its radioactivity content. This is one issue we are struggling with right now. We are trying to get byproduct gypsum into a special waste category so that it can be handled differently than hospital wastes or very high contaminated wastes. It may develop that the best way to handle the by product gypsum, that is not used as a soil amenment, is to pile it up and keep it in one place and not let it get out into the environment, so to speak. This is where we really have to do our homework from now on, working to make sure that the requirements they place on the industry are those that have some reason and are things we can handle without raising the cost to a ridiculous level. There were draft regulations for general facilities that involved fencing, limited access, posting signs, all kinds of things that you would have to do. Can you imagine fencing a 15,000 acre mining site or a 26 acre gypsum cooling pond or the pile itself? The cost of this kind of thing would be astronomical. So, what we are faced with, then, is trying to get the best deal out of this in terms of requirements for management practices. My estimate is that the way we are handling gypsum now is probably as good a way as you possibly can.

QUESTION FROM THE AUDIENCE: Is any Industry Committee working with the Government?

KARL JOHNSON: Yes, through the TFI and its Manufacturing or Environmental Committee, we have created a task force which is working with the agency. As I mentioned, we met with them three times already as a group plus several individual contacts on my part. I also understand that the Florida Phosphate Council has a hazardous wastes task group which will be in direct dialogue with the EPA also. So, hopefully, by combined efforts, we can get this thing resolved equitably.

DOUGLAS CAINE: Thank you Karl. This will conclude our program for today. Thank you all. (Applause).

Wednesday, November 1, 1978

Morning Session
David W. Leyshon, Moderator

MODERATOR LEYSHON: My name is David Leyshon with Jacobs Engineering in Lakeland, Florida. I am your Moderator this morning. I would like to remind everyone here to please registar if you haven't. This entitles you to a set of reprints of all the papers so the registration fee is really very modest, especially compared to some of the charges that other meetings of this nature have. We also have past issues of Proceedings available and Paul Prosser would be happy to unload a few of those.

This morning we have a number of papers on the subject of Phosphoric acid. I think the phosphate speaker yesterday pointed out the rather large tonnage of phosphoric acid which is presently being manufactured and the projection for future trends in this area. In 1977 there was a million and a half tons of phosphoric acid being traded on an export, import basis. The United States exported some 400,000 tons; all of this is at least at the strength of 52 or 54% P_2O_5. There is a lot of interest in higher strength acid processes and we have some papers on that subject this morning.

Our first speaker today will be Dr. Fernando Orẽ of Occidental. Dr. Orẽ was born in Peru, South America and obtained his PhD from Washington University in Chemical Engineering, in Seattle. He joined American Potash where he was part of a team that won the Chemical Engineering Kirkpatrick Award in 1962-63 for their novel process on boron extraction. In 1970 he joined Occidental where he became Director of Phosphates Research. His areas of specialization are computer modeling, salt extraction, crystallization and phosphate technology. He has recently been selected by Chemical Engineering Magazine to receive their 1978 Award for Personal Achievement. Dr. Orẽ (Applause).

DR. ORẼ: Mr. Chairman, thank you very much for your kind introduction. I want also to thank you for the opportunity to present some of the features of the Occidental Hemihydrate Process. I have selected as a topic, Oxy Hemihydrate Process Crystallization Kinetic and Slurry Filterability.

Oxy Hemihydrate Process Crystallazation Kinetics And Slurry Filterability

Dr. F. Orẽ

The hemihydrate process is not a new process, it is almost as old as the dihydrate process; however, its development toward a competitive commercial level is new and timely for world conditions. The advantage of the hemihydrate process of producing a more concentrate acid product, reducing concentration cost, has been recognized from the onset, but this advantage at the time when energy was abundant and inexpensive was not incentive enough for its development, especially if we consider the technical limitations associated with the process:

- Low filtration rates
- Conversion of filter cake at filter
- Scaling
- High corrosion rates
- Low product recovery

These technical limitations have prevented the early commercialization of the process, and even now when several hemihydrate processes are available, their commercialization is still limited. On the other hand, the dihydrate process which became the conventional process has been fully developed and perfected, through several plant generations, to become a very reliable process; however, it is energy-intensive and does not fit very well in present world conditions.

- High energy cost — and limited
- Declining rock quality
- No commercial technology to process low grade rock
- High acid concentration required for liquid fertilizers
- Growing phosphate market

As a result of the energy shortage, the declining quality of phosphate rock, and the trend of the market toward liquid fertilizer, which requires acid of higher concentration and purity, the hemihydrate process has become more desirable. In addition to producing a more concentrate acid, the hemihydrate process has higher driving force for rock dissolution, which makes it more suitable for processing unground rock, eliminating the cost and energy involved in grinding rock.

Occidental's Appraoch

In view of the need for a low energy phosphoric acid process, ORC started the development of a hemihydrate process a few years ago. ORC's approach was:

- Conduct basic reactions in separated vessels
- Optimize conditions in each vessel for reaction taking place
- Control crystallization kinetics
- Develop a crystal modifier
- Operate in the hemihydrate region to produce stable crystals

Advantage was taken of the new technology available, which make it possible to overcome the process limitations encountered in the development of the process. For instance, new crystallization technology based on population balance techniques were applied to improve the crystal size distribution and obtain higher slurry filterability, minimize scaling problems, and optimize the size of the reactor. A better understanding of the phase chemistry and more advanced process control techniques helped to minimize the risk of cake conversion at the filter. New materials of construction were available, which could be successfully used in the hemihydrate process. In summary, the present world conditions, especially the high cost and limited amount of energy as well as the availability of new technology makes the hemihydrate process now a most viable process.

The Chemistry of the Process

The two overall basic reactions of the hemihydrate and dihydrate processes are basically the same:

Rock dissolution:

$$Ca_{10}F_2(PO_4)_6+14H_3PO_4 \blacktriangleright 10Ca(H_2PO_4)_2+2\ HF$$

Calcium sulfate hydrate formation:

$$Ca(H_2PO_4)_2+H_2SO_4+xH_20 \blacktriangleright CaSO_4xH_20+2H_3PO_4$$

The first reaction corresponds to the dissolution of the rock in phosphoric acid to form monocalcium phosphate solution, and the second reaction to the reaction of the monocalcium phosphate with sulfuric acid to produce calcium sulfate hydrate in phosphoric acid. The operating conditions of the basic reactions are adjusted to crystallize the calcium sulfate in the dihydrate or in the hemihydrate form.

	Liquid phase	**Solid phase**
Dihydrate	28-30% P_2O_5 acid	$CaSO_4$, $2H_2O$
Hemihydrate	40-50% P_2O_5 acid	$CaSO_4$, $1/2H_2O$

Due to the similarity of the basic reactions, the trend in the development of the hemihydrate process has been to follow a parallel route to that of the dihydrate process, except for the operating conditions. However, the crystallization kinetics of the hemihydrate crystals is different from that of the dihydrate crystals and must be carefully controlled in order to produce filterable crystals.

With respect to the phase chemistry, this has been clearly defined for pure systems (and is published in the literature). See Fig. 1. This phase diagram, however, varies with the level of impurities present in the system. In the hemihydrate zone there are areas which produce a more stable type of crystal and there are also areas where there is a high rate of scaling. These areas are also related to the type of rock and the impurities.

Crystallization Kinetics and Filtration Rates

The major factors controlling filtration of slurries are: Crystal size distribution, crystal shape, viscosity, and percent solids in the slurry. In the case of the hemihydrate process, there is little or nothing we can do to control the viscosity* and, to a certain degree, the sludge density, since these are established as required by process conditions. There is also little we can do about the shape of the crystal, except by using crystal modifiers; however, this technology is still not well known. It is possible to use crystal agglomerators, but then limits our flexibility for mechanical handling of the slurry. The only thing we can really control is the crystal size distribution, and it is here where modern crystallization technology becomes a very important tool. A few years ago Larson and Randolph** introduced the "Population Balance Technique" in treatment of particulate systems, which made it possible to control particle size distribution by controlling nucleation and growth rates. These techniques were developed mostly for systems where the solids were the product, and these should meet certain product quality specifications in-

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*Except by using an additive (see "Effect of a Surface Active Viscosity of Suspension", Sikdar and Ore, AICHE Journal, Vol. 23, No. 3.)

**Randolph, A.D., and Larson, M.A. "Theory of Particulate Processes", Academic Press, New York (1971).

cluding crystal size distribution. In such case, the control of crystallization kinetics eliminates the need for screening, grinding, redissolving fines, etc. to meet particle size specifications. The same crystallization technique can be used in the hemihydrate process to have a crystal size distribution which favors high filtration rates.

At Occidental Research we have conducted extensive experimental work on crystallization kinetics, process factors that affect it, and corresponding filtration rates. This work included the following:

- Pilot plant tests with several types of rock
- Crystallization kinetics studies
  - + Using monocalcium phosphate solution
  - + Using monocalcium phosphate slurries
- Crystallization kinetics in commercial operation

Pilot Plant Tests

The pilot plant tests were conducted using mostly North Florida rock; however, we have made some tests using Kola rock and a high metallic rock. Table 1 shows a summary of the kinetic data and filtration rates obtained in one of the series of pilot tests using different types of rock and operating under relatively similar conditions. In this particular series, higher nucleation rates and lower filtration rates were obtained for calcined North Florida rock than those corresponding to other types of rock. It is also interesting to note that the growth rate was consistently around .1M/min. for all cases. The dependence of filtration rate on nucleation rate can be derived from the graph presented as Fig. 2, obtained by plotting nucleation rate vs. filtration rate data from Table 1. Although this graph has not been corrected for the effect of viscosity on filtration rate and crystallization kinetics, the strong effect of nucleation rate on filtration rate can still be inferred from this graph.

Crystallization Kinetics Studies

Since the filtration rates obtained in the earlier series of pilot plant tests were too low for a competitive commercial process, it was necessary to establish the process factors that controlled the nucleation and growth rates of the hemihydrate crystals so that the filtration rates could be improved to more practical levels. In order to determine the effect of process variables on nucleation and growth rates, experimental tests were conducted by contacting monocalcium phosphate solutions or monocalcium phosphate slurries with sulfuric acid in a mixed suspension, mixed product removal continuous crystallizer (MSMPR crystallizer) to form calcium sulfate hemihydrate crystals. The independent variables controlled were temperature, free sulfate ion concentration in the liquor, and residence time. Agitation was varied within relatively narrow range and the primary dependent variable was crystal size distribution, which was determined by a very reliable and reproducible procedure using a Model TAII coulter counter. Nucleation and growth rates were determined from crystal size distribution data. A summary of the kinetic data obtained for different process conditions, when monocalcium phosphate solutions were used is presented in Table 2. As can be appreciated, the growth rate varies between 0.12 and 0.24 M/min., which is higher than the 0.1 M/min. obtained in the first set of pilot plant tests, but still in the same range. The nucleation rates appear to vary with process conditions, within a wider range, as it was in the case of the data obtained in pilot plant work, but one to two order of magnitude smaller. These data indicate that even in relatively pure systems, the growth rate could not be improved substantially, but we could control, to a better degree, nucleation rates.

The same tests were conducted using monocalcium phosphate slurries, which are more similar to phosphate slurries. Crystallization kinetic data corresponding to these tests is presented in Table 3. As shown in Table 3, the nucleation and growth rates in this case approached those obtained in the pilot plant tests. These data permitted the establishment of a relationship between free sulfate ion concentration and nucleation and growth rates.

Figure 3 shows the relationship between free sulfate ion and nucleation rate for tests conducted using monocalcium slurries. This graph was obtained by plotting percent free SO_4 vs. nucleation rate data from Table 3. A correlation between these two variables has been established, and is included. The effect of free sulfate ion on growth rate is presented in Fig. 4, where growth rate is plotted against percent free SO_4. A correlation between these two variables has also been established and is presented in Fig. 4. As should be expected, retention time enters into this correlation.

Crystallization Kinetics in Commercial Plant Operation

After optimizing the proper parameters to minimize nucleation, test were conducted in the hemihydrate pilot plant using North Florida rock. The crystallization kinetic data obtained in these tests very closely matched the kinetic data developed using monocalcium phosphate slurries in the MSMPR crystallizer. The same nucleation and growth rates were found to hold for a 350 TPD P_2O_5 commercial hemihydrate plant when operated at similar conditions with filtration rates equal or better than those usually obtained in the dihydrate process.

In summary, crystallization technology, in conjunction with other technology developed in the areas of process control and phase chemistry, has permitted Oxy to develop a very competitive hemihydrate process, which is now in the commercial stage. A 350 TPD P_2O_5 hemihydrate plant has been built in North Florida, and has been tested satisfactorily. A new plant with a design capacity of 1430 TPD P_2O_5 is presently in the design phase. The advantages of the Oxy Hemihydrate Process are as follows:

- High filtration rates (equal to or higher than dihydrate)
- High acid concentration (40-44% P_2O_5)
- Clean acid product
- No conversion at filter cake
- Can use unground (and lower grade) rock
- Lower sulfuric acid usage

The high filtration rates indicated is the result of controlling crystallization kinetics, specifically by minimizing nucleation. The acid obtained in the Oxy Hemihydrate Process has lower levels of free sulfate, fluorine, calcium, aluminum, and solids content than dihydrate made from the same rock, as shown in Table 4. The analysis of the dihydrate acid presented in this table has been adjusted to equal the P_2O_5 concentration of the hemilydrate acid.

The incentives of the Oxy Hemihydrate Process at its present level of development are presented in Table 5. Economic studies, based on actual commercial plant performance indicate decisive advantages of the Oxy Hemihydrate Process over the dihydrate process in both capital requirement and production cost. Even greater advantage should be expected in the coming years and in new plant generations as the process is optimized.

FIGURE 1

HYDRATES OF $CaSO_4$ PRECIPITATED VS % P_2O_5 AND TEMPERATURE

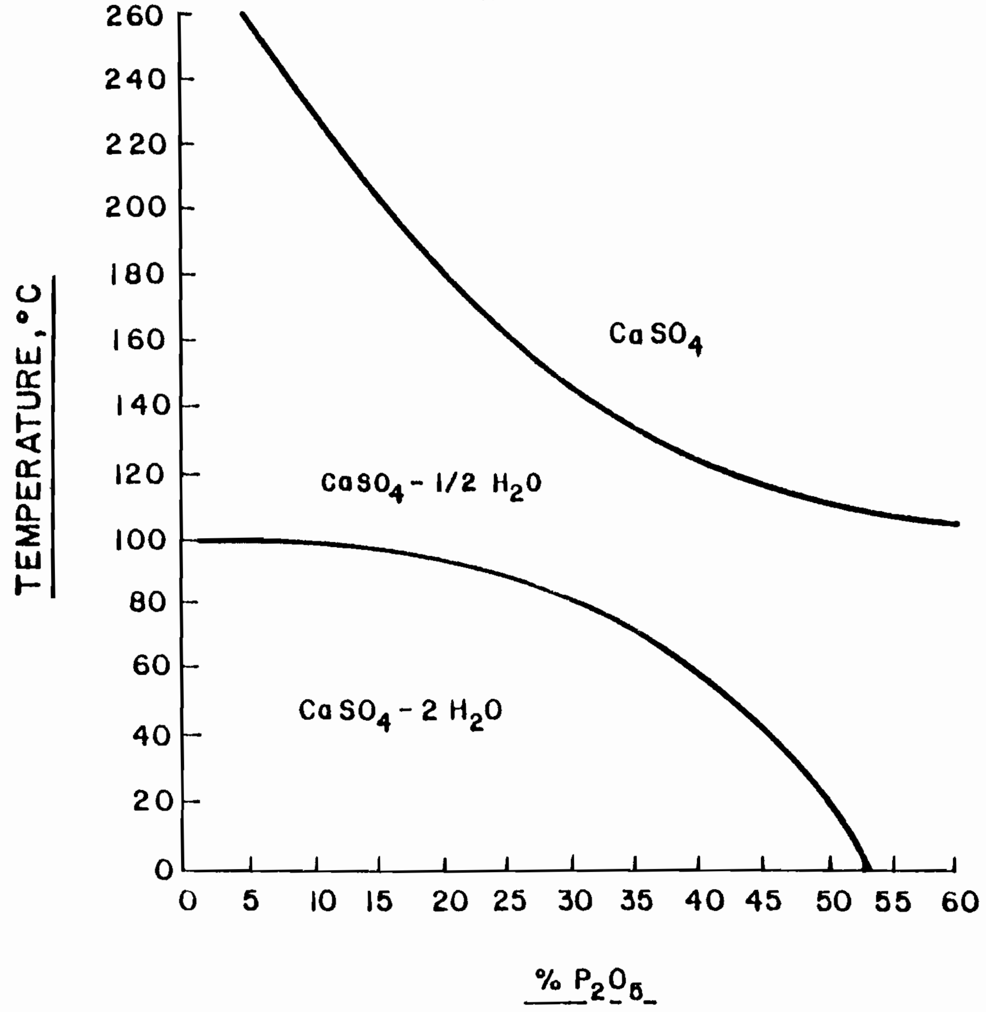

FIGURE 2

FILTRATION RATE VS NUCLEATION RATE

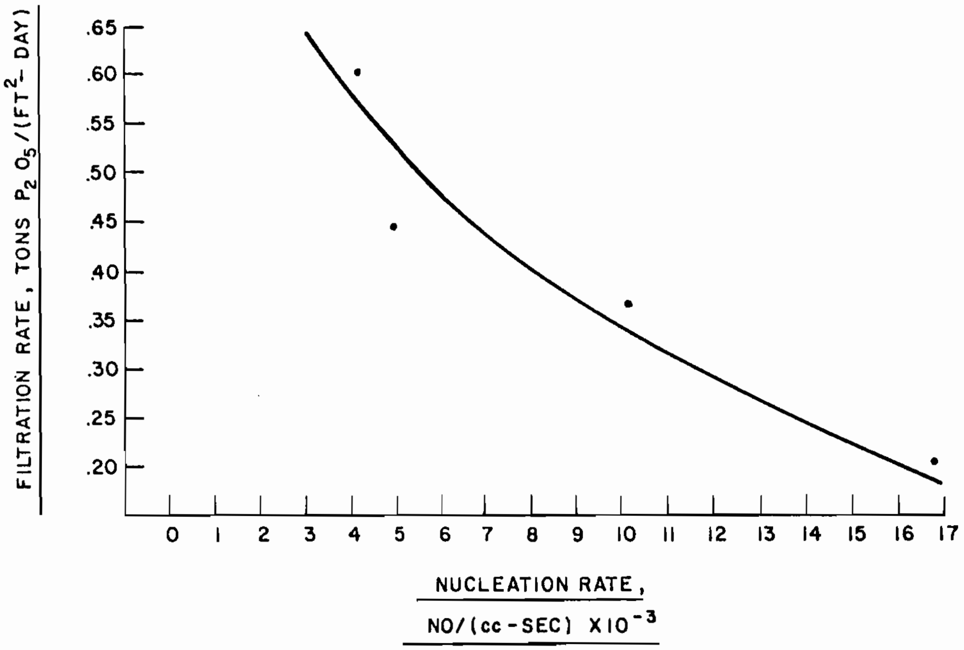

FIGURE 3

EFFECT OF SULFATE ION CONCENTRATION ON NUCLEATION RATES FOR MONOCALCIUM PHOSPHATE SLURRIES

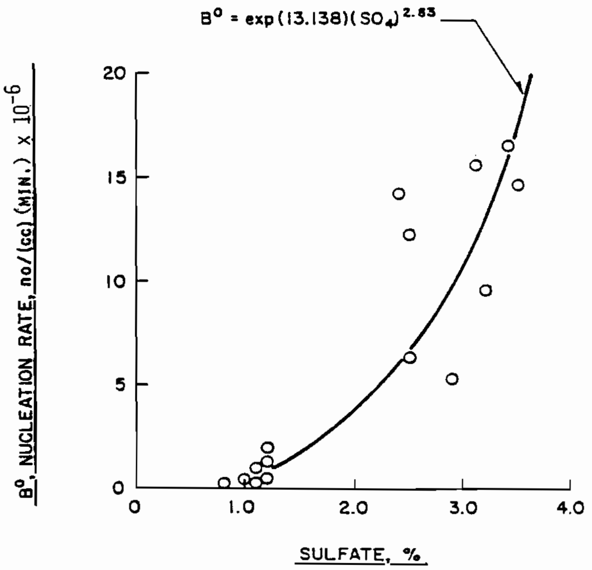

FIGURE 4

EFFECT OF SULFATE ION ON GROWTH RATE FOR MONOCALCIUM PHOSPHATE SLURRIES

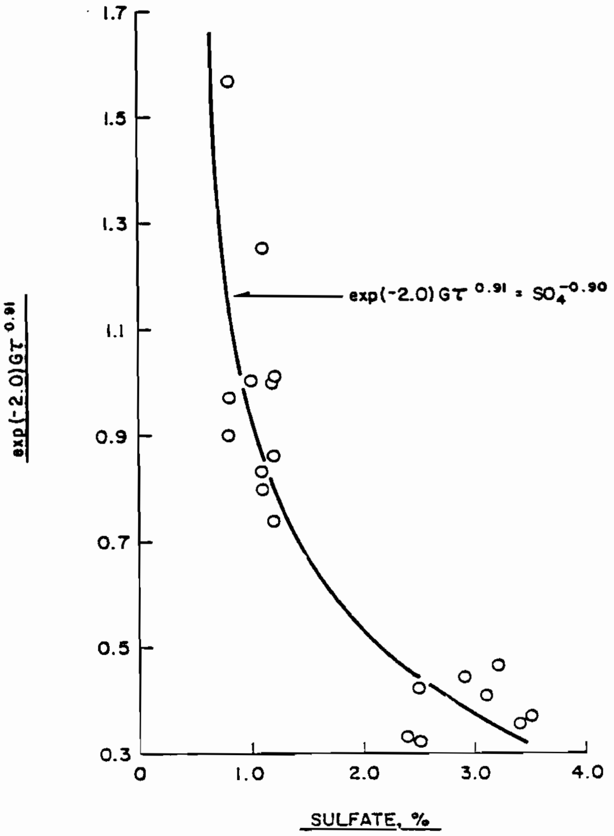

TABLE 1

CRYSTALLIZATION OF CALCIUM SULFATE HEMIHYDRATE IN PHOSPHORIC ACID

SUMMARY OF KINETIC DATA

TYPE OF ROCK	RESIDENCE TIME FOR SOLIDS IN ENTIRE SYSTEM,HR	FREE $SO_4^=$ IN SLURRY TO FILTER %	NUCLEI DENSITY, NO./CM^4	DOMINANT SIZE, μ	GROWTH RATE, MIN.	NUCLEATION RATE, NO. / CC – MIN.	FILTRATION RATE, TONS P_2O_5/ (FT^2 DAY)
FLORIDA	4.12	2.20	5.89×10^{10}	31	0.104	6.1×10^5	0.366
FLORIDA CALCINED	4.12	1.00	9.87×10^{10}	27	0.103	10.1×10^5	0.200
KOLA	6.6	2.62	3.05×10^{10}	31	0.097	3.0×10^5	0.442
HIGH METALLIC ROCK	4.0	2.20	2.17×10^{10}	35	0.117	2.5×10^5	0.600

TABLE 2

CRYSTALLIZATION KINETICS OBTAINED FOR MONOCALCIUM PHOSPHATE SOLUTION

TEMP, °K	SO_4, %	RES. TIME MIN.	RPM	B° #/(cc)(MIN)	G, μm/MIN
345.7	0.97	45.0	550	6.394×10^4	0.126
363.7	1.20	45.0	700	1.178×10^4	0.245
344.0	2.81	45.0	700	3.200×10^4	0.191
363.3	2.49	45.0	550	1.853×10^4	0.234
342.7	1.06	90.0	700	4.736×10^3	0.136
362.7	1.25	90.0	550	3.833×10^3	0.127
343.3	3.01	90.0	550	8.670×10^3	0.134
343.0	3.11	90.0	550	8.307×10^3	0.120
326.7	2.95	90.0	700	6.003×10^3	0.129

TABLE 3

CRYSTALLIZATION KINETICS DATA OBTAINED FOR MONOCALCIUM PHOSPHATE SLURRY

TEMP, °K	SO_4, %	RES. TIME MIN	RPM	B^o #/(cc)(MIN)	G
343.0	1.20	45	550	1.243×10^{6}	0.198
343.0	1.20	45	550	1.886×10^{6}	0.170
363.0	1.10	45	700	9.591×10^{5}	0.193
362.0	1.10	45	700	9.701×10^{5}	0.183
345.0	3.20	45	700	9.568×10^{6}	0.107
344.0	3.10	45	700	1.555×10^{7}	0.094
363.0	3.40	45	850	1.648×10^{7}	0.082
361.0	3.50	45	850	1.458×10^{7}	0.078
343.0	0.80	90	700	1.839×10^{5}	0.193
344.0	1.10	90	700	2.902×10^{5}	0.154
367.0	1.20	90	700	3.938×10^{5}	0.132
361.0	1.20	90	700	4.254×10^{5}	0.123
363.0	0.80	90	700	4.578×10^{5}	0.119
362.0	1.00	90	700	4.473×10^{5}	0.122
343.0	2.50	90	700	6.261×10^{6}	0.052
343.0	2.50	90	700	6.261×10^{6}	0.056
363.0	2.40	90	700	1.441×10^{7}	0.041
361.0	2.50	90	700	1.230×10^{7}	0.039

TABLE 4

COMPARISON OF PRODUCT ACID QUALITY

19 DAYS PLANT OPERATION-ADJUSTED TO SAME P_2O_5 CONCENTRATION

	DIHYDRATE PLANT %*	HEMIHYDRATE PLANT %
P_2O_5	42.00	42.00
Fe_2O_3	0.92	0.87
Al_2O_3	1.49	0.96
MgO	0.50	0.48
F	1.86	1.28
CaO	0.48	0.31
SO_4	4.18	1.94
SOLIDS	3.46	0.78
SP. GR.	1.529	1.493

TABLE 5

INCENTIVES OF THE OXY HEMIHYDRATE PROCESS

- LOWER CAPITAL REQUIREMENTS
  - A. SIMPLER PLANT
  - B. LOWER FILTER AREA REQUIREMENT
  - C. LESS EVAPORATION REQUIRED
- LOWER PRODUCTION COSTS
  - A. SAVINGS IN CONCENTRATION COST
  - B. LOWER ENERGY REQUIREMENT
  - C. LOWER PROCESS WATER REQUIREMENT
  - D. LOWER SULFURIC ACID USAGE
  - E. MORE STEAM AVAILABLE FOR POWER GENERATION

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*Adjusted to 42% P_2O_5 concentration.

DR. ORĒ: I want to thank all of you for your attention and if you have any questions I will try to answer them. (Applause)

MODERATOR LEYSHON: Do we have any questions from the floor? I think we have time for a few.

BUD DAVIS (TVA): I would like to ask Dr. Ore what his P_2O_5 recovery was in flat tests, particularly, what his lattice P_2O_5 was?

DR. ORĒ: I have got the answer for you here. We are doing work at 3 different levels. At the fundamental level we recover 94-95% P_2O_5. We control the lattice bound P_2O_5 around 2 to 3%. At pilot plant level we have not gotten that high. In pilot plant work we are recovering around 94% P_2O_5, and lattice bound P_2O_5 is about 4%. In commercial plant operation recovery has been 90-95% and the lattice bound P_2O_5 around 6%. We have had some mechanical problems in the plant which have been corrected and we expect that when the plant is back in operation, in a couple of months, it will match the pilot plant recovery of 93-94%.

MODERATOR LEYSHON: Could you introduce yourself? The microphone is on the right there.

WALTER WATERMANN ("Uhde" from Germany): You mentioned a higher filtration rate. What is the filtration rate in equal parts per effective square meter?

DR. ORĒ: Well, I don't have the figures for tons per square meter, but I do have the figures for tons of P_2O_5 per square foot per day, and that is going to change with the rock. I'm talking for our operation about .7 to .8 tons of P_2O_5 (per day) square foot filter area.

MODERATOR LEYSHON: .7 to .8 tons of P_2O_5 per foot per day multiplied by about 9.8 for tons of P_2O_5 per square meter.

ERIC SCHWEHR (Fisons): I would like to ask Dr. Orē whether they have produced 50% or 50% plus P_2O_5 acid and in that case, whether their filtration rate is equivalent to Di-hydrate and whether and what their lattice P_2O_5 losses are at that acid strength?

DR. ORĒ: We have not produced 50% P_2O_5 acid in pilot plant operation. We have done some work on production of 50% acid in a two stage process, however, we did not measure the filtration rates in this particular case. We have produced 46% acid in the pilot plant, but no higher than that.

WALTER WATERMANN: During reaction, do you need any steam to get on temperature and so on?

DR. ORĒ: No, we don't need any steam, on the contrary, we have to cool a little bit.

GRANT LAWSON (C.I.L.): What is the minimum of acid concentration that you can use in your reaction stage? We might have a problem using 80% acid. Can you use 80% acid and not have this?

DR. ORĒ: There is a water problem, as you know, if much water is introduced into the process. We have operated with 93 and 98% sulfuric acid. I have not done any water balance calculations for 90% or 80% sulfuric acid. The use of this dilute acid will cause a reduction of the water available to wash the cake and consequently the soluble P_2O_5 losses may increase. I cannot give you the exact figure on that, however, let me mention one thing. In testing at our plant with wet rock we have reduced the amount of water available for washing the cake and its effect on recovery was less than 1/2%.

AL PETERSEN (Stauffer): Do you use a crystal habit modifier to achieve the filtration rate you stated?

DR. ORĒ: We use a crystal habit modifier in addition to controlling the kinetics. Yes, it is a nucleation suppressor.

MODERATOR LEYSHON: I think that was a very interesting paper. (Applause)

MODERATOR LEYSHON: I would like to introduce, next, Mr. Egbert Hoffman, who has come here from Germany to present the next paper on the program, which is entitled, "Design of A Phosphoric Acid Plant Based On Low Grade Phosphate Rock." Mr. Hoffman is a chemical Engineer graduate of the University of stuttgart in Germany, and he has been with "Uhde" in a process engineer role for five years,— Mr. Hoffman. (Applause)

Design of a Phosphoric Acid Plant Based on Low-Grade Phosphate rock

Egbert Hoffman

The aim of this short paper is to describe the different steps involved in a project for processing phosphate to phosphoric acid by the 'Nissan wet phosphoric acid process', where the properties of the phosphate rock have not yet been tested in a commercial plant. The amounts of phosphate rock available were limited and, consequently, tests could only be performed on a laboratory scale.

To refresh our memory, let us take a brief look at the conventional Nissan process, which uses commercial-grade dry phosphate with the following grain size distribution:

100 Tyler mesh 90%
200 Tyler mesh 70%

Appendix I

For energy reasons, as-mined phosphate with a moisture content of 8% was specified for the Maroc Phosphore project II. The P_2O_5, Si02 and Mg0 content of the various screen fractions was determined. The distribution of these in the phosphate is shown on the slide.

Appendix II

In view of the moisture content of approx. 8%, only a wet grinding process is possible, as already used on a commercial scale in the USA. The first grinding tests did not produce any satisfactory results regarding the relationship between water content, pumpability and grain size. As you know, the reason for this was the high content of Mg compounds. Because of the distribution of S_i02, P_205 and M_g0, screening tests were performed with the aim of removing the fines and the oversize with the high M_g0 content.

Wet screening at 0.06 mm and 4 mm mesh was proposed in order to obtain an optimum ratio of P_2O_5 to M_g0 to S_i02. The remaining grains between 0.06 mm and 4 mm were wet-ground to minus 1 mm. In parallel tests the upper limit of 1 mm was found to be acceptable for the Nissan process.

The following analysis values at a moisture content of 40% were found:

P_205: 30.2%
M_g0: 0.6%
S_i02: 7.2%

The grain size as well as the chemical analysis were acceptable.

Screening and grinding tests on a laboratory scale showed that screening, wet grinding and subsequent dewatering of the phosphate (e.g. on a filter) would function satisfactorily. The customer entrusted the screening of the phosphate to reduce the M_g0 content to a company specialized in this field.

This unit for the benefication of phosphate produced phosphate with a water content of 17 - 20%. This was followed by grinding tests to establish the design criteria for the commercial-scale mill, the aim being to determine the largest possible size of the phosphate and the lowest water content. The modified Nissan process permitted a maximum water content of 40% and a grain size of +16 Tyler mesh 0%
+28 Tyler mesh 5%

It was agreed to cooperate with DPG, who possess know-how on phosphate wet grinding. Using a phosphate sample, all tests necessary to obtain the design criteria were performed, namely:

- grinding tests (at Hardinge)
- agitation tests, pumping tests and screening tests

The requirements mentioned above could be met in closed grinding circuit, in that

1) Phosphate rock is fed to the mill with water,
2) Ground phosphate slurry is passed through screens and the coarse grains are returned to the mill,
3(The screen underflow is pumped into the reaction section of the Nissan plant.

The chemical analysis of this phosphate sample differed only slightly from that stipulated in the contract with the customer.

P_205: 30.50 - 30.20%
M_g0: 0.63 - 0.65%
F_e203, A_l203: 0.62 - 1.6%

The customer sent another phosphate sample at a later date in order to conform the previous results. The chemical analysis showed the following deviations from the first sample:

P_205: 29.4%
M_g0: 1.1%

With the required water content of 40% it was no longer possible to screen this phosphate; agitation tests also showed that intensive agitation for several hours increased the viscosity and this considerably impaired the pumpability.

This meant that a modification of the basic design was necessary in order to satisfy the customer's requirement of being able to process this phosphate of inferior quality.

Hence:
- Open circuit grinding system; therefore: screening facilities no longer necessary.
- Enlargement of the mill with higher driving power.

Laboratory tests carried out at Nissan using the first phosphate sample demonstrated that this phosphate is suitable for processing in a commercial-scale plant by the Nissan process. All the parameters necessary for establishing the design criteria were determined during these tests:

- Decomposition rate and time
- Hydration rate and time
- Filterability of the gypsum
- Mass balance

Using these results and interim analyses, the various plant sections could be rated precisely, in particular:

- sizes of vessels
- agitator performance
- cooling and exhaust air fan performance
- pump performance
- filter size
- pipelines

and the following points being most important of course:

- P_205 yield
- consumption figures
- acid quality

In view of the fact that dry phosphate is used for conventional processes but wet-ground phosphate was available for this project, modifications to the equipment as well as to the process itself had to be made.

As the maximum grain size is 1 mm, the phosphate is pre-digested with return acid in the premixer, before adding H_2S04 in the subsequent stage, the digester. This method of digestion (decomposition by return acid) is employed in the 'New Nissan Process'.

A definite gypsum/acid ratio in the digestion stage is characteristic for the Nissan process. The return acid must have a higher concentration because part of the water required for the process is introduced with the phosphate. The sulphuric acid for digestion must be diluted from 98% to 80% and not to 75%. If higher concentrations were used, firstly the heat generated in dilution would go directly into the digestion process, and secondly, the heat necessary for the hot filter wash water would not be available.

In order to achieve the higher return acid concentration and the same washing efficiency of the filter cake with a lower quantity of wash water, an additional washing step with a separator and pump was installed. The filter wash system is therefore disigned such that all the necessary wash water is returned to the process, the gypsum itself being discharged in dry state with 20 -30% water.

The laboratory tests were performed as part of the detailed tests by our licensor, Nissan, taking into consideration the process modifications already mentioned. The decomposition ratio and the hydration ratio were determined as a function of time. One of the parameters is the free sulphuric acid content, which has a direct influence on the decomposition ratio and thus on the yield. An important point is the formation of crystals in the hydration stage. The filtration and thus the yield is directly dependent on size and shape of the gypsum crystals, because in the event of poor filtration due to adherent acid, greater P_205 losses are obtained.

The equipment can be designed on the basis of the values determined in this way. For the present case, namely Ben Guerir phosphate with a grain size of 1 mm, the process had to be modified to the extent that:

1. return acid is first mixed with the phosphate
2. H_2S0_4, which is diluted to 80%, is fed to the digester
3. the free H_2S0_4 content is raised to 4%
4. the return acid concentration had to be raised to 26 - 28%

As a result it was necessary to:

a) cool the digesters, due to the sulphuric acid concentration being 80%
b) install a desulphation step to reduce the free H_2SO_4 content
c) modify the filter division in order to achieve the high P_205 content in the return acid.

The acid quality specified by the customer was as follows:

54.0% P_205
0.5% solids
3.5% H_2s0_4

In order to be able to guarantee a H_2S0_4 content of 3.5% and, on the other hand, maintain 4% in the weak acid, a desulphation step must be installed, as already mentioned. If desulphation takes place downstream of the filtration section in the 30% acid, this will result in an enrichment of solids, namely approx. 3% in the 30% acid, consequently approx. 5.5% in the acid with 54% P_205. If these solids were to be removed from the 54% acid, large quantities of acid would also have to be returned. These solids cannot be filtered, or can only be filtered with great difficulty because they consist of minute gypsum crystals. However, centrifuging presented no difficulty, although a solids concentration of max. 25% can only be achieved. This means that approx. 24 t/h acid with 54% P_2O_5 and 25% solids must be returned, in other words more than 20% of the entire production.

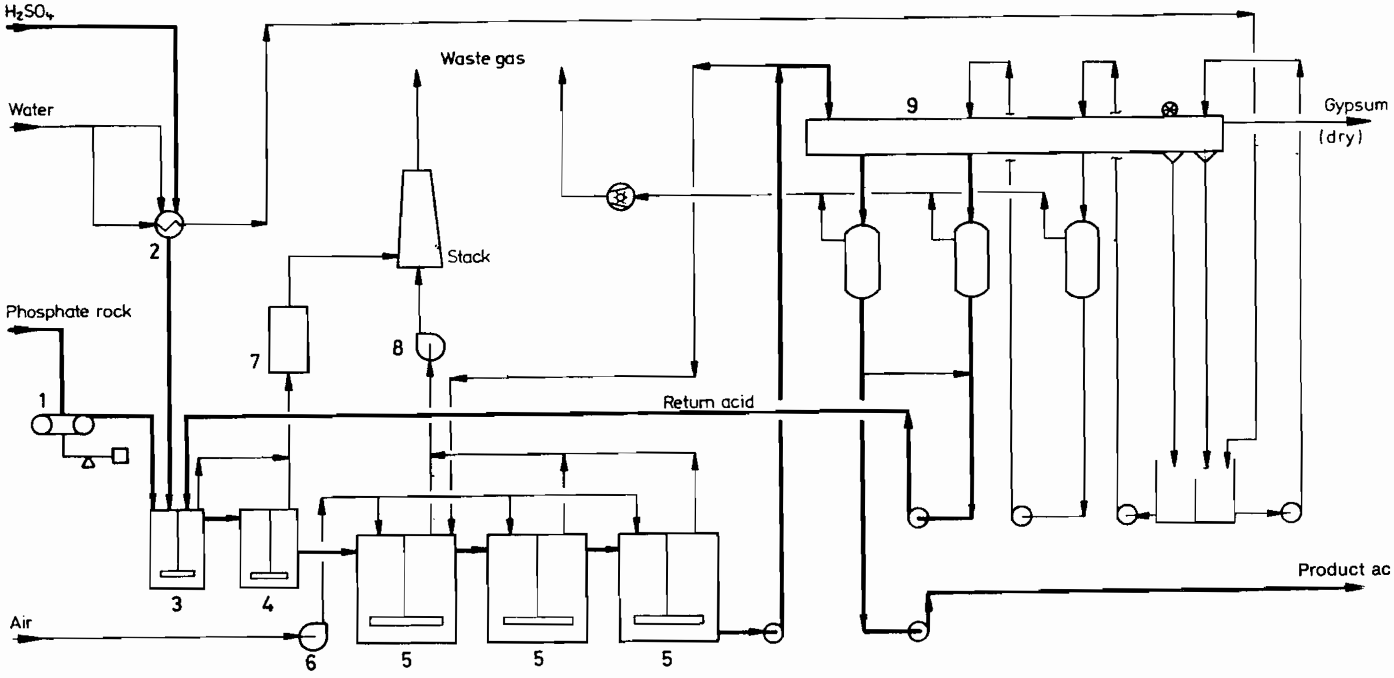
It seemed reasonable to effect the desulphation of the slurry upstream of the filter. Tests on a laboratory scale produced a very higher digestion rates for the subsequently added phosphate rock as when the desulphation was performed in the already filtered acid and the filterability of the slurry was also the same. The residual solids content in the 30% acid was thus reduced from approx. 3% to 0.5%. In order to reduce the solids content of the 54% product acid to the required value of 0.5%, centrifuges are installed which enrich the solids to approx. 20%. The sludge thus produced is returned to the process. In a plant already constructed, attempts to feed these solids with the 54% acid directly on to the filter failed because:

1. The return acid concentration became excessive
2. The P_2O_5 yield decreased as the sludge was very difficult to filter

The gypsum crystals must become larger, in other words they must be returned to the process. As this procedure of returning the gypsum crystals has not yet been practised in a commercial-scale plant, this was simulated in the laboratory. The digestion rate, hydration, filterability were again measured. As part of the acid (approx. 12%) is recycled, this must be taken into consideration for the design: larger equipment, machinery, vessels and higher concentrations.

Appendix III

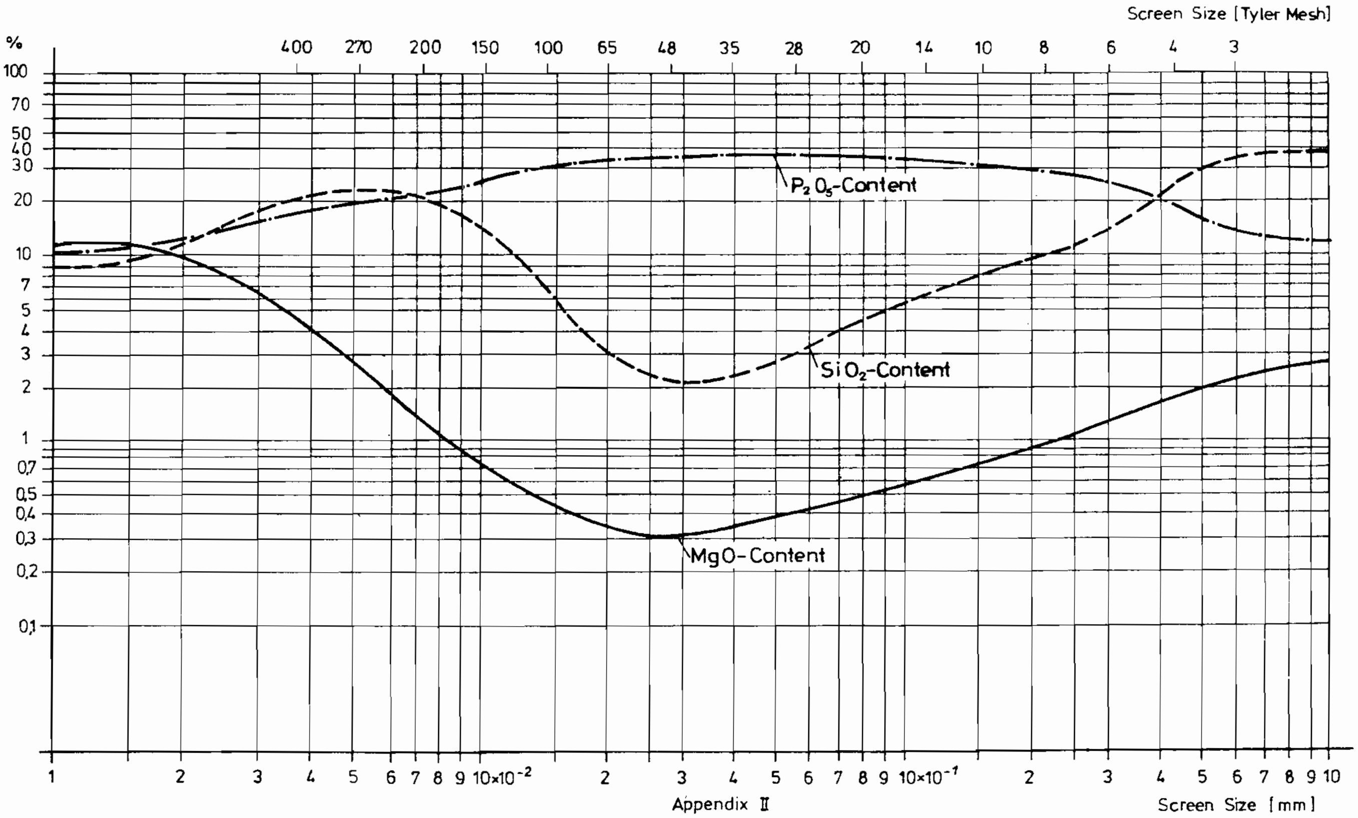
Note: Appendix I, II and III
on pages 68 and 69



1 Belt weigher
2 H_2SO_4 dilution cooler
3 Premixer
4 Digester
5 Crystallizer
6 Cooling air blower
7 Scrubber
8 Waste gas blower
9 Filter

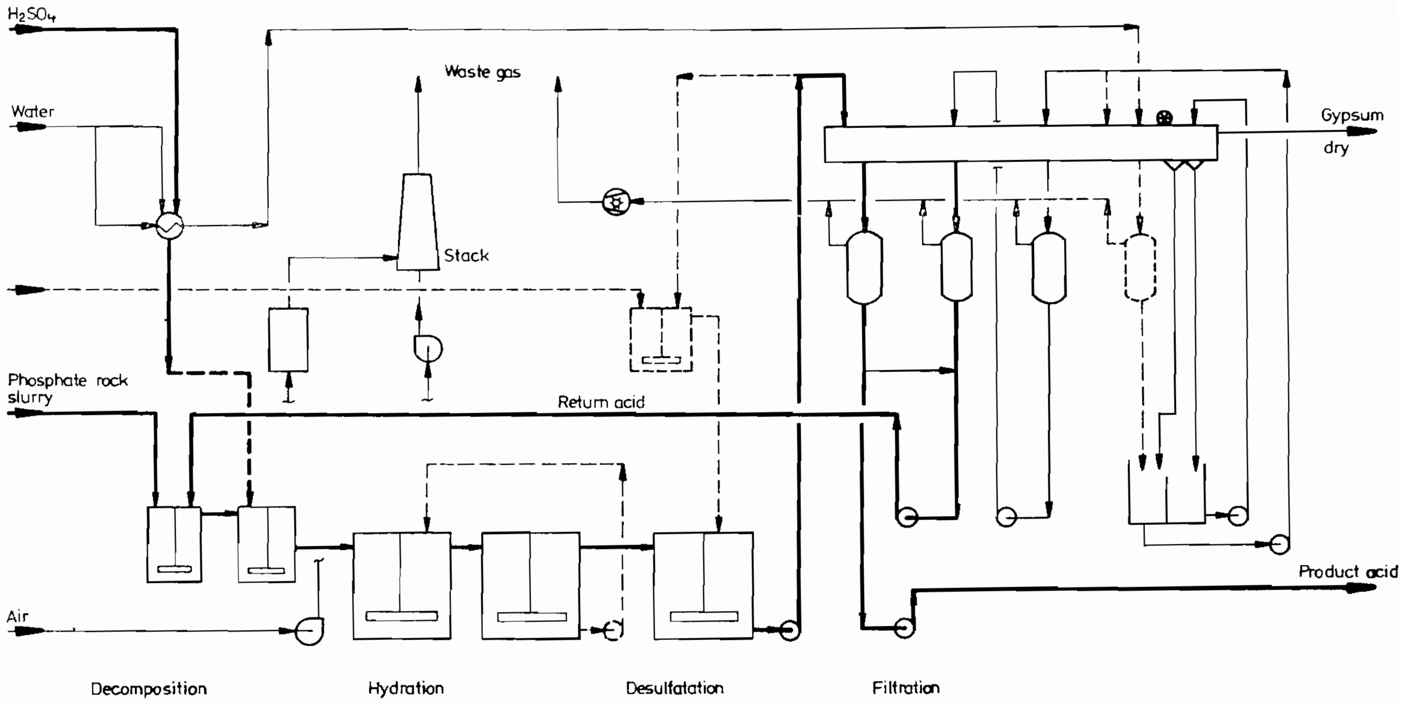
Appendix I

Conventional Nissan Process



Distribution of P_2O_5, MgO; SiO_2

Appendix II



Appendix III Conventional Nissan Process - modified UHDE

MODERATOR LEYSHON: Do we have any questions from the floor, please.

ART HENSEN (Bodger): Could you tell us the retention time in your crystallization tanks and the temperature?

EGBERT HOFFMAN: The retention time in the crystallizer is about 10 to 12 hours. It depends on the rock, especially for this rock, Benguelan, we had about 10 hours.

QUESTION FROM AUDIENCE: The generally recognized advantage of the Nissan Process is a very high recovery. What was the recovery with this low grade phosphate in Morocco. Could you tell us that number?

EGBERT HOFFMAN: It ranged between 96 to 97%.

MODERATOR LEYSHON: Thank you. If there are no more questions at this time, thank you Mr. Hoffman. (Applause)

MODERATOR LEYSHON: Our third paper is entitled "The Development of Fisons Hemihydrate Processes for the Manufacture of Phosphoric Acid". This paper will be given by Eric Schwehr who is the Commercial Manager of Fison's Licensing and Consulting Services. He is a graduate of the University College of London, and has made the journey here from Felixstowe to deliver this paper; has been in the fertilizer industry for nearly 27 years, (He really doesn't look that old.) and has occupied a number of different posts in that time, mainly concerned with production and development. He is a past president of the Fertilizer Society of London. Mr. Schwehr, (Applause).

The Development Of Fisons Hemihydrate Processes

E. W. Schwehr - B. T. Crozier

Presented by E. W. Schwehr

Introduction

The production of wet process phosphoric acid by the Hemihydrate Process is often considered to be the *modern* method. In fact it is not. Work on the development of the Hemihydrate Process has been recorded as early as 1927. Since that time the technology has progressed and led to the establishment of economic, large scale process plants.

Fisons mobilized its interest in the hemihydrate route in the mid-1960's when serious activity began in the form of laboratory and pilot plant studies. No one at that time could have predicted the social and economic conditions under which today's phosphoric acid producer has to operate:

high phosphate rock prices
high energy costs
expansion of Third World fertilizer production
strict pollution control legislation.

Nevertheless the development of both Fisons Hemihydrate Processes progressed to meet the changing needs of the industry. This paper traces that development and its culmination in the successful operation of large scale plants.

Fisons Hemihydrate Processes

Fisons offer two hemihydrate processes, their most striking features being the direct production of up to 52-54% P_2O_5 acid without the need for an evaporation stage, and a P_2O_5 recovery efficiency of up to 99%. The product acid is clean and comparable to clarified acid.

There is the single stage Hemihydrate (HH) Process which is a simple to operate route to produce 50% P_2O_5 acid directly from the reaction system. This reaction mechanism is such that P_2O_5 is co-precipitated with the calcium sulphate hemihydrate which leads to a lower P_2O_5 efficiency (93-94%) however this is more than offset by the ease of operation and the savings in steam. The more elegant two stage Hemidihydrate (HDH) Process overcomes the loss of coprecipitated P_2O_5 and its recovery enables efficiencies of 99% to be achieved. The first stage of this process is similar to the single stage HH process but with the addition of a second stage the calcium sulphate hemihydrate is converted to the dihydrate form and thus releases the lattice P_2O_5 which is recovered. The by-product dihydrate is very pure and as such could be put to further uses, say in the building industry.

General Background

Although the dihydrate method, producing 30% P_2O_5 acid is by far the most common of the processes operating today, other wet processes have been under investigation for a long time. In 1927 work under Nordengren[1] at Landskrona was directed towards the development of a strong acid process through a hemihydrate or anhydrite route. This did not reach any industrial application at that time due to technical difficulties and the lack of suitable materials of construction, particularly for the filter. In 1953 after further work at Landskrona a plant was designed[1] having a maximum capacity of 12 - 13 tonnes/day P_2O_5 which was built at Vercelli, Italy. This process was based on the anhydrite method and produced acid of 40 - 45% P_2O_5 concentration. The crystals were in the form of agglomerates and to obtain satisfactory operation it was found necessary to employ a reactor which was intermittently charged. Based on this experience, a larger plant was built (2) at landskrona in 1956 which was operated at about 30 tonnes/day P_2O_5, first by an anhydrite and then in 1958 by a hemihydrate method. The main reasons given for this change to a hemihydrate process were lower maintenance costs, the avoidance of external heat requirements due to a lower reaction temperature and the elimination of the need for intermittent reactor operation. In 1963 the plant was converted to a dihydrate process producing 30% P_2O_5 acid.

Of more recent years other processes have been described in the literature[3] based on a recrystallization step and producing acid of approximately 40% P_2O_5 concentration. These processes consist in first forming hemihydrate, filtering this off from the concentrated acid, followed by recrystallization to gypsum, refiltering and completion of washing.

Societe de Prayon have published[4] details of a process for producing phosphoric acid of 35 - 38% P_2O_5 concentration. In this process gypsum is first produced which is separated from the phosphoric acid using a centrifuge. The gypsum is then transformed to hemihydrate in a further reaction stage before filtering on a tilting pan filter. The filterability of the hemihydrate is claimed to be as good as gypsum and efficiencies of 99% or higher were quoted by Prayon.

Fisons have for many years been carrying out studies on the manufacture of wet process acid with the primary objectives of improving the Company's existing manufacturing plants and of developing new processes. At first work proceeded simultaneously using laboratory and pilot plant equipment. As early as 1967 Fisons designed and operated a single stage hemihydrate plant to produce 40 tpd P_2O_5 as 50% P_2O_5 acid at the King's Lynn site.

Theoretical Considerations

Following an early study of the limits of stability of calcium sulphate in the system $CaS0_4$ —P_2O_5 —H_20 it was concluded that it should be possible to produce calcium sulphate hemihydrate in a stable form over a wide range of P_2O_5 concentrations. There appeared to be no advantage in operating under conditions favouring the formation of anhydrite. It was also realized at an early stage that one of the main problems to be faced would be to produce hemihydrate crystals in an environment which would promote satisfactory crystal growth. This was one of the main reasons which had so far prevented the successful development of a concentrated acid process. Other difficulties which are present in all wet process phosphoric acid development work lie in the number and interaction of variables and the need for long residence times within the reaction system. This means that a systematic study of a large number of variables, although feasible, becomes unrealistic in practice due to the extensive time involved. To minimize this disadvantage Fisons developed rapid tests methods to classify the hemihydrate crystals produced under a given set of operating conditions. This allowed test runs to be terminated as soon as equilibrium was confirmed and so shortened the investigation.

Early Laboratory And Pilot Plant Investigations

The initial laboratory investigation of this process aimed at indicating the most favourable reactor sequences and operating variable ranges which could later be assessed on a pilot plant. Although the main criterion by which trials were compared was crystal size, other factors such as rates of rock dissolution and the nature and magnitude of P_2O_5 losses were also evaluated.

Both the laboratory and pilot plant work were carried out under continuous operating conditions thus ensuring that precipitation rates and concentration levels approached commercial practice. Samples were taken at regular intervals from the reaction system and the approach of equilibrium conditions was indicated by the trend in specific surface area measurement.

Laboratory trials showed at any early stage that it was not possible to grow hemihydrate crystals to a satisfactory size when using a single reaction vessel. Consequently this led to a study of multiple reactor systems in which all other variables were investigated. For a given P_2O_5 product acid concentration the variables which had the most effect on the hemihydrate crystal size were:

a) the relative reactor volumes,
b) the amount and rate of precipitation at different parts of the system,
c) reaction temperatures,
d) mixing.

Apart from the effect of agitation which was investigated only to a limited extent in the laboratory, the most promising operating ranges for the other variables were evaluated and this information was used as a basis for the design of pilot plant equipment.

Up to July 1967, the total experience obtained on pilot plant operation amounted to over 7,000 hours. Generally the pilot plant results confirmed the effects of process variables indicated from the laboratory unit. There was one main difference, however, in that the hemihydrate produced on the pilot plant filtered and washed more rapidly than in the laboratory. Reasons for this were the differences in impurity levels between the two systems and the fact that on the pilot plant the slurry had a much higher solids content. Both these factors influence the crystallization of hemihydrate.

Variables Affecting Crystal Size

Precipitation

Both laboratory and pilot plant results showed that where precipitation of calcium sulphate occurred substantially in one vessel, hemihydrate of a very high specific surface area was produced. By allowing the precipitation to occur stepwise in a multi-reactor system a means was found of substantially reducing the surface area and obtaining satisfactory filtration and washing properties. Figure 1 illustrates this effect by relating the specific surface area to the amount of hemihydrate precipitated in the first vessel of a multi-reactor system.

Reactor Sequence

For most phosphate rocks two stages are normally sufficient and better crystals are obtained when the first stage is larger than the second.

Recycle

To provide the right degree of hemihydrate crystal seeding it is necessary in this process to recycle slurry from a later stage back to the first reaction vessel. This influences the sulphate level in the first reactor and this must be allowed for to ensure that precipitation remains in the optimum region as illustrated in Figure 1.

Reaction Temperature

The specific surface area of the hemihydrate is influenced by a change in reaction temperature. The optimum level depends in the P_2O_5 concentration within the reaction system, but will fall within the range 85 -100°C.

Mixing

At all points where precipitation occurs the degree of mixing can influence the size of hemihydrate crystals produced. On the pilot plant many agitation systems were investigated and these included variation in impeller design and the total number of agitators.

Variables Affecting P_2O_5 Losses

The major P_2O_5 loss in the wet process is that contained in the calcium sulphate crystal lattice. This is termed "lattice" P_2O_5 but other definitions are used which indicate broadly the same thing, i.e. "citrate — soluble P_2O_5" or "co-precipitated P_2O_5". For similar conditions of precipitation hemihydrate will contain much less "lattice" P_2O_5 than gypsum. This is usually attributed to the fact that gypsum and dicalcium phosphate dihydrate are isomorphous.

In the hemihydrate process there are two main process variables which affect "lattice" P_2O_5 losses for a given phosphate rock, these are:—

a) Product acid P_2O_5 concentration

and

b) Ratio of $S0_4/Ca0$ fed to the first reaction stage.

Other variables such as reaction temperature and sulphate ion concentration in the recycle slurry also affect lattice P_2O_5 losses but only to a small extent.

Figures 2 and 3 illustrate the variation of lattice P_2O_5 loss with product acid P_2O_5 and $S0_4/Ca0$ ratio respectively.

The product acid P_2O_5 concentration also influences the rock P_2O_5 losses (Figure 4) and filtration wash losses.

The successful outcome of the laboratory and pilot plant development led to the design and erection of a plant having a nominal design output of 40 tonnes/day P_2O_5. This was completed and commissioned during 1967, and its main objective, apart from determining the operating characteristics of the process, was to determine the effect of a 700 fold increase in reactor volume on crystal size and P_2O_5 extraction efficiency. The plant was intended to be temporary only and was incorporated into the Fisons site at King's Lynn. Sufficient information was obtained on plant operation and results to allow the design of commercially sized plants.

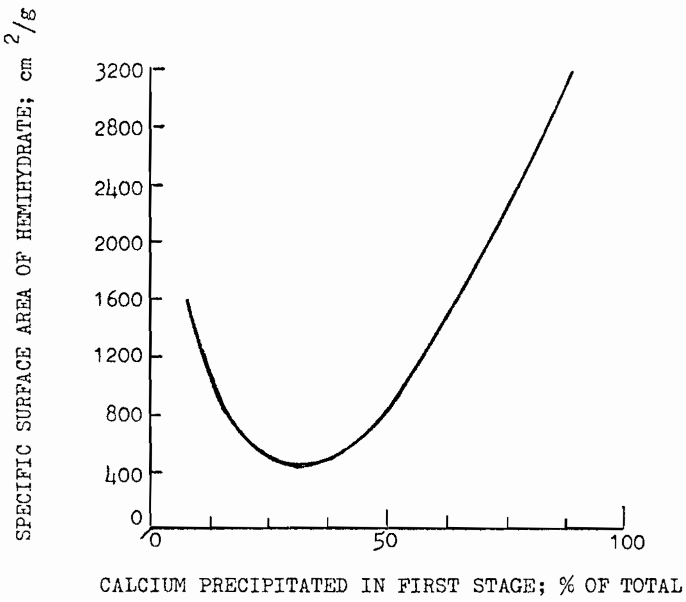


Figure 1 VARIATION OF SPECIFIC SURFACE AREA OF HEMIHYDRATE WITH PRECIPITATION RATIO

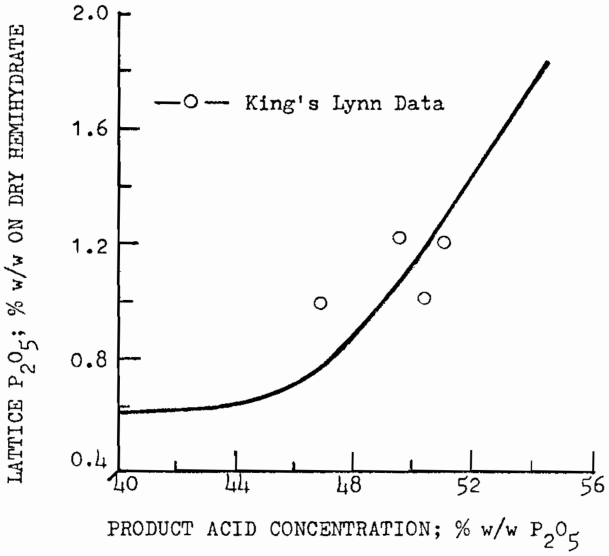


Figure 2 VARIATION OF LATTICE P_2O_5 LOST WITH PRODUCT ACID P_2O_5

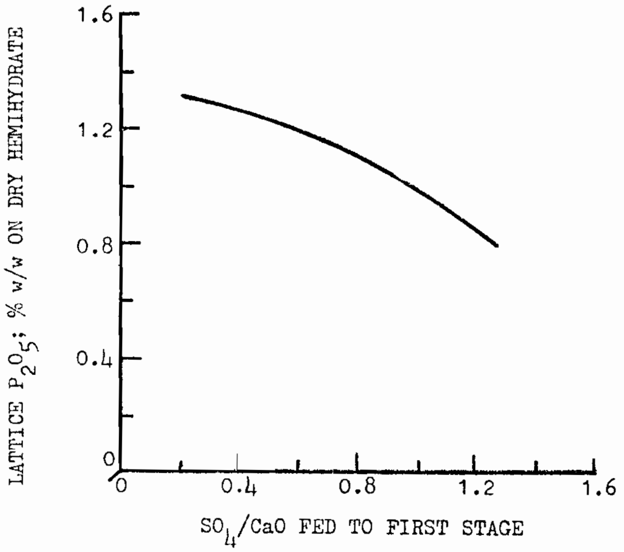


Figure 3 VARIATION OF LATTICE P_2O_5 LOSS WITH SO_4/CaO RATIO

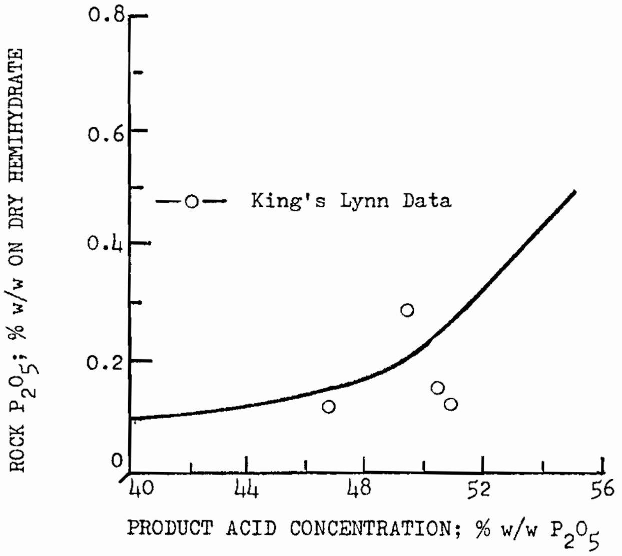


Figure 4 VARIATION OF ROCK P_2O_5 LOSS WITH PRODUCT ACID P_2O_5

Commercial Production of 50% P_2O_5 Acid Using The Fisons HH Process

Following the successful laboratory, pilot plant and production scale operation of the HH process, Fisons with their contractor Lurgi Chemie were awarded a contract for a 60,000 tpa P_2O_5 plant by Windmill Holland NV. The Fisons process was chosen after a thorough technical and economic survey by Windmill of both dihydrate and "new-process" routes available. The plant was built at Windmill's Vlaardingen factory near Rotterdam in Holland and commissioned in the summer of 1970.

The plant was designed to produce 45-50% P_2O_5 acid from Togo rock by a single reaction and filtration system.

Process Description

The overall chemical reaction for the hemihydrate process may be expressed as:

$$Ca_{10}(PO_4)_6F_2.CaC0_3 + 11H_2\,SO_4 + 5\tfrac{1}{2}\,H_20$$

$$6H_3P0_4 + 11CaSO_4.\tfrac{1}{2}H_20 + 2HF + C0_2 + H_20$$

This represents complete release of the P_2O_5 content in the rock feed as H_3PO_4. It is the aim of all commercial processes to get as near to this ideal state as possible. As is well known, some of the P_2O_5 can leave the system as unreacted rock losses, these being generally very small; and as lattice P_2O_5 which has co-precipitated in the calcium sulphate crystal in the form of HPO_4 ions. Additional physical losses also occur during filtration when acid (P_2O_5) is left in the cake as a result of inefficient cake washing. Mechanical losses resulting from poor filter pan drainage, pump leaks, line failures, etc., are other forms of P_2O_5 losses which are often ignored, mainly because they are difficult to measure and more often result from inadequate housekeeping and maintenance, rather than from faults in the basic process design.

The physical resemblance of the hemihydrate process to the reaction and filtration section of the dihydrate process is immediately obvious by reference to the Simplified Flowsheet of Fisons Hemihydrate Process. There are, however, two important differences from the general requirements of most other phosphoric acid processes.

(a) The process requires only a coarse ground rock, 100% passing through 10 mesh (approximately 1.7 mm). Grinding costs are therefore reduced.

(b) The acid strength is already up to 50% P_2O_5 and requires no further treatment. Intermediate storage, concentration and clarification equipment are not needed.

Phosphate rock, 100% passing through 1.7 mm, is fed to reactor No. 1 via the rock weigh belt. This reactor has a reaction volume approximately twice that of reactor No. 2. The slurry from reactor No. 1 overflows to reactor No. 2, to which the sulphuric acid and return acid are added. The temperature in both reactors is controlled within 95-102°C. by circulating the slurry through a flash cooler to remove the excess heat of reaction and dilution.

Fluorine evolved from the flash cooler can be recovered in a fluorine scrubber.

The reaction conditions in both reactors are critical since the success of the process depends on the satisfactory growth of uniform crystals with a high filtration and washing rate. The actual conditions vary slightly from rock to rock, and these are established initially by pilot plant testing and finally by optimisation on the full-scale plant during commissioning. Slurry is pumped from reactor No. 2 to the flash cooler. From the flash cooler the slurry is recycled to the first reactor at a controlled rate to maintain the correct $SO_4/Ca0$ level in reactor No. 1. Any slurry in excess of the recycle requirement is returned to reactor No. 2. This facility to recycle back to reactor No. 2 enables correct control of the reaction conditions during plant shut-down and start-up operations. The recycle slurry flow to reactor No. 1 is controlled to give a sulphate deficiency in the reaction slurry to control the calcium sulphate precipitated in this tank. Precipitation is completed in reactor No. 2 at the higher sulphate level.

The design of both reactors was established after an extensive model testing programme, in which the flow pattern of all inlets and outlets was analyzed and the efficiency of mixing optimized. Reactor No. 1 is a fully baffled tank with four six-bladed agitators, two pumping up and two pumping down to achieve a highly efficient 'turn-over' flow-pattern of the slurry.

The reaction slurry overflows from reactor No. 1 into reactor No. 2 via a chimney and launder. The sulphuric acid is diluted with the return acid and mixed with the slurry in reactor No. 2, which is also fully baffled and has a single six-bladed agitator pumping downwards.

The slurry then overflows to a third tank, the filter feed tank. This vessel allows further time for the slurry to mature before filtration by providing additional retention time during which the reaction is completed and the hemihydrate crystals are allowed to grow as the acid supersaturation is reduced. At start-up slurry is normally fed to the filter when this tank is about one-third full. In this way the filter loading can be 'eased up' to its full rating whilst the tank continues to fill.

The filter is a standard horizontal tilting pan vacuum filter with two counter-current wash stages. Process water at between 50°C. and 60°C. is used for the final cake wash.

The acid from the first wash stage together with some product acid from the first section of the filter is returned to the reaction system. This is the so-called 'return' acid which is used to dilute the sulphuric acid in reactor No. 2. This return acid contains the water necessary to control the P_2O_5 concentration in the system and also contains the recycle product acid to control the slurry solids content. The flow and concentration of this return acid is controlled so that any change in the filtration composition and rate, resulting from fluctuation in filter operation, is corrected, and the return acid delivered back to the reaction system is held constant. Clear product acid from the filter is pumped to the product acid storage tanks.

The hemihydrate can be removed as a 'dry' cake after discharge from the filter, as a hemihydrate slurry, or as a transformed dihydrate slurry. The exact form of disposal will depend on local facilities, legal requirements and marginally on the type of rock used. With Morocco rock for instance the stability of the hemihydrate is such that it can be safely handled as a 'dry' cake for up to 24 hours after filter discharge.

The exhaust gases from the reaction tanks pass via a water sprayed gas scrubbing duct to a counter-current void spray gas scrubber before being discharged to atmosphere. Fumes withdrawn through the ventilation hoods over the filtrate seal tanks and the filter are also washed.

Acid spillages are collected in a floor sump and returned to the reaction system.

A wash tank is installed to allow a routine closed circuit wash for the filter equipment with hot water or chemical washing if needed. No regular washing is required for reaction slurry equipment.

It is worth recording that the scale-up factors involved in the project were approximately as follows:

Levington Pilot Plant : 1
Kings's Lynn Plant : 700 (40 tpd P_2O_5 — Morocco rock)
Windmill Plant : 3700 (210 mtpd P_2O_5 — Togo rock)

Some Aspects of Operation[5]

Scale Deposits

The reaction system has remained completely free from any scale deposits. When inspecting equipment it is normally only necessary to wash-down the rubber or brick lining and to remove any sedimentation from the base of the reactor.

By producing 50% P_2O_5 acid directly from the filter, the product and return acid sections are operating under stable hemihydrate conditions and no dihydrate scale is formed, rubber receivers and filtrate equipment remain clear to the rubber.

If no special precaution are taken, the remaining filtrate strengths are low enough to allow transformation to dihydrate to take place, causing scaling in the equipment. With the use of special chemicals, scale formation is prevented and also in these stages the filtrate equipment remains clear to the rubber.

As with traditional dihydrate processes, the Fisons HH process experiences problems with the formation of fluosilicate scale in the return acid filtration system, when processing rocks which contain sufficient quantities of sodium, silica and fluorine. Morocco and Florida are such rocks.

Fluorine Distribution

The distribution of fluorine predicted from pilot trials and the actual plant data are given in Table 1, as percentages of fluorine in the rock feed. For comparison, data is also given for the distribution in a typical dihydrate plant.

Table 1

Fluorine Distribution from Hemihydrate and Dihydrate Processes

Rock : Togo	Pilot Plant Hemihydrate	Windmill Plant Hemihydrate	Typical Dihydrate
	(%) w/w	(%) w/w	(%) w/w
Acid	12	12	15
Cake	50	50	45
Reactor off-gases)	38	8	5
Flash cooler)		30	-
Concentration unit	-	-	40

Table 1 shows that the available fluorine which can be recovered is about the same for both processes. However, it is not normally considered worthwhile to attempt recovery from the gas scrubber of the dihydrate process but this is certainly worthwhile for the hemihydrate process by combining the recovery circuits of the flash-cooler scrubber with the reactor off-gas scrubber.

The recovered fluosilicic acid from the Windmill hemihydrate process plant is used on-site for the production of fluorine compounds.

Product Acid Quality

The acid is very clean with less than 1.0% suspended solids and lower sulphate and aluminium contents than the dihydrate acid. Typical analyses of hemihydrate acids from Togo and Morocco rocks are given in Table 2. For comparison the analysis is also given for Togo acid from a typical dihydrate process after concentration and clarification.

Table 2

Typical 50% P_2O_5 Acid Analyses

	Togo Rock		Morocco Rock
	Hemihydrate (Ex Windmill)	Dihydrate (Ex Windmill)	Hemihydrate (Ex King's Lynn)
	(%) w/w	(%) w/w	(%) w/w
P_2O_5	50.0	50.0	50.1
CaO	0.5	0.4	0.2
SO_4	2.0	4.0	2.0
SiO_2	0.1	-	0.4
F	0.7	0.8	0.7
Fe_2O_3	1.6	1.5	0.3
Al_2O_3	0.3	0.9	0.1
MgO	0.2	0.3	-
Solids	0.5	0.8	less than 1.0

The product P_2O_5 concentration can be controlled between 45-54% P_2O_5 by adjusting the cake wash water flow. No other changes are necessary other than to adjust the return acid flow and concentration to compensate for the changed water flow.

The product hemihydrate acid is stored without further treatment and has presented no problems in storage or during transport. Using this acid also gives a significant upgrading of intermediate products such as monoammonium phosphate, when used in place of unclarified dihydrate acid.

Plant Maintenance and Availability

It should be borne in mind that the Windmill plant is the first commercial hemihydrate process plant in operation. Maintenance costs, based on materials and direct labour, including some alterations in the plant equipment, were approximately 10% and 7% of the installed equipment costs for the first and second year of operation. For a dihydrate process plant, including the high maintenance concentration units, maintenance costs are also 6-8% of the installed equipment cost. Since the actual capital investment for a hemihydrate process plant is approximately 30% less than an equivalent dihydrate process plant, including rock **grinding, concentration and clarification, the maintenance costs are therefore actually less for the hemihydrate plant.**

Planned downtime comprises an annual shut-down of 14 days and one day every 4 weeks for cleaning and some repairs.

Allowing an additional 10% for unforeseen downtime, the plant is available for production for over 300 days per year.

Fisons Hemihydrate Process — Further Developments

Since the successful start up and operation of the Windmill plant, development work on the pilot plant and large scale have followed various paths.

The success of the subsequent improvements and optimisations can be measured by the fact that the Windmill plant can now operate at almost 50% above its design capacity.

Perhaps more important than these general improvements has been the realization that the features and benefits of the hemihydrate process are becoming more significant in changing conditions of the industry and thus development work has moved to ensure that these benefits can be maximized. For instance the high energy cost today have made the savings in steam of the hemihydrate process even more significant, none more so than in developing countries where the energy is essential for other services. The hemihydrate process is simple, easy to operate and of relatively low capital cost and Fisons developments in process design have accentuated these benefits. These aspects make the process ideal for a user with little or no previous experience of phosphoric acid and fertilizer manufacture. Again many phosphate rock sources are situated in developing countries and the trend there is to produce phosphoric acid, intermediates and fertilizer products for domestic consumption and export. Consequently much of Fisons research has centered on examining as many grades and types of phosphate rock as possible. The information obtained is being used to rationalise the process and make it more suitable for a wider range of rocks. This development is probably even more valuable where the benefits of the hemihydrate process are strongest — that is at a rock mine site where the use of low grade rocks is becoming more common, and where the lower efficiency of the single stage hemihydrate process is more than compensated for by the ease of operation and savings in steam.

To make the suitability of the single stage hemihydrate process even more widespread it was necessary to overcome the disadvantage of the loss of co-precitated P_2O_5 in the discharged hemihydrate filter cake. Therefore after 1970 one of the major areas of investigation was how to release and recover this lattice P_2O_5. After considerable pilot plant work it was achieved by adding a second stage to the process, in which the hemihydrate was converted to dihydrate and the lattice P_2O_5 passes into solution and is thus recoverable. The outcome was the FISONS TWO STAGE or HEMIDIHYDRATE (HDH) PROCESS which can achieve P_2O_5 recovery efficiencies of 99%. The development and establishment of the FISONS HDH process on the large scale is discussed in the following sections.

Development of the Fisons HDH Process

Background

The hemidihydrate (HDH) phosphoric acid process is a further development of the Fisons hemihydrate process which was designed to produce 40-54 per cent P_2O_5 phosphoric acid directly without the need for evoporation. The HDH process not only retains the advantages of the hemihydrate process but enhances certain features of the single stage process.

There were two area in which the hemihydrate process could be improved; these were (a) to increase P_2O_5 efficiency and (b) to improve the quality of the calcium sulphate produced.

P_2O_5 efficiences for the single stage hemihydrate process lie within the range 90-97 per cent for a wide range rocks and the production of acids of 40-54 per cent P_2O_5 concentration. This range compares with 95-97 per cent for conventional dihydrate processes. The possibility of developing a strong acid process with a P_2O_5 efficiency higher than either the single stage hemihydrate or conventional dihydrate process became apparent during Fisons development of the hemihydrate technology in the 1960's and 70's. Results from laboratory experiments coincident with the hemihydrate development indicated that by recrystallization of the hemihydrate to dihydrate P_2O_5 efficiencies in excess of 98 per cent could be obtained. With the recent escalation in phosphate rock prices, high efficiency processes become even more attractive economically.

Hemihydrate and dihydrate produced from certain rocks by many of the conventional processes are unlikely to be directly suitable for use as a building material in the form of plasterboard, gypsum block, or as a retarder for cement. This unsuitability is due partly to the relatively high P_2O_5 and fluoride contents of these calcium sulphates. The dihydrate produced in the hemidihydrate process contains less P_2O_5 than calcium sulphates paroduced from hemihydrate or dihydrate processes (0.1 - 0.3 per cent P_2O_5 compared with 0.5 -2.0 per cent P_2O_5) and generally less fluoride and should be potentially more suitable for use as a building material. It is realized that the higher purity of the dihydrate from the HDH process can be an advantage only in areas where there is an economic outlet for the calcium sulphate by-product. However, it is possible that environmental legislation may change and demand a purer effluent or an alternative method of disposal.

Following an initial laboratory investigation of recrystallization of hemihydrate, a pilot plant was constructed to study the feasability of a hemidihydrate process. The results from this pilot plant confirmed the success of the laboratory investigation and were used in the design of a production plant for RMHK TREPCA in Yugoslavia. This plant was designed to produce 50,000 tpa P_2O_5 as 50 per cent P_2O_5 phosphoric acid from Morocco rock, the contractor was Lurgi Chemie, Frankfurt. Commissioning of this plant took place in 1975.

Laboratory and Pilot Plant Investigations

Because the first stage of the HDH process is basically the same as the single stage HH process then the development work concentrated on the determination of the conditions under which hemihydrate from various phosphate rocks would crystallize to dihydrate containing very small amounts of P_2O_5. Although the laboratory investigations of the second stage of the HDH process were initiated during the pilot plant studies of the single stage process (1964-70), the detailed work began in earnest after 1970 with the commencement of pilot plant work. The programme was designed to confirm and extend laboratory data and determine efficiences and filter area requirements for the process.

Results of Investigations

The conditions under which large filterable hemihydrate crystals could be produced from many rock has been well established and only brief reference will be made to results obtained from the first stage of the two stage process.[6]

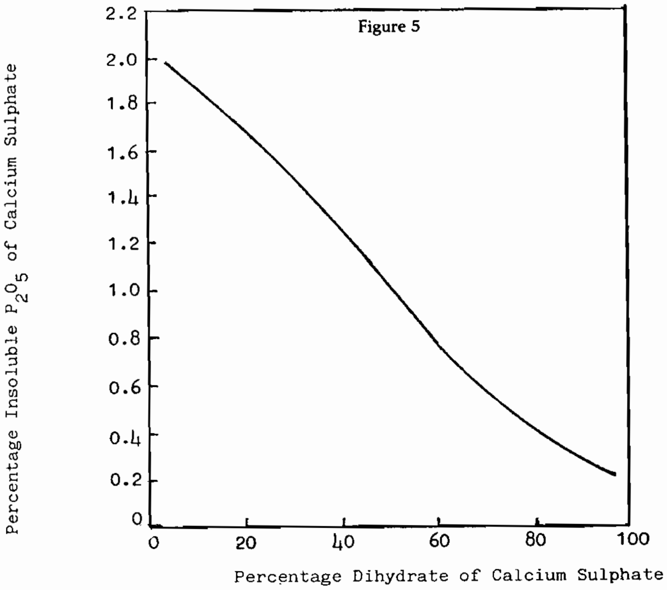
The areas of investigation and results from both the laboratory and pilot plant studies are summarized below.

Recrystallization of Hemihydrate to Dihydrate

The efficiency of a hemidihydrate process depends on the completion and maintenance of the recrystallization of hemihydrate to dihydrate. Partial recrystallization of the hemihydrate to dihydrate results in high insoluble P_2O_5 losses approaching the levels from the single stage process.

The variation of insoluble P_2O_5 loss with conversion of hemihydrate to dihydrate is illustrated in Figure 5. The data were obtained during the processing of Florida rock and show that the insoluble P_2O_5 of the calcium sulphate dihydrate decreases from 2.0 per cent to 0.2 per cent as the dihydrate percentage of the calcium sulphate increases from 0 to 100 per cent.

For a recrystallization process in which 30 per cent conversion of hemihydrate is obtained, the calcium sulphate would contain 1.5 per cent P_2O_5 . This level corresponds to a P_2O_5 efficiency of approximately 93.5 per cent which represents little improvement over the 91 per cent obtained for Florida rock in the hemihydrate process when producing a 50 per cent P_2O_5 acid.



Relationships Between Insoluble P_2O_5 Loss And Conversion Of Florida Hemihydrate

In addition to high insoluble P_2O_5 losses, partial recrystallization may produce problems due to setting of the calcium sulphate during disposal when the recrystallization process would be slowly completed.

Effect of Holding Time

The results from the laboratory investigation indicated the wide differences in rates of recrystallization to dihydrate of hemihydrate from different rocks.

An illustration of the difference in rates is given in Table 2. For each hemihydrate of Table 2, sulphuric acid was added to the recrystallization reactor to maintain equal concentrations of P_2O_5 and SO_4 in the recrystallization acid. The presence of sulphuric acid can in some cases accelerate the recrystallization process and at the same time produce dihydrate which contains low amounts of insoluble P_2O_5.

TABLE 2

Recrystallisation of Hemihydrate - Laboratory Results

Hemihydrate	Holding Time (hr)	Conversion to Dihydrate
Morocco	4	100%
Togoland	10	Partial
Kola	10	Partial

The relative ease with which hemihydrate from rocks such as Morocco rock recrystallizes to dihydrate is evident from Table 2. In fact, it was found that Morocco hemihydrate would recrystallize within a four hour holding time without the addition of sulphuric acid, i.e. by the addition of water alone. For hemihydrates from both Togo and Kola rocks, reactor residence time in excess of ten hours are required to complete and maintain the recrystallization process. The use of such large single reactors for a production plant would be costly and in most cases impractical. Methods of acceleration of the recrystallization process were investigated (see Effect of Additives).

The laboratory results with respect to Morocco and Togo hemihydrates were confirmed during the pilot plant investigation.

Effect of Temperature

The recrystallization reactor of the pilot plant was operated at slurry temperatures from 25 to 70°C., and over this range satisfactory recrystallization of the Morocco hemihydrate was obtained. The rate of recrystallization of relatively unreactive hemihydrates from rocks such as Togo and Kola was not increased by this variation in temperature.

Effect of Additives

The recrystallization of hemihydrate from rocks such as Morocco rock is virtually completed and sustained by the addition of sulphuric acid alone to the second reactor.

During the pilot plant processing of Togo and Florida rocks, satisfactory recrystallization of the hemihydrate could not be obtained under the conditions used for Morocco hemihydrate. The continuous addition of specially prepared gypsum seeds failed to accelerate the recrystallization. It was concluded that chemical inhibition of the recrystallization process was occurring and by a suitable choice and continuous addition of a second chemical to the second stage reactor to counter this inhibition, satisfactory recrystallization of the hemihydrate was obtained. It was found, however, that hemihydrate from Kola rock would not recrystallize satisfactorily even under these conditions and to date a satisfactory accelerator for the recrystallization of Kola hemihydrate has not been found.

Insoluble P_2O_5 Losses

The major insoluble P_2O_5 loss in the hemihydrate process is that which is co-precipitated with the calcium sulphate. This is often termed "lattice" P_2O_5 but doubt exists as to whether the P_2O_5 actually forms an integral part of the crystal lattice of hemihydrate. The doubt originates from the fact that the dicalcium phosphate isomorph of calcium sulphate hemihydrate has not been identified.

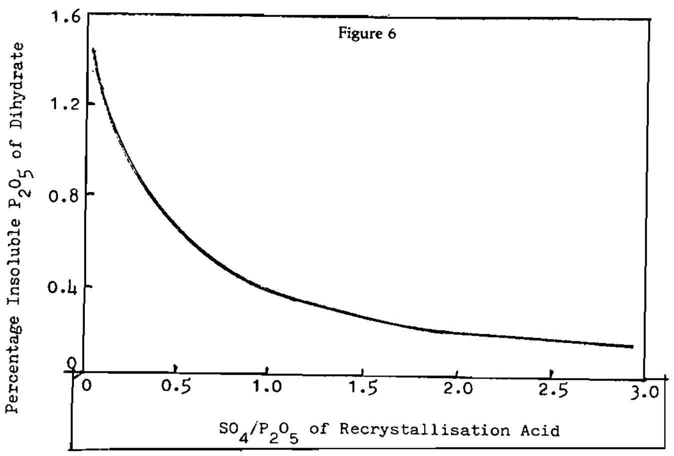
The amounts of "lattice" P_2O_5 contained by hemihydrate range from 0.6 - 2.0 per cent and depend on the nature of the phosphate rock processed and the product acid concentration.

The minor insoluble P_2O_5 loss is that contained by the unreacted rock filtered with the hemihydrate which normally contains less than 0.2 per cent as unreacted P_2O_5.

During the recrystallization process, the insoluble P_2O_5 losses are drastically reduced, due mainly to the decrease in lattice P_2O_5 loss. The effect of variable on the amount of insoluble P_2O_5 contained by the dihydrate are discussed below.

Effect of SO_4 and P_2O_5 Concentrations of Recrystallization Acid

Figure 6 illustrates the variation of insoluble P_2O_5 of dihydrate with the P_2O_5/SO_4 weight ratio of the recrystallization acid. The data was obtained during the laboratory recrystallization of Morocco hemihydrate and refers to conditions when near to 100 per cent conversion of hemihydrate was obtained.



Variation Of Insoluble P_2O_5 Loss With SO_4/P_2O_5 Weight Ration Of Recrystallization Acid

Based on this data, a $SO_4/P_2O_5 = 1.0$ was chosen as an operating condition for the pilot plant recrystallization reactor. Although lower insoluble losses could be obtained by operation at values of SO_4/P_2O_5 1.0, the benefit would be small and sulphuric acid losses in the dihydrate filter cake would increase.

The levels of insoluble P_2O_5 of the Morocco dihydrate produced in the pilot plant by operation at $SO_4/P_2O_5 = 1.0$ were lower than the 0.3 per cent indicated by the laboratory results. Small increases in insoluble P_2O_5 were indicated with increases in the P_2O_5 concentration of the recrystallization acid:—

TABLE 3

Variation of Insoluble P_2O_5 with P_2O_5 Concentration of Recrystallisation Acid – Pilot Plant Data

Recrystallisation Acid		Dihydrate
P_2O_5%	SO_4%	Insoluble P_2O_5
3.3	3.3	0.13
4.2	4.2	0.14
7.8	7.8	0.17

Effect of Temperature

The insoluble P_2O_5 of the dihydrate was not significantly changed by operation at temperatures between 25 and 70°C.

Effect of Phosphate Rock Source

The dihydrate produced from the phosphate rocks processed contained from 0.1 - 0.22 per cent insoluble P_2O_5. This range is small to the 1 - 2 per cent insoluble P_2O_5 contained by hemihydrates produced with a range of rocks during production of 50 per cent P_2O_5 acid in the single stage hemihydrate process.

Effect of Product Acid Concentration

The level of insoluble P_2O_5 of dihydrate from the second stage is unaffected by the P_2O_5 concentration of the product acid over the range of 43-55 per cent P_2O_5.

Dihydrate Crystals and Filtration

The shape of the crystals of the dihydrate from the second stage of the process was similar to the shape of the crystals of hemihydrate from the first stage, i.e. approximately spherical. Although the shapes of the two crystals are similar, the dihydrate crystals are smaller in size than the hemihydrate crystals. This can be illustrated by reference to typical values of specific surface area obtained during the pilot plant investigation:—

	Specific Surface Area (cm^2/g)
Hemihydrate	800-1000
Dihydrate	1300-1500

Although the dihydrate crystals were smaller in size, the filtration rate of the dihydrate slurry was much higher than the filtration rate of the hemihydrate slurry produced in the first stage. For example, results from the filtration tests indicated that the filter area required for the filtration of the dihydrate from Morocco rock would be approximately 25-35 per cent of the area required for the first stage filter. The higher filtration rate of the dihydrate slurry can be explained by the lower viscosity of the recrystallization acid compared to that of the product acid.

The dihydrate crystals exhibited excellent washing characteristics.

Hemihydrate Crystals and Filtration

The return of diluted recrystallization acid from the second stage through the hemihydrate filter to the hemihydrate reactors can reduce the growth rate of hemihydrate crystals. This reduction is attributed to an effect of impurities such as aluminium, fluoride and silicon present in the dilute recrystallization acid. For example, when 50 per cent P_2O_5 acid was produced from Morocco rock by the two stage route, the crystals of hemihydrate were smaller than crystals produced in the hemihydrate process (HH) under similar conditions. This difference can again be illustrated by reference to the results of specific surface area:—

Process	**Hemihydrate Specific Surface Area (CM^2/g)**
HH	500-700
HDH	840-940

This comparative decrease in crystal size of the hemihydrate from the HDH process was reflected in the results from the laboratory filtration test. These results indicated that the filter area required for the Morocco hemihydrate from the HDH process would be 25-30 per cent higher than the filter area required for the hemihydrate from the single stage process.

If a product acid of less than 50 per cent P_2O_5 is required, this increase in filter area could be minimized by dilution of the acid from the hemihydrate stage with dihydrate return acid. For an effective product concentration of 43 per cent P_2O_5, the relative increase in filter area could be limited to 10 per cent.

For some rocks other than Morocco, the relative increase in the hemihydrate filter area was much lower than the 25-30 per cent.

Product Acid

In general, phosphoric acid produced by the hemidihydrate process is expected to retain the advantages in quality of hemihydrate acid compared with acid of the same P_2O_5 concentration produced by the dihydrate process. These advantages are:

a) lower solids concentration
b) lower sulphate concentration and
c) lower aluminium concentration

Acids produced by the HDW process are expected to contain slightly larger amounts of aluminium than the corresponding acids from the single stage hemihydrate process. This is due to the return to the first stage of additional aluminium contained by the dihydrate return acid from the second stage filter. For example, acids produced from Togo rock (Al_2O_3 = 1.1 per cent) had the following analyses:—

Process	**Acid Composition**	
	P_2O_5%	**AL_2O_3%**
HH	50	0.3 - 0.4
HDH	50	0.5 - 0.7
DH	50	0.9

For all components other than aluminium, analyses of acids from HH and HDH processes are expected to be similar.

By-product Dihydrate

The direct use of by-product calcium sulphate as a raw material for the manufacture of building materials is restricted by the amounts and nature of certain impurities, e.g. phosphate and fluoride, contained by the calcium sulphate. If the amounts of phosphate and fluoride exceed certain levels, the setting and other properties of the building materials are adversely affected to an unacceptable extent.

Table 4 shows a typical analysis of dihydrate produced from Morocco rock in the two stage process. For comparison, analyses of calcium sulphates produced by the single stage hemihydrate (HH) and dihydrate (DH) processes are included.

TABLE 4

<u>Analyses of Calcium Sulphate Hydrates</u>

Process	Acid P_2O_5 %	Hydrate	Percent w/w			
			P_2O_5	F	$CaSO_4½H_2O$	$CaSO_42H_2O$
HDH	50	Dihydrate	0.2–0.3	0.4–0.6	NIL	97–98
HH	50	Hemihydrate	1.3–1.5	0.8–1.2	91–93	NIL
DH	30	Dihydrate	0.6–0.8	0.8–1.0	NIL	94–95

The analyses in table 4 indicate the high purity of the calcium sulphate dihydrate from the HDH process. In particular, the relatively low phosphate and fluoride makes the dihydrate from the HDH process the most potentially suitable for further use.

Commercial Operation of the Fisons HDH Plant

The results of the pilot plant and large scale development work were used to design the first hemidihydrate plant for RMHK TREPCA in Yugoslavia. The plant capacity was 50,000 tpa P_2O_5 as 50% P_2O_5 acid from Morocco rock. Comissioning took place in 1975.

A brief examination of the commercial operation of the plant will give a view of how the development work was translated into practice.

Process Description

The Fisons Two Stage Hemidihydrate or HDH Process as constructed for TREPCA is for the production of 50-52% P_2O_5 phosphoric acid at high efficiency — generally 98.5%. The process consists of a hemihydrate reaction system, hemihydrate filtration, a recrystallization stage and dihydrate filtration. The process is illustrated in the flow sheet.

As the first stage is essentially the same as the single stage HH process no further details will be given here. The second stage of the process is as follows:—

The hemihydrate, discharged from the 1st stage filter, passes via a chute into an agitated recrystallization tank. In this tank the residence time, solids content and chemical composition are controlled to ensure complete recrystallization of the hemihydrate to dihidrate. Co-precipitated lattice P_2O_5 is released from the hemihydrate during the process. Sulphuric acid is added to the recrystallization tank to fix the calcium ions so released, and to maintain optimum conditions for maximum P_2O_5 recovery and for the growth of good dihydrate crystals.

The dihydrate slurry is pumped to a continuous belt filter where it is washed with incoming fresh water. The filtrate, the so-called "Dihydrate return acid" which contains the recovered lattice P_2O_5 is recycled to the hemihydrate filter as the final cake wash and pan wash.

The dihydrate cake is discharged dry from the filter and re-slurried in an agitated tank and pumped to disposal. Alternatively, a dry discharge could be used.

Some Aspects of Operation[7]

Maintenance

Major causes of shut-down maintenance on a phosphoric acid plant are corrosion and erosion. At TREPCA, only two pump impellers on the slurry recycle pumps were changed in the first nine months operation and all other slurry and acid pump impellers will exceed their expected life. The material used for most of the pump casings and impellers is Ferralium (25/5/2/3. Cr, Ni, Mo, Cu) which has proved satisfactory in service.

Rubber lining failures have occurred on minor items of equipment and these would be judged normal by comparison with dihydrate plant experience.

Glass fibre reinforced polyester pipes have been used extensively on the plant for acid lines, and these have given good service.

Reactor slurry lines are constructed from mild steel with a double rubber lining. These have given no problems apart from two areas where high grade stainless steel has now been successfully used as a substitute.

The filter cloth life on the hemihydrate filter is about two months, and one to two months on the dihydrate filter. Mechanical damage of the dihydrate cloths is the sole reason for cloth change and proposed modifications to the cloth guiding systems are expected to give a longer life. Polypropylene cloths have given longer life than polyester cloths.

Scaling

Reaction System

There has been a complete absence of sodium fluorosilicate scaling in the hemihydrate reaction system. This may be compared with the build-up of thick layers of scale in dihydrate reactors. Slight scaling has occurred in the recrystallization reactor in the form of a 5 mm layer of glass-like sodium fluorosilicate.

Hemihydrate Filter System

Scaling has only occurred in the hemihydrate filter system and analyses have shown that this is predominantly sodium fluorosilicate scale,. not transformed hemihydrate. These deposits have mainly occurred in the first filter wash, or return acid section. Scale of the same type has also been formed, but at a much lower rate in the product and cloudy acid sections of the filter. Both scales have been easily removed manually, being a soft amorphous type material unlike the normal hard, layered and glassy fluorosilicate scale which is produced in a dihydrate process.

Dihydrate Filtration System

In the dihydrate filter system where high scaling rates were anticipated, no scale has been formed.

The use of a chemical recrystallization inhibitor to prevent scaling in the hemihydrate filter circuit has not affected conversion in the recrystallization tank.

Comparison of Predicted And Actual Performance

	Pilot Plant Results	Predicted Performance	Actual Performance
			Typical Ranges*
Production Rate mtpd P_2O_5		160	100-170
P_2O_5 Acid Efficiency (DH cake analyses) %	99.0	98.5	97.0-99.0
Product Acid Analysis			
P_2O_5 % w/w	50.0	50.0	47.5-52.0
SO_4 % w/w	2.0	2.0	1.6-2.4
Solids % w/w	0.8	1.0 max	0.9
Dihydrate Cake Analysis			
Total P_2O_5 % dry basis	0.21	0.32	0.20-0.65
w/s P_2O_5 % dry basis	0.10	0.15	0.05-0.20
Insoluble P_2O_5 % dry basis	0.11	0.17	0.15-0.45
F % dry basis	0.4-0.6	0.4-0.6	-
H_2O % dry basis	25.0	25.0	20.0-25.0

* November, December 1976, 70/72 and 75/77 BPL Morocco Rock

The close agreement shown here between the results predicted by the pilot plant tests and the full scale HDH plant results reaffirms the excellent correlation also obtained during the commissioning of the single stage process and reported to the ISMA Conference in Seville 1973. Fisons has complete confidence in its ability to predict the operating parameters of other phosphate rocks for a full scale plant. Further scale up from 50,000 tpa size plant is only limited by availability of proven items of equipment. The critical factor would undoubtedly be the hemihydrate filter which is likely to restrict maximum single train size to 150,000 - 180,000 tpa capacity at this time.

Fisons HDH Process — Further Developments?

The advantages of the HDH process are now clear, it is a well proven process route offering a very high P_2O_5 recovery efficiency and useable by-products as gypsum and fluosilicic acid which obviously reduce the effluent discharge from the plant. So where do the future developments lie?

The first priority is to overcome the limitation on single stream capacity of 180,000 tpa P_2O_5 caused by the hemihydrate filtration. Current work is concentrated on improving crystal habit in the hemihydrate reaction system and thus providing better filterability.

It is quite clear from the cost assessments of the different process routes given in Appendix III that the HDH process produces phosphoric acid at a lower cost than the traditional dihydrate route. Nevertheless Fisons are continuing with development work in an attempt to make the process even more attractive. Consequently another aspect of research is the study of the effects of reduced reaction volumes and varying configurations. In addition different types of agitation systems are being investigated.

Conclusion

The development of the single stage hemihydrate process and the two stage hemidihydrate process by Fisons culminated in full scale plant operation in 1970 and 1975 respectively. There is of course no substitute for large scale plant experience and without it no development work can be claimed to be totally successful. The production plants at Windmill, Holland and Trepca, Yugoslavia, confirmed the results of the laboratory and pilot plant investigations. In addition they provide the opportunity to develop the processes further and ensure that they remain compatible with the needs of today's industry.

At the moment the processes offer the benefits of high P_2O_5 efficiency, low energy consumption, and usable by-product gypsum and fluosilicic acid which when combined with ease of operation and product acid quality are sufficient to meet the requirements of phosphoric acid manufacturers throughout the world.

The reputation of the HH and HDH processes has been enhanced by new orders, from Hellenic Mining Co., Cyprus for a 130 tpd P_2O_5 HH plant, from Albright and Wilson, England for a 500 tpd P_2O_5 HDH plant, and from the Phosphate Co-operative of Australia for a 100 tpd P_2O_5 HDH plant (letter of intent received at time of writing).

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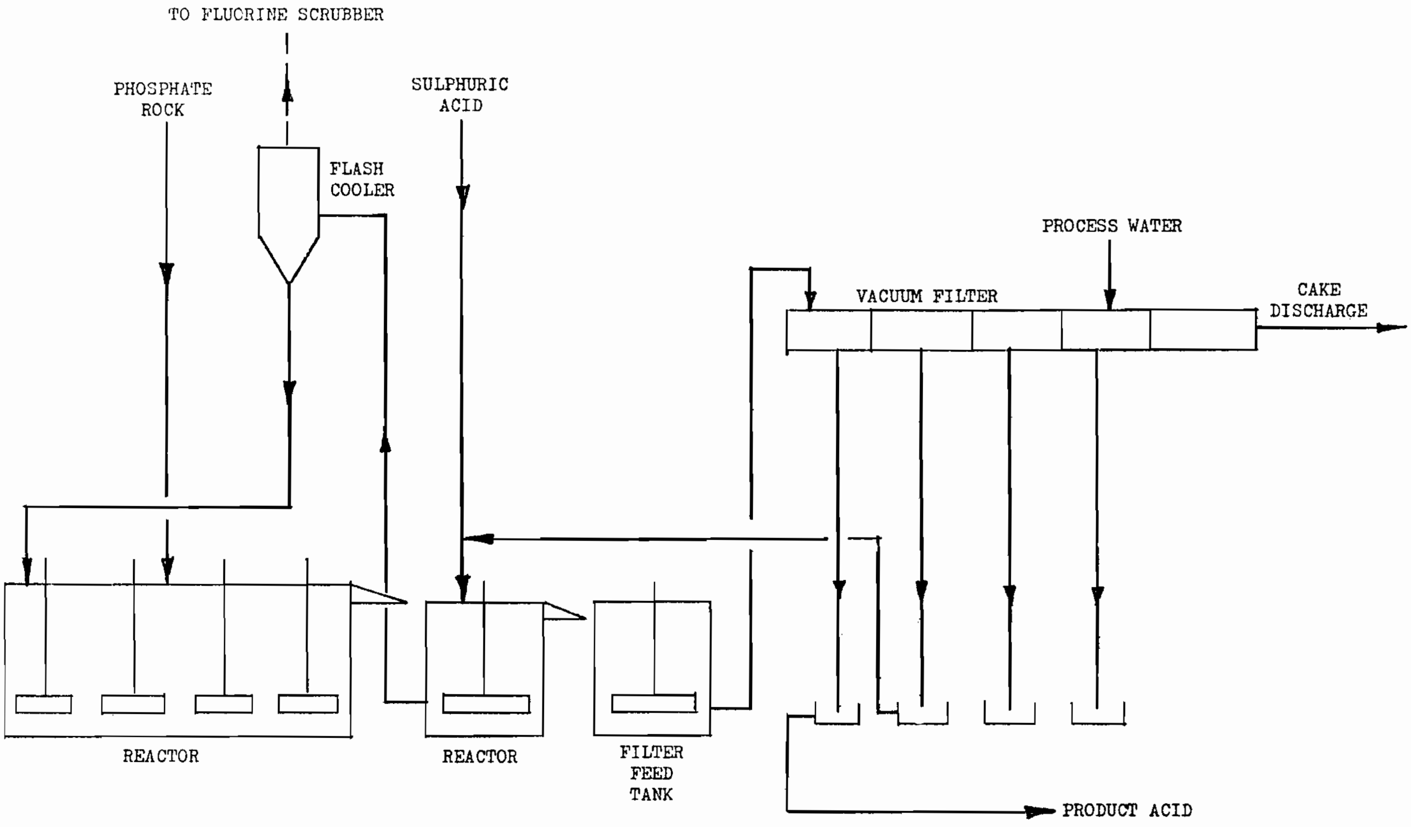
   American Institute of Chemical Engineers, Philadelphia 1978.

Note: Appendices on pages 82 through 84

APPENDICES

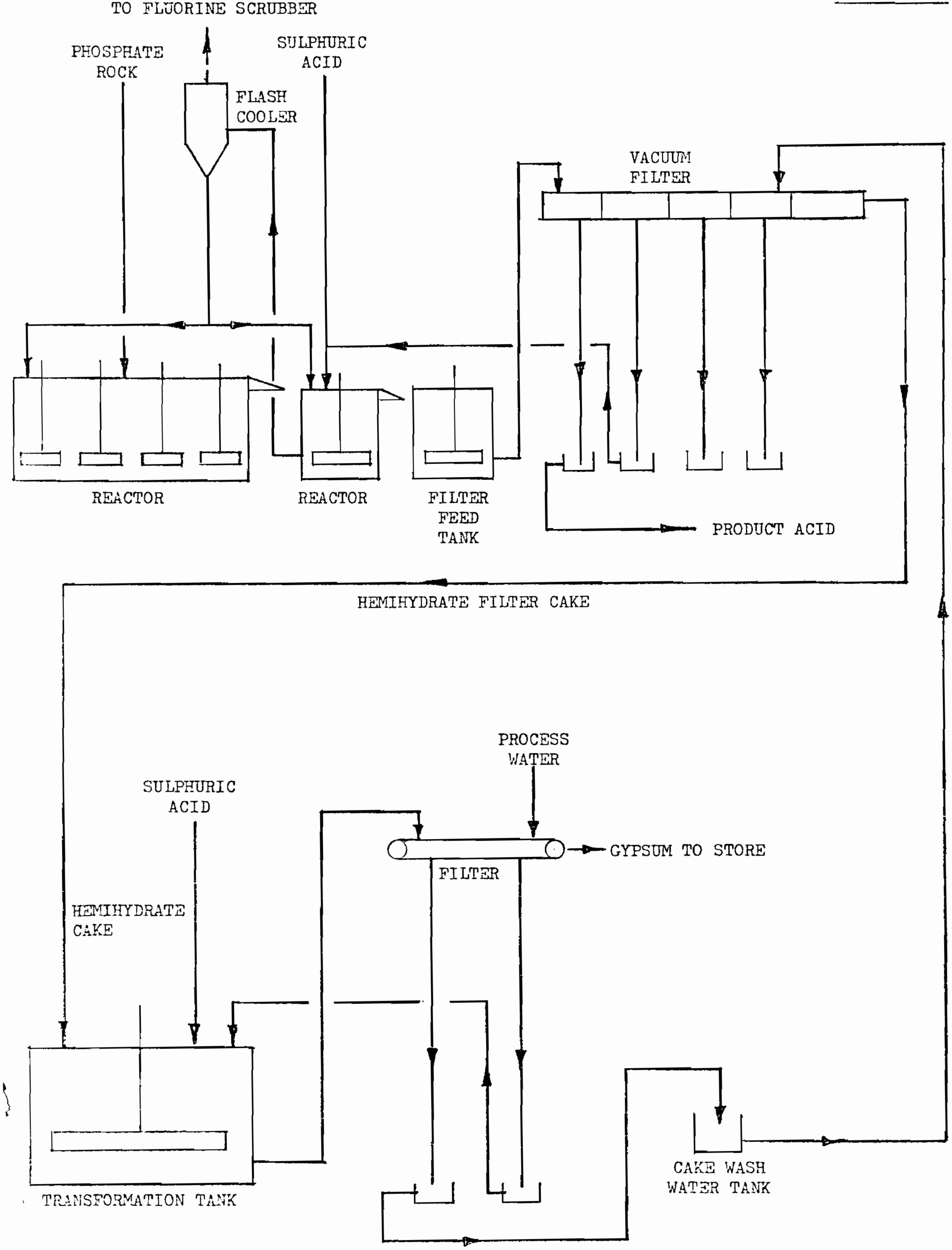
Appendix I Fisons Hemihydrate Process — Simplified Flowsheet



FISONS HEMIHYDRATE PROCESS

Appendix II Fisons Hemidihydrate Process — Simplified Flowsheet

APPENDIX II



FISONS HEMIDIHYDRATE PROCESS

Appendix III Comparative Production Costs by the Fisons Processes

COMPARATIVE PRODUCTION COSTS BY THE FISONS PROCESSES

Basis: 160,000 tpa P_2O_5 produced as 50% P_2O_5 acid from a commercial rock of 30% P_2O_5

Plant location: Western Europe 1978 Budget costs

ITEM	UNITS	COST £/unit	DIHYDRATE PROCESS		HEMIHYDRATE PROCESS		HEMIDIHYDRATE PROCESS	
			Capital cost £7.05m Expected efficiency = 96.5%		Capital cost £6.0m Expected efficiency = 93.5%		Capital cost £6.62m Expected efficiency = 98.5%	
			Unit/t. P_2O_5	Cost/t. P_2O_5	Unit/t. P_2O_5	Cost/t. P_2O_5	Unit/t. P_2O_5	Cost/t. P_2O_5
Phosphate rock	tonnes	18.0	3.45	62.1	3.57	64.26	3.38	60.84
Sulphuric acid	tonnes	10.2	2.80	28.56	2.89	29.49	2.74	27.95
Cooling water	m^3	0.004	37.5	0.15	22.0	0.09	23.5	0.09
Process water	m^3	0.04	7.0	0.28	6.0	0.24	7.0	0.28
Steam	tonnes	5.94	2.0	11.88	0.2	1.19	0.2	1.19
Electricity	kWh	0.04	115	4.6	125	5.0	135	5.4
Chemicals	£	-	-	-	-	1.2	-	1.2
Labour (1)	man hours	5.11	0.6	3.07	0.45	2.30	0.6	3.07
Maintenance (2)				2.20		1.88		2.06
Depreciation (3)				2.84		2.63		2.90
ROI (4)				6.61		5.63		6.21
Interest (5)				5.29		4.5		4.97
Rates (6)				1.32		1.13		1.24
				128.90		119.54		117.40

Appendix IV Fisons Phosphoric Acid Experience — A Brief Survey

Fisons Experience

Fisons is a major manufacturer of phosphoric acid in the United Kingdom consuming more than three-quarter of a million tonnes of phosphate rock annually. Over the years phosphate rocks from many sources have been processed but those originating from Morocco and Florida, USA have pre-dominated. Fisons Fertilizer Division operates three phosphoric acid plants, producing about one-quarter of a million tonnes of P_2O_5 per annum by the Dihydrate route. One of these plants is to Fisons own design.

Since 1958 a considerable amount of work has been carried out in the field of phosphoric acid technology at the Company's Fertilizer Research Centre at Levington. Originally this work was aimed at improving the performance of the Division's production plants and significant progress has been achieved in this direction. Eventually this work led to the development of new phosphoric acid processes, first, based on the Dihydrate route and later by a new generation of Hemihydrate and Hemidihydrate (HDH) routes. These processes have been licensed to various companies through Fisons Licensing and Consultancy Services in collaboration with Foster-Wheeler, Lurgi Chemie and Davy Powergas (UK). Currently, 8 Dihydrate plants, 2 Hemihydrate plants and 2 HDH plants are in operation or at different stages of construction. Details of these plants and the phosphate rocks which are processed are given in Table 1. Table 2 and Table 2 continued.

Note: Tables 1 and 2
on pages 85, 86 and 87

Table 1: Phosphoric Acid Processes Licenced by Fisons Licensing and Consultancy Services

Company	Country	Capacity tpa P_2O_5	Type of Process	Rock	Constructor	Start Up
BCL	UK	75,000	DH	Morocco	Lurgi	1968
AE and CI	South Africa	27,000	DH	Phalaborwa	Davy Power Gas	1970
Windmill	Holland	60,000	HH	Togo	Lurgi	1970
Quimbrasil	Brazil	65,000	DH	Jacupiranga	Davy Power Gas	1973
Trepca	Yugoslavia	50,000	HDH	Morocco	Lurgi	1974
Omnia	South Africa	25,000	DH	Phalaborwa	Lurgi	1975
Zletovo	Yugoslavia	50,000	DH	Morocco	Lurgi	1978/1979
Sabac	Yugoslavia	75,000	DH	Gafsa	Lurgi	1978/1979
HMC	Cyprus	40,000	HH	Syrian	Lurgi	1980
Albright and Wilson	UK	160,000	HDH	Morocco	Lurgi	1980
Kutina	Yugoslavia	160,000	DH	Youssoufia	Davy Power Gas	1981
Abu Zabaal	Egypt	66,000	DH	Egypt	Lurgi	1981
*Pivot	Australia	32,000	HDH	Florida	Lurgi	1981

In parallel with the development of new phosphoric acid processes, laboratory and pilot plant test procedures have been developed to allow phosphate rocks to be assessed for phosphoric acid manufacture. Since 1967 many rocks have been evaluated at Levington Research Station using the Dihydrate and Hemihydrate process routes. These assessments have been carried out for F sons own use, for other phosphoric acid producers and for phosphate rock mining companies. A list giving the rocks assessed and the process route used is given in Table 2.

(* Letter of intent at time of writing)

Table 2: Phosphate Rocks Assessed by Fisons for the Manufacture of Phosphoric Acid and Phosphates

Phosphate Rock		Country	Company	Process	Year
Type	Grade				
Khouribga	All	Morocco	Fisons	DH, HH	
Youssoufia	72% BPL	Morocco	Fisons	DH	1976
Calcined N Carolina	73% BPL	USA	N Carolina Phosphate Corp	DH	1967
Calcined N Carolina	73% BPL	USA	Fisons	DH	1976
Calcined N Carolina	73% BPL	USA	Texas Gulf	DH	1974
Calcined N Carolina	73% BPL	USA	Agrico	HH	1974
Uncalcined N Carolina	73% BPL	USA	Fisons	DH	1978
Syrian	72% BPL	Syria	State/DPG	DH	1969
Syrian	72% BPL	Syria	Hellemic Mining	HH	1977
Sahara	75% BPL	Sahara	Fosbucraa	DH	1970
Sahara	80% BPL	Sahara	Fisons	HH	1974
Jacupiranga	77% BPL	Brazil	Quimbrasil	DH	1970
Lady Annie	74% BPL	Australia	Broken Hill	DH	1970
Phalaborwa	77% BPL	S Africa	Fisons	DH, HH	1975
Langebaan	67% BPL	S Africa	Amcor	HH; DH	1972
Florida	Many	USA	Fisons Occidental Windmill Gardinier	DH HH HH DH	 1972 1972 1977
Araxa	75% BPL	Brazil	Arafertil	DH	1974
LKAB	80% BPL	Sweden	LKAB	DH	1974
Nauru/Christmas Island Nauru	82% BPL	Nauru	Pivot	DH, HH	1975 1978
Tapira	85% BPL	Brazil	Titansa	DH	1975
Abu Zaabal	63% BPL	Egypt	Lurgi/DPG	DH	1977

...... continued

Table 2 continued ......

Phosphate Rock		Country	Company	Process	Year
Type	Grade				
Taiba	80% BPL	Senegal	APC Fisons	DH HH	1977
Kola	82% BPL	USSR	Fisons	DH, HH	1969 1971
Jordan	67% BPL 72% BPL	Jordan	Fisons	DH	1976 1978
Gafsa	63% BPL	Tunisia	Fisons	DH	1970
Togo	80% BPL	Togoland	Windmill, Fisons	HH, DH	1970

DH = Dihydrate Process Route

HH = Hemihydrate/Hemidihydrate Process Routes

The above assessments normally include the manufacture of Superphosphates and Ammonium Phosphates using the phosphoric acid and rock under test.

The determination of corrosion rates of a range of steels normally used to fabricate phosphoric acid plant equipment is also carried out and the assessment includes the measurements of physical properties to aid design.

MODERATOR LEYSHON: Thank you Eric, I think we have time for a few questions, and then we will take a five minute stretch. (Applause)

BUD DAVIS, TVA: I wonder if Fisons has done any work on the Hemihydrate process with Central Florida rock of 62 to 68 BPL concentration, and if so, how the filterations of P_2O_5 recovery compare with those for local and Morocco rock?

ERIC SCHWEHR: Can I look up my list? 62, you say?

BUD DAVIS: 62 to 68, BPL

MODERATOR LYSHON: The printed proceedings will have a list of the rocks which Fisons has tested.

ERIC SCHWEHR: We have certainly tested 67-68% BPL Florida, and lower grades are under investigation at the moment for our own internal use in the company. We've tested a 63% BPL from another source, so we have been down to these levels. We have also tested rocks from another source, other than Florida, of mixed tailings and beneficiated rock. You do suffer a loss of efficiency, but you can control it so that the filtration area required is reasonable.

BOB SOMMERVILLE, Landskrona: I have been cautioned that you can run into problems with inpurities accumulating in your recrystallization circuit causing trouble. Can you comment on that?

ERIC SCHWEHR: [Answer] In the transformation stage?

BOB SOMMERVILLE: Yes

ERIC SCHWEHR: I don't think we have yet experienced it, and it doesn't look as though this will happen on a mass balance.

BOB SOMMERVILLE: Thank you.

MODERATOR LEYSHON: Any other questions? Yes, Frank Achorn.

FRANK ACHORN, TVA: What is your investment cost a ton of P_2O_5 produced?

ERIC SCHWEHR: This, of course would depend on the size of the Plant very considerably.

FRANK ACHORN: On about a 500 ton per day P_2O_5.

ERIC SCHWEHR: The table shows the investment and operating costs for a battery limits plant for Western Europe in 1978 for all three processes. The hemihydrate capitol costs six million pounds.

ERIC SCHWEHR: Yes, and the hemi-dihydrate 6.62 million pounds.

MODERATOR LEYSHON: Does anybody know the current rate for this "Pound"? [Laughter]

FROM THE AUDIENCE: $2.00

ERIC SCHWEHR: Oh, No Sir, that was a week ago. [Much laughter]

MODERATOR LEYSHON: thank you Eric Schwehr and Mr. Crozier, for your most interesting paper and discussion. (Applause). Let's take a 5 minute recess to stretch and then come right back for our "Belt Feeder Discussion" (Applause)

MODERATOR LEYSHON: The next paper is entitled "Belt Filtration in Phosphoric Acid Plants". It is being presented by Brian McNally and Doug Robertson of Western Cooperative Fertilizers of Medicine Hat, Alberta, Canada. Brian McNally is Superintendent of Plant Engineering and Maintenance there. Doug Robertson is Chemical Process Engineer and has been with Western Coop for 5 years. Mr. McNally will start the paper. (Applause)

BRIAN McNALLY: Well, after those last three papers, this is going to be a real change of pace, so you can drop your brains into low gear.

Horizontal Belt Filters In Wet Process Phosphoric Acid Plants

Prepared and Presented
by
R. J. B. McNally — D. R. Robertson

INDEX

INTRODUCTION

Let's begin this presentation on the horizontal belt filter by the oversimplification of comparing it to a wide, flat-belt conveyor onto which is fed a liquid — solids slurry at one end rather than dry solid material. By means described in the following pages, the liquid is separated from the solids while travelling along the conveyor (filter) and the solid material is discharged off the other end. While the authors have only had first-hand experience with one make of horizontal belt filter, the Landskrona, most of the basic design features will be found on other makes. Our 45 square meter filter has been in service since April, 1976, so we think we have encountered most of the maintenance and operational problems that are likely to develop. We have also maintained a very good exchange of information with other users of this make and size of filter, in Canada and the U.S.A.

Basic design features include the following (refer to Sketches M1 and M2):

1. A continuous filter cloth belt of specifications appropriate to the service conditions.
2. Filter cloth belt supported on a ribbed top flat rubber belt with flexible standup sides.
3. Both belts carried together on the load side of the filter on large diameter rotating drums with support rails or beds in between, and on the return side by idler rollers, similar to a sliding belt conveyor.
4. Filter cloth and rubber belt are separated on the return side by carrying them on separate sets of return idlers, allowing through-washing of the filter cloth on a continuous basis and, likewise, washing both top and bottom of the rubber belt.
5. The underside of the rubber belt acts as a continuous seal against the flanged top of a full length vacuum box with vacuum applied in a similar manner to that used for tilting pan filters or drum filters.
6. Phosphoric acid — gypsum slurry is fed onto one end of the filter with separation occurring on the filter cloth and acid drawn down between the ribs of the top surface of the rubber belt through openings in the centre of the belt into the vacuum box to which the belt seals. The solid cake discharges off the other end of the belt into a disposal chute.
7. The active surface of the filter is divided into several stages of filtration by means of flexible, adjustable dams above the filter cloth and adjustable partitions in the vacuum box, with recycle acid feed points positioned as required.
8. The discharge end drum acts as a driving drum turned by a variable speed drive, in our case two hydraulic motors supplied by a single pressure unit.
9. Tracking and tensioning of the filter cloth belt and the rubber carrier belt are carried out separately by methods similar to those used on belt conveyors.
10. Friction resisting the travel of the rubber belt over the vacuum box is dissipated by use of lubricated slidestrips fixed to the vacuum box flanges, with water commonly used as a lubricant. Friction between the rubber belt and the support rails or beds is dissipated by using water or air cushioning as a lubricant and/or supporting medium.

A. *OPERATION OF THE FILTER*

The main operational advantages of a horizontal belt filter are:

1. Its operation is straightforward and easy to control.
2. The cloth is continually backwashed on the run, reducing production losses and eliminating the downtime required for washing the cloth to prevent blinding.
3. The throughput capacity per unit of filtration area is generally higher than for other types of filters with the same efficiency, as filtration cycle times as low as 40 seconds and as high as 80 seconds can be used.
4. The gypsum breaks cleanly at the discharge end without water cleaning jets. This dry gypsum can then be transported, using a conveyor, reducing the water normally used to transport the gypsum to the pond.

The support equipment and piping for this filter are arranged in much the same manner as for any other type of vacuum filter. See Sketch 0-1.

As you can see, the operation is straighforward and the systems used to handle the fluctuating conditions further simplify its operation.

The fourth filtrate tank overflows into the third filtrate tank which, in turn, overflows into the second filtrate tank.

The first and second filtrate tanks are on level control.

To solve the problems of fluctuating filtration while still maintaining a flooded condition on the belt, a simple vacuum overflow system was devised. Please refer to the attached Sketch, 0-2. This system is fabricated from 6" poly pipe, as shown, with a small line continually drawing a vacuum. When the liquid level is below the pipe nothing happens, but when it seals off the open end, the unit becomes a syphon and maintains the level.

The operator has two basic controls for any given feed rate: (1) the filter speed, and (2), the vacuum.

1. The filter speed is set to maintain a ½" to ¾" thick cake on the belt, but can be thicker if the gypsum filter-ability is high.
2. The vacuum is adjusted to maintain good filtration at a hydraulic drive pressure of 1700 psi or less. If the filtration is still poor at a vacuum of 12-15 inches, the belt speed is increased until good filtration occurs. Operating speed range is normally 60-130 fpm. Obviously the faster the cloth speed, the thinner the cake and the faster the wash can penetrate.

Cloth

The cloth problems have been interesting as several thicknesses and weaves of cloths have been tried.

The original problem was creasing of the cloth in the center, drawing the outer edges in. This would break the seal and allow slurry to bypass the cloth between the cloth and the belt at the sides. The thin cloth creased immediately, allowed more solids (5%) to pass through, and the gypsum cake did not break cleanly at the discharge end. A thick flexweave cloth creased after a few days, but reduced the solids to 3% and the cake broke cleanly at the discharge end.

The cloth we are now using is a thick flexweave cloth and had a fiber filler woven into it. This cloth is Albany Style 386 with a controlled permeability of 300. The solids are usually 2-2½% and the cake breaks cleanly. The creasing problem has been eliminated by means discussed further on. The cloth life is three to four months compared with less than one month when creasing was a problem. Failure of the splice between the ends of the cloth is now the limiting factor. With an improved splice, a cloth life of six months or more should be possible for this cloth.

The fiber filler in the cloth concerned the operations people as a similar cloth had been tried on a pan filter, blinding off in a few hours. The key is the continuous reverse washing of the filter cloth on the belt filter which effectively prevents blinding.

Pumps

To reduce the wear on pumps, valves and piping handling high solids slurries, pump speed is regulated to adjust capacity to the flow and head requirements. This is accomplished by using remote controlled hydraulic drives on the filter feed pumps and first and second filtrate pumps.

We also use a dual, independent, tank and pump setup for the filter feed system, first and second filtrate systems. This allows us to wash and do maintenance on the fluid handling systems without shutting the filter down. Unlike pan filters, the horizontal belt filter does not require a daily wash period. In our case the vacuum box is lowered at intervals of one to two weeks to check for scaling and we have run as long as one month before doing so.

An interesting benefit resulting from the use of hydraulics is the use of only one pressure unit to provide the power fluid to both hydraulic drives in each dual pumping system. The pressure units are grouped together in a separate "clean" room and pump from a common reservoir with dual banks of filters on the return header.

Fume Control

A large plastic tent, at a cost of $400, was installed over the filter and is peaked up to an exhaust fan. The change in humidity in the building was quite noticeable. The nice feature of this tent is that it can easily be removed for major maintenance and easily replaced if it becomes damaged.

Water Quality To Slide Rails

The most critical flow to the filter is the clean water flow to the teflon slide strips on the vacuum box. Any solid impurities will accelerate the wearing on these strips. Therefore, if re-use water is to be used, an elaborate filter system is required.

This water is diluting the phosphoric acid as it is being sucked into the vacuum box. However, a new vacuum box is being designed to reduce this dilution.

B. *DESIGN, INSTALLATION AND MAINTENANCE*

A major advantage of the horizontal belt filter, other than those mentioned above, is the low space requirement and simplicity of buildings design. For our 45 square meter filter, we added a 30 ft. wide by 125 ft. long by 50 ft. high leanto extension to our existing building. A 25 ft. wide by 115 ft. long extension would have been sufficient except for the addition of a number of features which were improvements for the existing plant or provisions for a possible second filter. The long narrow shape of the building results in a very simple support structure for the filter because of the short span lengths of the support steel, eliminating the need for any interior support columns.

The basic components of our particular horizontal belt filter have been briefly described in the "Introductory" section of this paper and will be described and discussed in more detail below.

First, some general comments on the erection and installation of the filters:

1. For ease of installation and maintenance, an overhead travelling crane rail, designed into the building structure, is essential.
2. Our experience has proven the importance of precision alignment of the filter frame, the cloth and belt return idlers, the belt support drums and rolls and of the vacuum box. The frame must be mounted and anchored on a rigid concrete base support, in our case the two foot high reinforced concrete curbs of the filter drainage basin, and then shimmed and grouted true level transversely and lengthwise.
3. At the time we first put our filter into service there was considerable concern among the users of large horizontal belt filters over cloth creasing problems, and many different positionings of vacuum box and belt support rolls and drums were being tried out. We are now convinced that the correct relationship is to have the top of the support rails and the vacuum box level across the filter and throughout their length as well as at the same height as the tops of the two belt drums. We were not successful in eliminating cloth creasing until we did this, although there were other contributing factors which will be discussed later.

Now some comments on specific components of the horizontal belt filter.

Cloth Support Belt

This is a very large and very expensive item of industrial rubber goods and must be treated with care. Life expectancy of the belt supplied for Landskrona filters has been five years, barring severe accidental damage. To keep the economics of operating this filter favorable, it is essential that belt life be extended as much as possible, and repair costs minimized.

The belt initially supplied for our filter and for others like it on this continent is a heavy belt, 1½" thick and 6'-6" wide by approximately 189 ft. long, with polyester cord and covered with a natural rubber compound. The cover has excellent resistance to wear but less than desirable resistance to hot acid slurry. The stepped block curbs initially supplied, as indicated on Sketch M-2, are of a very resilient natural rubber but one which is subject to fairly rapid aging.

The most persistent maintenance problem has been cracking of the curbs under the extreme tension to which they are subjected when the belt passes around the feed and discharge end drums. Although a straight vertical split in the curb closes up effectively when the belt returns to the flat horizontal run, these splits must be repaired by volcanizing with a specially made vulcanizing unit or by cementing before the curb begins to separate from the main belt at the split. This is a frequent and time-consuming occurrence and the biggest reason for downtime. Repeated vulcanizing for curb repairs also hastens deterioration of the belt edges.

At least three other curb designs are being tried, with indications of significant improvement. We are designating the other designs of which we are aware as follows:

1. Corrugated Curb — actually standard corrugated curb used on flat conveyor belts for bulk material handling.
2. Fold-Down Curb — see Sketch M-3.
3. Wedge Curb — see Sketch M-4.

We have been operating our filter for over three months with a ten foot length of corrugated curb inserted in one side and cold-cemented in place. The only problem experienced so far is some leakage by the dam at the feed point which can be largely overcome by adding trailing ends to the rubber dam.

The fold-down curb is supplied by another manufacturer of belt filters but also appears in the catalogs of some conveyor belt suppliers as a cleat for steep-slope conveying of bulk materials. It has an outward-leaning narrow cross-section which allows the curb to flatten down as the belt passes over the drums, thus avoiding the severe tensile stress that starts the cracking at the top edge of the standup types of curbs. We know of two filters which have been running for 4 to 5 months with this type of curb with little or no trouble. We are now replacing the curbs on our belt with this type also.

The wedge curb, now available from the suppliers of our belt, has also a much reduced cross-section and is made from a very resilient rubber formation which has improved resistance to aging and chemical attack. We are not aware of any operating experience for this curb.

The important operational advantage of the fold-down and wedge curbs is that the width of the filter cloth can be increased so that it actually rides up on the sloping inner surface of the curb, providing more positive sealing against leakage of solids into the filtrate. There is also less tendency for the edge of the cloth to fold over on itself if it happens to track to one side.

The most significant long term maintenance problem with belts of the design used on our filter is the rate of deterioration of the top cover due to high temperature and chemical attack, which results in progressive failure of the belt to the point of requiring replacement. Plans for a new generation of belts are now in process using a more resistant rubber for the top cover and retaining the original highly wear-resistant cover on the bottom. One user has already received one of these new belts but has not yet put it into service.

Another proposed improvement is the narrowing of the drainage ports through the centre of the belt, the design of which is discussed further on with respect to cloth creasing and vacuum box slide strips.

We believe that if further improvements were made to the belt support system, and perhaps to the lubrication system, a lighter weight and less costly belt could be used without sacrificing quality or life expectancy.

One of the worst accident hazards to the rubber belt is fire, started by welding in the area, vulcanizing equipment or any other source of ignition. Personnel working in phosphoric acid plants have a tendency to underrate the possibility of fire because of the large volumes of water used and the fire-retardancy of phosphates, but we know of at least two belt fires, one started by welding and one by vulcanizing equipment. If only the belt cover is damaged, on-site repairs are possible but costly. The belts for our particular size and make of filter are made in Sweden by Trelleborg AB who have the large specialized vulcanizing equipment and the technicians to make field repairs. Depending somewhat on the distance from Sweden, the cost of replacing a 40 foot square area of the belt cover will be approximately $18,000 to $20,000; for an 80 foot square area, $25,000 to $30,000, U.S. funds. The cost of attaching new rubber by the chemical cure method would be approximately 50% of these figures, but the repair may not be as reliable.

Belt Lubrication

Referring again to Sketch M-2, the areas requiring lubrication are the top surfaces of the belt support rails and the sealing surfaces of the vacuum box. We do this with water, using a system designed to the principle of establishing a water cushion or pad under the belt rather than maintaining a water film between the sliding surfaces. Air instead of water is used in a similar manner by at least one manufacturer of horizontal belt filters, and may be preferable in areas where the supply of clean water is at a premium.

With this type of lubrication system, and the proper relationship between water supply pressure and water area against the belt, frictional drag and wear are minimized. Another advantage is that the power requirement, in our case measured by hydraulic pressure to the drive motors, holds to a fairly narrow range over a wide range of filter loading, again helping to make the filter very flexible in operation. To achieve this the water supply system is generously sized with separate multiple supplies to each support rail and each vacuum box slide strip. This insures that increased leakage from wear or distortion at any one point doesn't rob the water from the rest of the system. Pressure gauges and manual adjustment valves are installed on the water supply to each rail and slidestrip to allow good balancing of the system.

Belt Tensioning

After considerable experimentation with tension loads of up to ten tons on each side of the belt, we have established that the tension should be maintained at a level just high enough to prevent slippage on the drive drum. With a good lubrication system the tension required on our type and size of filter will range from four to six tons on each side, depending on the surface condition of the drive drum. We use a jack and a hydraulic load cell with gauge to set this tension.

Belt Tracking

Depending on how truly cylindrical the belt has been made by the manufacturer, it will have a tendency to wander from side to side as it travels the length of the filter. We found that correcting alignment with adjustment of the end drums was not sufficient and it was also necessary to adjust at each of the belt return idlers. This may have been partly due to these idlers being covered with a baked-on PVC coating which doesn't allow the belt to shift readily. the importance of good tracking and alignment is better understood when reviewing its relationship to cloth creasing and vacuum box slide strips, discussed further on in this paper.

Belt Wearstrips

Our belt was originally provided with cemented-on rubber wear strips designed to protect the belt at the areas of contact with the vacuum box. These wearstrips proved to be a significant maintenance problem and have been found to be unnecessary if good lubrication is maintained. One user operated a belt for several years without these wearstrips, to the point of failure of the top cover, without significant wear of the bottom cover.

Vacuum Box

The vacuum box is of seamless construction formed from 3/16" thick type 316 stainless steel (see Sketch M-5). As provided with the filter, it had a top opening 4¼" wide. This proved to be unnecessarily wide and a contributing factor to cloth creasing as well as a major cause of slidestrip failure. It allowed the belt to trough slightly at the centre from the vacuum being pulled on it and this resulted in accelerated wear on the inside edges of the slidestrips.

To counteract this problem we reduced the width of the opening to 2" with the addition of a stainless steel angle on each flange. This allowed the use of wider slidestrips extending to the edge of the new opening, almost eliminating the more rapid rate of wear on the inner edges of the slidestrips.

One user may have accidentally discovered the optimum width of vacuum box opening for this particular type and size of filter. When modifying the vacuum box on an older filter, difficulty was encountered in maintaining the reduced opening at a uniform width and this varied from 2-1/4" wide down to 1-7/8" wide over the length of the box. After a period of operation, inspection of the vacuum box revealed that wear of the inner edges of the slidestrips varied from significant wear on the 2-1/4" wide opening to minor wear on the 2" width, to zero wear on the 1-7/8" width.

With this information, it appears that the drainage ports in the centre of the belt, which are also approximately 1-7/8" wide, need to be narrower. Any significant wandering of the belt from side to side can allow gympsum in the filtrate to contact the top face of the slidestrips resulting in clogging of the water grooves and accelerated wear of the strips. This also adds emphasis to the need for close tracking of the rubber belt.

Of course there may be other approaches to the solving of this problem, such as use of a more resistant slidestrip material, reducing the need for such a narrow vacuum box opening. The improved lubrication recently applied may allow a wider choice of slidestrip materials other than the teflon now most commonly used without increasing the risk of wear of the bottom cover of the belt, and without increasing the frictional drag. Another approach we are considering is to improve the supporting of the centre of the belt and reduce the load on the vacuum box slidestrips by locating support rails as close to the vacuum box as possible. Redesigning of the vacuum box to match the reduced top opening would allow the support rails to be set even closer to the centre of the belt.

An important feature of our vacuum box is the steam heating and insulation of the first filtrate section. This has virtually eliminated scaling of the vacuum box in this area and improved the operating time.

One other problem which can arise is distortion of the vacuum box due to uneven supporting, especially when raising or lowering the box for inspection. It would be an advantage to have the box constructed more rigidly against twisting.

Filter Cloth

The cloth has already been described in the discussion of filter operation so we will concentrate here on the problems of cloth creasing, splice failure and tracking of the cloth.

Cloth Creasing

This is a problem with many facets and it is difficult to separate and evaluate them. As we see it, the factors contributing to cloth creasing and the treatment required to counteract them are as follows:

1. Distortion of the support belt due to excessive frictional drag. This results in the centre of the belt tending to lag behind the outside edges due to the heavier loading at the centre, in turn causing the cloth to "work" and shift as it moves along the filter.

   Good belt lubrication reduces this.

2. Troughing of the belt over the vacuum box, the severity of which depends on the level of vacuum drawn, the cloth is drawn down at the centre with the belt and tends to pull away from the sides of the belt. When the vacuum is released by the belt travelling past the end of the vacuum box the cloth is not able to move back and flatten out due to the weight of the cake and the friction between the cloth and the belt, so it remains slightly humped at the centre. The effect is compounded each revolution until the cloth develops a permanent crease.

   Reducing the width of opening in the vacuum box to support the belt closer to the centre reduces the degree of troughing. Assuming the cloth has become slightly humped at the centre, it is important to give it every change to flatten out during its travel back to the feed end. This is best achieved by supporting the cloth on the minimum number of return rollers with the minimum angle of wrap, and using stainless steel rollers which are quite slippery when wet. The use of warm water for washing may also reduce the tendency for permanent set of the cloth after humping.

   It also appears to us that the use of a heavier cloth with a box type of weave resists humping and improves the tendency to flatten out when released from the belt.

Another approach to the cloth creasing problem is the use of two separate cloth belts overlapping at the centre of the filter. This improves two separate sets of return idlers, tracking rollers and tensioning devices. One user installed such a system and used it successfully with the lighter, flat-weave cloths but abandoned it in favor of the heavier cloth and a less complex system.

Spice Failure

During our 2½ years of operation of this filter, we have tried a number of different splices with varying degrees of success, and make no pretense of having found the ultimate splice. Splices we have tried, and the results, are as follows:

1. Sewn lap splice with single row of stitching using a variety of threads for sewing.

Working of the splice passing over the drums and rollers, coupled with abrasion from the gypsum, resulted in early thread failure.

2. Sewn lap splice with more overlap and a row of stitching each side of the lap.

   Results same as for the single splice.

3. Pin splice with loops woven into ends of cloth and using a small diameter plastic or stainless steel rod or pin through the loops.

   Breakage of the pins and wearing out of the loops have been the problems with this splice. The higher permeability at the splice allows more solids to pass through, wearing the splice loops faster than the rest of the cloth. The cloth supplier is trying to devise a pin splice with more loops and/or some method of reinforcing the ends of the cloth.

4. Lap seam similar to 2, with two stainless steel clipper splices, one at each end of the lap.

   Problems were breakage of the pins and the clipper splices wearing through at the lap.

5. Single stainless steel clipper splice with trailing flap of cloth to cover the splice and reduce passage of solids.

   This is the most promising splice tried so far but we still have problems with pin failure. We are working on the use of larger diameter pins and better pin materials.

Cloth Tracking

Continuous tracking of the cloth is achieved by using a Sandy Hill tracking roller installed as close as possible to the point where the cloth re-enters the rubber belt (see Sketch M-1). We use a rubber covered stainless steel roll so that the roll isn't damaged by corrosion when the rubber wears off. A Hypalon covering may reduce the maintenance cost (see comments under Belt Drums).

A reliable system for operating the roll is a pneumatic valve positioner or position controller mounted outside the splash area of the filter and activated by a paddle follower in contact with the edge of the cloth, connected by a wire cable to the valve positioner. The positioner controls the air flow to the positioning cylinders at one end of the Sandy Hill roller. It is also important to have the cloth return rollers properly aligned so that the Sandy Hill roller is only required to make minor corrections.

Cloth Tensioning

Cloth tensioning is handled by a simple weighted roller on pivot arms, with the roller riding on top of the cloth (see Sketch M-1).

Belt Drums

The belt drums on our filter are approximately 4'6" O.D. x 7' long and rubber-covered. After some problems with shaft breakage due to the excessive belt tensions we used initially, and corrosion problems with the carbon steel shell under the rubber covering, we have modified these drums. We now use a stainless steel shell under the rubber covering and have modified the shaft design to make the shaft removable, using Ringfedder locking assemblies to fix the shaft in the drum.

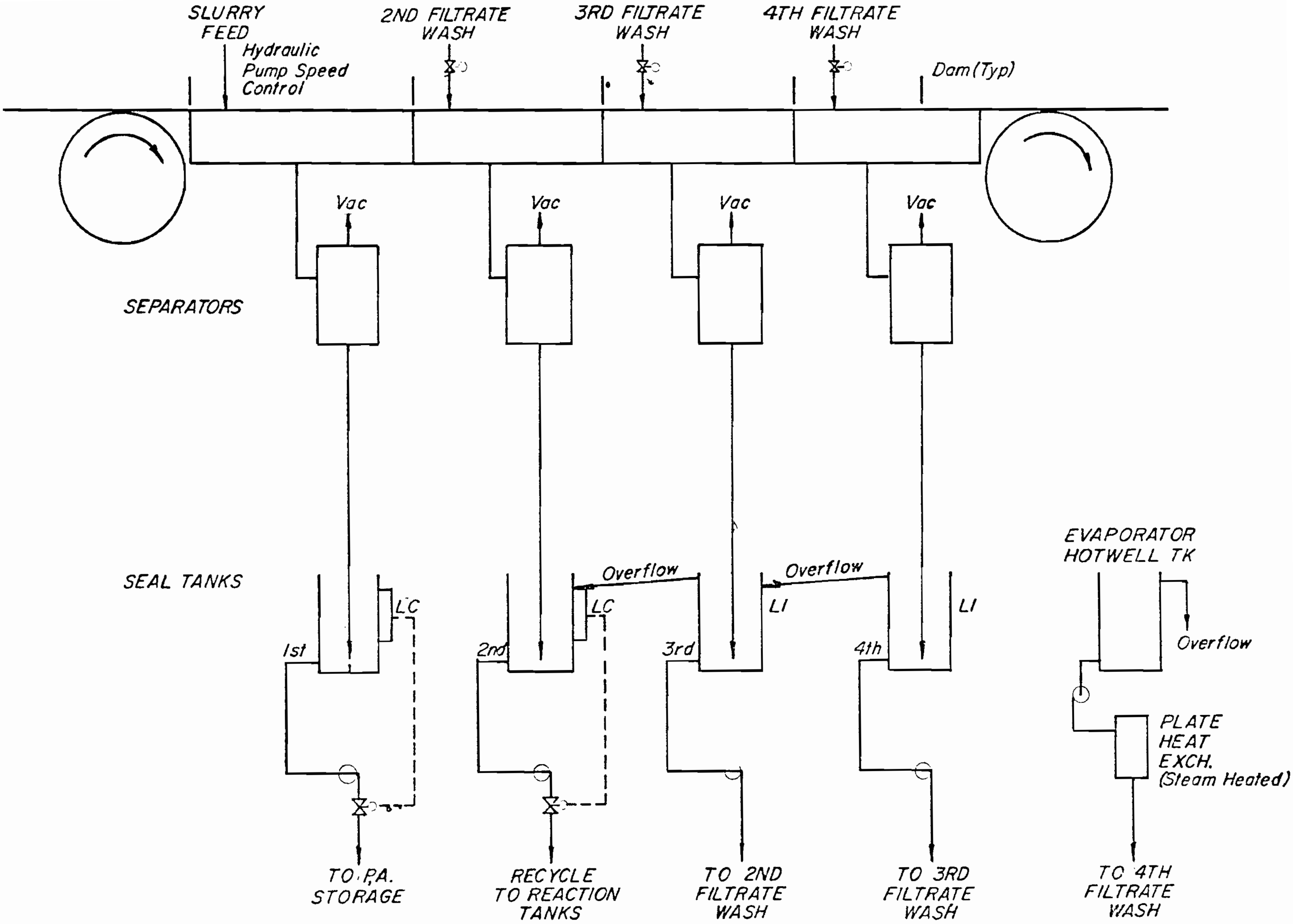
The rubber covering of the drums is a maintenance problem due to the fairly rapid wear. One user has recovered two drums with Hypalon material and, after over one year of service, finds it to be superior to rubber.

Conclusion

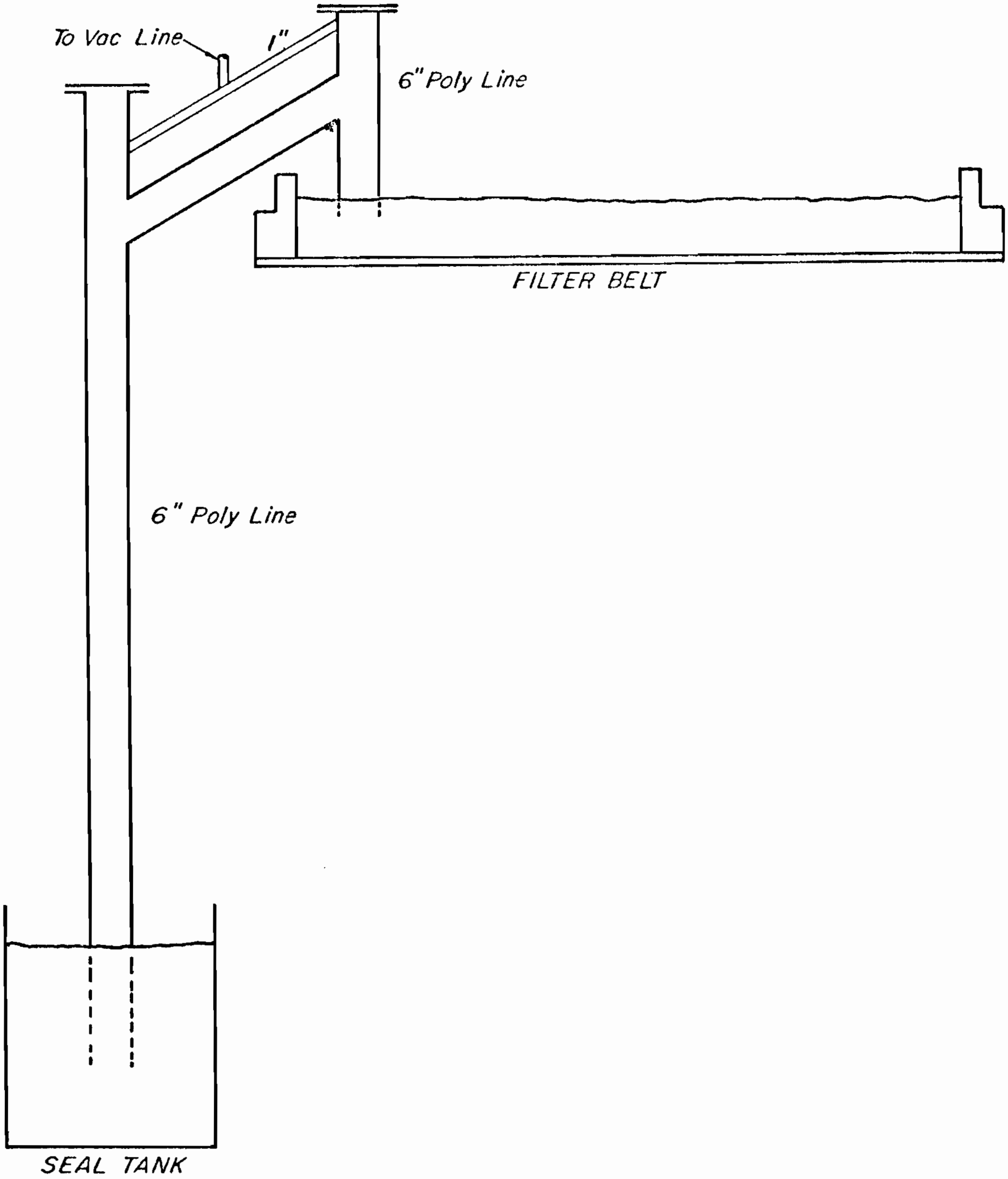
The foregoing review of experience with large horizontal belt filters may well cause one to wonder if the advantages of this type of filter are not outweighed by the problems encountered to date. However, we are convinced that practical solutions to the most significant problems have been developed and, in most cases, proven in operation. Recognition of these problem and their solutions in the design of future filters should result in horizontal belt filters competitive in every way with the long-established tilting pan filters in phosphoric acid service.

In addition, the basic simplicity of this type of filter makes further improvements relatively easy to carry out and test. We are confident that this will result in rapid improvements in the areas of reliability and maintenance, and that future users will not regret a decision to go with the horizontal belt filter.

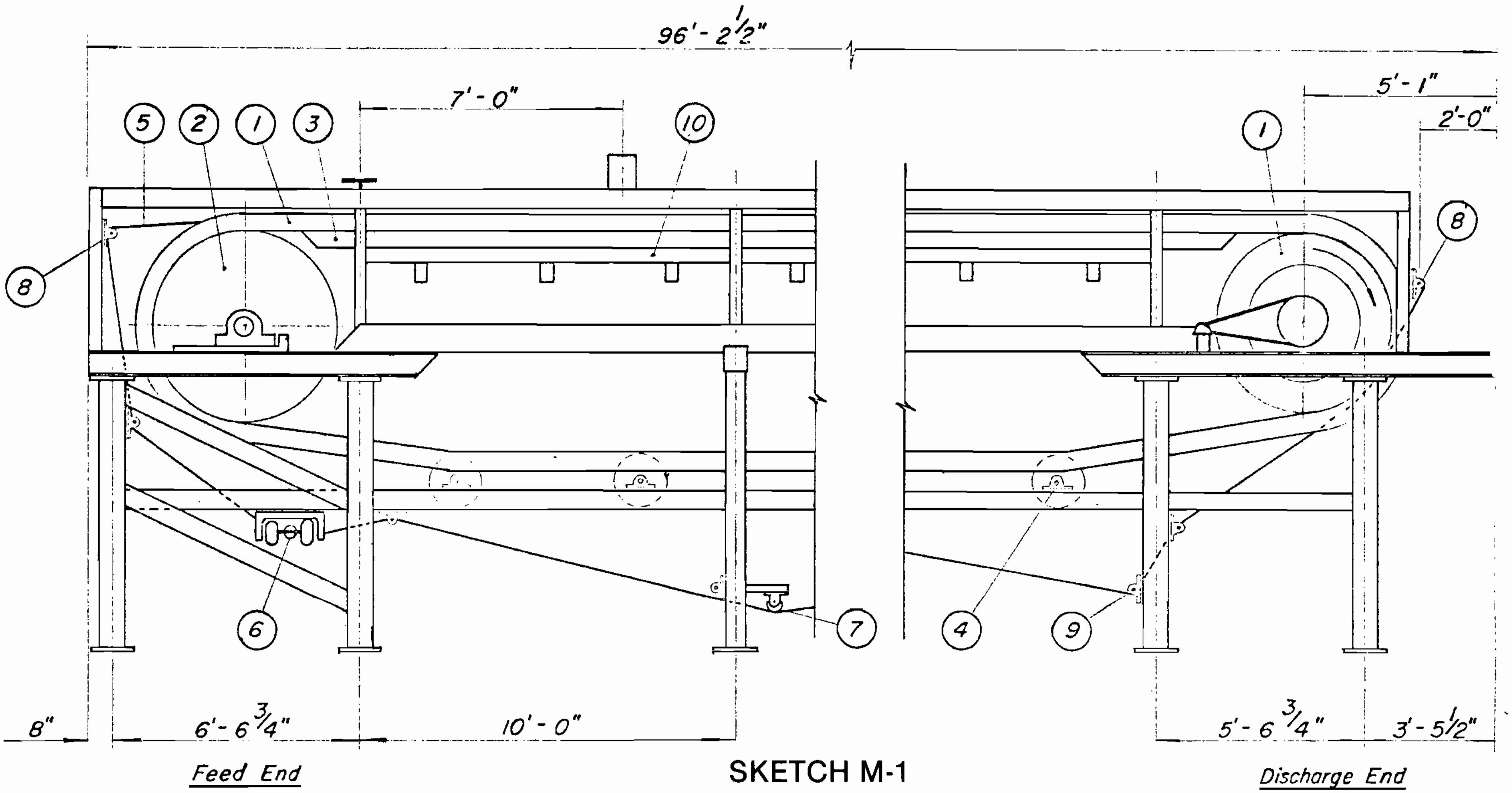
Note: Charts on pages 95 through 99



SKETCH 0-1
LANDSKRONA FILTER OPERATION



SKETCH 0-2
LANDSKRONA SLURRY LEVEL CONTROL SYSTEM



SKETCH M-1
LANDSKRONA FILTER
SIDE ELEVATION

① Cloth Support Belt

② Belt Drums

③ Belt Support Rails

④ Belt Return Idlers

⑤ Filter Cloth

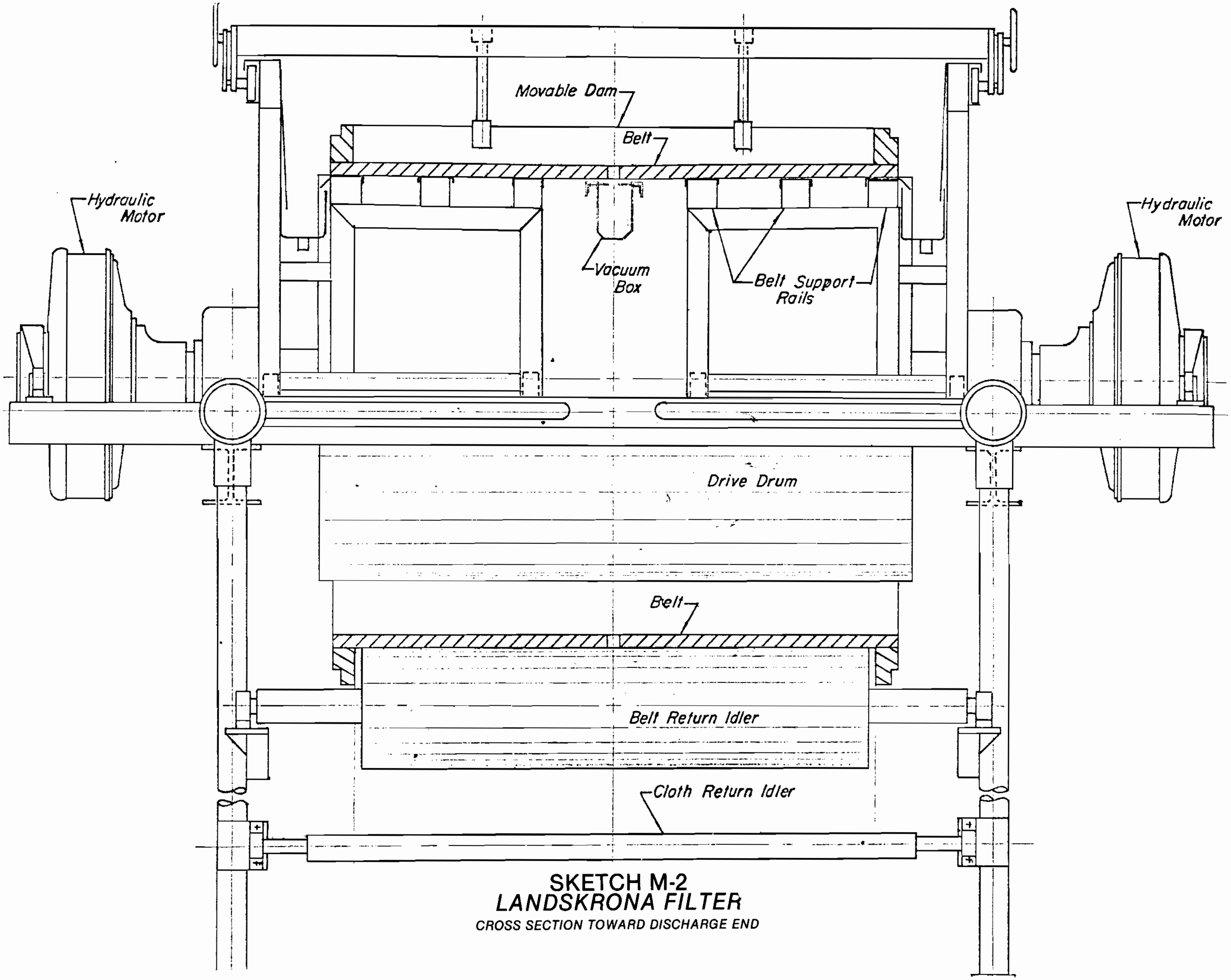
⑥ 6" Cloth Tracking Roller - Sandy Hill

⑦ 4" Dia. Cloth Tension Roller

⑧ 8" Dia. Cloth Feed and Discharge End Rollers

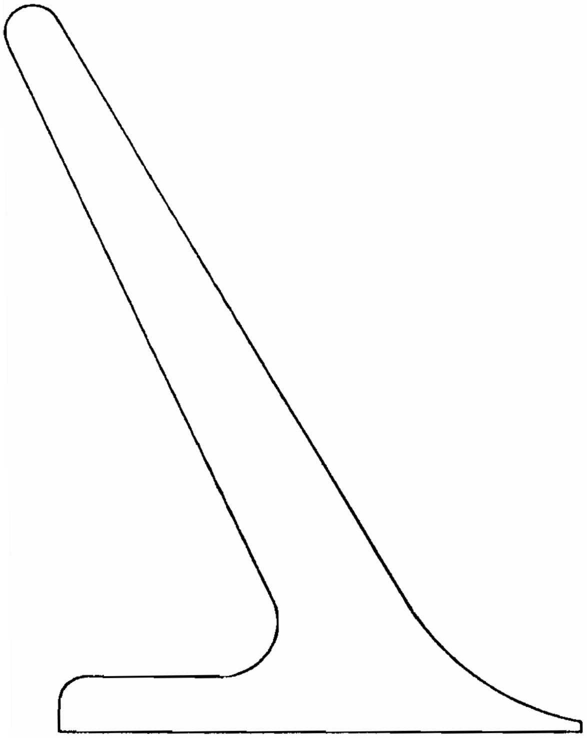
⑨ 6" Dia. Cloth Return Idlers

⑩ Vacuum Box

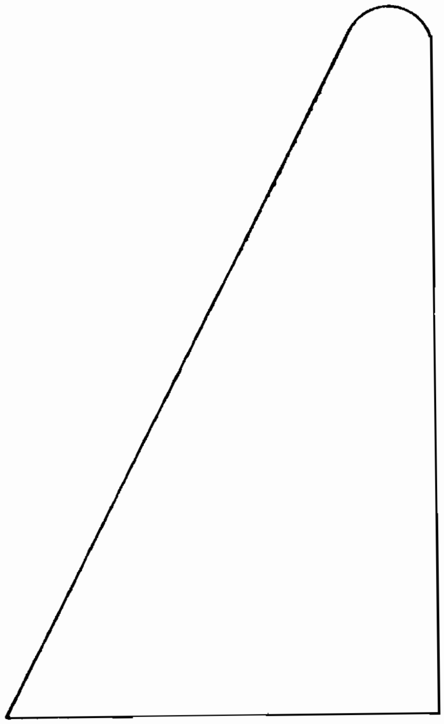


SKETCH M-2
LANDSKRONA FILTER

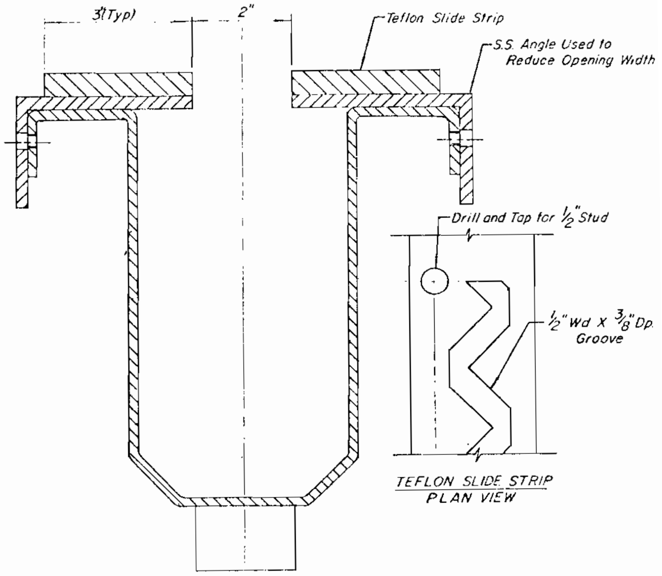
CROSS SECTION TOWARD DISCHARGE END



SKETCH M-3
"FOLD-DOWN" CURB



SKETCH M-4
WEDGE CURB



SKETCH M-5
LANDSKRONA FILTER
CROSS SECTION OF VACUUM BOX
Scale: Half Size

MODERATOR LEYSHON: Thank you Brian and Doug. (Applause)

We will postpone questions until after our next paper "New Techniques / Old Technology Nissan Hemihydrate Process". The author is Walter E. Goers, Manager of Fertilizers, The Heyward-Robinson Co., Inc. Walter has twenty years of experience in the fertilizer area. He is a graduate of Northwestern University and a licensed professional engineer of New York. Walter, please. (Applause)

New Technique / Old Technology Nissan "C" Hemihydrate Process

Walter E. Goers

Introduction

By this stage of the morning, I am sure that most of you present are already saturated with the many advantages of the hemihydrate technology. Therefore, I will not attempt to burden you any further with details on this aspect of the process. I would like however just to mention why the hemihydrate technique appears to be *now* at the forefront of many phosphate discussions.

Worldwide increases in utility and raw material costs mandate the consideration of more efficient technology. While the hemihydrate method for manufacture of phosphoric acid is not new to the phosphate industry, its ever present potential advantage of a much lower manufacturing cost added to savings in fuel consumption are of far greater interest today. Consider ten to fifteen years back when phosphate rock sold for $5-$6/ton and natural gas for 20¢/MMBTU and compare with the present where phosphate rock is

\$20-\$35/ton and natural gas \$2.00-\$2.50/MMBTU. Therefore we should look upon the hemihydrate process as a more economical machine much in the way the small four cylinder automobile is valued today.

Now having dispensed with "why hemihydrate?" I would like to devote most of the balance of my time explaining the superiority of the Nissan "C" Process. We at Heyward-Robinson after a thorough investigation of world-wide technology are convinced that Nissan is far and away the most knowledgeable in this area of phosphate chemistry.

Nissan Chemical

Think for a few minutes with me about the country of Japan. Here we have a small land mass of approximately 143,000 square miles with a population density of 780. In fact its capital, Tokyo, is the most populated city in the world — 14 million. By contrast the U.S.A. has an area of 3,700,000 square miles with a population density of 58. The second point to consider, when thinking of Japan, is that it has relatively few natural resources. Mountains cover six of every seven square miles and only 15% of the land is suitable for farming. Can you picture in your mind having to provide housing facilities for all these masses of people without a native source of gypsum for wallboard.

Nissan Chemical faced this National need some twenty-five years ago when they first developed the NISSAN Phosphogypsum Process. These plants were designed to produce a high quality phosphogypsum raw material for wallboard manfacture and the phosphoric acid was considered as a by-product. This fact is borne out by the relative small size of the Nissan phosphoric acid plants in Japan (max. 300 MT/D capacity). Since the phosphogypsum mass is approximately five times the mass of the acid, it was not necessary to erect large phos acid plants to satisfy the need for wallboard. The phosphoric acid by-product was used for domestic manufacture of synthetic fertilizers.

Now to produce a high quality phosphogypsum having low levels of P_2O_5 and fluorine required special technology. Nissan discovered that if they precipitated the phosphogypsom in the hemihydrate crystalline structure form and then redissolved and crystallized the phosphogypsum in the dihydrate form they could produce a solid product suitable for wallboard. The Nissan hemihydrate process also embodied another benefit important to a country that pays high prices for imported raw material. Nissan observed that their hemidydrate process enabled almost complete digestion of the phosphate rock. This together with the essentially complete removal of phosphate from the solid resulted in high yields of P_2O_5 from the phosphate rock, (a required must) when importing raw materials. Thus while the balance of the world phosphate industry was manufacturing phosphoric acid by the conventional dihydrate process, Nissan was employing their slightly more detailed hemihydrate process. To finalize this point it would appear appropriate to state that "Nissan Chemical has always produced phosphoric acid by their old hemihydrate technology, the Nissan "H" Process." [Slide No. 2]

Now having given a brief background on Nissan's role in the phosphate industry, I will describe the original Nissan "H" Hemihydrate process. I will then review how the old Nissan "H" technology has been modified into the new technique (the Nissan "C" Hemihydrate Process).

Nissan "H" Process

The original Nissan hemihydrate scheme, designated the "H" Process, was developed about twenty-five years ago. Some 30 phosphoric acid plants utilizing this technology are presently in operation or under construction. The largest is 600 MT/D located in Holland and the latest are three 500 MT/D plants in Morocco awarded in the fall of 1977.

The Nissan "H" Process reacts phosphate rock with sulfuric acid using digestion conditions which produce a stable hemihydrate form of calcium sulfate crystals. The temperature is maintained at 190-200°F. with a P_2O_5 level of 30% in the acid media. After allowing suitable retention time for hemihydrate crystals formation, the reaction slurry is transferred to another vessel where the mass is cooled to 130°F.

During this stage of the process the hemihydrate crystal is dissolved and the calcium sulfate is recrystallized as the dihydrate form. This dissolving and recrystallization frees the crystal lattice dicalcium phosphate and thus makes possible the high P_2O_5 yields (97.5 - 98.5§) and the high quality phosphogypsum. The 30% P_2O_5 level phosphoric acid is separated from the phosphogypsum by means of the dihydrate filter. Please remember that the Nissan "H" Process even though producing a 30% acid filtrate is not a conventional dihydrate scheme.

The 30% P_2O_5 acid level was chosen for several fundamental reasons. The hydration of hemihydrate to the dihydrate form of calcium sulfate becomes more difficult as the P_2O_5 concentration is increased. Thirty percent strength acid is the practical limit for feasible hydration operations. Secondly, the conventional dihydrate process normally produces a filtrate acid in the 28%-30% P_2O_5 strength range. Thirdly, remember also that the basic purpose of the Nissan "H" Process was to produce a high quality phosphogypsum for the manufacture of wallboard and cement retarder. Thus the by-roduct acid strength would be controlled at that maximum level which would enable the production of a suitable phosphogypsum.

Please refer to "H" Process block flow sketch.

Nissan "C" Process

In the middle 1960's Nissan theorized that since their "H" Process was already designed for hemi digestion conditions, why not take full advantage of this type operation and increase the acid media strength to 45%-50% P_2O_5. The direct production of a concentrated filter acid would negate the requirement for fuel for removal of water. Further it does not appear to be good engineering practice to add water for dilution and then remove it at a later stage in the process.

Thus the development of the New Nissan "C" Hemihydrate Process. By adding a hemihydrate filter to their reliable "H" Process, Nissan was able to produce a product filter acid of 45%-50% P_2O_5 and still maintain the previous advantages of the Nissan "H" Hemihydrate Process; namely, high yields and high quality phosphogypsum.

The first Nissan "C" plant (40 MT/D) began operation at their Toyama works in 1974. The RASA Nissan "H" plant (100 MT/D) was converted to the Nissan "C" Process and began operation in November 1975.

The RASA plant was converted in six months time at a total downtime loss of production of just twenty-four hours. This feat was accomplished by tying in the sections of the converted unit during shutdowns of the "H" Process plant.

Both of these Nissan "C" plants have been in operation since startup and represent the world's longest successful manufacture of concentrated phosphoric acid by the hemihydrate technique.

Now to briefly detail the process scheme for the Nissan "C" Process.

Phosphate rock is digested with sulfuric acid under stable hemihydrate conditions; 190°-200°F. and 45%-50% P_2O_5 in liquid phase. The reaction slurry is cooled to 165°-170°F. and then filtered on the hemihydrate filter. The 45%-50% P_2O_5 #1 filtrate is separated as product phosphoric acid. The hemihydrate filter cake is washed with 15% P_2O_5, the #3 filtrate from the dihydrate filter. The wash effluent liquor, the #2 filtrate from the hemi filter, (32% P_2O_5) is recycled to the digester to control solids content during the reaction stage.

The washed hemihydrate cake is then repulped with 8% P_2O_5, the #4 filtrate from the dihydrate filter. In the hydration tanks at 140°-150°F. the hemihydrate crystal is dissolved and then recrystallized as the dihydrate form of calcium sulfate. The hydration slurry is then transferred to the dihydrate filter where the 15% P_2O_5, the #3 filtrate is separated from the dihydrate cake. The 15% P_2O_5 acid stream is used to wash the hemihydrate cake as mentioned previously. The dihydrate cake is then washed with fresh or pond water. The effluent wash liquor of 8% P_2O_5 is used to repulp the hemi cake as cited before. The dihydrate phosphogypsum cake is then collected for processing to plasterboard or discarded to the gypsum pond.

Design Of Large Capacity Nissan "C" Plants

When you consider that the only real change in the new process is the addition of a hemihydrate filter, it becomes obvious that data for large hemihydrate plants is available from large operating Nissan "H" plants. H-R, using Nissan parameters, is prepared to design new plants or conversions in the 1,000+ TPD capacity range. The hemihydrate filter can be accurately sized from pilot plant filtration data. The hemihydrate digestion stage is essentially the same as the "H" process, of which a 600 MT/D plant is in successful operation. The hydration stage at the 15% P_2O_5 level, if anything, is considerably simpler than the hydration at 30% P_2O_5 practiced in the 30 operating Nissan "H" plants. No additive is required. Thus the feasible design of large scale Nissan "C" plants presents no difficulties.

Please refer to conversion block flow sketch and to Nissan "C" Process diagram.

Phosphate Rock Experience

As you might guess, a competent company like Nissan, in the phosphoric acid design field for 25 years, would have accumulated considerable experience with virtually all types of phosphate rock. You have guessed correctly. Nissan has commercial know-how with phosphate rocks from Central Florida, Northern Florida, Jordan, Morocco, North Carolina, Spanish Sahara, and Russia. In addition, pilot tests have been carried out on high I & A phosphate type rocks; Hazara (2.8%), Christmas Island (4.6%), Laokay (Vietnam -3.1%), and Taiba (Senegal - 3.0%). No foreseeable difficulties were observed and high P_2O_5 yields would be expected for all these types of phosphate rocks.

The Nissan hemihydrate process is the only worldwide technique which can successfully handle igneous type phosphate rocks such as Kola apatite. As a matter of interest, Nissan has within the last year successfully operated with Kola rock in their 40 MT/D commercial plant for a continuous demonstration run of one month's time.

Just recently, Nissan carried out an extremely successful bench scale testing program feeding Western U.S.A. phosphate rock of 32% P_2O_5 and 0.6% MgO as part of a Heyward-Robinson program. P_2O_5 yields of 97.5% to 98.3% were obtained.

It is extremely interesting to note that the Nissan "C" Hemihydrate filtration rate was found to be comparable to that obtained by Nissan with Central Florida 68 BPL phosphate rock. The dihydrate filtration rate was at least 50% above the rate presently obtained by the U.S.A. phosphate manufacturer. Nissan reported process reaction characteristics of this Western U.S.A. phosphate calcined ore to be very similar to those experienced on other types of phosphate rock. This is in sharp contrast with usual experience in the U.S.A. for the conventional dihydrate process feeding calcined phosphate rocks.

Thus it would appear obvious that the Nissan "C" Hemihydrate Phosphate Acid Process is the "great equalizer,"

Nissan is presently performing bench scale tests on Central Florida phosphate rock of 65 BPL and 4.2% I & A. All of Nissan's experience, both pilot and commercial, to the present time, has been with Florida phosphate rock of 68 to 72 BPL containing 2.2% to 3.0% I & A. The results of these present pilot plant experiments will provide data for conparison with 68 BPL rock concerning such information as splits of Fe, A1, & Mg and other parameters of the Nissan "C" technique.

Please see following tabulation for list of phosphate rocks handled by Nissan "C" Process.

Dihydrate Conversions

The U.S. phosphate industry is presently approaching a demand/supply capacity equilibrium situation. Most market analysts are forecasting no real addition of new phosphate capacity until the early 1980's.

There is no need for U.S. manufacturers to wait for a new plant to take advantage of the economic and operating benefits of the Nissan Hemihydrate process since an important feature of the technology is how readily it can be adopted by existing facilities. Heyward-Robinson has completed several retrofitting design schemes that can be adapted to virtually any conventional U.S. plant making it possible to integrate the hemihydrate process as part of a production expansion or merely to benefit from the technology at existing capacities. This revamping should be of particular interest to producers contemplating a new plant in the future because operating an existing facility which still has years of life left in it can additionally serve as a training center for a new unit using this modern technology.

The following new equipment will be necessary for most conversions:

. . . Hemihydrate Filter & Filtration Bldg.
. . . Hydration Tanks
. . . Hydration Cooling Media

The existing phosphate rock grinders will be oversized as ground rock of 100% minus 16 Tyler mesh is particle size requirement for Nissan "C". This contrasts with ground rock size of 3% + 35 mesh requirement for most dihydrate plants.

The existing digesters and related cooling facilities can be used in most instances without any modifications.

The existing dihydrate filter will continue to be used for this service. However, the feed slurry for the dihydrate filter will now be from the new hydration section.

The existing fluorine removal facilities will possibly have to be modified. The fluorine evolution will be about the same, but the bulk of the SiF_4 & HF will now come from the digestion section rather than the evaporation facilities.

New Capital For Conversions

Heyward-Robinson has now made 40 presentations of the Nissan "C" Process in the U.S. during this year. We have developed capital costs for conversion of existing plants having capacities from 70 ST/D to 1250 ST/D. Most of the U.S. older dihydrate installations were designed with little thought for the addition of more equipment at a later time. Thus even attempting to "shoehorn" in the equipment addition is undesirable if almost near impossible. Therefore we have taken the usual approach to add the new conversion equipment as a package in itself usually across an access road some 200 - 300 ft. away from the filtration building. This method of design has advantages in that the installation of the new facilities can be accomplished with minimum interference of the operation of the existing production plant. The necessary lines for hookup to the existing facility can be installed and connected in during a shutdown period. Using this philosophy Nissan was able to tie in completely the conversion of the RASA phosphoric acid plant in Japan with only 24 hours of lost production.

Economics

The return on investment or payoff of the capital for the conversion facilities will be justified by the large decrease in the manufacturing cost. The savings in operating cost is \$23/Ton P_2O_5 for phosphate rock at \$35/Ton and \$20/Ton P_2O_5 for rock at \$17/Ton. The savings in H_2SO_4 consumption was given a value of \$40/Ton. This price level for sulfuric acid was determined by calculating the manufacturing cost, including depreciation on capital for the H_2SO_4 plant and then adding a 20% R.O.I. on the plant investment.

Using these raw material values and \$2.00/MM for fuel, results in a R.O.I. before taxes from 3.8 to 1.4 years for conversions ranging in capacity from 250 to 1250 ST/D. No credit is taken for increasing the plant capacity.

The table gives an economic summary for converting existing dihydrate plants.

CONVERSION ECONOMICS

Plant Capacity	Conversion Capital	R.O.I.	
ST/D	$MM	* $35/Ton	$20/Ton
250	4.2	3.8	4.7
400	5.5	2.8	3.4
500	6.5	2.5	3.1
600	7.0	2.1	2.6
850	8.5	1.7	2.1
1250	10.5	1.4	1.6

* Phosphate Rock Costs

Notes:

R.O.I. - yrs. before taxes

Cost of new capital - 18%

Conversion Capital includes cost of piling plus transfer lines to and from the new equipment module.

Heyward-Robinson has been engaged by several manufacturers to study conversion of existing dihydrate plants of capacities ranging from 200 to 1,000 ST/D. The purpose of the H-R studies is to develop a conceptual type estimate for conversion to the Nissan "C" Hemihydrate Process. These studies will provide, in addition to the estimate; Process Flow Diagram, heat and material balance, process description, detailed equipment list with sizes indicating existing, modified, and new plot plan, and economic evaluations.

Indications are that several additional studies will commence before the end of this year — 1978.

Nissan Services

Nissan Chemical can offer assistance to Heyward-Robinson's clients in one or both of the following avenues:

Bench Scale

Nissan operates a 1 Kg/Hr. continuous batch pilot plant at its Toyama works west of Tokyo. The personnel in charge of this pilot plant size facility have been with its operations for some ten years time. They have become extremely proficient and expert in the handling of all types of phosphate rock by the Nissan "C" Process. The length of test time is normally 4-5 weeks duration, allowing Nissan to carry out a professional type program. In other words, the test program does not merely consist of a conglomeration of beakers, glass stirring rods, test tubes, and bunsen burners.

Nissan uses these pilot plant test results to establish the yields and the process operating parameters for the particular phosphate rock under consideration. Nissan has been very successful in predicting full scale plant operation from these test data results. The rock quantity necessary for these tests is 300 Kg.

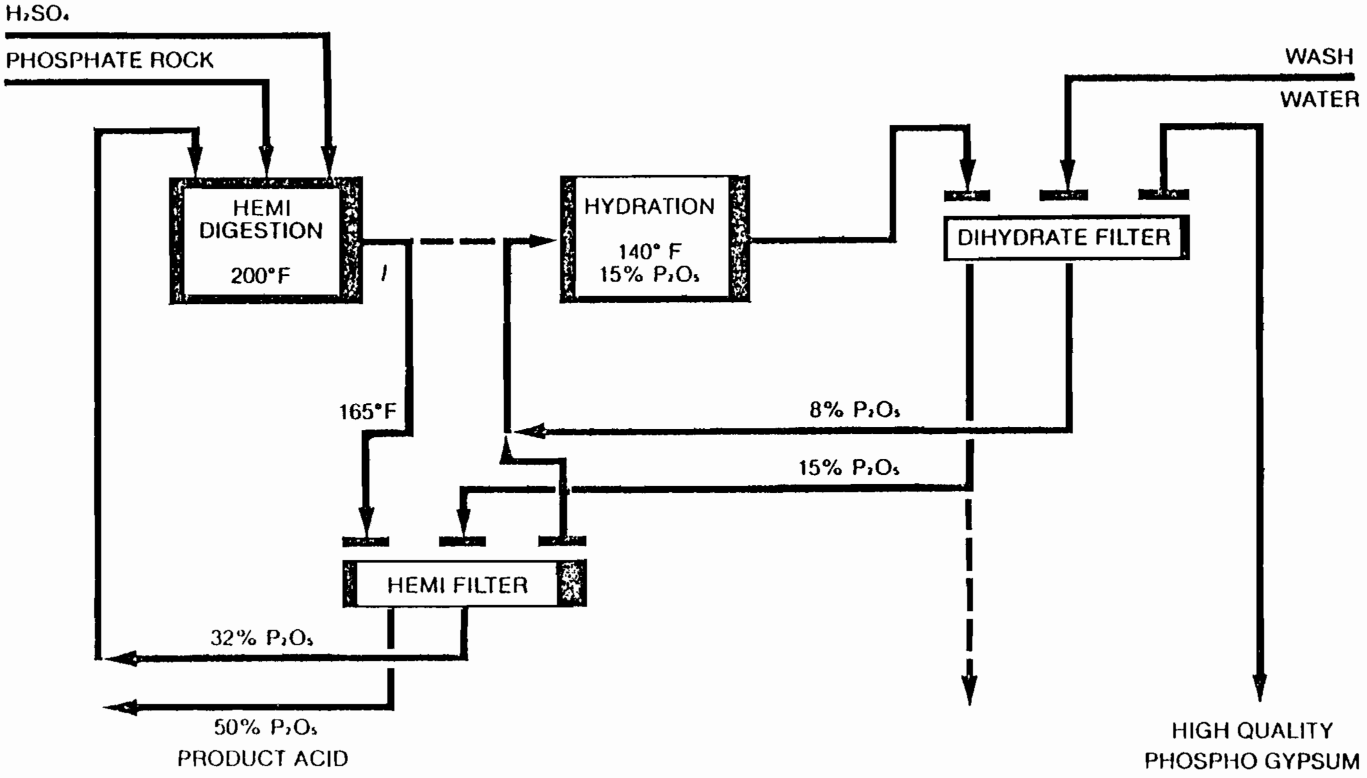
Commercial/Demonstration Scale

In many cases H-R can arrange to have Nissan operate their 40 MT/D Hemihysrate plant for U.S. manufacturers. It is probable that some phosphate manufacturers would prefer to observe the operation of a large scale facility such as the Nissan 40 MT/D plant feeding their phosphate rock. The usual practice is to purchase the rock, charge a handling fee for data, and dispose of the phosphoric acid. A thirty day demonstration run would require approximately 4500 short tons of phosphate rock. To our knowledge, Nissan Chemical is the only company in the world that can and is willing to provide this type of service to the phosphate industry.

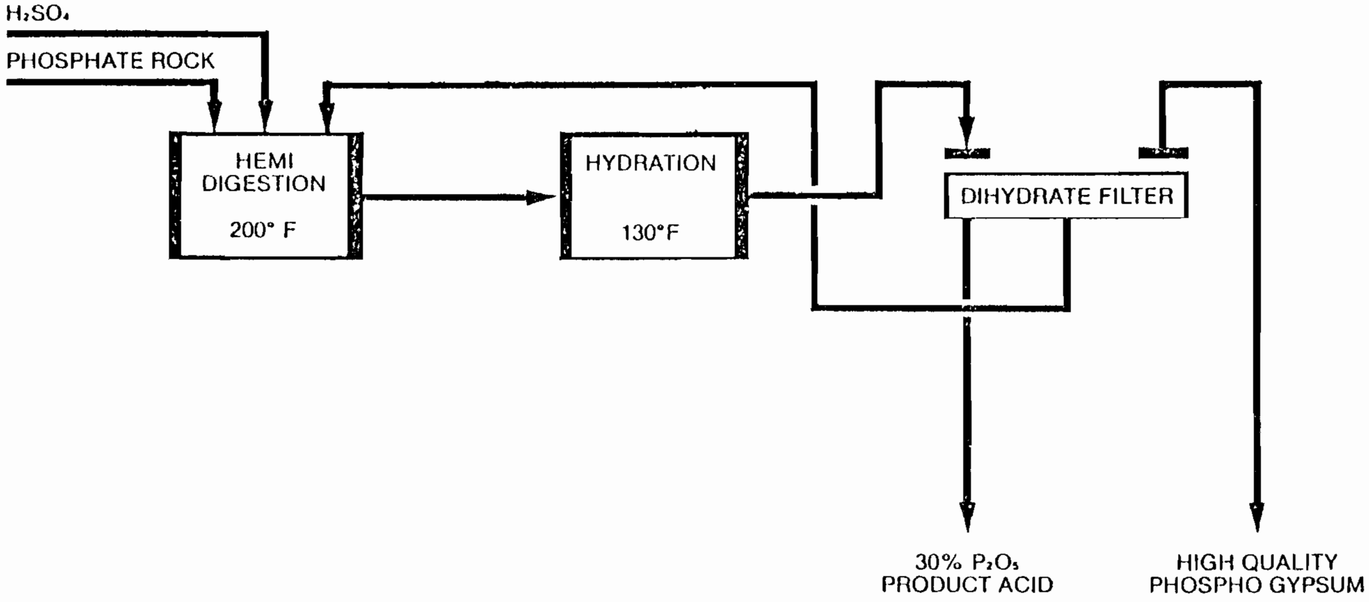
Final Remarks

Heyward-Robinson would like to extend an invitation to all P_2O_5 manufacturers to contact us for arranging a visit and inspection of the Japanese Nissan "C" Process plants.

NEW TECHNIQUE
NISSAN “C” PROCESS

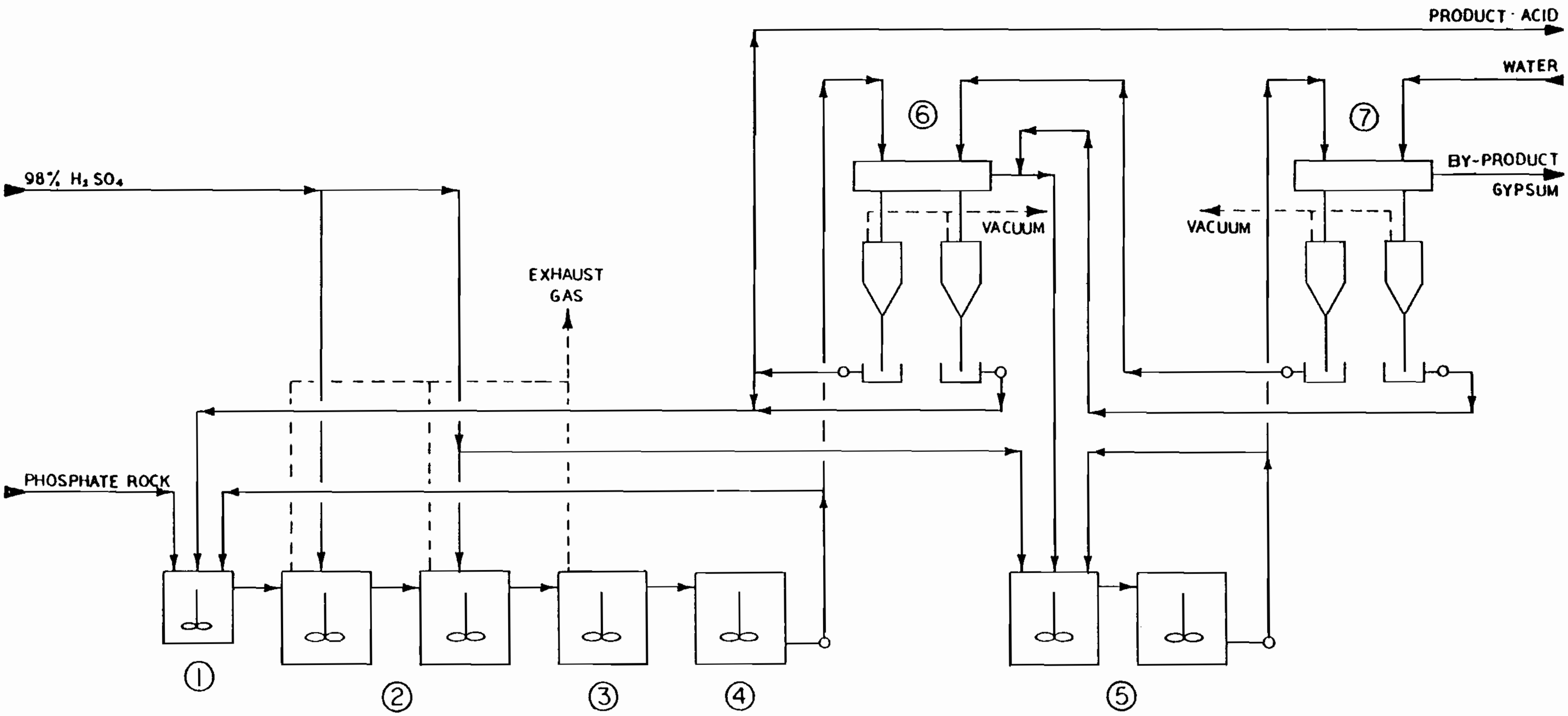


OLD TECHNOLOGY
NISSAN “H” PROCESS



PHOSPHATE ROCKS TESTED

LEVEL OF EXPERIENCE	**TYPE ROCK**
■ Commercial	— Central Florida — Northern Florida — North Carolina — Jordan — Moroccan — Spanish Sahara — Russian (Kola)
■ Pilot Plant	— Hazara — Christmas Island (4.6% I&A) — Laokay—(3.1% I&A) — Taiba—(3.0% I&A)
	— Western U.S.A. — Low quality Central Florida (65 BPL—4.2% I&A)



① PREMIXER
② DIGESTION TANKS
③ COOLING TANK
④ PUMP TANK
⑤ HYDRATION TANKS
⑥ HEMIHYDRATE FILTER
⑦ DIHYDRATE FILTER

THE HEYWARD — ROBINSON COMPANY
NEW YORK, NEW YORK

NISSAN "C" PROCESS
(HEMIHYDRATE)

ITEM NO.	PROJ. NO.	DWG. NO	REV.

MODERATOR LEYSHON: We will carry over the two papers from this morning to the first two this afternoon.

We will now have questions on the papers by McNally and Robertson and by Walter Goers.

QUESTION FROM AUDIENCE: Do you have any feel for what the impact can be on the uranium recovery operation.

WALTER GOERS: I sometimes think this question is intentionally asked at a meeting on hemihydrate technology. I would like to report that Heyward Robinson has developed a process, which we are now contemplating for a pilot plant scale operation, where we will recover 95% of the uranium in a process that employs the Nissan "C" Process. This is very much in the forefront, of course, uranium recovery.

QUESTION, BUD DAVIS TVA: Can you feed the wet ground phosphate rock to the Nissan Hemihydrate process?

WALTER GOERS: That is another question that I get asked frequently. The answer is yes, although you know, in the hemihydrate technology the water balance is very tight. In other words, it is not like a di-hydrate process where you are making 30% acid and you can be somewhat sloppy with your water addition. With the Nissan "C" Process we are making 45-50% acid. We cannot tolerate the conventional method of wet grinding, so I have developed a process where we grind the rock, "as is," at 8 to 12% water. We have carried out pilot plant tests on this. We have to take the corresponding amount of water off the filter in order to keep water balance the same. We do not use ball mills. We use a rod mill. The grinding of wet phosphate rock poses no particular problem, only that we have to, and this is true with all hemihydrate technology, be more careful with your water balance.

MODERATOR LEYSHON: Maybe I missed this, Walter, but what is the product acid strength that you make in the C process?

WALTER GOERS: Between 45-50% P_2O_5. The two plants running in Japan have been running now for four years. They run around 47% acid, and at average yields of 98%. These yields are not over a 24 hour period. In many instances you do not need a more concentrated acid than 42%. This is the reason that the Japanese plants do not go beyond 47%.

QUESTION, TRAVIS P. HIGNETT, Int. Fert. Develop. Center: Is it possible to use the Belt Filter in the hemihydrate process?

WALTER GOERS: I will give you my theory now, and I am not a PhD, I'm just a Master in Chemical Engineering. On a theoretical basis I think the belt filter would be better for hemihydrate filtration than would the tilting pan. The reason we believe this is that you can wash the cloth on both sides, which you cannot do with the other type of filters. This is quite important with the hemihydrate which tends to blind the cloth quicker than the di-hydrate crystals.

MODERATOR LEYSHON: Thank you all for your kind attention and many thanks to our Speakers. Our afternoon session will start promptly at 1:30 PM. (Applause)

Wednesday, November 1, 1978

Afternoon Session
Moderators
David W. Leyshon — Edwin Cox III

MODERATOR LEYSHON: We will now continue with the two discussions carried over from this morning's schedule.

Our first paper is a two part discussion.

Experience with TVA Cone and Rubber Belt In Manufacturing Single Super Phosphate With Fluorine Recovery

B. S. Avant (Part 1)
and
John L. Medbery (Part 2)

Bob Avant is plant manager, IMC Rainbow Division Plant, Americus, Georgia and John L. Medbery is Director of Production of IMC Rainbow Division. Bob is a graduate of Mississippi State University. Has been with IMC since 1963. John has been with IMC since 1952.

Part 1 — Bob Avant

Experience with TVA Cone and Rubber Belt In Manufacturing Single Superphosphate

GOOD AFTERNOON! This will be a two-part presentation. I will discuss our experience with a belt-type continuous den used for the production of normal superphosphate at Americus, GA. Mr. J. L. Medbery will tell you about the methods we employ to control the fluorine emissions from the process.

AMERICUS PLANT: In 1975, we decided to increase our normal superphosphate production capacity. We were using about 100,000 tons per year in our granulation unit. Our 20 ton per hour Broadfield continuous den could not keep us supplied; especially during peak production periods.

We purchased a 40 TPH rated belt type continuous den from J & H Equipment Company of Atlanta.

CONCONSTRUCTION OF UNIT: This equipment was installed by IMC personnel adjacent to the Broadfield den, and was so designed that we could connect it to our existing equipment during a brief shutdown. Installation of the new equipment was completed in May, 1976 and placed in operation in June, 1976.

The start-up of the new system presented no problems. Within a few days we were producing 40 TPH and this is still our normal production rate.

We found no difference in physical or chemical properties between the super made in the two units. The den itself (see Figure 1) consists of two 6 foot wide by 112 foot center-to-center belts mounted one above the other. The top belt travels at 12 feet per minute and discharges onto the lower belt. This belt travels in the opposite direction at 6 feet per minute. The total retention time in the den is 28 minutes.

BELT: These belts are made of a special heat and chemical resistant compound on a multi-ply polyester carcass by B. F. Goodrich. They are made endless at the factory.

BELT WITH COVER; DUCTS: Both belts are almost totally enclosed by wooden housings. Fumes are drawn off to the scrubbers through two 30 inch fiberglass ducts lined with Hetrol #197 plastic. Approximately 14,000 CFM of gases are evacuated.

SUPER STORAGE: The bottom belt discharges onto a 30 inch inclined belt which conveys the super to storage. We can store 5,000 tons.

COLLECTION HOOD & DUCT; FLUORINE SCRUBBERS: It was necessary to install a fluorine collection system (Figure 2) on this inclined belt. We used a 4,000 CFM venturi scrubber and circulate 60 GPM of absorbing water. 15 GPM of water is removed and used as dilution water in the cone. It is replaced with make-up water.

CONTROL ROOM BULDING: The Control Room is maintained under a slight positive pressure. No fumes can enter the room either from the den or cone. The entire den is enclosed in a tight building, which is free of fumes except just under the roof.

CONE OVERALL VIEW WITH TOP; CONE CLOSE UP: The 24 inch diameter cone (Figure 3) is lined with sheet lead. It has a 4 inch AAA lead discharge pipe set at a 45° angle. Acid and water manifolds constructed of 1¼ inch PVC pipe are located on top of the cone. Four nozzles are used on each manifold; set 90° apart. The nozzles (Figure 4) are positioned so that the liquid mixes with and flushes the rock through the cone.

NOZZLES CLOSE UP; CONE BOTTOM: The arrangement and adjustment of these nozzles is very important for proper cone operations.

The quantity of water can be varied as necessary to make a product with good physical properties. With fairly reactive rock we use an equivalent acid strength of 54-55° Bé at 60°F. With less reactive rock we have to add more water even using 50 to 51° Bé acid equivalent.

FOXBORO METER; HYDROMETER POT: The acid and water are metered to the cone through Foxboro magnetic flowmeters. The acid strength is continuously monitored by passing a small stream through a hydrometer pot (Figure 5) and then into the cone.

ROCK BAFFLE: We use phosphate rock which has been ground at the mine to 90% through 100 mesh, 70% through 200 mesh.

It is fed into the cone through a distribution baffle (Figure 6) by a belt-type gravimetric feeder (Figure 7).

The rock flow rate is measured via a pneumatic output signal to a Foxboro recorder. The flow rate is controlled by adjusting the speed of the 9 inch supply screw.

DEN TOP: Since starting up, we have produced over 200,000 tons of super. Den maintenance has been very low, mainly one cone liner and the wooden hood on the top belt.

However, the upper belt is now showing wear. We feel we will have to replace it this June, after about 300,000 tons.

LOGO: We are pleased with the performance of our belt-type den. The processing problems we have experienced have been caused by radical changes in the rock phosphate supplied to us.

Now I will turn the program over to John Medbery who will discuss Part 2 — Recovery of Fluorine. (Applause)

Part 2 —

Recovery of Fluorine

John L. Medbery

Good Morning! It is a pleasure to be here today. My talk will discuss the equipment and operating practices which we use at the Americus plant to recover fluorine released from the superphosphate process.

Phosphate rock is a complicated natural mineral consisting of many compounds. The principle constituent is apatite. The chemical formula for apatite is commonly written as:

$$Ca_{10}(PO_4)_6F_2$$

Part of the fluorine which is contained in the apatite particle is released as a gas when the finely ground apatite is mixed with sulfuric acid in the acidulation process.

Most Florida phosphate rock contains about 3.5 to 4.0% fluorine. The amount of fluorine which is released in the acidulation process depends upon the grind of the rock, the temperature of the rock and the acid reactants, the mixing action and the contact time. Approximately 1/4 to 1/3 of the fluorine is released when normal operating conditions prevail.

The fluorine, once it is released, is a very objectionable irritant gas. It is generally thought to exist in the form of silicontetrafluoride, SiF_4. It would be impossible for workmen to stay in the mixing area if the obnoxious gases were not drawn off and absorbed in water.

Fortunately, silicontetrafluoride is quite soluble in water and lends itself to scrubbing by this method. With the advent of E.P.A., it has become necessary to do an extremely efficient job of scrubbing. We normally design our scrubbing equipment to achieve 99.5• efficiency or better. We also prevent the leakage of fluorine gases from the equipment. It is most important that the fluorine go to the scrubber and not by-pass the scrubber through openings in the ductwork, sides of the den, or top of the cone mixer.

IMC first began using water scrubbers, making use of the jet eduction principle, in 1952. This type of scrubber utilizes a pump which forces a large volume of fluid through a nozzle in the top of a Venturi-shaped tower. (Figure 1) The fluid consists of water and absorbed fluorine gases and suspended solids. The force of the fluid flow through the throat of the Venturi creates a vacuum in the upper portion of the scrubber tower. The gases released by the chemical reaction are drawn into the scrubber passing through ductwork connecting the den to the scrubbing tower and entering at one side of the nozzle. The liquid discharge from the nozzle is aimed directly downward through the center of the narrow part of the Venturi. The gases are contained by the liquid droplets and the silicontetrafluoride is absorbed by the water.

The chemical reaction which occurs is sometimes written as:

$$SiF_4 + H_2O = H_2SiF_6 + SiO_2$$

The obsorbing liquid has the ability to hold only a limited amount of silicontetrafluoride. When the amount of hydrofluosilicic acid contained in the water exceeds about 25%, the absorption efficiency falls off rather rapidly. We have found that virtually no absorption or scrubbing affect will take place if the strength exceeds 35% hydrofluosilicic acid contained in the scrubbing medium.

Our scrubbers today consist of three stages. That is, three separate scrubbers connected together in series. The most concentrated gas enters the first stage scrubber where about 90% of the SiF_4 is removed. Of the remaining 10%, approximately 85% is removed by the second stage scrubber and of the remaining amount approximately 70% is removed by the third stage scrubber.

The efficiency drops off because the fluorine concentration in the gas grows weaker as it moves toward the exit end of the scrubbing train. However, we are dealing with compounded scrubbing efficiencies and find that we have successfully removed well over 99% of the fluorine-containing gases by the time we reach the exit stack from the scrubber system.

The liquid contained in the first stage tank increases in concentration rather rapidly and must be withdrawn when it achieves a strength of about 23 to 25% H_2SiF_6. This is removed by opening a valve on a side branch of a "T" on the discharge of the first stage pump. (We presently monitor the acid strength and operate the valve manually, although this has been accomplished by instrumentation in some installations.) This valve allows the concentrated liquid to pass through piping to a filter press.

The filter press (Figure 2) consists of plates and frames made of rubber protected iron or of laminated polypropylene. The filter removes suspended silica which is formed in the reaction of SiF_4 with water, and which accumulates in the first stage tank. It is necessary to remove silica from the 23-25% hydrofluosilicic acid to make it suitable for sale as a by-product.

Periodically, the accumulated silica cake must be removed from the filter press.

The filtration medium is a tightly woven Dynel or polypropylene fabric, which is resistant to hydrofluosilicic acid. The filtrate from the press is transformed to storage tanks, which are lined with an acid-resistant material. We generally use a bag made of polyvinyl chloride of a thickness of approximately 40 mils installed in a steel or wooden tank. All of the piping, both before and after the storage system, must be made of resistant materials.

The tank outlet is generally constructed of rubber-covered steel and is carefully fitted and gasketed so that no steel is exposed to the corrosive attack of the acid.

Figure 3 depicts the operating procedure. As product is withdrawn from the first stage of the three-stage scrubbing system, the liquid level in the scrubber tank drops. It is necessary to replace this volume of liquid with material transferred from the second stage scrubbing tank. In turn, the liquor removed from the second stage tank is replaced with material removed from the third stage tank.

By following this procedure, it is possible to keep the strong concentration of acid limited to the first stage tank.

The small amount of concentration build up in the second stage and third stage tanks is kept in equilibrium by removal of fluid from these vessels as it is pumped forward, counter flow to the gases passing through the scrubbing system. Make-up water is added through sprays installed in the exit stack.

The process operator uses a specific gravity hydrometer to measure the concentration of hydrofluosilicic acid in the scrubber liquid. A chart is available which shows the hydrometer reading at any given temperature as it compares to the concentration of HFS in that liquid. Once a week the plant chemist will determine the phosphate content of the HFS and supply the foreman in charge of the superphosphate plant with an additional correction factor for P_2O_5 .

The Americus 40 TPH den requires the removal of 14,000 CFM of fluorine-carrying gases. We desired to make use of the scrubbing system previously used for the 20 TPH Broadfield den, which had a 7,000 CFM gas handling capability. We installed a second two-stage train of scrubbers paralleling the original two-stage system. These two 7,000 CFM trains then feed into a larger third-stage scrubber for a combined flow of 14,000 CFM. (Figure 4).

The first and second stage scrubbers are all 30" size, the third stage scrubber is a 36" size Venturi.

We use Galigher size 4 x 6 horizontal pumps (Figure 5) to deliver the scrubbing liquor to the nozzles in the tops of the Venturis. The first stage pumps require 40 HP motors to handle the 450 GPM of liquid of a density of 1.2. The second stage pumps deliver a like volume, but at lower density, and need 30 HP motors. The third-stage scrubber pump carries 750 GPM and uses a 50 HP motor. The pumps are equipped with a replaceable butyl rubber lining for corrosion and abrasion resistance.

The nozzles which we use are of two types, rubber covered steel or machined teflon (Figure 6). Generally, we have obtained better service life from the teflon nozzles. The orifice diameter at the tip is critical, and the nozzles must be replaced when the tip becomes enlarged through wear and the conical spray pattern is too wide.

The three-stage scrubbing system allows us to concentrate hydrofluosilicic acid to a strength of 23 to 25% which is sold as a by-product. At the same time, it effectively removes the pollutants from the process exit gas. The fluorine remaining in the stack emission is less than allowed by state environmental regulations.

Thank you. (Applause)

FIGURE 1

VENTURI TOWER

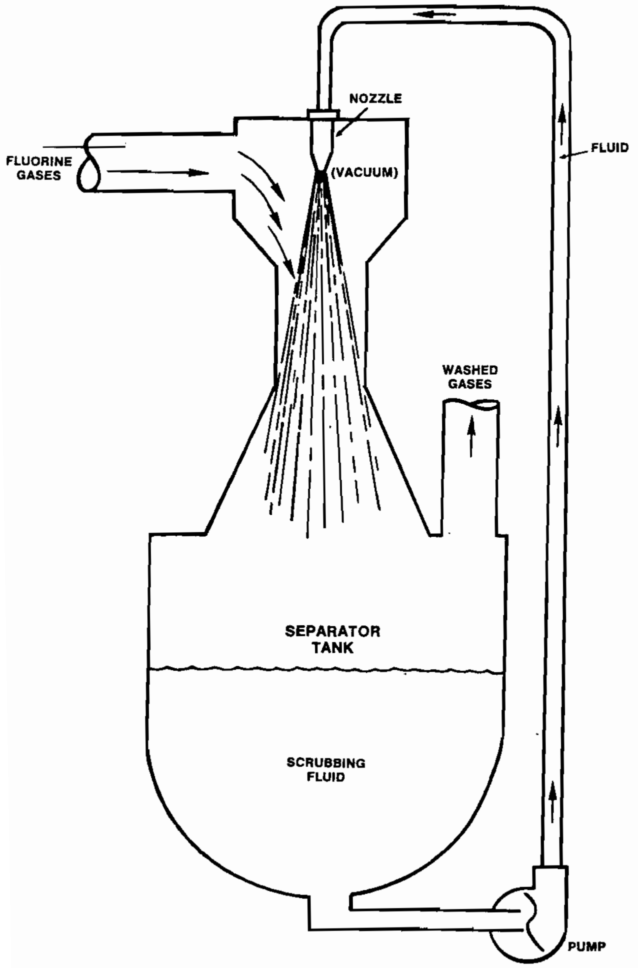


FIGURE 2

FILTER PRESS

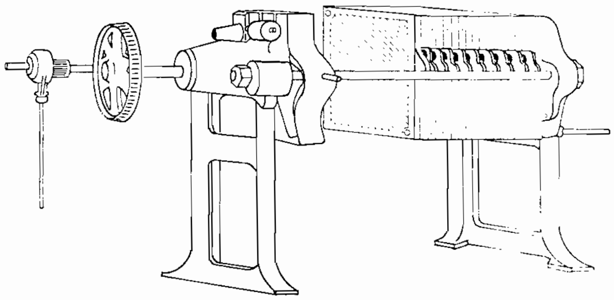


FIGURE 3

3 STAGE SCRUBBER

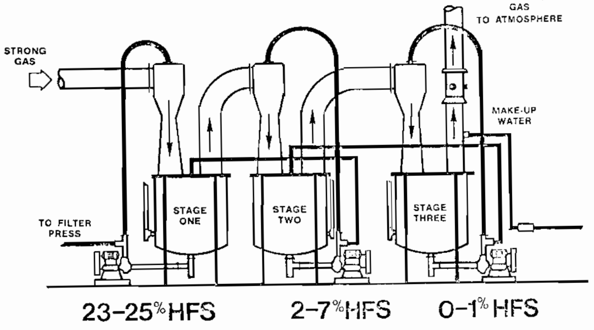


FIGURE 4

AMERICUS SCRUBBER

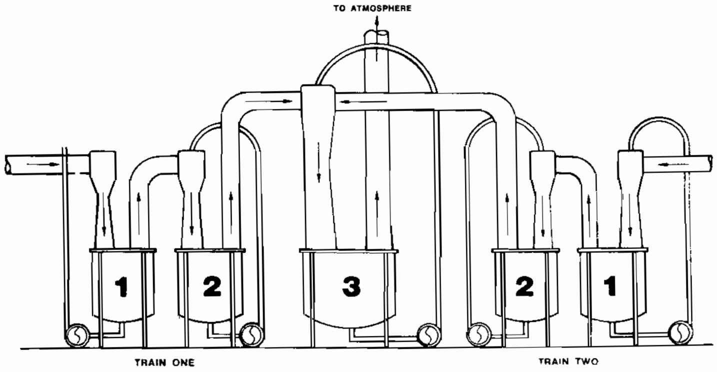
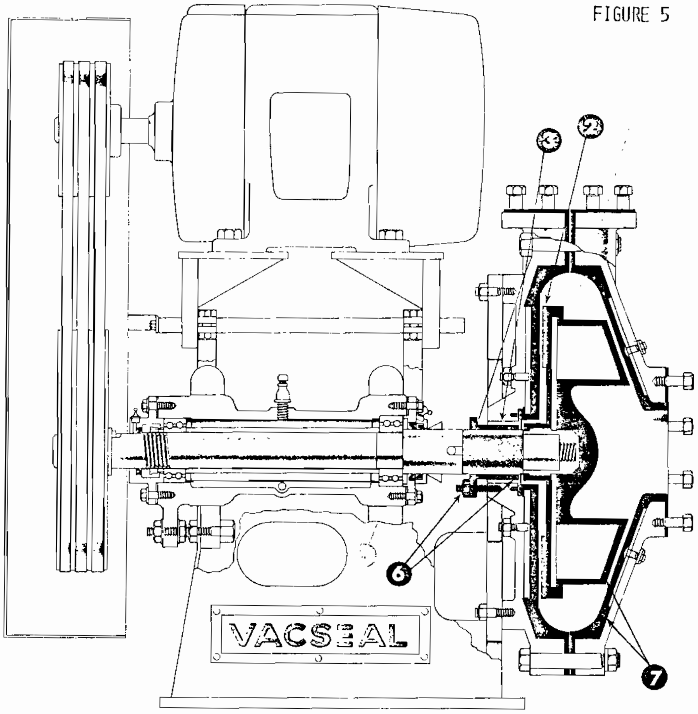


FIGURE 5

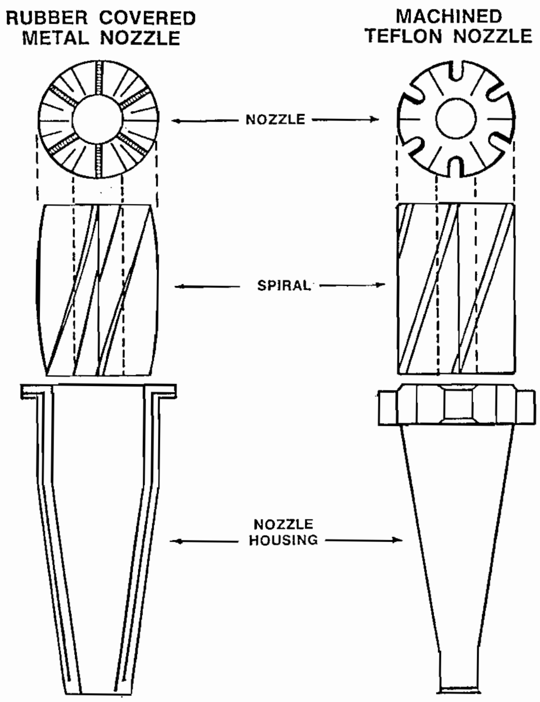


1	Three blade semi-open rubber covered impeller prevents clogging — gives maximum service.
2	Expelling blades on reverse side of impeller are of greater diameter — keep packing under suction. No sealing water required.
3	Gland bushing of alloy or plastic and shaft sleeve to suit service.
4	Adjustable bearing assembly compensates for impeller wear.
5	Heavy duty bearings.
6	Packing gland is provided to prevent pump leakage while pump is not operating.
7	Heavy duty replaceable rubber liners vulcanized to metal reinforcing plates.

COURTESY OF THE GALIGHER COMPANY

FIGURE 6

NOZZLES



MODERATOR LEYSHON: Thank you Bob Avent and John Medbery for your up-to-date discussions covering your experiences with TVA Cone, Rubber Belt and Fluorine Recovery in "Manufacturing Single Super Phosphate".

We have time for questions.

QUESTION FROM AUDIENCE: Mr. Medberry have you noticed any difference in the rate of absorption of either silicon tetra fluoride or hydrogen fluoride as a function of concentration in the scrubbing liquid?

JOHN MEDBERRY: Oh, definitely! We have plotted this information and it forms a curve. In other words, as the concentration goes up the absorption efficiency goes down, and it is also proportional to the temperature. The colder the liquid, the better it absorbs.

QUESTION, Eric Schwehr: At what temperature do you withdraw 23-25% acid?

JOHN MEDBERRY: We take a temperature reading at the time it is pumped off from the first stage. Now, the plant is running continually, and in the course of time the temperature will finally reach equilibrium. We get an equalibrium condition in the winter time at around 140°F. and in the summer time at around 160°F. The temperature is the same in both the gas exiting the first stage scrubber and the liquor contained in the first stage scrubber. Now, on one occassion we were acidulating with 93% acid and added a much greater amount of water. We did this in "The Broadfield" rather than in the "Cone Mixer" and at that time the temperature got all the way up to 200__. Now, under these conditions the scrubber does not work effectively.

QUESTION, John Kronseder: What proportion of HF and Sif 4 do you have coming off the "Den"?

JOHN MEDBERRY: I do not have that information here. It has been calculated, of course, and I have the complete assay of all the gases, including CO_2 water vapor and the air. I think we possible could calculate it just in our head almost. We are talking about 1200 lbs. of rock to make a ton of super, right? Of that amount say 3.9% is fluorine, of which 1/3 is released, so we are talking about 1.3% of 1200 to come up with the percent fluorine. From that we come up with a weight ratio of SiF4 to air, but I do not quite remember the number, however we could work it out in a few minutes, if you would like.

QUESTION FROM THE AUDIENCE: What is the typical P_2O_5 level in that 23-25%.

JOHN MEDBERRY: Typical would be about .2%. It sometimes is as low as .1% and sometimes as high as .5%. The americus Unit is quite consistent at around .2%.

MODERATOR LEYSHON: O.K., the Lady from Finland.

QUESTION: My question is about Superphosphate Manufactureing. When the material comes on to the first belt is it already a solid or is it a slurry?

JOHN MEDBERRY: It is in good physical condition and has developed a nice honeycomb. It breaks apart easily and falls right into the second belt. There is really no problem at all with it being sticky and makes a nice transfer.

MODERATOR LEYSHON: What is the retention time on the first belt?

JOHN MEDBERRY: Well, let's see. The first belt is 112 feet long and travels at 12 feet per minute, we have approximately 10 minutes.

QUESTION FROM AUDIENCE: What is the fluosilic acid per ton of super made?

JOHN MEDBERRY: It will average right at 60 or 65 pounds of 23% acid per ton of super.

MODERATOR LEYSHON: John, have you had trouble with the Galigher Pump leaking? Are you using any special type packing or seal for the pump?

JOHN MEDBERRY: I am not aware of any problem. Anytime I visit the plant they are not leaking. Bobby, do you care to comment on that?

BOBBY AVANT: We have Hasteloy 'C' Sleeves and Teflon packing around them. It is a mechanical packing and we have absolutely no leaking.

QUESTION: Do you get these from Galigher?

BOBBY AVANT: We get everything except the packing from Galigher.

QUESTION: We have a world of trouble with this type of thing and that is the reason I am asking the question. I just want to get something done. We have cut down on the level of the liquid in the scrubber itself, carrying about 6 or 7 feet an hour thru the scrubber.

JOHN MEDBERRY: The first stage tanks are all 8 feet diameter and 8 feet deep and they are filled to about 50%. There is about another 12 inches of connections below the bottom of the tank leading to the pump so we have about 5 feet of static head on the pump section.

QUESTION: Have you had any trouble with the heavy metals in these acids? Do you then expend all that emerging acid?

JOHN MEDBERRY: No, we have not, however, we do check it for arsenic because it is sold as an additive for drinking water, and we have never detected any problem with arsenic.

QUESTION: I see. Have you used any spent acid, then?

JOHN MEDBERRY: We are using some spent acid at the present time which we get from Hercules in Bessemer, Alabama. That is the only spent acid we are using at the present time. In years gone by we have used different acids but at no time did we have a heavy metals problem.

QUESTION: I would like to know how thick a bed of super gets on the belt.

BOBBY AVANT: It is about 8 inches to 10 inches but it virtually flattens out.

JOHN MEDBERRY: When it transfers to the lower belt, of course, the honeycomb structure kind of breaks apart as it tumbles from one belt to the other. It is about 8" high on the second belt, but, of course, the second belt is travelling half as fast.

QUESTION: What do you do with the silica that you filter off?

JOHN MEDBERRY: Aha! I said it is periodically removed from the filter press. Disposal of the silica could be a problem, however, it does not need to be. We dump the filter press out into a tractor or bucket. Our filter press is on a raised platform so we can put the bucket directly under the plates and frames and we break the press open and we knock the cake out into the payloader bucket. We drive the payloader around into the superphosphate storage building and spread it out about one inch thick on the floor directly under where we are going to be dumping the freshly made super. So, the super covers it up and it is scooped up and shipped out with the super. (Much laughter). I knew I would get a laugh on that one. I might add that in Amercus, Georgia, which is the plant we are talking about, we do not sell any of the super. We use it all in the plant.

MODERATOR LEYSHON: Could you give us an estimate of the amount of tonnage per day, or per week, of the silica?

JOHN MEDBERRY: Again it is stoichiometric from the formula, and, it would be something on the order of 3 pounds of SiO_2 per ton of super. I would think.

MODERATOR LEYSHON: O.K. we can calculate it.

QUESTION: Do you have any trouble with the color of the product?

JOHN MEDBERRY: It will come out kind of yellowish or amber color. If our customer requires water-white product we add an activated charcoal. We put this directly into the first stage scrubber. It will bleach the liquor water-white. The charcoal residue will be in the filter press along with the silica cake and that eliminates that problem.

MODERATOR LEYSHON: Thank you John Medbery and Bob Avent. (Applause)

The next paper is a "Fluid Fertilizer Update - 1978 and the author is Frank Achorn and I really should not have to make an introduction. Frank is Mr. TVA. Presently he is head of TVA Process and Production Improvement Section. (Applause)

FRANK ACHORN: I do not want you to get the wrong impression that I am: Pro Liquids, Pro Solids, Pro Acid or Pro anything. I think that every marketing system can support another marketing system and that when you learn how to get the marketing systems supporting each other, you will get the other fellow's business, and you will get the new business.

Fluid Fertilizers
1978

Frank P. Achorn
David G. Salladay
Discussion by Frank P. Achorn

The U.S. fluid fertilizer industry is about 25 years old. In recent years other countries, such as Canada, Mexico, Denmark, Belgium, France, Colombia, the United Kingdom and the Netherlands have manufactured and used significant amounts of fluid fertilizers for direct application. In the U.S. fluid fertilizers are asumed to be nonpressure solutions and include nitrogen solutions and fluid mixed fertilizers. If anhydrous ammonia also is considered as a fluid, over thirty-one percent of the total fertilizers applied in the U.S. would be applied as fluids. However, anhydrous ammonia usually is considered to be a gas. The consumption of nonpressure fluid fertilizers in the U.S. during recent years is shown below:

Year	**1970**	**1975**	**1977**
Material, thousands of tons per year (1)			
Nitrogen solutions	3243	4110	5796
Fluid mixtures	2541	3170	4000
Total	5784	7280	9796

These data show that total consumption of fluids has almost doubled during the last 8 years. Other data show that 19.2 percent of total nitrogen, 10.9 percent of total P_2O_5 and 6.6 percent of total K_2O are consumed in the U.S. as nonpressure fluids.

The fluid fertilizer industry is divided into two major marketing segments, one for manufacture and application of solutions and the other for production of suspensions. It is estimated that clear liquids comprise 60 percent of the fluids and suspensions the remaining 40 percent. Most clear liquid fertilizers are applied as straight nitrogen solution containing 28 to 32 percent N. Most are applied by broadcasting using various types of nozzles.

Nonpressure nitrogen solutions also are applied through sprinkler, gated pipe, and ditch irrigation systems. This practice has often been referred to as "spoon-feeding" of the crop because solution is added with irrigation water several times during the growing season. The apparatus for feeding these solutions to the irrigation unit usually consists of a storage tank and a piston-metering pump.

Fluid Mixtures

Solution mixtures usually are free of solids and have enough clarity to be seen through. Suspensions are of higher concentration than solution mixtures and have crystals of plant nutrients suspended in saturated fertilizer solutions. These crystals are suspended by gelling clay such as attapulgite mined in the Florida-Georgia region of the U.S. Other gelling clays such as sodium bentonite from South Dakota and sepollite from the western U.S. also have been used successfully as gelling agents. The low cost of these clays makes their use practical in producing suspension mixtures. Objectives of the fluid production and marketing systems are the same as those for manufacturing solids;

1. Production of a product with a low raw material cost
2. Production of a product having high nutrient concentration
3. Production of a product of good quality (storage, handling, etc.)
4. Use of a manufacturing process having low pollutant emission
5. Production of a product having good homogeneity
6. Production of a product having good versatility
7. Production of a product that can be uniformly applied
8. Production of a product that is compatible with additives such as pesticides and micronutrients

Producers of fluids believe their products provide an easy way to meet these objectives. A large number of materials recently have become available in large quantities for manufacture of fluid mixtures. There has been considerable adaptability by the fluid fertilizer industry in accepting these new materials as they become economical and available for use.

Solution Fertilizer Mixtures

The marketing system for solution mixtures usually consists of regional fertilizer plants which use wet-process superphosphoric acid in TVA's pipe reactor process to produce ammonium polyphosphate solution of 10-34-0 grade. Superphosphoric acid usually contains 68-70 percent P_2O_5 of which 20-35 percent is present as polyphosphate. The chemical and physical characteristics of a typical superphosphoric acid are tabulated below:

Rock source	**North Carolina**	**Western U.S.**
Chemical Analysis, %		
Total P_2O_5	70.0	68.5
Polyphosphate, % of total P_2O_5	30.0	25.0
Sulfate (SO_4)	3.8	3.6
Aluminum (Al_2O_3)	1.1	2.8
Iron (Fe_2O_3)	1.0	1.25
Magnesium (M_gO)	0.4	1.00
Fluorine (F)	0.27	0.36
Solids (Insol. in CH_3OH)	0.15	nil
Solids (Insol. in H_2O)	0.01	nil
Specific gravity at 75°F	1.96	1.96
Viscosity, centipoises at 126°F	400	660

Essentially all of the nonorthophosphoric acid content of wet-process superphosphoric acid is in the form of pyrophosphate.

Conversion to superphosphoric acid increases the cost somewhat, but long distances in the U.S. result in freight savings that reduce or eliminate this disadvantage.

More than 100 U.S. plants use the TVA pipe reactor process to poroduce an estimated 1.4 million tons per year of the 10-34-0 grade. Two typical plants which use superphosphoric acid to produce this grade are shown in Figure 1. The plant on the left of the figure has a combination mix tank-cooler. The upper part of the tank consists of a section filled with plastic Pall ring packing; liquid is recirculated to this section while air is drawn through to partially cool the liquid. Liquid from the bottom of the tank is passed through a heat exchanger where it is further cooled before it is pumped to storage. Cooling is supplied by liquid anhydrous ammonia which also is passed through the heat exchanger, where it is vaporized and then passed to the tee section of the pipe reactor. Superphosphoric acid is pumped by a positive displacement pump to this same tee section, where the acids and gases react to form hot melt at 600 to 700°F. Usually some ammonia is added to the recirculating liquid to adjust the pH to 6.0 for production of the 10-34-0 grade. Water content is controlled by addition of water to the recirculating line.

The plant shown on the right of Figure 1 uses a separate mix tank and an evaporative cooler. The mix tank is used for mixing but melt from the pipe reactor with recirculating liquid. By having a separate mix tank it is possible to maintain a liquid temperature of 180°F. This enhances mixing of melt in liquid and also provides an excellent means of evaporating and super heating anhydrous ammonia used in the pipe reactor. This plant has an efficient, inexpensive evaporative cooler. Both plants have production capacities of 20 to 30 tons per hour. Essentially no contaminants are lost from either plant. There is considerable water loss as steam and water vapor.

Much of the 10-34-0 grade is used for direct application in the wheat belt and other areas in which potassium is not deficient. However, most of these solutions of 10-34-0 or 11-17-0 grades are used by small mix plates to produce NPX mixtures. A typical plant is shown in Figure 2. Ammonium polyphosphate solution is mixed with urea-ammonium solution and potash to produce various clear liquid mixtures such as the 7-21-7, 8-8-8, and 21-7-0 grades.

Sometimes liquid mix plants produce potash base solution such as the 2-6-12 or 4-11-11 grades and transport it to a satallite station where it is mixed with nitrogen solution and the 10-34-0 grade to produce various NPK mixtures. At the satellite station each liquid is metered and mixed in the farmer's nurse tank.

Most clear liquid fertilizers are applied as starter fertilizers or injected during or just prior to planting of seed. Few farmers apply fluid through irrigation units. Many fruit and vegetable growers use solution mixtures. Many others are considering use of solution mixtures because they can be accurately metered and are easy to place where they can best be used.

Suspension Fertilizers

Use of suspension fertilizers has grown very rapidly in the U.S. during the past 5 years. Some reasons for their increased popularity are the same as for other fluids. Suspensions are becoming as popular as solution mixtures because:

1. They have lower material costs than solutions and can use a wider variety of less porous materials.
2. They are of higher analysis than other fluids; this is particularly true when grades containing potash are produced.
3. Larger quantities of micronutrients can be suspended in them than can be dissolved in solutions.
4. Powdered herbicides and insecticides which are not soluble in solutions can be suspended in suspensions.

One of the main reasons for production of suspensions is to produce high potash grades. The most popular suspension grades are those which have high potash contents such as the 7-21-21, 3-10-30, and 4-12-24 grades. High nitrogen suspension grades such as 14-14-14, 20-10-10, 21-7-7, and 24-8-0 have become popular recently. A survey of fluid fertilizers manufacturers shows that 67 percent of fluid fertilizer plants in the U.S. produce suspensions. These plants use the following materials (2):

Materials	**% of Plants Reported**
Potash	66
Nitrogen solutions	96
Ammonia	30
10-34-0	90
Phosphoric acid	29
Solid phosphates	11

These data show that the most popular phosphate material for suspensions is still ammonium polyphosphate. However, economic pressures have encouraged use of other materials. The next most popular phosphate source is phosphoric acid. In the last two years, use of granular materials such as ammonium phosphates have become popular. Numerous new plants have been instalaled for converting granular materials to fluids. Many companies that formerly used the 10-34-0 grade for production of suspensions now plan to use base suspension of 11-33-0 or 13-38-0 grades or they will use phosphoric acid or granular phosphates (3)

Two types of procedures are used to produce suspensions from granular ammonium phosphate materials. In one procedure mechanical energy primarily is used to fluidize granular materials. Figure 3 shows three typical plants that mechanically fluidize granular materials such as monoammonium phosphate (MAP).

These plants have large agitators or wet grinding equipment for fluidizing granules. Usually when MAP is used enough anhydrous or aqua ammonia is added during mixing to convert the product to an 11-33-0 grade base suspension. Although this releases some chemical heat, most of the energy required for fluidizing granules is supplied by mechanical energy of the agitators, grinders, and large recirculation pumps. These plants have good flexibility because of the wide range of materials used.

Materials that have been used include granular MAP of 11-52-0 grade, powdered MAP of 10-50-0 grade, prilled urea, crystalline ammonium sulfate, standard potash, compacted elemental sulfur, ammonia, and nitrogen solutions. Investment costs for these plants are considerably higher than for small fluid mix plants formerly used by the fluid industry. Part of this higher cost is a result of using larger equipment and electrical motors in the plants. Some plants have total power capacity greater than 100 hp. Usually the plants have large transfer pumps and piping. Two of the plants use primarily intense agitation for degradation of granules. Another uses a specially designed wet grinder. All plants are equipped to add ammonia when MAP is used. Most manufacturers do not add phosphoric acid and at least one recommends that it not be used in their plants.

The second procedure uses chemical energy to fluidize granules. Several equipment companies have developed small mix plants in which mostly chemical energy is used to convert granular products into suspension mixtures. A plant of this type is shown in Figure 4. In this plant diammonium phosphate (DAP) of 18-46-0 grade is reacted with phosphoric acid and either anhydrous or aqua ammonia to produce an 11-33-0 grade base suspension (4). While using larger quantities of chemical heat, less mechanical energy is required. Use of high intensity agitation, wet grinders, etc., can be avoided. However in using larger quantities of chemical heat the expense of installing phosphoric acid storage facilities is necessary. Usually the investment cost of mixing equipment which uses large quantities of chemical heat is less than that in plants which use large amounts of mechanical energy. In this type plant, 30 percent of the P_2O_5 usually is supplied by merchant grade wet-process phosphoric acid and the remainder by DAP. A typical formulation for two grades is shown below:

Grade	11-33-0	14-14-14
Formulation, lbs per ton of product		
Water	552	520
Gelling clay	20	20
Diammonium phosphate (18-46-0)	1004	426
Phosphoric acid (0-54-0)	367	156
Ammonia (82-0-0)	47	20
Urea	—	406
Potash	—	452

In the formulation for 11-33-0 grade, about 400,000 Btu of chemical heat per ton of product is released; this heat causes rapid deterioration of DAP. At this degree of ammoniation all crystals in suspension are present as diammonium phosphate. The same results are produced in manufacture of the 14-14-14 grade. It is desirable that the major phosphate crystalline phase be diammonium phosphate because the relative light weight and shape of the diammonium phosphate crystal is such that it has less tendency to plug nozzles than do other ammonium phosphates, such as monoammonium phosphate. Therefore, experience in TVA field programs shows that the quality of suspension produced from DAP is good.

TVA is introducing into its demonstration program a new granular ammonium phosphate material (APP) that has a polyphosphate content of about 10 to 20 percent of the total P_2O_5 and grade of 11-55-0. Because the product contains some polyphosphate, it can be fluidized easily in a small low cost plant that has a small agitator and a large recirculation pump. Figure 5 shows a typical plant of this type. Plant tests indicate that ammonium polyphosphate will absorb ammonia readily and it is possible to produce a suspension simply by mixing the ammonium polyphosphate with anhydrous ammonia, water, and gelling clay. When the resulting 11-33-0 grade contains more than 10 percent polyphosphate, it usually has excellent winter storage characteristics and can be handled in the early spring season without difficulty. Similar results have been produced with other new TVA products such as urea-ammonium phosphate of 35-17-0 and 28-28-0 grades.

Some companies that manufacture fluids prefer not to use solid materials in manufacturing suspensions. Several plants now produce an 11-33-0 grade base suspension with all P_2O_5 being supplied from merchant-grade phosphoric acid containing 54 percent P_2O_5. A large quantity of chemical heat is released during the neutralization of the acid, and some cooling of the suspension is required. A typical batch plant for production of suspension of this type is shown in Figure 6. In this plant the suspension is rapidly cooled by an evaporative cooler. Crystals in the suspension are small in size and are present as diammonium phosphate. The cooler usually has a capacity to remove 5 million Btu per hour. Companies that use this process often obtain phosphoric acid during the off season and store it in pits such as shown in Figure 7. By using a low cost nitrogen source (ammonia) and phosphoric acid they usually are able to produce an 11-33-0 grade phosphate base that is competitive with delivered cost of ammonium phosphate (DAP and MAP). A plant of this type has material costs comparable to those for a bulk blend plant.

Some companies have installed regional plants for production of high analysis suspensions such as the 13-38-0 or 12-35-0 grades of base suspension. In production of these suspensions all P_2O_5 is supplied by phosphoric acid. To avoid a highly viscous product and produce a product that can be transported and stored without excessive settling, TVA developed a three-stage ammoniation process such as shown in Figure 8. In this process the first stage is a boiling reactor and the second stage is equipped with an evaporative cooler for the rapid cooling of the suspension. The third stage is for addition of a small amount of clay and ammonia. Two companies now use the process, one in the Midwest and the other in the Netherlands. Other companies have shown interest in this process. Product from the process has excellent storage characteristics, it will not settle in transit and it has an excellent viscosity at temperatures above 30°F.; however, it will not freeze to a solid mass at 10 to 15°F. Large crystals are not formed during prolonged storage. TVA has successfully demonstrated the production and use of large tonnages of the material.

Base suspension of 13-38-0, 12-35-0, and 11-33-0 grades are usually cold mixed in a small mix plant such as the one shown in Figure 9. In this plant phosphate base material is mixed with nitrogen solutions containing 28 to 32 percent N; potash and sometimes supplemental clay is added. It is a simple cold mixing procedure; no specialized equipment is required. Tanks used to store the suspensions are equipped with air spargers. These spargers usually consist of open end pipes that extend from the top of the tank to about a foot from the bottom. Once a day the suspension is agitated by air blasting with about 300 gallons of air. In this way crystals of plant nutrients remain suspended in the fluid. Usually these plants make a wide range of grades such as 14-14-14, 3-9-27, 4-12-24, 7-21-21, and 20-10-10. TVA recently has developed a nitrogen suspension made from urea and ammonium nitrate; it contains 31 percent N and 1½ percent clay. When this suspension is used in combination with phosphate base materials of 11-33-0, 33-38-0 and 12-35-0 grades, no supplemental clay is required to produce a good quality product. This is advantageous because it eliminates the problems of dust and labor in handling usually associated with use of dry clay. This nitrogen suspension is also used to produce X-O-X grades such as 22-0-11 and 14-0-28. The companies that have used this new suspension report that it flows freely during cold weather conditions normally encountered in the midwestern part of the U.S. They also report that it is an excellent product for suspending powdered pesticides and micronutrients. These types of mixtures are frequently injected into irrigation systems. Frequently these plants ship both a phosphate and a potash base to satellite stations such as that shown in Figure 10. The materials are weighed and mixed in the small mix tank. Usually the pump is used to produce this mixing. A wide range of grades such as 14-14-14, 20-10-10, and 9-18-18 are produced in these plants.

TVA and some commercial companies have developed computer programs which give formulations and application rates that will meet soil test requirements. Sometimes when commercial nitrogen solution containing 28 to 32 percent N is used in production of high nitrogen grades such as 20-10-10, problems occur in settling of material in the applicator because insufficient amounts of suspending clay are introduced by the base suspensions. TVA has developed a fluid clay to help alleviate these problems (5). This fluid clay contains 9 percent nitrogen as urea and 25 percent clay. The urea content of the product helps to lower its freezing point so that it will remain fluid during cold seasons. When fluid is used a completely separate handling system is installed. The companies that have used fluid clay report that its viscosity is not excessive in extremely cold weather conditions and that it provides a convenient way for addition of supplemental clay to suspension mixtures. They also report that it eliminates problems they formerly encountered in using dry clay and labor associated with handling the clay.

Application of Fluids

Figure 11 is a photograph of spray nozzles usually used to apply fluids. The nozzle on the right usually is used for solutions and pesticides. The one on the left is preferred for application of solution through a flooding nozzle and is used to apply suspensions. Flooding nozzles emit drops about the size of an average raindrop. When the viscosity of the suspension exceeds 800 centipoise, the fluid sometimes is applied nonuniformly from the flooding nozzle.

Summary

If anhydrous ammonia is considered to be a fluid fertilizer, over 55 percent of total nitrogen consumed in the U.S. is in the fluid form. Use of nonpressure nitrogen solution appears to be gaining in acceptance and now over 15 percent of the total nitrogen consumed is in this form. Fluid mixtures are also becoming quite popular and suspensions can be produced at a material cost comparable to that used in bulk blending. Also equipment has been developed for fluidizing granular ammonium phosphate and other solid sources of plant nutrients for suspensions. It is expected that fluid fertilizers will continue to grow at a rapid rate. They now are one of the major marketing systems of the U.S. It is the opinion of the author that fluid fertilizers will also become popular in other countries, particularly in Canada, Mexico, and western Europe.

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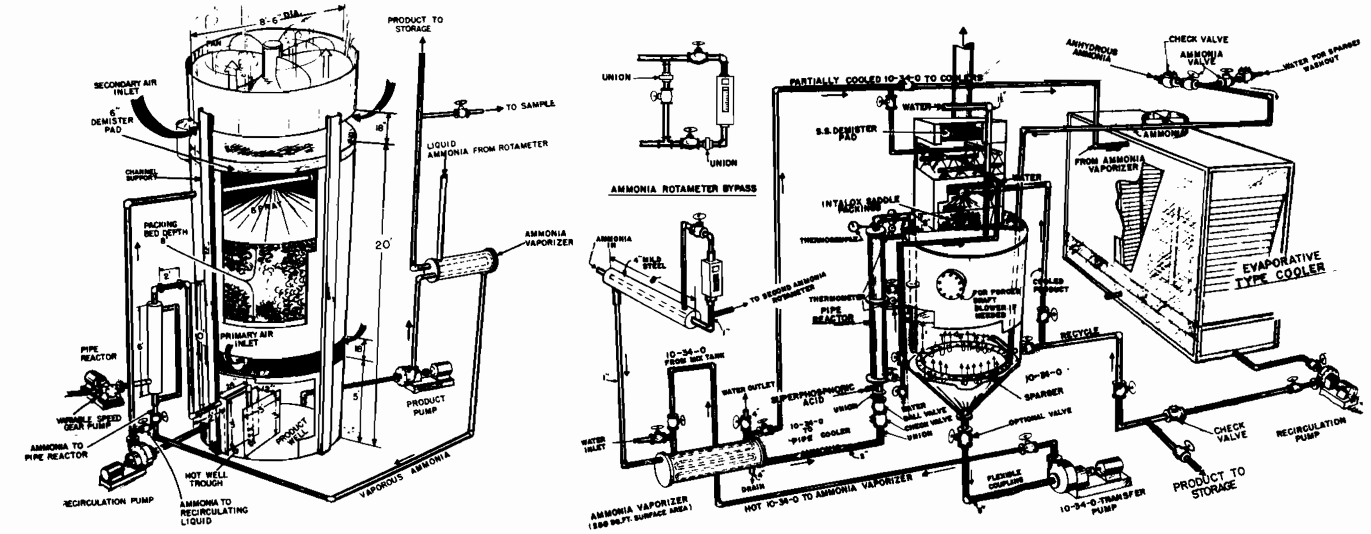


PLANT USING PIPE REACTOR PROCESS WITH INTEGRAL MIX-TANK, COOLER AND SCRUBBER

PLANT USING PIPE-REACTOR PROCESS, SEPARATE MIX TANK, AND EVAPORATIVE COOLERS

FIGURE 1
TYPICAL PIPE-REACTOR PLANTS FOR PRODUCTION OF AMMONIUM POLYPHOSPHATE SOLUTION

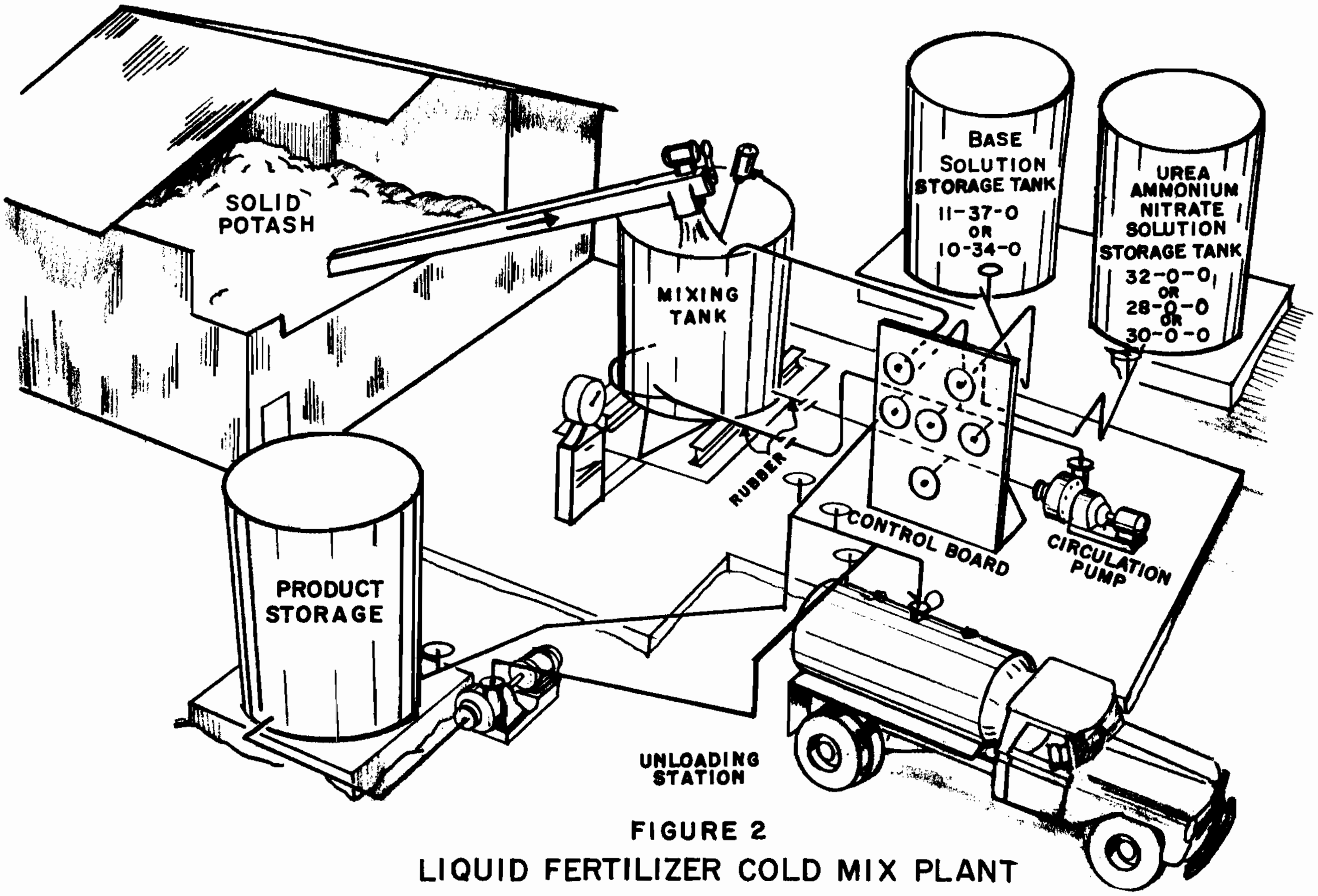


FIGURE 2
LIQUID FERTILIZER COLD MIX PLANT

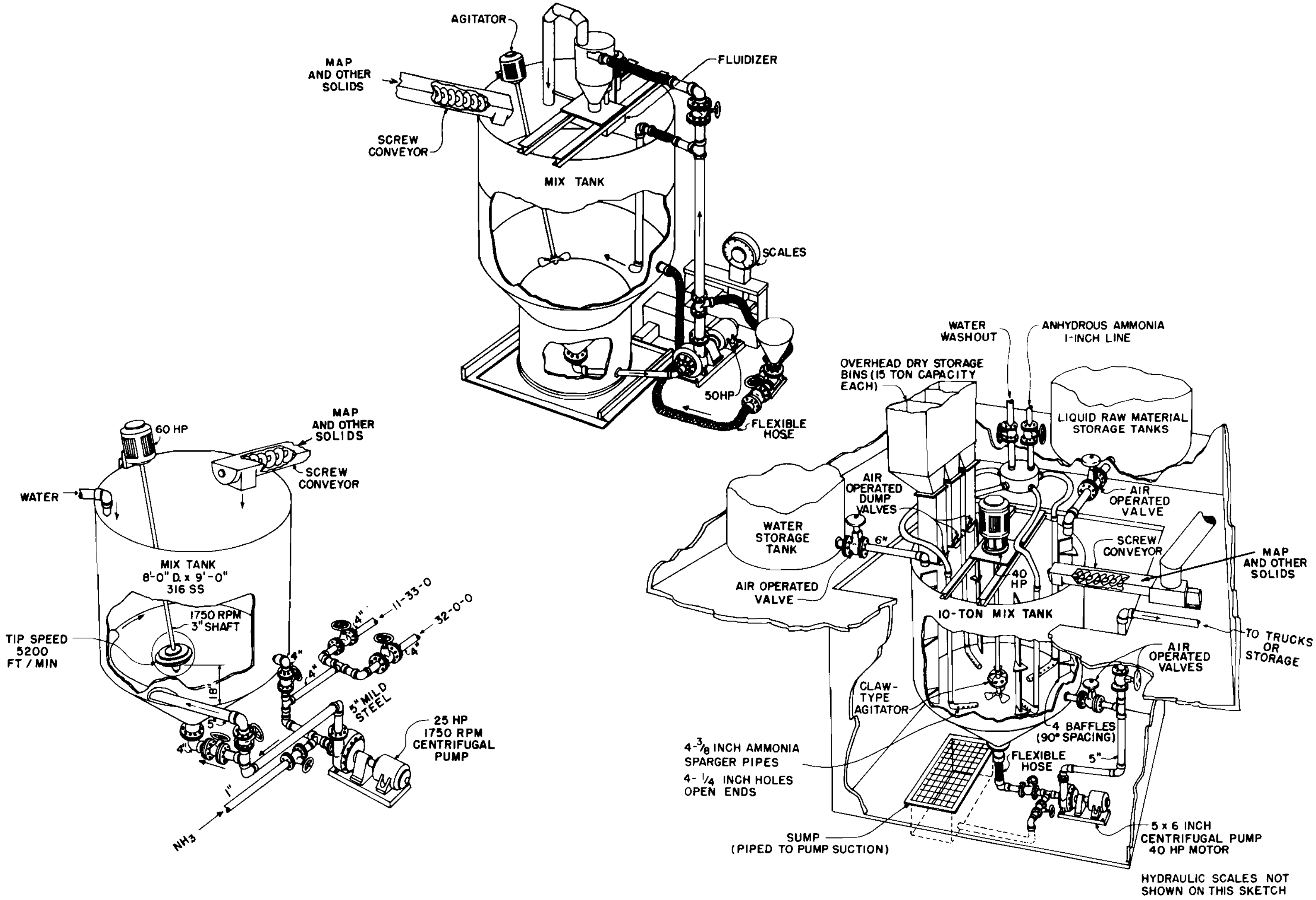


FIGURE 3
HIGH ENERGY TYPE MIX TANKS FOR SUSPENSIONS FROM GRANULAR AMMONIUM PHOSPHATES

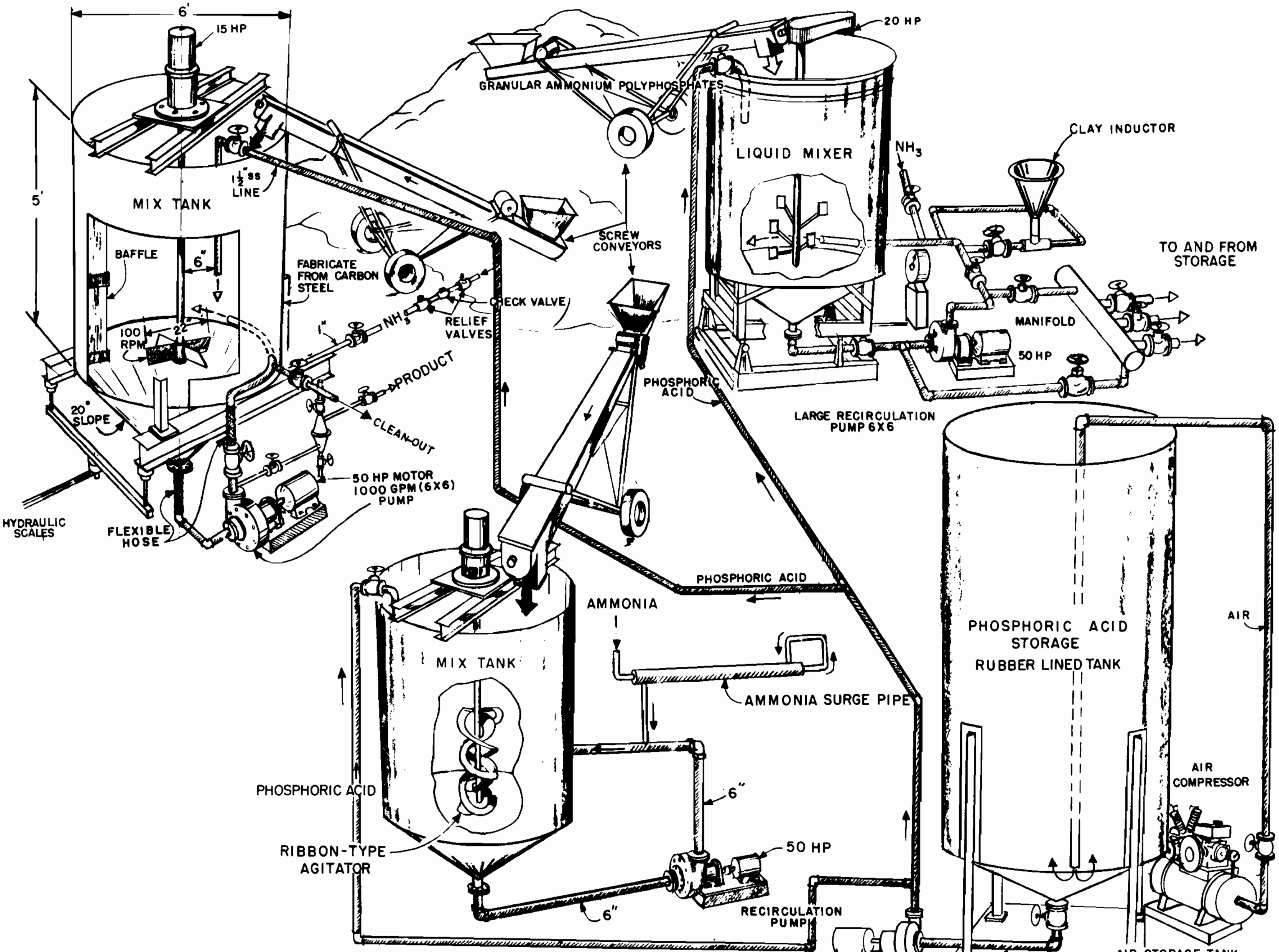


FIGURE 4

PLANTS THAT DEPEND ON CHEMICAL HEAT AND RECIRCULATION FOR FLUIDIZING GRANULAR MATERIALS

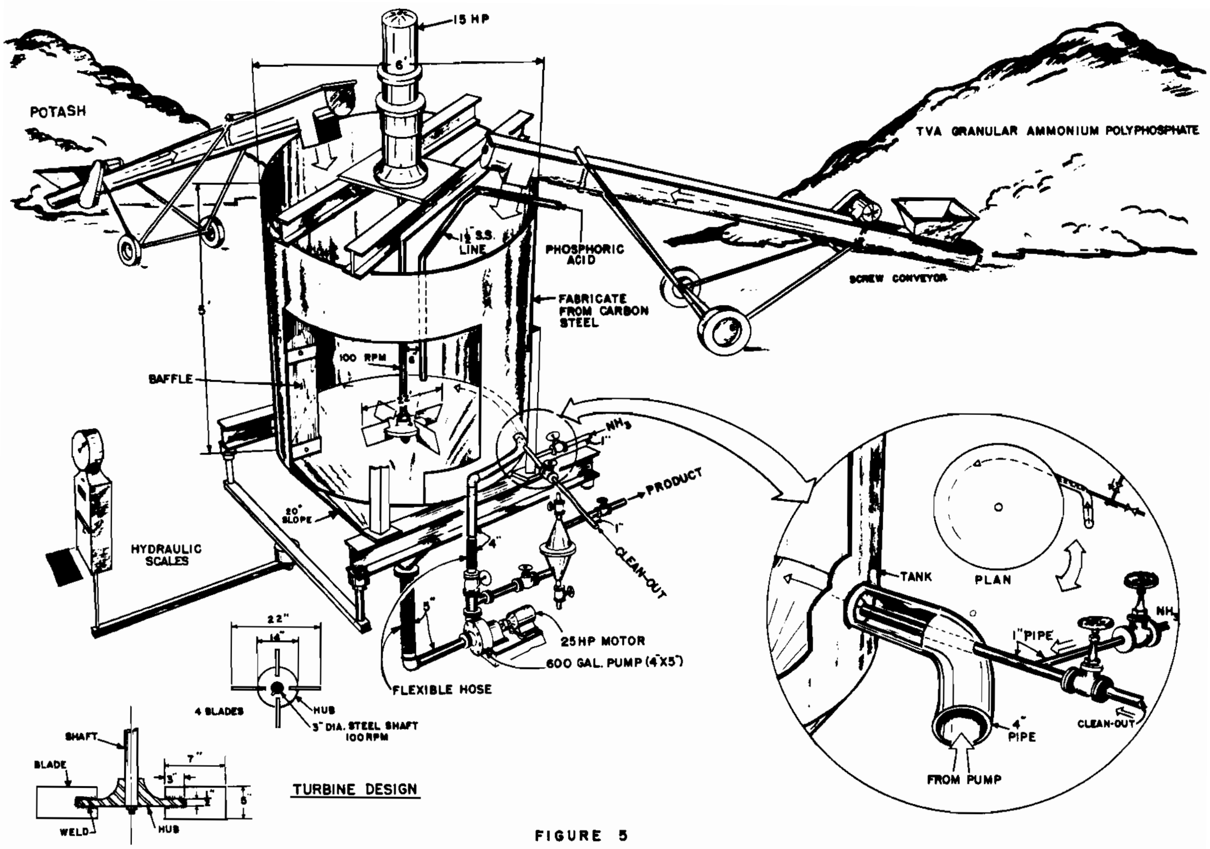


FIGURE 5

MIX TANK FOR PRODUCTION OF SUSPENSIONS FROM TVA GRANULAR APP.

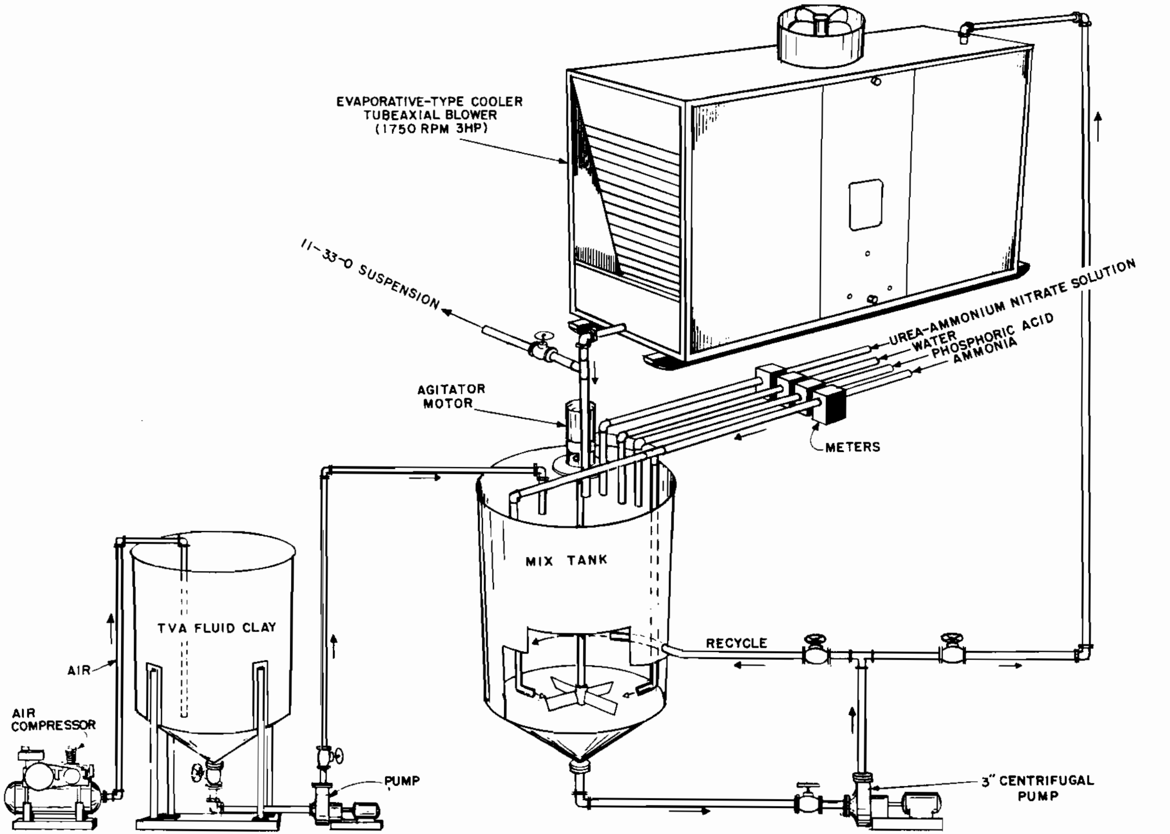


FIGURE 6

USE OF PHOSPHORIC ACID FOR NP AND NPK SUSPENSIONS

PPI SEC.-TVA

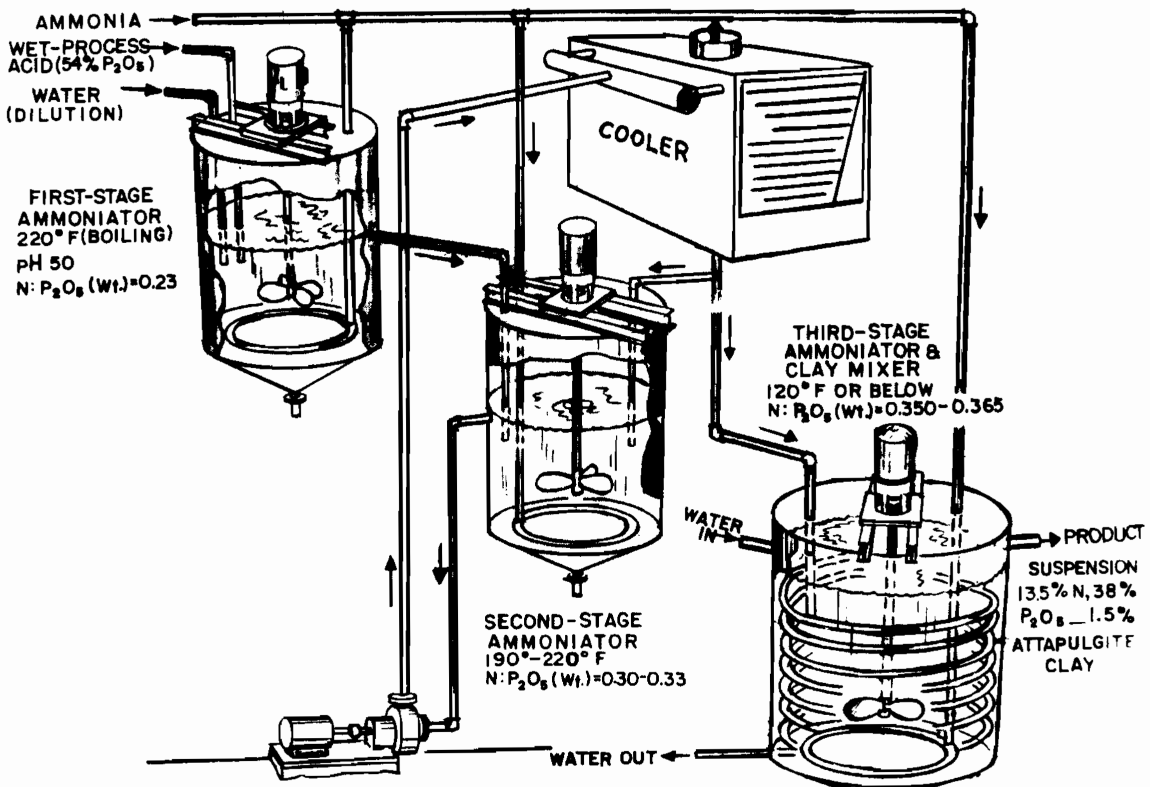


FIGURE 8

THREE STAGE CONTINUOUS AMMONIATION PROCESS FOR PRODUCTION OF 13-38-0 ORTHOPHOSPHATE SUSPENSION

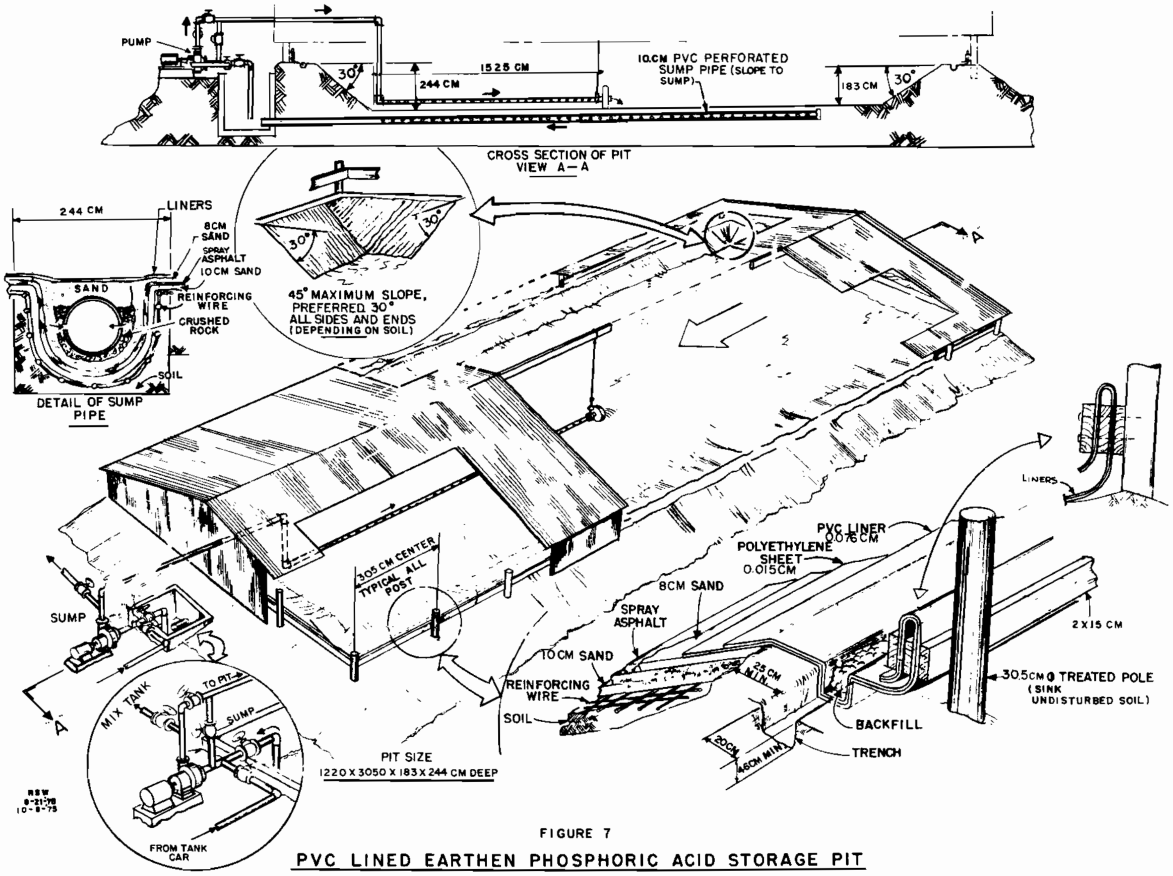
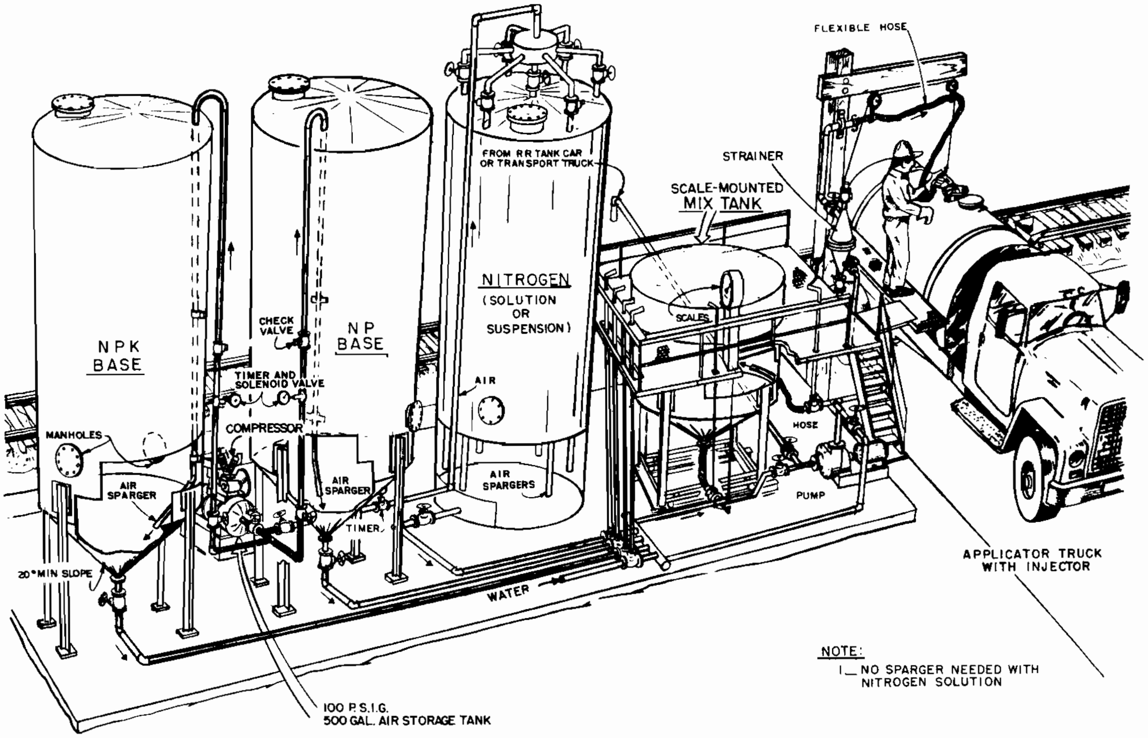


FIGURE 7

PVC LINED EARTHEN PHOSPHORIC ACID STORAGE PIT



NOTE:
1_ NO SPARGER NEEDED WITH NITROGEN SOLUTION

FIGURE 10
SUSPENSION SATELLITE PLANT

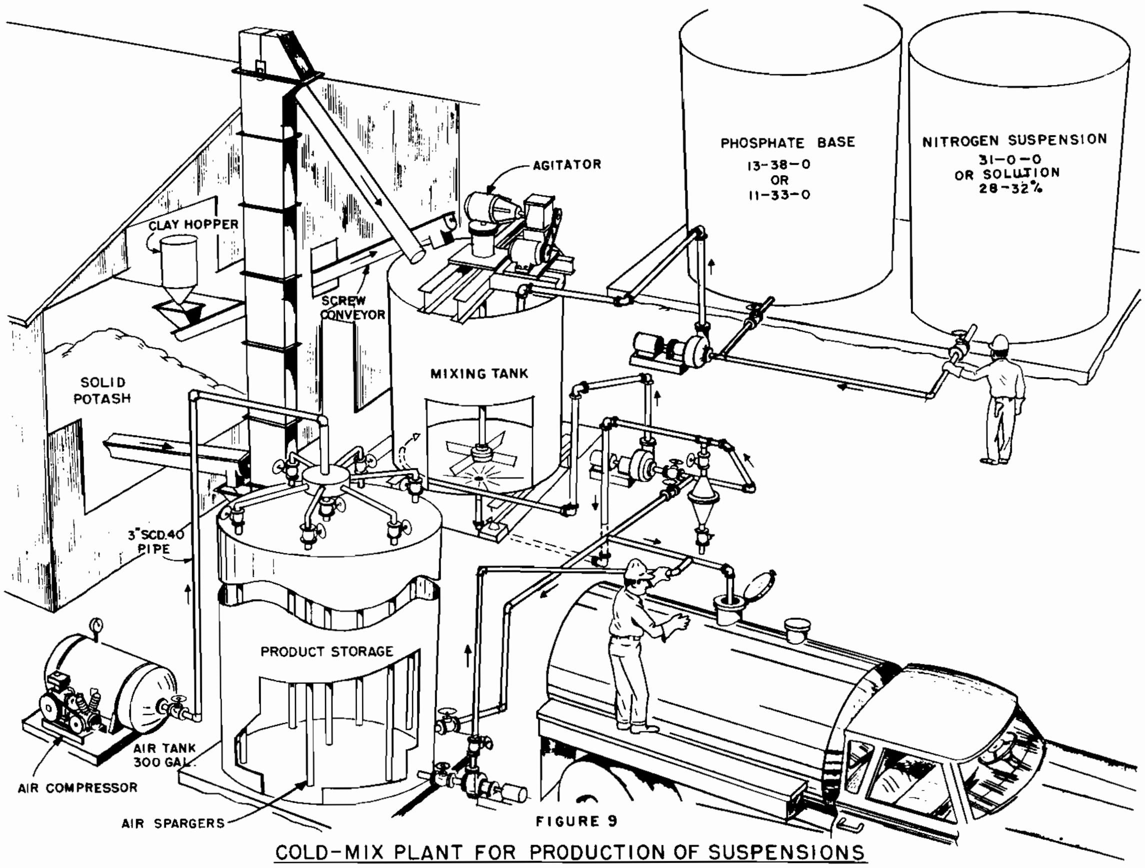
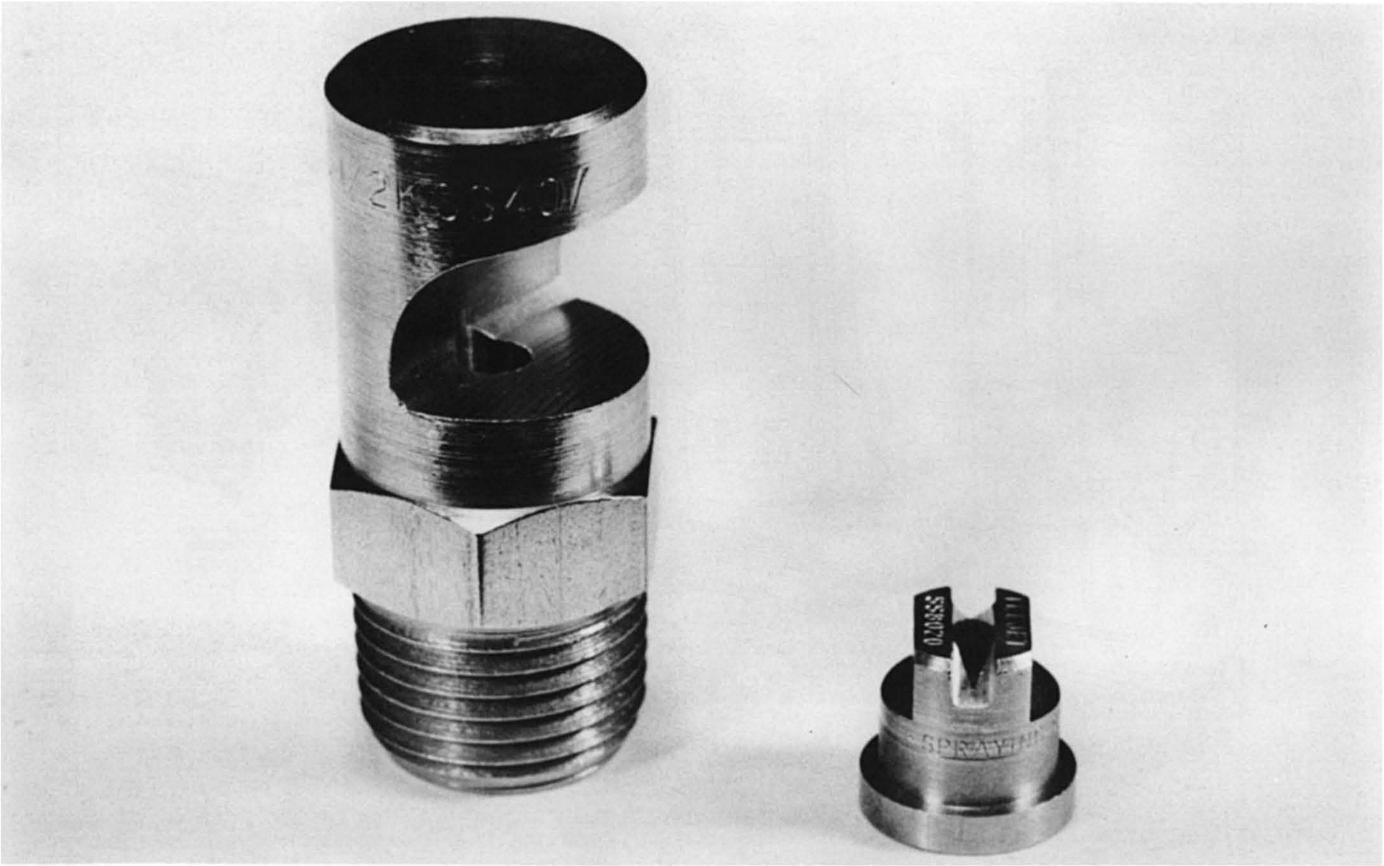


FIGURE 9
COLD-MIX PLANT FOR PRODUCTION OF SUSPENSIONS



MODERATOR LEYSHON: Thank you Frank Achorn and David Salladay. (Applause) We have time for questions.

QUESTION FROM THE FLOOR: Why use granular material if you just have to bust it up? They not non-granular?

FRANK ACHORN: That is an excellent question. I would say it would be very good if you had storage to store your phosphoric acid. Certainly you would not want to use granular material. However, if you have solid storage already available and have a blending plant, it might be practical for you to use DAP or MAP without having to put in a lot of storage for phosphoric acid and utilize the storage that is already available to you. If you decided to go with phosphoric acid storage you would need to install a pit. I see no problem in putting in a pit. some have resisted including TVA, by the way.

QUESTION: What about your storage pit meeting State and EPA's regulations?

FRANK ACHORN: We have a pit that most state agencies, at least the states of Indiana, Iowa and Carolina, have O.K.'s. The installation of this pit will meet the standards that they have set up. It is very simple. Beneath the liner in the pit is a perforated pipe. If a leak occurs in your liner, it leaks into a pipe which goes into a sump and you pump it right back into the pit again until such time as you have to repair that liner. Actually it is safer to store the acid in the pit than it is in the tank.

QUESTION, Dale Elliott: When you are storing high solid acids in a pit, how do you keep it agitating to keep the solids in suspention?

FRANK ACHORN: I wish we had the slide. It would show that the base of the pit slopes to a sump at the end, and a pipe sits in the sump, so that you suck the material out as it settles out. That is the first material you use; is the sludge that settles out in the sump.

QUESTION: With that sort of an arrangement, can you store 6 to 8% solids containing acid and could you thin it enough so that you do not have to periodically clean your pit?

FRANK ACHORN: We have had one fellow in South Carolina and I do not know what the acid solids concentration was, however, he has stored acid in pits for 10 years now, and I do not believe he has cleaned any sludge out of it yet.

DAVID LEYSHON: Thank you Frank. (Applause)

We are going to change Moderators here and I would like to introduce our Board of Director Edwin Cox III. (Applause)

MODERATOR EDWIN COX III. Welcome to the second part of this afternoon session.

Our next discussion will be given by David W. Bixby. He was born in Los Angeles, reared in upstate New York and had the good taste to move to Virginia. He is a graduate Chemical Engineer of Syracuse University, has been with the Sulphur Institute since 1962, and is currently its Director of Fertilizer Technology and Research. He has had a background which includes manufacturing, research and Engineering in Sulphur,-Phosphoric Processes and Products. He is well known to many of us either personally or by reputation.

It is my pleasure to introduce to you David W. Bixby who will speak to us on the subject of the "Addition of Sulphur in All Types of Mixed Fertilizer Including Fluids". (Applause)

DAVID W. BIXBY: Thank you Pete and Good Afternoon Ladies and Gentlemen.

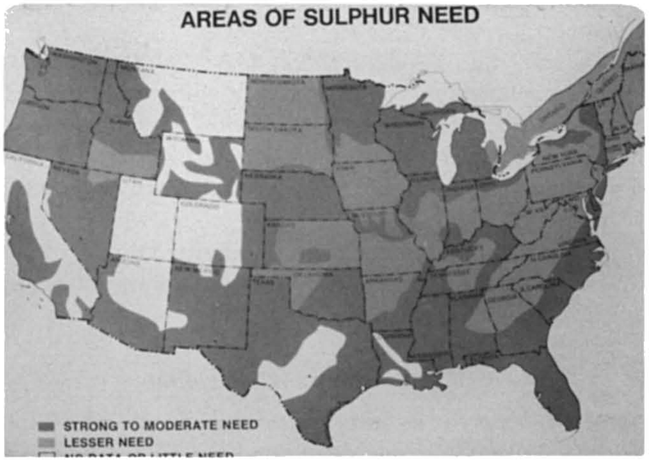
Addition of Sulfur In All Types Of Fertilizer Including Fluids

D. W. Bixby

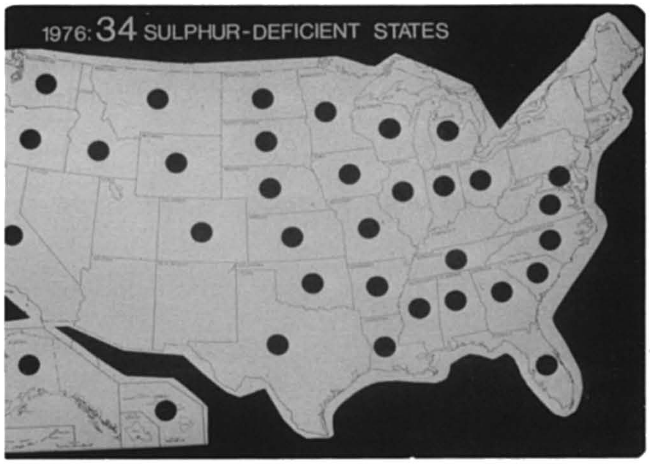
The need for sulfur in plant nutrition has been known for many years. For almost as many years, it was given little attention, because of its more than adequate incidental supply in normal superphosphate, ammonium sulfate, and the atmosphere. In the last fifteen years or so, with the advent of high analysis fertilizers and enforced reduction in atmospheric emissions, areas of sulfur deficiency have increased (Slide 1) and may now be observed (Slide 2) in 35 states in the U.S. as well as in many other countries. This story is now familiar to most of you. One thing today's agribusiness has is awareness, and its thinking is usually ahead of existing farm practices and technology — they are the leaders rather than the led. So we do not need to dwell on the need for sulfur, at least in the U.S. Further, many of you could tell me of innovations you have made in order to incorporate adequate sulfur in your fertilizer products. However, I have been asked to review the subject, and will do my best.

Elemental Sulfur

The use of elemental sulfur in pH reduction and reclamation of alkalai soils is well known, but problems of dustiness (Slide 3), unpleasantness and fire hazards have limited its utility as a fertilizer. These problems can be overcome, and advantage taken of the purity of elemental S by minimizing reduction in grade of the other plant nutrients. Several fertilizers containing elemental S which have been developed in recent years will be briefly discussed (Slide 4).



Slide 1
Areas of Sulfur Need



Slide 2
34 Sulfur-Deficient States

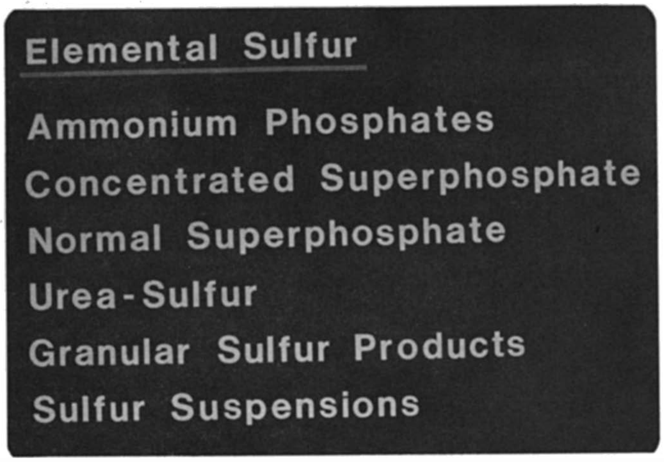
Slide 3
Problems of Dustiness,
Unpleasantness and Fire Hazard

Ammonium Phosphates

S may be added to MAP, DAP, and ammonium polyphosphates by metering it as a solid or liquid feedstream to an agglomeration device such as a TVA ammoniator-granulator, pregranulator, or blunger. These products, containing up to 15% are not known to be commercial but experimental batches showed growth response to S equivalent to finely divided S or gypsum, and were suitable for both bulk blending and direct application.

Concentrated Superphosphate

A process for making concentrated superphosphate with S (0-35-0-20) was developed by TVA using both drum and pan granulators and a spray of molten S. J. R. Simplot made a product called "Golden Triple" and although it was enthusiastically accepted in the field, it is no longer manufactured because of the fire and explosion hazards in the plant, which I believe were mostly related to. grinding of oversize. I am told that the product would be produced again, under inert atmospheric conditions, if sufficient price incentive were to develop.



Elemental Sulfur

Ammonium Phosphates

Concentrated Superphosphate

Normal Superphosphate

Urea-Sulfur

Granular Sulfur Products

Sulfur Suspensions

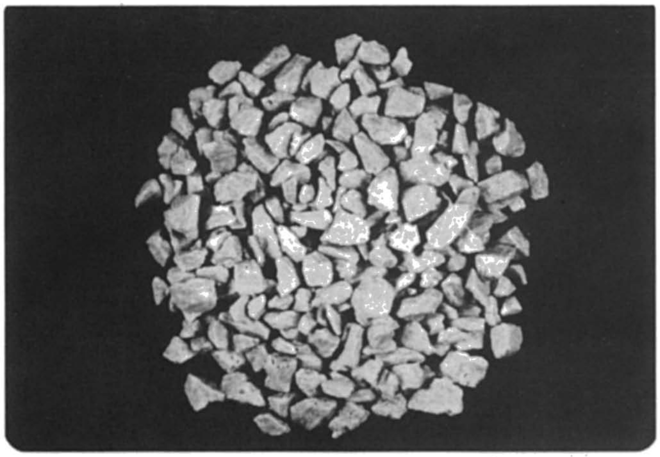
Slide 4
Elementary Sulfur

Normal Superphosphate

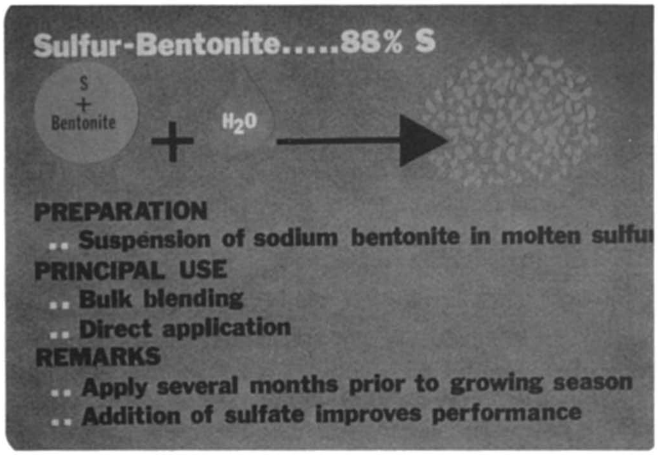
Sulfur fortification of normal superphosphate is widely and successfully practiced in Australia and New Zealand. After much experimentation the mixer emerged as the preferred point of addition with liquid S used for continuous operation, the fine solid for occasional operation. Calibrated gear pumps are used for the liquid S. In Australia a product containing 45% S added as a liquid is routinely applied from the air.

Urea-Sulphur

Urea and liquid sulfur are completely miscible and a prilled 40-0-0-10 fertilizer was marketed by Shell for a few years in the Western states. The product had excellent storage and handling properties, but the S component did not exide rapidly enough to provide adequate available S early in the growing season although it subsequently became available. A product with the same analysis but made by coating urea with finely divided sulfur using oil and calcium lignosulfonate as a binder, is being used on rice and coastal bermudagrass in the West South Central States and in Mississippi and New Mexico.



Slide 5
Prilled Sulfur



Sulfur-Bentonite.....88% S

PREPARATION
.. Suspension of sodium bentonite in molten sulfu
PRINCIPAL USE
.. Bulk blending
.. Direct application
REMARKS
.. Apply several months prior to growing season
.. Addition of sulfate improves performance

Slide 6

Granular Sulphur Products

Pure sulfur is easily prilled, but the product is agronomically unsuitable, because it takes too long to become available. (Slide 5) By incorporating 5-10% of a swelling clay such as bentonite, either a granular or prilled product which will disintegrate in the presence of soil moisture may be obtained. (Slides 6-7-8) In the finely divided state, bacteria can then oxidize it to the sulfate form which crops require. A surfactant may be sprayed on the granules, to reduce dusting and provide wettability. The material lends itself to bulk blending, (Slide 9) direct application and even aerial application. "Agri-Sul" and "Disper-Sul" are two commercial examples. Another way of achieving high surface area is to make a porous irregular granule, this is the approach taken by the producers of "Popcorn Sulphur" and "Poro-Sul." Flake Sulfur is also in use, with its effectiveness depending on flake size and thickness. For first season availability about 25% of the particles should be less than 60 mesh.

Sulfur Suspensions

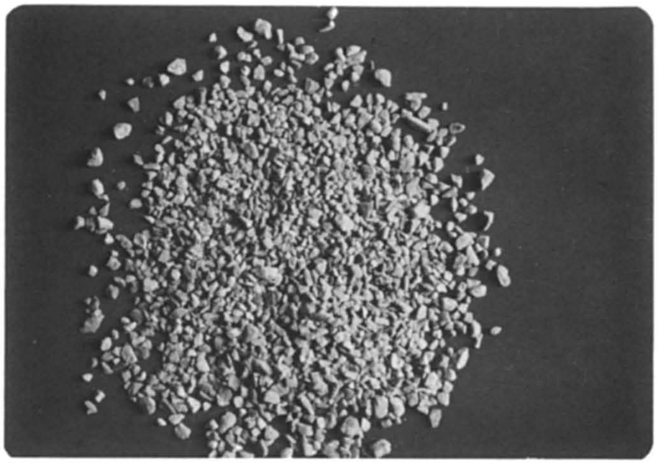
Suspensions (Slide 10) using elemental S are readily formulated. At TVA, suspensions containing 60% S and 1% clay were prepared from —20 mesh crushed lump sulfur. Complete formulation, some including micronutrients, were also prepared, using 12-40-0, UAN potash, and sulfur. a portable mixer, using engine driven impeller blades, was used by one company to make a similar product, (Slide 11) which was pumped to a field applicator (Slide 12) and sprayed with existing liquid fertilizer equipment. (Slide 13) In an Englehard brochure, (TI66), directions for a 52% suspension, using —100 mesh sulphur, call for either 1% predispersed liquid clay or 2% regular clay, plus 1% surfactant and a mixing time of three minutes.

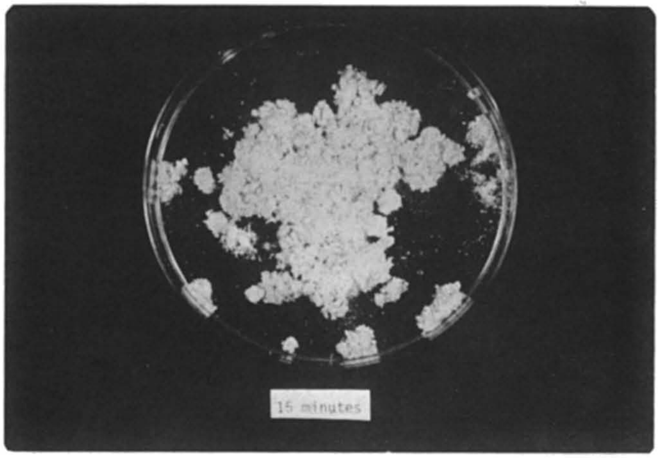
Although it was originally hoped that crude elemental lump sulfur could be readily reduced to suspension size by the suspension equipment itself, we cannot say that this method is as yet practical. Energy requirements, and required mixing efficiency and mixing times are not really reasonable. The use of dry ground sulfur is more efficient, but this product also has obvious drawbacks. It appears that the sulfur-bentonite product previously mentioned, when ground or using fines from the manufacturing process, does offer a practical solution. It is relatively less dusty than flowers of sulfur, yet is of sufficiently fine particle size to give a good short term suspension. Two or three companies are looking into this possibility and we may hear more about it in due time.

One may, of course, purchase sulfur suspensions already made up, primarily for fungicidal purposes, and use it in a fertilizer formulation. One such product is a cream yellow liquid containing 40-54% S, with particle sizes of only 1-2 microns.

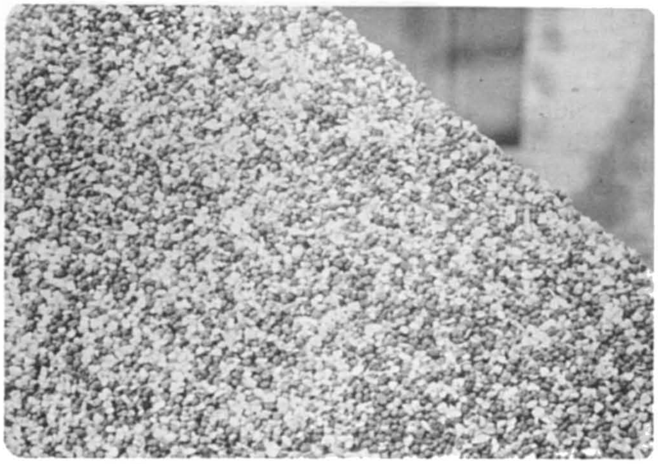
Other Fertilizers

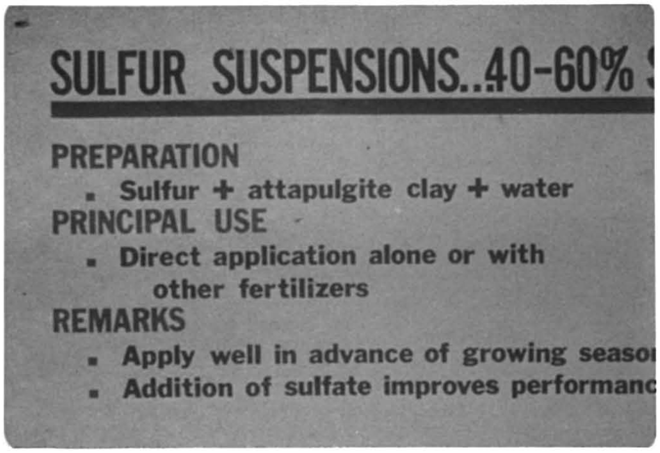
Time prevents our mentioning other fertilizers which have been combined in one way or another with elemental S such as potassium chloride, sulfur-coated urea, rock-phosphate, anhydrous ammonia and micronutrients. If these are of interest, we invite further inquiries at The Sulphur Institute. Sulfur coated urea is, of course, a special case, developed at TVA for its economical controlled release properties. However, in the process of development, TVA has accumulated a great deal of know how, in the technology of handling sulfur for fertilizer uses, which they will gladly show with you and with me.


Slide 7



Slide 8


Slide 9

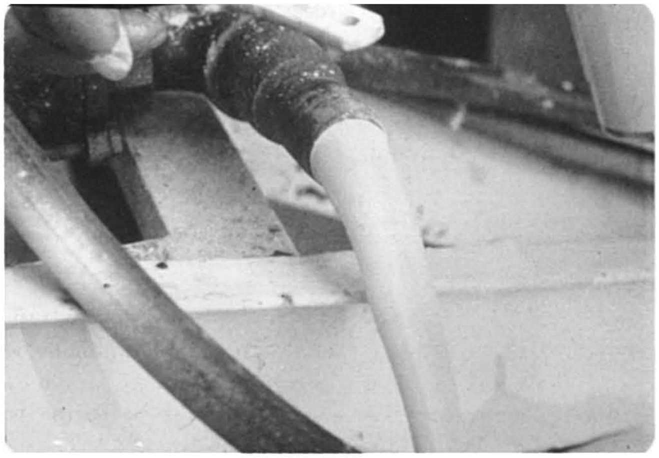

SULFUR SUSPENSIONS..40-60%

PREPARATION
- Sulfur + attapulgite clay + water

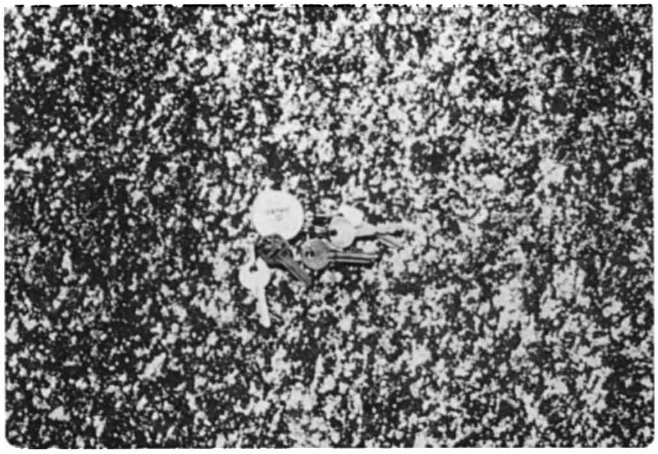
PRINCIPAL USE
- Direct application alone or with other fertilizers

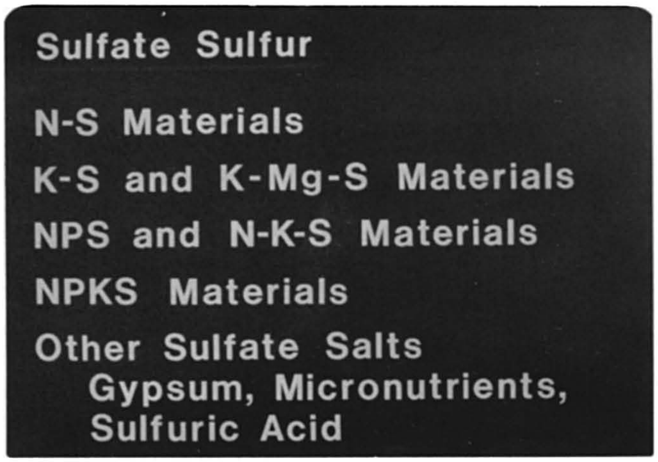
REMARKS
- Apply well in advance of growing seaso
- Addition of sulfate improves performanc

Slide 10


Slide 11

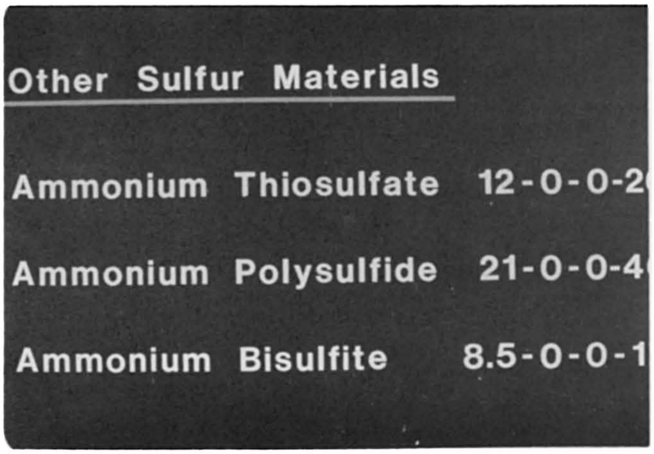

Slide 12


Slide 13
Sprayed with existing liquid fertilizer equipment


Sulfate Sulfur

N-S Materials
K-S and K-Mg-S Materials
NPS and N-K-S Materials
NPKS Materials
Other Sulfate Salts
  Gypsum, Micronutrients,
  Sulfuric Acid

Slide 14

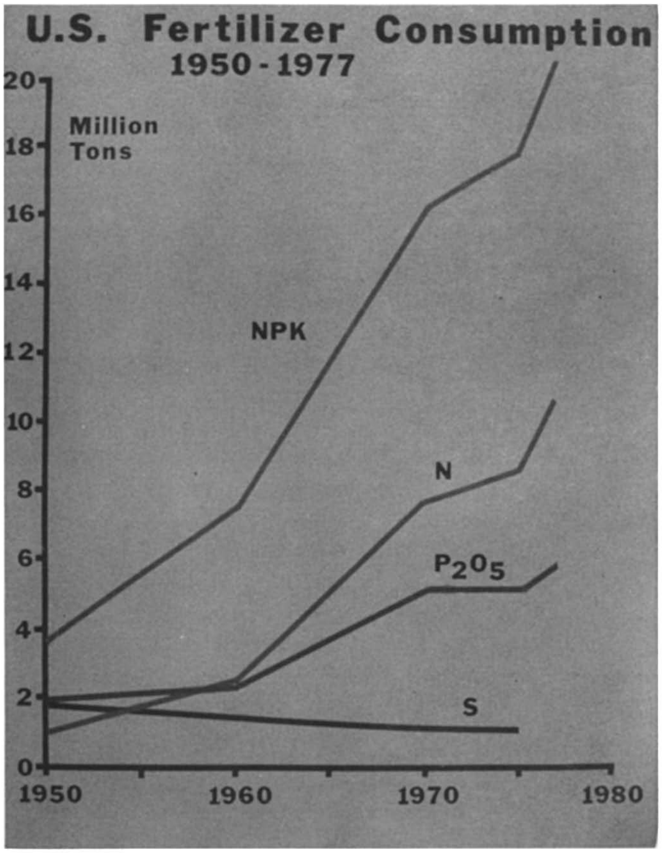

Other Sulfur Materials

Ammonium Thiosulfate	12-0-0-2
Ammonium Polysulfide	21-0-0-4
Ammonium Bisulfite	8.5-0-0-1

Slide 15

Slide 16

Slide 17



Slide 18

Sulfate Sulfur

(Slide 14) Let us now turn to the fertilizers containing sulfur in the sulfate form. These are the vehicles for by far the greater part of sulfur in fertilizer and have the advantage of supplying the element in a form immediately available to plants.

N-S Materials

Ammonium sulfate remains popular. It now accounts for perhaps four million tons of plant nutrient S worldwide. Of this, about 58% is synthetic, 16% byproduct and 26% as a coproduct from synthetic fiber manufacture. Its popularity has been due to its ability to compete in the N price area, although sometimes writing off certain costs against associated primary products. The S content is assuming increasing importance to consumers and is being actively exploited by some producers. Its uses in solid fertilizers are well known, but it can also supply up to 10% S in suspensions and being used in clear liquids as well. One example of the latter is Columbia Nitrogen's "S-25," basically a UAN solution (25-0-0-3.5) with the sulfur coming from the ammonium sulfate.

A couple of weeks ago many of you observed the production of a urea-ammonium sulfate suspension at the TVA Demonstration Program. This product made by reacting ammonia and sulfuric acid with simultaneous addition of a urea-water solution, with 1.5% clay added after cooling, has an analysis of 29-0-0-5. Handling and storage properties are good and the N:S ratio of roughly 6:1 is favorable.

Ammonium nitrate-sulfate, containing approximately equal amount of both these compounds, is less hygroscopic than either individually. The proportions of N and S (30-5) are close to actual plant requirements. At TVA the product was made by neutralizing nitric and sulfuric acids with ammonia and feeding on to recycling product in a pan granular. It is made commercially by at least two firms, for both bulk blending and direct application.

Granular urea-ammonium sulfate may be made by a variety of methods. Many of you have seen it made by oil prilling at TVA, where grades ranged from 40-0-4, to 30-0-0-13. It was also made by coating ammonium sulfate fines with urea in a granular and by air prilling. The granules have been shown to be more resistant to attrition and less hygroscopic than urea prills and may be further improved by the addition of gypsum, which forms a complex with urea. The N:S ratio may be varied from 3:1 to 7:1 enough range to correct N and S deficiencies in most soils.

Commercially, a urea-ammonium sulfate product analyzing 40-0-0-6 has been very well received in western U.S. and Canada.

Here, perhaps, is as good a place as any to mention the apparent utility of the pipe cross reactor, which with its introduction of sulfuric acid to the system, offers a method of preparing a number of grades containing sulfur. In Europe, SA Cros is engaged in development work on urea based N:S combination two of which are 40-0-0-5 and 26-0-0-15. Sulfuric acid, liquid ammonia and urea solution are fed to the reactor under concentration conditions controlled so as to avoid urea decomposition.

K-S and K-Mg-S Materials

Potassium sulfate and potassium magnesium sulfate are important sources of plant nutrient S. They have speical uses such as when chlorine-free K is preferred, as on tobacco, or in areas where the chloride ion is unwanted because of already high levels of soluble salts in the soil. In some areas they are applied as sources of K, Mg and S individually, or to remedy multiple deficiencies of these elements. Both are doing very well in the fertilizer market place these days, being adaptable to direct application with granular material available for bulk blends and fine material for suspensions.

In the suspension area, potassium sulfate, being less abrasive then the potassium magnesium sulfate, may have had a certain advantage. However, at least one company has some coming out with a potassium magnesium sulfate product that is ground to —20 mesh, then regranulated. Without the sharp edges the abrasion problem will be considerably reduced if not eliminated.

NPS and NKS Materials

Ammonium phosphate sulfate 16-20-0-14 remains a very popular grade. It contains about 40% MAP and 60% ammonium sulfate. It is commonly made by neutralizing a mixture of phosphoric and sulfuric acid into a phosphoric acid plant reaction circuit. Other NPS materials have included 15-30-0-8, 19-9-0-20, 13-39-0-20 and 23-0-27-7. The latter uses some urea. A recently offered soluble granular NKS material has a 20-0-20-7 analysis, with sulfur supplied by potassium sulfate.

At TVA the latest modification of their pipe cross reactor has been used to make three NPS grades; 12-48-0-3.6, 16-20-0-14, and 32-16-0-3.6, as well as DAP using some sulfuric acid. Details of these operations were presented in a paper given by Mr. I. W. McCamy at the ISMA technical meeting last week. Rates of sulfuric acid up to 500 lbs./ton of product (7.5% S) were used, and could have been higher if higher feed pressures were available. There are presently about 15 such reactors being used in the U.S., which presumably have the capability of making sulfate grades in this manner. And of course you heard yesterdays Panel discuss several aspects of their pipe reactor operations, some of which included sulfuric acid.

Any complete fertilizer making use of ammonium, potassium, or potassium magnesium sulfate is of course automatically an NPK plus sulfate sulfur-material. Many manufacturers are now exploiting this sometimes newly discovered aspect of their products which are too numerous to list here.

Other Sulfuric Salts

Gypsum is used as a source of S in some areas where it is mined or produced as a byproduct. Its low nutrient analysis, 13-10% S, limits the extent to which it can be profitably used for fertilizer purposes. Nevertheless, it has an important part of the market, assisted by its present availability in an easily spreadable granular form, and the added bonus of its calcium content.

The sulfate salts of micronutrients are also incidental carriers of S. The group consisting of copper, zinc, iron, and manganese for example, range from 13 to 21% sulfur as sulfate.

Lastly, there is sulfuric acid itself, which, like gypsum, is used primarily as a soil amendment but supplies incidental plant nutrient sulfur.

Other Forms Of Sulfur

(Slide 15) There are three materials containing reduced or partially oxidized S compounds which are used in the rapidly growing market for fluid fertilizers. These are ammonium thiosulfate, ammonium polysulfide, and ammonium bisulfite.

Ammonium Thiosulfate

Ammonium thiosulfate solution 12-0-0-26 is the product most widely used in clear liquid fertilizers today and is being used in some suspensions as well. It is prepared by reaction of SO_2 and aqueous ammonia followed by further reaction with elemental S, although variations on this method may exist. Solutions of ammonium thiosulfate are compatible in any proportion with neutral to slightly acidic ortho and polyphosphates, aqueous ammonia and nitrogen solutions. Blending of a wide variety of NS, NPS and NKS formulations is usually feasible although trial blends are recommended, especially for potash grades, before going to large scale mixing. Storage temperatures should be between 30° and 100°F. Steel and aluminum are suitable materials for storage containers.

Ammonium thiosulfate is applied directly to open ditch and sprinkler irrigation systems as well as to row crops. It should be at least 1" away from seed. It has favorable soil amendment properties as well, but there are less costly alternatives for that purpose.

Ammonium Polysulfide

Ammonium polysulfide, 20-0-0-45, is a highly alkaline (pH10) reddish brown solution with a strong odor of H_2S. It is made by reacting aqua ammonia with H_2S and elemental S in the presence of heat and agitation.

The product is compatible with anhydrous ammonia but not with acidic solutions in which it decomposes to yield H_2S and elemental S. Generally it is not considered suitable for mixing with phosphate solutions although there are exceptions. Complete liquids containing up to 7% K_2O have been made. Black iron, aluminum or stainless steel should be used for handling. Storage temperature are the same as for ammonium thiosulfate. While competing with ammonium thiosulfate in many plant nutrient S applications, ammonium polysulfide is often used primarily as a soil amendment. (Slide 16) It is applied in open ditch irrigation systems, by injection, and when diluted, applied by spray applicators.

Urea ammonium polysulfide solution is marketed and applied in irrigation water to vegetable crops on problem soils, when additional N is thought necessary. One grade (29-0-0-10) is a blend of 32% N solution and ammonium polysulfide, another is 25-0-0-35 made with the polysulfide and dry urea.

Ammonium Bisulfite

(Slide 15) This byproduct of smelting operations is made by absorbing SO_2 gas in aqua ammonia. It is available commercially at least in the northwest as a 55-60% solutiuon containing 8.5%N and 17% S. The solution is non pressure with a pH of 5.2. Like ammonium thiosulfate and ammonium polysulfide, it cannot be used in acidic solutions. Inhibited mildsteel, aluminum and plastic are suitable container materials.

There are still other forms of sulfur which have been the subject of successful experimentation but which have not become commercial for economic reasons or because of handling problems. These included sulfur dioxide and several more exotic materials.

CONCLUSION

(Slide 17) We have briefly reviewed the most important sulfur-containing fertilizer materials all of which are being used in one way or another by the fertilizer industry today. Some are being used deliberately to enhance S content. With others, the sulfur which was not too long ago though of as a dilutent or at most incidental, is now given recognition and in many cases guaranteed. We must say that it is still the old standby that are supplying the bulk of the sulfur— ammonium sulfate either added or made *in situ*, potassium sulfate or potassium magnesium sulfate and of course the gypsum in normal super. The roughly 2% residual S in MAP, DAP, and triple are often a prominent part of the sales description and an important part of the analysis even if not charged for.

(Slide 18) In closing, we would like to show you this chart, showing the trend in U.S. consumption of NPK, N, P_2O_5 and S. The three top lines are familiar to you, but the bottom one representing S may be less so. Back in 1950, the sulfur content of fertilizers was more than it needed to be, even exceeding N. In 1975, it was, on the average, less than the recommended 5:1 N:S or 3:1 P_2O_5:S rates. In urban areas the deficiency was probably made up by atmospheric S, but in rural areas it was not. The S curve appears to be leveling off and will need to rise a bit to keep pace. With the present awareness of the need for plant nutrient sulfur, indications are that it will.

Although only superficial treatment of our subject was possible at this time, we would be glad to furnish further detail on request to those with a particular interest.

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"Production, Marketing and Use of Sulphur Products." J. D. Beaton. Fertilizer Technology and Uses, 2nd Ed., Soil Science Society of America.

Safety in Handling of Sulfur

National Safety Council Data Sheet 592, "Handling Liquid Sulfur."

National Safety Council Data Sheet 612, "Handling Storage of Solid Sulfur."

MCA Chemical Safety Data Sheed SD-74, "Sulphur."

National Fire Protection Association Bulletin No. 655, "Prevention of Sulphur Fires and Explosives."

MODERATOR COX: We have time for questions.

QUESTION, Robert Sommerville: Out in the West it was noted that organic sulphur seemed to work better than elemental sulphur, which is attributed to the presence of sulphur bacteria along with the sulphur. I wonder if any thoughts have been given to inoculating sulphur mixtures?

DAVID W. BIXBY: I am not aware that thought has been given to inoculation of sulphur mixtures in the United States. You may or may not be familar with the work of one Dr. Souave, I think, in Australia, who for many years has been promoting a product called biosuper. This is not quite the same thing, really. No I know of no instance where Bio-Bacilli have been deliberately introduced in order to help the sulphur break down more readily.

QUESTION, Robert Sommerville: The other question was: In your sulfide chemicals has anyone been using liquid lime sulphur? It is easily prepared. It is calcium-poly-sulfide and you make it by cooking sulphur and lime.

DAVID W. BIXBY: I guess they have. I tend to think of that as more in the fungicidal area and I was not really going to get into that subject at all, anymore than I was going to get into sulphur supply and demand, which is another subject altogether. Yes, I suppose they have, and I really cannot respond to that questional intelligently.

MODERATOR COX: Thank you David. (Applause)

Our next speaker was born in Lawrenceville, Pennsylvania and received a degree of Bachelor of Science in Horticulture from Penn State University. After service with the Marine Corps, during the second World War he returned to private life, next to Graduate School at North Carolina State and since 1952 has been with the J. E. Baker Co. He is currently the Sales Representative in the field of Sales and Marketing of agricultural and industrial limestone production. He was instrumental in developing, refining and marketing their product "Grandol" which is a granular dolomite to the Fertilizer Industry. He is a member of the Round Table Board and it is a pleasure to introduce to you Mr. Harold I. Jones, who will speak on the subject, "Granular Limestone In Blend Plants". Mr. Jones please. (Applause)

HAROLD I. JONES: Thank you Pete. I do not know how they get a limestone man in here. I guess maybe to help neutralize all this acid that has been tossed around today!

Several months ago at the last Board Meeting they asked if somebody would discuss "Granular Limestone In Blend Plants". We furnish this material for Blend Plants and Granular Plants as well. Perhaps many of you do not know our Company. We are located in York, Pennsylvania with plants in Millersville, Ohio and York, Pa. The products I talk about today will be from our York plant.

Granular Limestone For The Fertilizer Industry

Harold I. Jones

The J. E. Baker Company is located in York, Pennsylvania with quarries and plants in Millersville, Ohio and York, Pennsylvania.

We are primarily and basically manufacturers of dolomitic refractory products for the cement and steel industries, namely (1) Burnt Line, (2) Dead Burned Dolomite, (3) Dolomite Brick for Basic Oxygen Steelmaking Furnaces, (4) Dolomite Brick for Cement Kilns, (5) Raw Fluxing Limestone and (6) Specialty Dolomitic Products for the Steel Industry.

Second, because of having an excellent quality multicolored dolomitic limestone, ($Ca\ Co_3$ - 53.5%, $MgCO_3$ - 42.0%) our by-roducts, some natural, others manufactured with additional screening and pulverizing, make exceptionally good agricultural products for the farm, fertilizer manufacturing, lawn and garden trade and some industrial requirements, namely (1) Baker's Ag-Dolomite, (2) Sweet N' Grow, (3) Baker's RP-40, (4) Baker's Commercial, (5) Baker's 10-Mesh Dolomite, (6) Baker's RP-12, and (7) Baker's GRANDOL (granular dolomite) which is produced in two sizes. "Regular" GRANDOL, 6 x 20 Mesh used in both blend and granulation plants and "Fine" GRANDOL, 7 x 20 Mesh used in blend and granulation plants primarily for lawn and garden grades, can also be used in Commercial grades.

Material Flow & Major Equipment In Grandol Production

Quarry:

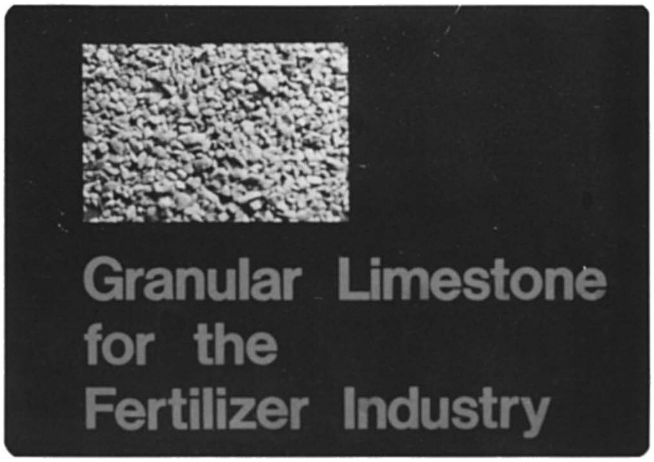
The amount of stone to be extracted from the quarry and processed is projected and determined by sales forecasts, each year, for all products.

(Slide 2) After blasting, stone 0" x 54", is hauled to the primary crusher (Cedar Rapids Universal Impactor) which has a maximum production, open circuit of 1200 TPH. Our present system, closed circuit is operating at 620 TPH. The stone leaving the primary crusher has a maximum size of 4-1/2" and is conveyed to four 4' x 14' Flat Deck Iowa Screens which are doubled decked. Material — 2" x 0" is conveyed to 15,000-ton covered storage and/or grinding plant. Material larger than - 2" x 0″ is recycled back to primary crusher for reprocessing.

Grinding Plant

(Slide 3) Material — 2″ x 0″ is conveyed directly and/or from covered storage to four Allis Chalmers 5′ x 14′ Triple Deck Screens. The — 3/16″ material that passes thru the bottom deck is conveyed to the Dryer System. Material — 2″ x +3/16″ is conveyed onto a Symons Crusher for processing.

Material, plus the — 3/16″ from Grinding Plant, and surge bins are then conveyed to the Dryer System.



Granular Limestone
for the
Fertilizer Industry

Slide 1

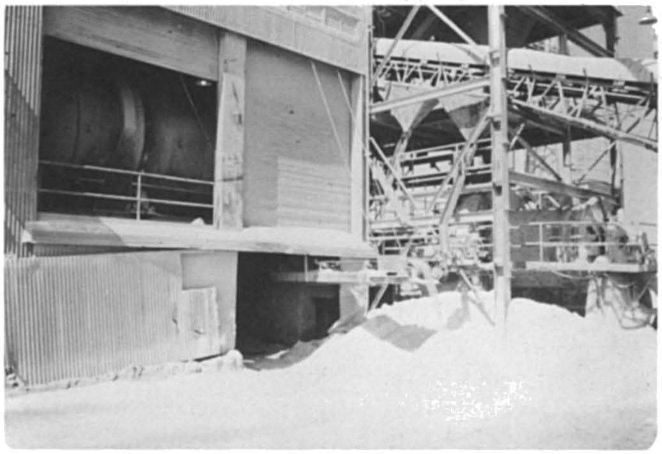
Slide 2

Dryer System:

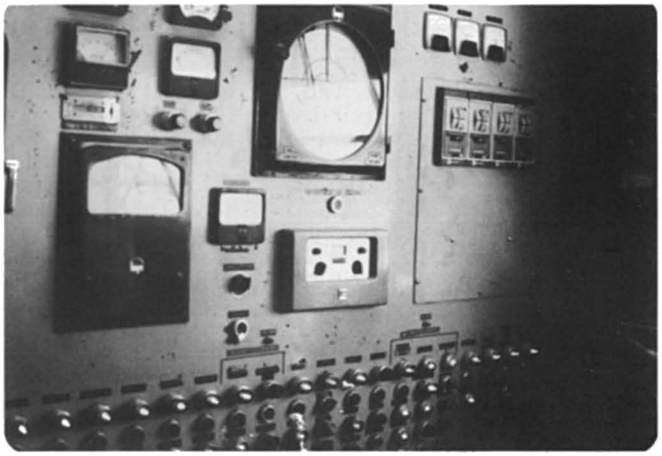
(Slides 4-5) The dryer, gas and/or oil fired, is a Simplicity Rotary Dryer 10′ x 23′ with double flow and handling approximately 72 TPH. The control panel is quite sophisticated so that the flow of product to and from the dryer will be under full control and is dried from an average of 2% to .05% moisture.

Material from the dryer is conveyed to Hewitt Robbins Double Deck Screen, 5′ x 14′ where 1″ and 6-Mesh splits. The — 6 Mesh is conveyed directly to the No. 1 Separator and the +1″ and +6 Mesh is conveyed to either the Bradley-Hercules Mill or the Pennsylvania Crusher (Impactor) for the production of Ag-Dolomite, GRANDOL plus other products.

Slide 3



Slide 4



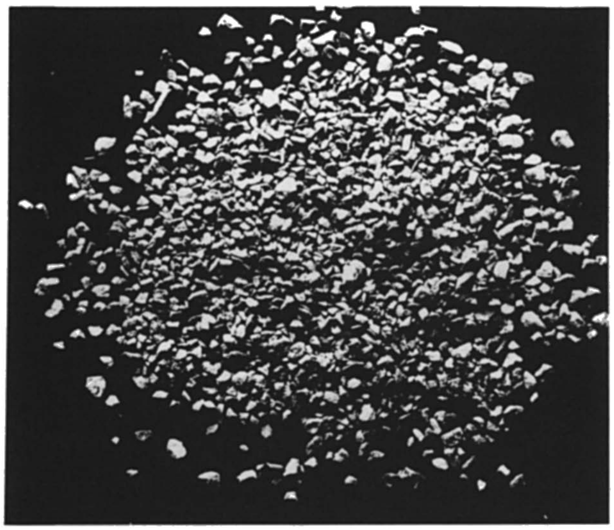
Slide 5

Bradley Cycle:

Material conveyed to Bradley with a 3/16″ screen will produce mostly GRANDOL However, with a 7-Mesh to 12-Mesh ton cap screen on mostly Ag-Dolomite is produced. Material from Bradley is conveyed to No. 1 Separator.

Pennsylvania Crusher System

This operation produces mostly GRANDOL. Material conveyed to Pennsylvania Crusher and then to Syntron Model RVS Single (6-Mesh) Deck Screen, 5′ x 14′. The plus 6-Mesh is returned to the Pennsylvania Crusher for additional processing and the — 6 Mesh is conveyed to the No. 1 Separator.



Slide 5A

No. 1 Separator:

This equipment is a Sturtevant, sixteen feet in diameter air separator set to separate at 20-Mesh. Twenty Mesh is Ag-Dolomite and is conveyed directly to storage.

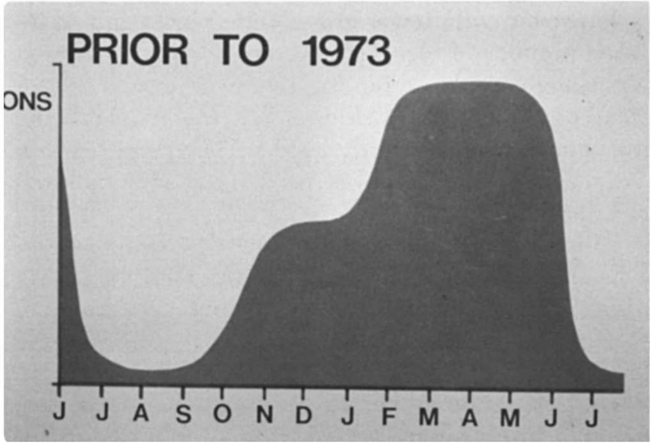
The plus 20 Mesh is conveyed to four Derrick Screens; one 2′ x 6′; one 3′ x 6′ and two 3′ x 8′. These four screens remove the "fines" and clean the GRANDOL and eliminates the 12 x 20 Mesh which is stockpiled or returned to the Ball Mill System to be milled into Ag-Dolomite.

The plus material goes over a Link Belt Double Deck 4′ x 8′ Screen where plus 6-Mesh is pulled off and put into kiln feed. In addition, at this point, the 6 x 7-Mesh fines can be pulled out to make "Fine" GRANDOL.

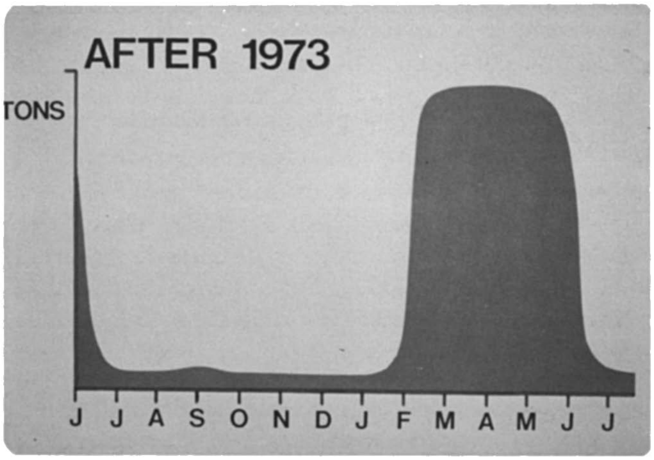
Finished Product:

(Slide 5A) The finished GRANDOL is produced at the rate of approximately 25 TPH which is stockpiled and/or put into bins DRY or OILED by a spray system (fan-jet nozzle) within the chutes leading to the storage bins. The oil used is Sunpar-110 and is applied at the rate of 1 gallon/ton of finished product.

AT the present time, our production is approximately 90% "Regular" GRANDOL and 10% "Fine" GRANDOL. Tonnage is shipped via rail (40%) and truck (60%).



Slide 6
Figure 1



Slide 7
Figure 2

Market Area:

Our market area consists of the Northeastern part of the United States shipping to the Eastern Shore of Virginia to the state of Maine.

It is our experience that granulation plants are becoming less in number in our market area, because of several reasons; (1) pollution problems, (2) too expensive to remodel some of the older plants, and (3) some granulation plants are being converted to blend plants. In addition, there has been an increase in the number of blend plants. For these reasons, the demand curve for GRANDOL has changed considerably within the past five to seven years.

(Slide 6) Figure 1 indicates that with a greater number of granulation plants, more raw materials were being shipped during September to February of the following year because of the first mixing and curing by the granulation plants. Shipment of the first mixing and starting of the second mixing occurring during February to June.

However, with fewer granulation plants and an increased number of blend plants, considerable less mixing is being done from June to the following February. Instead of mixing, the stocking of raw materials is being done during the same period. Then, starting in February, depending on weather, comes the quick demand for GRANDOL as shown in Figure 2 (Slide 7)

This situation added to the fact that rail cars and trucks are becoming more and more difficult to obtain during the time of shipment of additional raw materials, we strongly urge the fertilizer manufacturers to increase their amount of protective storage and not only obtain NP & K but granular limestone, as well, at an early date to help insure continuous running of their fertilizer operation.

MODERATOR COX: Do you have any questions for Harold? Thank you Harold for your most interesting discussion.

Our next speaker is known to many of you as a song, dance and harmonica man. He was born in Bloomer, Wisconsin and educated there. During the second World War he served with the Air Force. Subsequently he attended the University of Wisconsin from which he received a Bachelor of Science in Chemical Engineering. From 1964 to date has been with Fertilizer Engineering and Equipment Co., Inc. in Greenbay, Wis. He is Vice President in charge of Process Engineering and Equipment Design. He is a member of the Board of The Fertilizer Round Table. It is a pleasure to introduce to you Glen H. Wesenberg. He will discuss with you "Selection, Application and Desirable Features of Bag Type Collectors" Glen please. (Applause)

GLEN H. WESENBERG: Thank you Pete. Good afternoon Ladies and Gentlemen. I will make one correction. Our Company name was changed to FEECO International, Inc. Several years ago, and when I transmitted an old resume to Pete, thru an oversight, I failed to make the change.

I was pleased to get to Atlanta and was quite surprised, coming from the airport the other night, the Falcons seemed to support their fans about like they do in Green Bay. Our driver went about three miles in neutral coming from the airport.

Selection, Application and Desirable Features of BAG Type Dust Collectors

Glen H. Wesenberg

In the handling and processing systems of dry type fertilizer materials dust is commonly generated and the turbulence from handling and processing causes the dust to float with any air currents. Therefore, any open areas where sufficient process suction does not exist, will emit dust to the atmosphere. The first step in minimizing this dust emission is to enclose the system as much as possible. Clear plastic PVC strips can be used very successfully to decrease open areas where movement and periodic access are required.

Next, utilize any necessary process air movements that can be used beneficially to eliminate dust emission.

After these steps are taken, bag filter type dust collectors should be considered for purging dust from various basic application areas.

The function of a bag filter is to remove dust particles from a high velocity air stream by filtering or straining the dust from the air *without excessive resistance to air flow* and capable of having the dust periodically removed from the filtering media. The larger the filtering media area the slower the velocity and resistance to air flow. With slower particle impingement velocity the less the impaction and the easier it becomes to remove the dust upon cleaning.

Therefore, a well designed bag house will distribute the air uniformly through the filter media, provide a means of removing dust during continuous or intermittent operation, be structurally sound, chemically resistant, and having all components readily accessible for maintenance and inspection.

It is important to note that the filter fabric is only part of the filtering media. After a short time the fabric, either in tubular or cylindrical form vertically mounted, or in an envelope shape, becomes caked with a layer of dust, and this dust cake actually becomes the filtering medium. The first slide shows this cake buildup (Slide 1). Therefore, it is *extremely* important to initially develop a uniform, low resistant cake when starting with clean bags. Excessive moisture in the air or prolonged operation with extremely fine dust during this cake development period will result in low permeability, decreasigng cake porosity, and increasing resistance to air flow, and the filter will rapidly become inoperable.

FABRIC FILTER TYPES AND FEATURES

Let us review the latest basic types and features of fabric filters, commonly called bag filters, bag collectors or bag houses.

1. The next slide (Slide 2) shows a *REVERSE AIR FLOW FILTER* — This type filter is equipped with an auxilliary fan that forces air through the bags in the direction opposite to filtration. This back flush action flexes or collapses the bag releasing the dust cake.
2. The next slide (Slide 3) shows a *FLAT BAG FILTER WITH CONTINUOUS REVERSE AIR CLEANING TRAVELER:* — This type filter cleans one bag at a time with clean air from a reverse air blower and flexible traveling hose while stopping air movement in the adjacent two bags on each side of the bag being cleaned. Cleaning air is commonly heated with an electric heater, if required. With this type filter air is collected on the outside of the bag, units are compact; and cloth area, air volumes and velocities remain uniform. Bags are more difficult to remove and replace if washing is required.
3. The next slide (Slide 4) shows a *REVERSE AIR PULSE FILTER:* — Dust laden air is collected on the outside, or inside of the bags in some designs. At regular intervals each bag, or a number of bags sequentially in sections receive a blast of high pressure air flow. This primary pulse of air aspirates secondary air as it passes through a venturi or diffuser. The resulting air mass expands the bag and causes the dust cake to release. The reverse air pulse filter having the dust collected on the outside of the bag and clean air pulses blasting on the inside for cleaning is the most commonly used collector for *fugitive* dust pickup systems. The next slide (Slide 5) shows the internal assemblies. The next slide (Slide 6) shows how the air travels, and dust is collected on the outside of the bag. The next slide (Slide 7) shows reverse blast of air from the header sending a pulse ripple down a bag for cleaning.
4. The next slide (Slide 8) shows a *REVERSE JET FILTER:* — This type filter has a ring manifold surrounding each bag. The mainfold travels the length of the bag in a constantly repeating cycle. As the manifold passes over the surface of the bag a jet of high pressure air melts from the manifold orifices and blows the dust cake from the bag.
5. The next slide (Slide 9) shows a *SHAKER TYPE BAG FILTER:* — This is the most extensively used filter. The bags in a shaker type filter are supported at the top, or side for flat bags, by a structural framework that is oscillated by an eccentric mechanism driven by an *electric motor* or *vibrator* when manually or automatically activated for cleaning on a timed cycle. The next slide (Slide 10) shows the cloth cleaning air flow and dust removal.

The next slide (Slide 11) shows a two compartment automatic flat bag filters; flatbags are suspended and the vibrator is an eccentrically — weighed shaft, driven electrically.

Multiple compartments are used for continuous operations whereby bags in each compartment are sequentially isolated by closing a damper. The bags are shaken for a preset period. After shaking, a time delay *must be* programmed to allow dust to settle before the compartment damper is again opened.

Various type of rotary or butterfly type dampers are available, but I prefer a poppet or plunger type for most positive closure. Operators can be pneumatic, hydraulic or electric. Hydraulic systems work very well for operating.

The next slide (Slide 12) shows a typical poppet type assembly.

The next slide (Slide 13) shows the flexible perimeter plunger.

Various types of top connections are available for bags. The next slide (Slide 14) shows some typical types. I prefer the 3 prong suspension, or spring suspension type for shaker type collectors provided the springs, threaded hooks and nuts are made of stainless steel. For tensioning, if the bottom of the bag is fixed in position and a 90° twist of the bag can be readily made, the tension or slack is usually proper. The next slide (Slide 15) shows a simple hook attachment. The object is to have simplicity, provide uniform and proper bag tension or support, and good wear life.

The three must common bottom connections are as follows:

1. See the next slide (Slide 16) — Cell plates are punched with no raised surfaces; bags have *two flexible cord rings* sewn inside so the bottom ring is positioned under the cell plate and the upper ring above the cell plate. Plates required reinforcing or undesirable flexing can result.
2. Another type has cell plates with raised beaded thimble or neck for each bag bottom to slide over. A screw driver is used to tighten a stainless steel band around the outside of the bag.
3. Another type see next slide (Slide 17), has cell plates necked thimbles extending down toward the collection hopper section. The bags have a stainless steel snap ring in felt gasket sewn into the bag. The snap ring retains the bag in this thimble.

FILTER BAG MATERIALS

The most important single feature of a fabric collector is the filter media. Since the advent of synthetic fibers in the early 1950's, tremendous improvement has been made in the following important characteristics which are all important for filtering out fertilizer materials:

1. Filtration efficiency
2. Chemical resistance
3. Cake release

4. Low blinding
5. Dimensional stability
6. Mechanical resistance
7. Heat resistance

Automatic Shaker Filters require strong woven fabrics to withstand continued flexing during shake, a raised surface to provide efficiency, a flexible weave to transmit the shake down the bag, and fairly high permeability to maintain a low pressure drop. In view of the material characteristics and these requirements, bags fabricated from a homopolymer acrylic, flexible twill weave, heat set to retain dimensional stability, with permeability between 20-30 CFM, that can stand a maximum temperature of 285°F., are acceptable for fertilizer drying systems. Some suppliers report that a teflon coating properly applied will improve dust cake release and bag life before washing is required.

Reverse Air Type Filters operating at higher air to cloth rates require a non-woven felted fabric because a woven fabric, even with raised surface, results in emission due to the increased velocity of air forcing particles through the inter-weave spaces. Non-woven felted fabric is much less flexible than woven fabric. The surface can be treated to remove hairs for better particle release. Both polyester and polypropylene have acceptable characteristics; however, polyester is less flexible and wears slightly faster. Polypropylene is more expensive.

Let us now review typical Fabric Filter Applications in Fertilizer Handling and Processing Systems.

Fabric Filter Applications —
System Transfer Fugitive Dust

See next slide (Slide 18) — This slide lists typical dust emission control points such as elevators, conveyor transfers, screens, charging hopper, cluster hopper, weigh hopper, mixer, bag filling and bulk material loadout. Minimum recommended air velocities for purging these locations are also listed. *Example:* For an elevator top 100 CFM/sq. ft. of casing area is recommended, whereas 50 CFM/sq. ft. of cloth area is recommended for a screen.

To minimize air purge requirements, I feel the greatest emphasis should be placed in designing the Purge Pickup Assembly which consists of the *pickup transition, adjusting damper, balancing port, flexible access connection* and *velocity test port.* The typical assembly is shown in the lower left hand portion of the slide.

It is recommended that the pickup assembly be mounted in a vertical position whereever possible, and that the area of the pickup transition be at least *eight times* as large as the purge duct to provide a primary separator and to assure conveyance in the air stream of all particles purged, even if turbulence exists at the pickup location and where variations in flow conditions may exist as purge lines are merged.

A typical elevator boot purging location is shown in the lower central portion of the slide. A wing type hopper is shown having a minimum side slope of *60 degrees* so the pickup transition can be positioned with vertical air discharge and opposite the feed location so a slight suction results at the material feed location.

A typical elevator head pickup is shown at the lower right portion of the slide.

Purging from the top of a cluster hopper can be minimized considerably if a dust tight housing is built extending above the swivel spout and sealed around the stationary swivel feed chute. The housing becomes a settling plenum because of its large cross sectional area compared to the feed chute area.

Let us now follow the flow of air on a *typical fugitive dust purge and collection system.* Air is purged from various handling equipment and transfer openings through ducts *sized* and *maintained* to have a minimum of 3500 FPM air velocity, preferable 4000 to 4500 FPM velocity; then into a bag type dust collector where the dust is separated from the air stream by impingement filtering. The clean air continues on to the exhaust fan and is discharged to atmosphere inside or outside the plant.

The air pressure jet, or reverse air pulse type collectors are recommended for these applications. The cleaning air supply must be clean and dry. A high pressure (80 - 100 psig) air supply is required for most reverse air pulse types, some use an air pump instead of a compressor, whereby the cleaning pulse air pressure from the pump is 11 to 15 psig requiring a larger volume and heater for the cleaning pulse. A regenerative dessicant type air dryer is preferred. An after cooler is then required in the supply line between the compressor and dryer to keep the air temperature below 100°F. so the dessicant does not deteriorate. By locating the compressor near the bag filter, the clean exhaust air stream can be used for cooling the compressed air.

The next slide (Slide 19) shows a small unitized bag filter available for remote transfer locations. Material collected discharges back to the material system.

Let us now look at a typical Closed-Loop Cooler-Dryer Air-Dust Handling System. See the next slide (Slide 20).

Ambient Air is drawn through the cooler counter current to the material flow, dust laden air passes through cyclone collectors to remove coarse dust. The air then passes through an exhauster, enters the air feed distribution ring of the combustion ring of the combustion chamber and becomes the greater portion of the dryer air. It is then drawn co-current with material flow through the dryer, through a multiple compartment automatic shaker type bag collector, where the dust is filtered from the air stream, air flow balancing dampers, in addition to compartment shutoff dampers, are located in the exit air ducts for each compartment. The clean moisture laden air continues through a second exhauster and exhausts to atmosphere before condensation occurs.

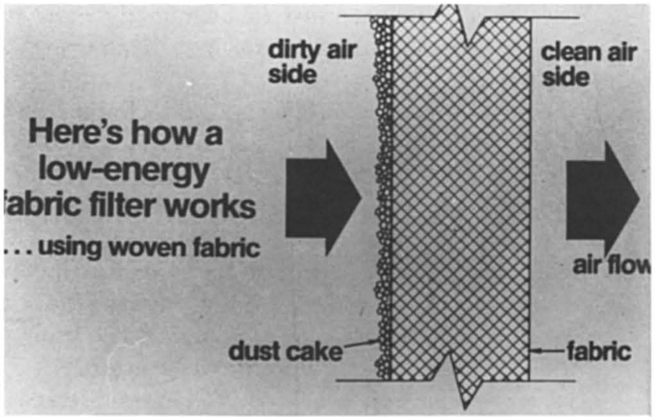
If you want to minimize problems for continued successful operation of a dry type fabric filtering system for a fertilizer handling system, the following considerations *are essential.*

1. *Air Measurements and Flow Rate — Initially* take and record *air measurements* — velocity (CFM) and static pressure measurements in *each branch* and *main* ducts; static pressure at each opening and at fan inlet and outlet; and pressure drop across collector. In making these checks adjust any dampers as required to balance system and assure each duct has an air velocity of *4000* CFM whenever the system is *operating,* having an absolute operating minimum of 3500 CFM and maximum to 4500 CFM in ducts handling dust laden air from purge pick up locations to the filter. Repeat taking these air measurements on a periodic scheduled basis and anytime a change is made that could affect the flow conditions. Use *ammeters* to indicate amperages of any exhausters; Note: Amperage will be proportionate to air moved. Use a manometer to check pressure drop which indicates bag buildup.
2. *Moisture* — Necessary steps must be taken to maintain any free *moisture* in a *vapor state* until clean air is released to atmosphere. Many times Strip Heaters, electrical tapes, and/or air heaters can assure this condition when properly installed, maintained and controlled, but first consideration should be given to avoid merging any high moisture laden warm air with lower temperature air. Before starting to dry any moist product, the system equipment *must be* adequately preheated so no condensation forms in the air handling system.
3. *Insulate — Insulate all bag houses* including the intake header used in fertilizer systems. On drying systems also insulate the duct between the dryer and collector, from collector to fan, and from fan to stack. If polyurethane is used outside, protective coatings are required to avoid breakdown from ultraviolet rays. Other types may be available, but a Neoprene, colored Hypalon sequence provides favorable characteristics. If polyurethane is used inside, a fire retardant material is generally required. Zonolite 3300, a blend of hydraulic binders and heat reflection materials; and Spray-Tec, a blend of cellulose fiber and flame and moisture resistant chemicals are two acceptable types.
4. *Dryer Air Velocity* — It is recommended that the air velocity through dryers not exceed 400 feet per minute if air is filtered through a bag filter.
5. *Filtering Area* — Do not have an air to cloth ratio exceeding 2 to 1 for shaker type collectors; or 6 to 1 for reverse air type filters.
6. *Initial formation of Filter Cake* — It is *extremely important* to initially develop a uniform, low resistant dust filter cake when starting with clean bags.

The results of pollution control can be rewarding. For example: The next slide (Slide 21) shows the results of a Northern Wisconsin outing.

I extend my grateful appreciation to the various bag filter unit suppliers; companies that have units in operation, and consultants, for their assistance, slides, and constructive comments given me for preparation of this presentation. Thank you.

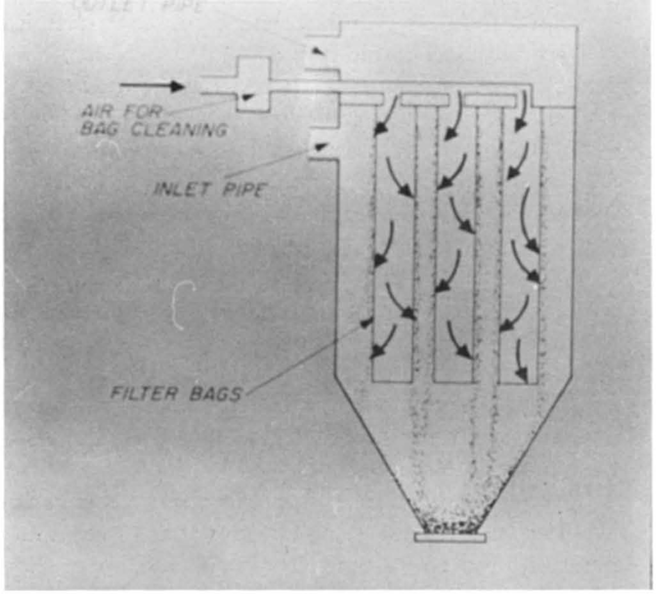
Note: Slides #1 through #21
on pages 139 through 144



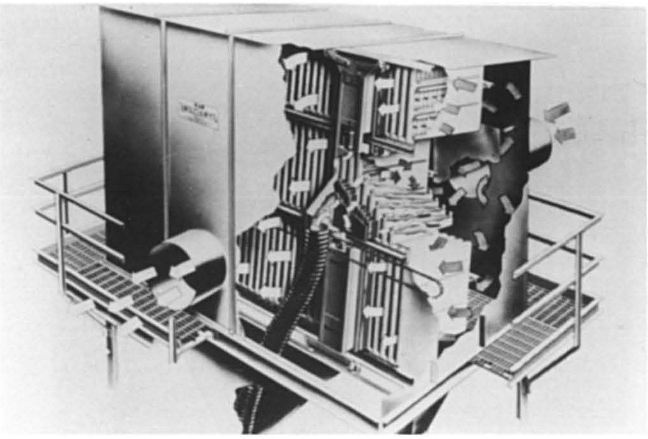
Here's how a low-energy fabric filter works

. . . using woven fabric

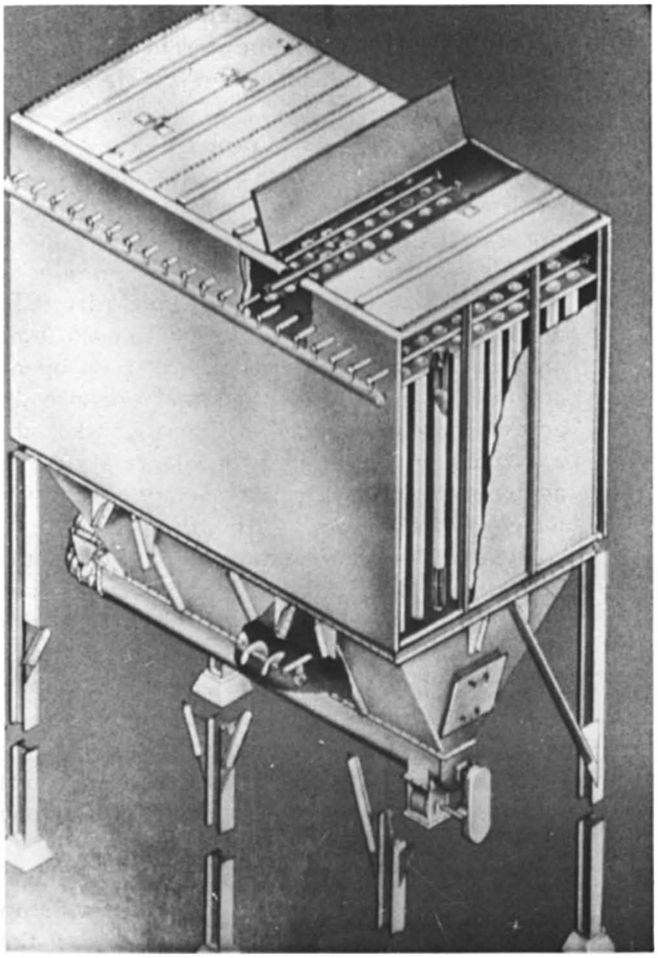
Slide 1



Slide 2



Slide 3



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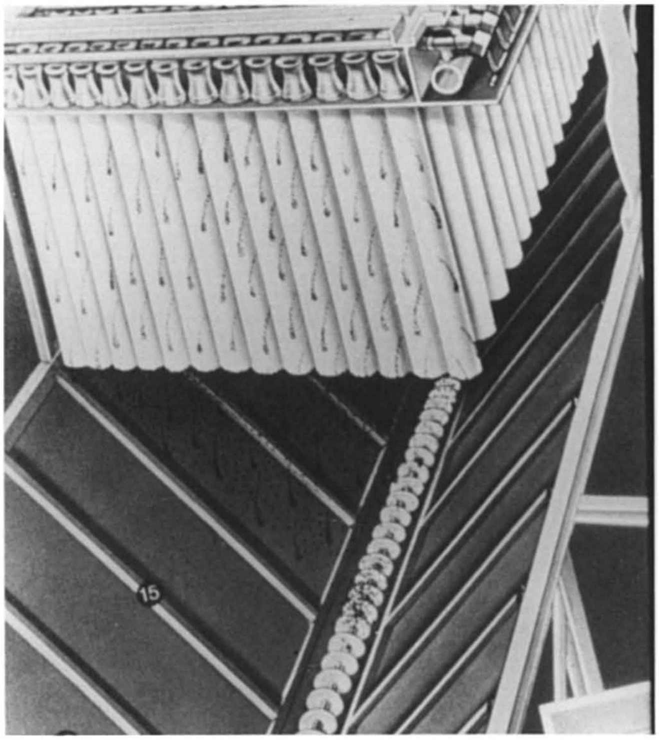
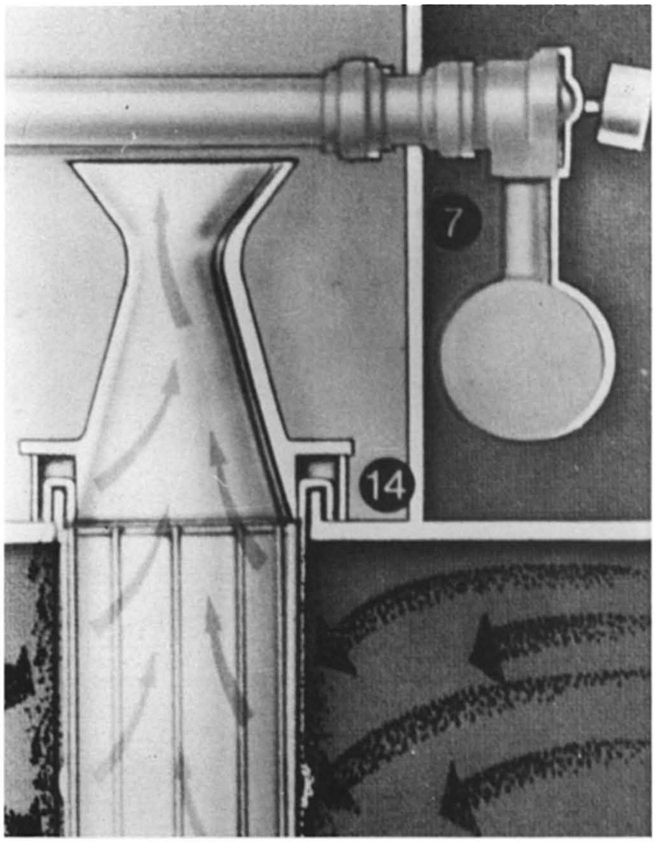
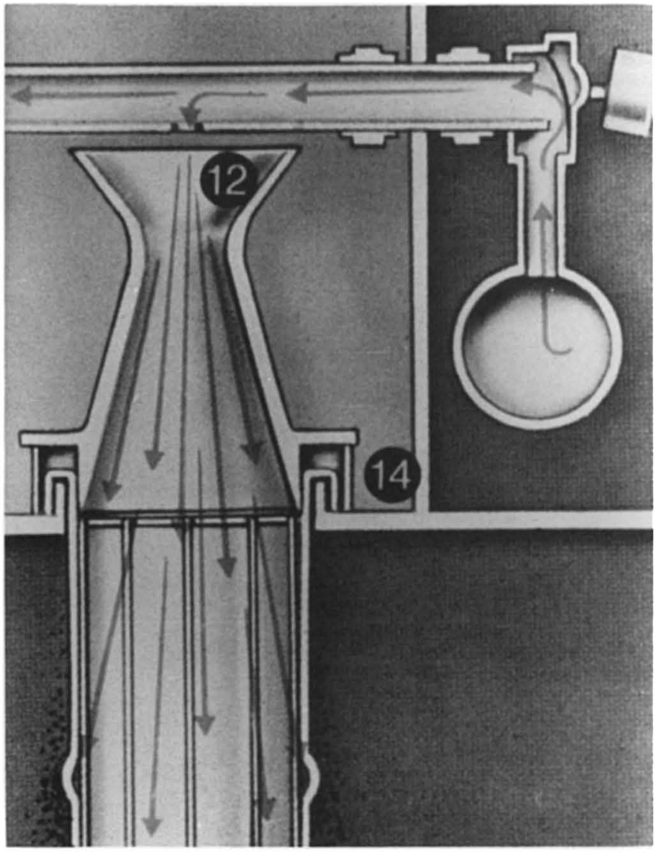


Slide 5



Slide 6



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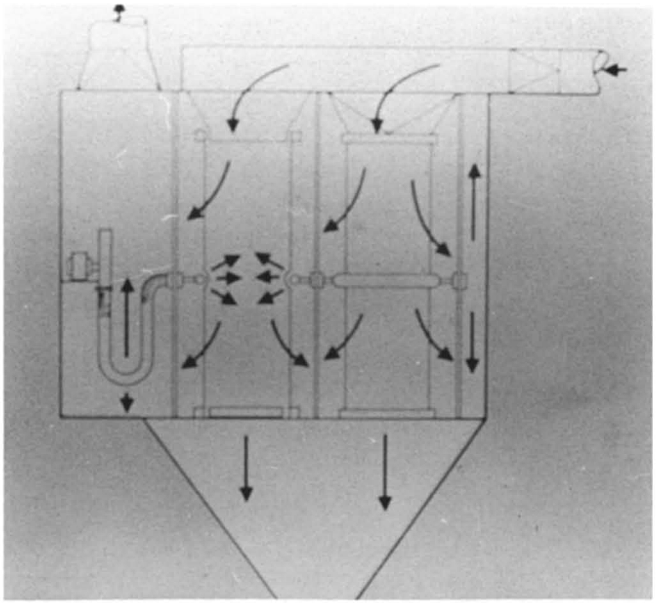

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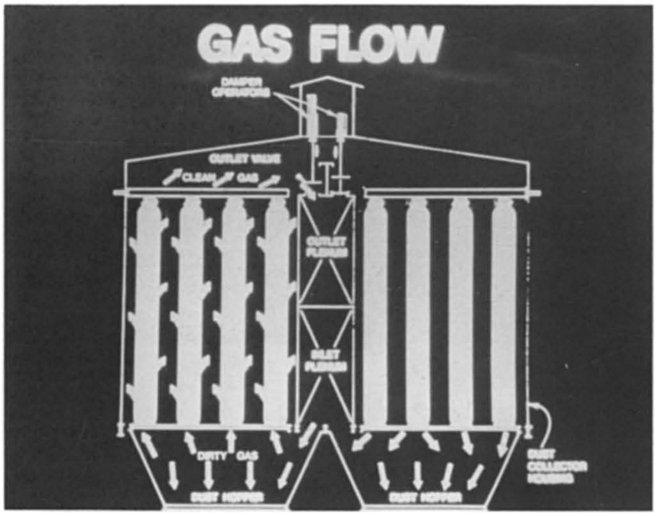
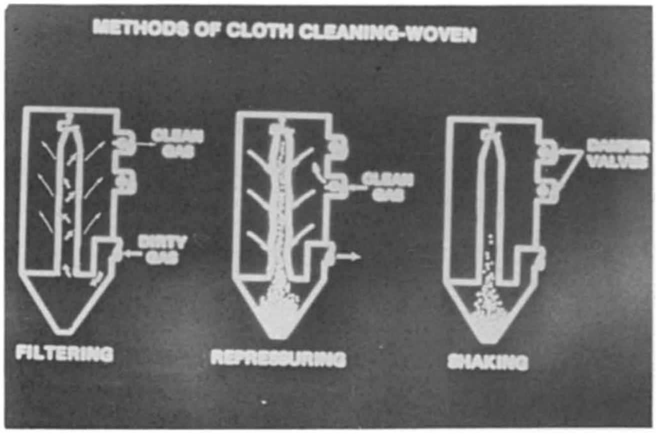
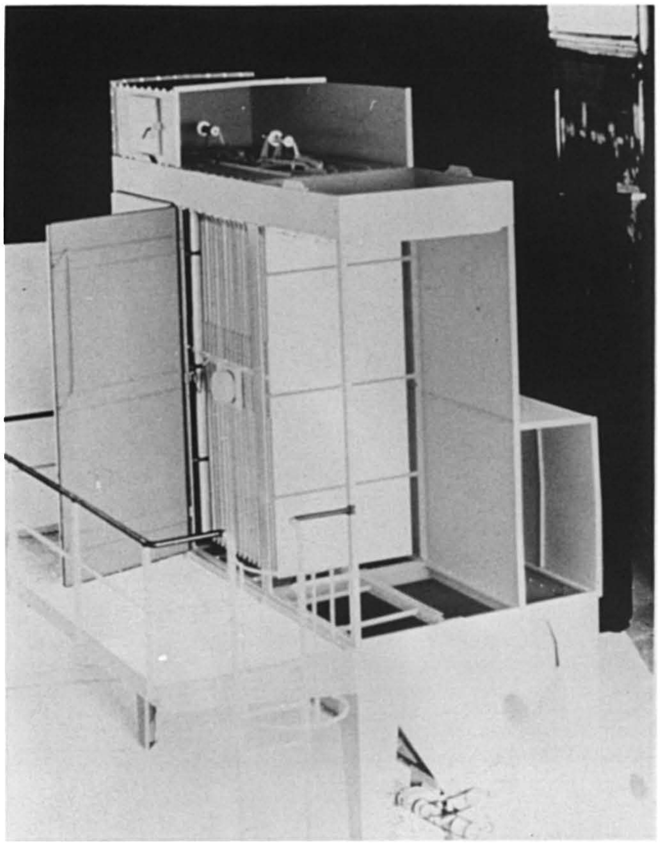

GAS FLOW

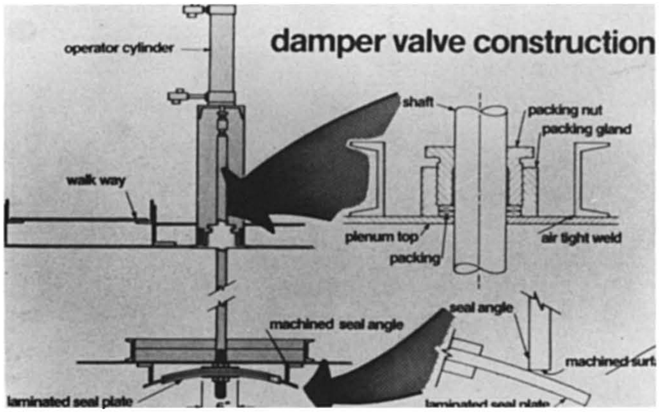
Slide 9


METHODS OF CLOTH CLEANING-WOVEN

Slide 10

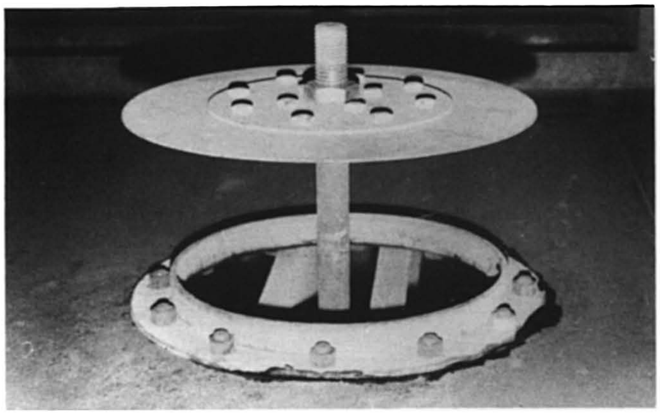


Slide 11

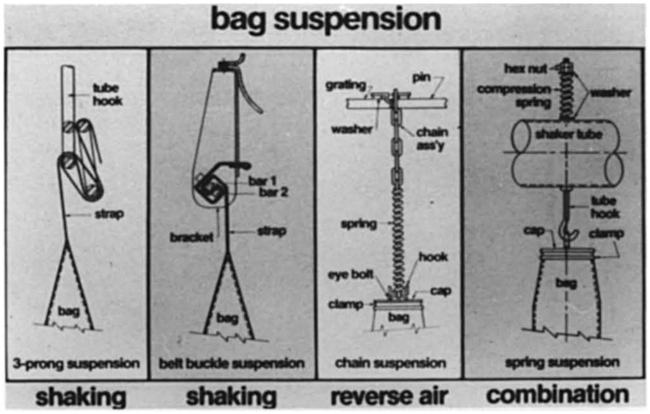


damper valve construction

Slide 12

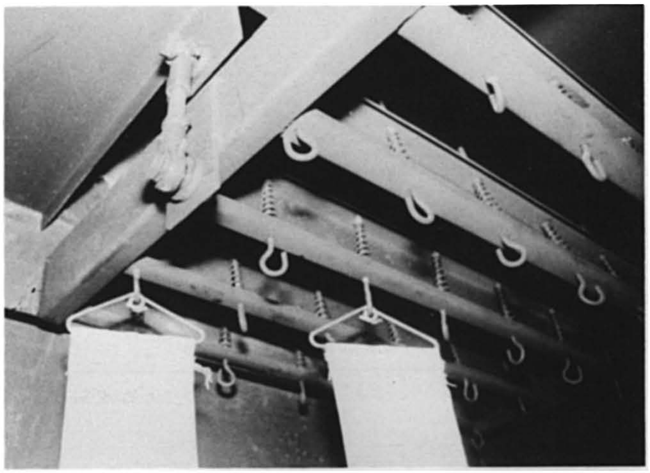


Slide 13



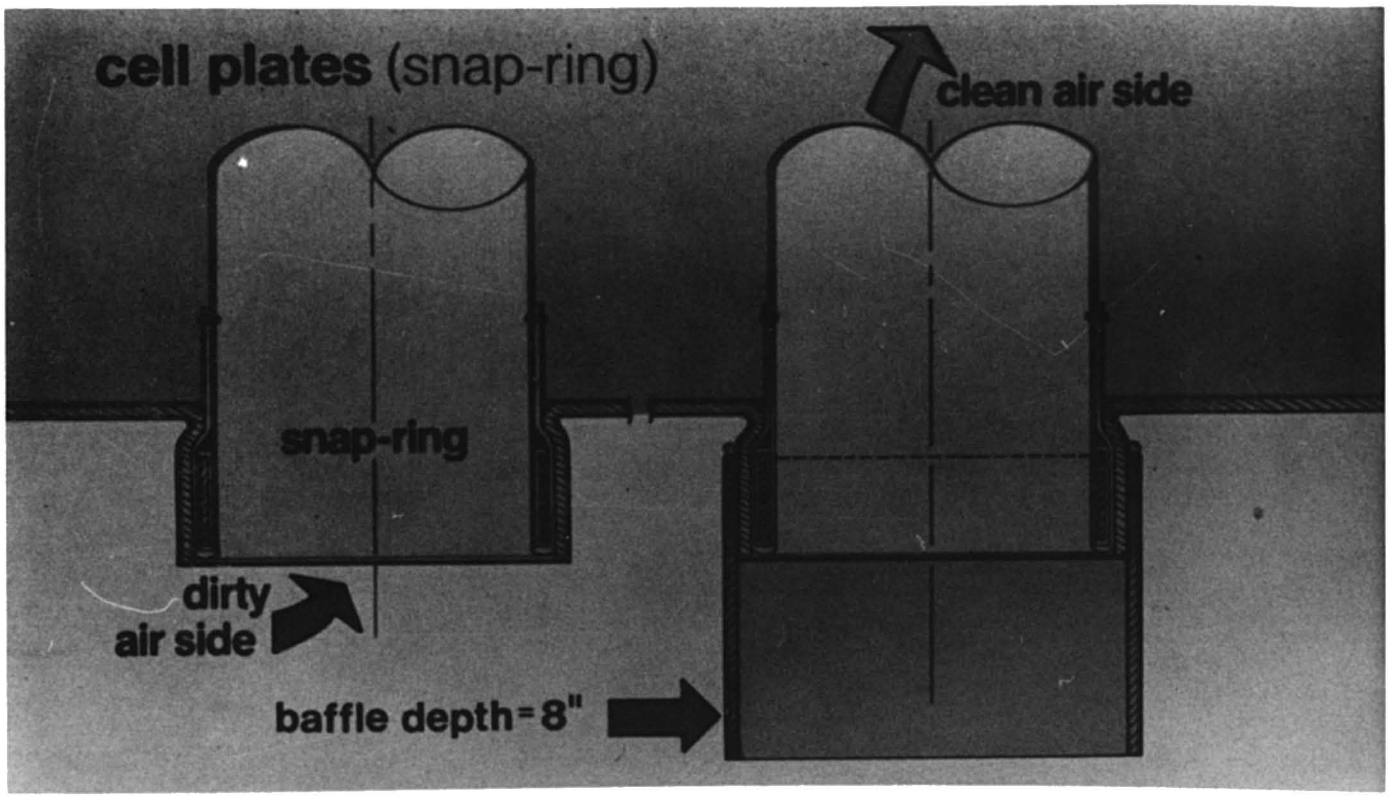
bag suspension

Slide 14

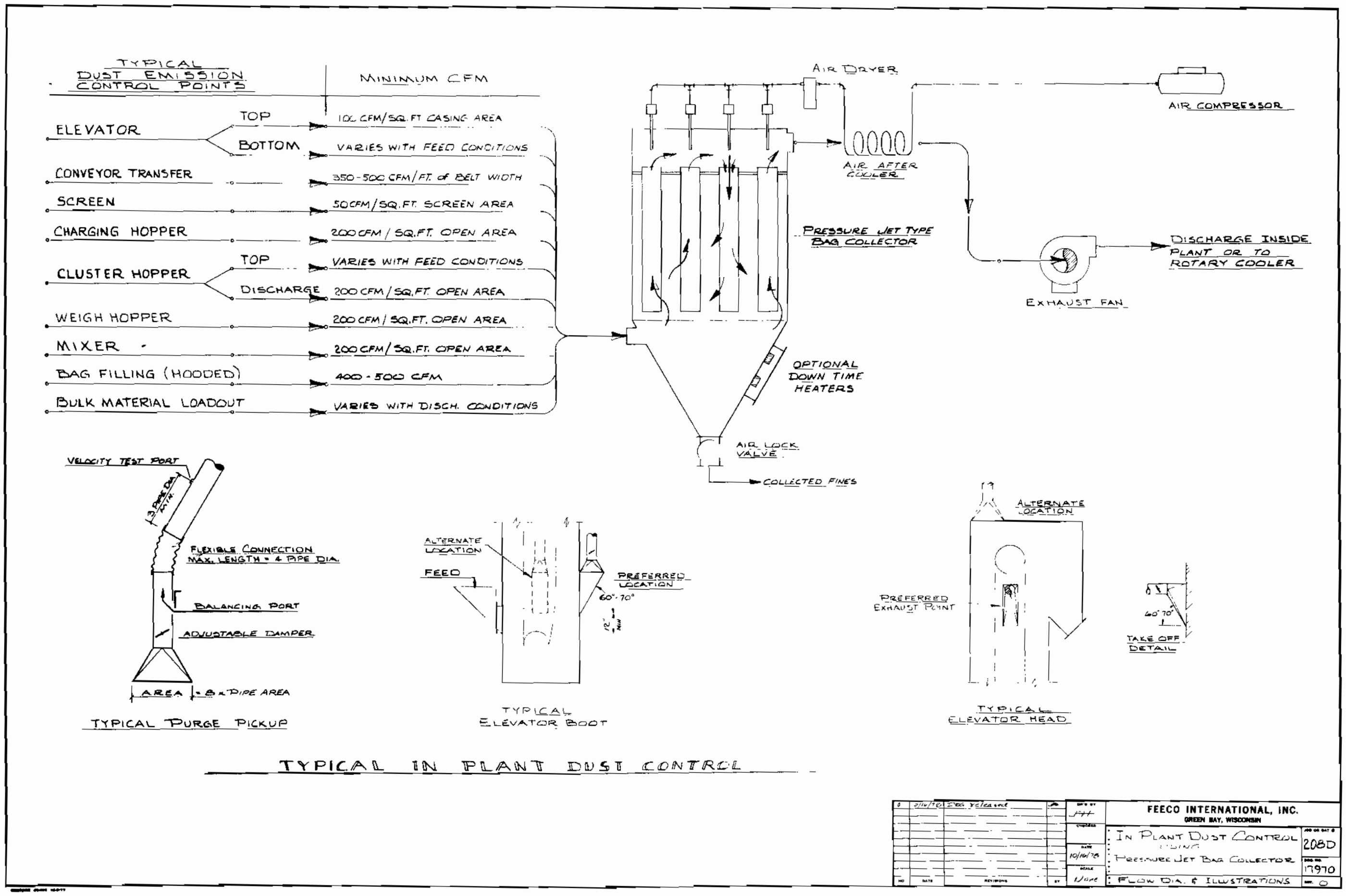


Slide 15

Slide 16



Slide 17



TYPICAL DUST EMISSION CONTROL POINTS		MINIMUM CFM
ELEVATOR	TOP	100 CFM/SQ.FT CASING AREA
	BOTTOM	VARIES WITH FEED CONDITIONS
CONVEYOR TRANSFER		350-500 CFM/FT. of BELT WIDTH
SCREEN		50 CFM/SQ.FT. SCREEN AREA
CHARGING HOPPER		200 CFM / SQ.FT. OPEN AREA
CLUSTER HOPPER	TOP	VARIES WITH FEED CONDITIONS
	DISCHARGE	200 CFM / SQ.FT. OPEN AREA
WEIGH HOPPER		200 CFM / SQ.FT. OPEN AREA
MIXER		200 CFM / SQ.FT. OPEN AREA
BAG FILLING (HOODED)		400 - 500 CFM
BULK MATERIAL LOADOUT		VARIES WITH DISCH. CONDITIONS

TYPICAL IN PLANT DUST CONTROL

NO	DATE	REVISIONS	BY
0	2/16/80	DWG released	

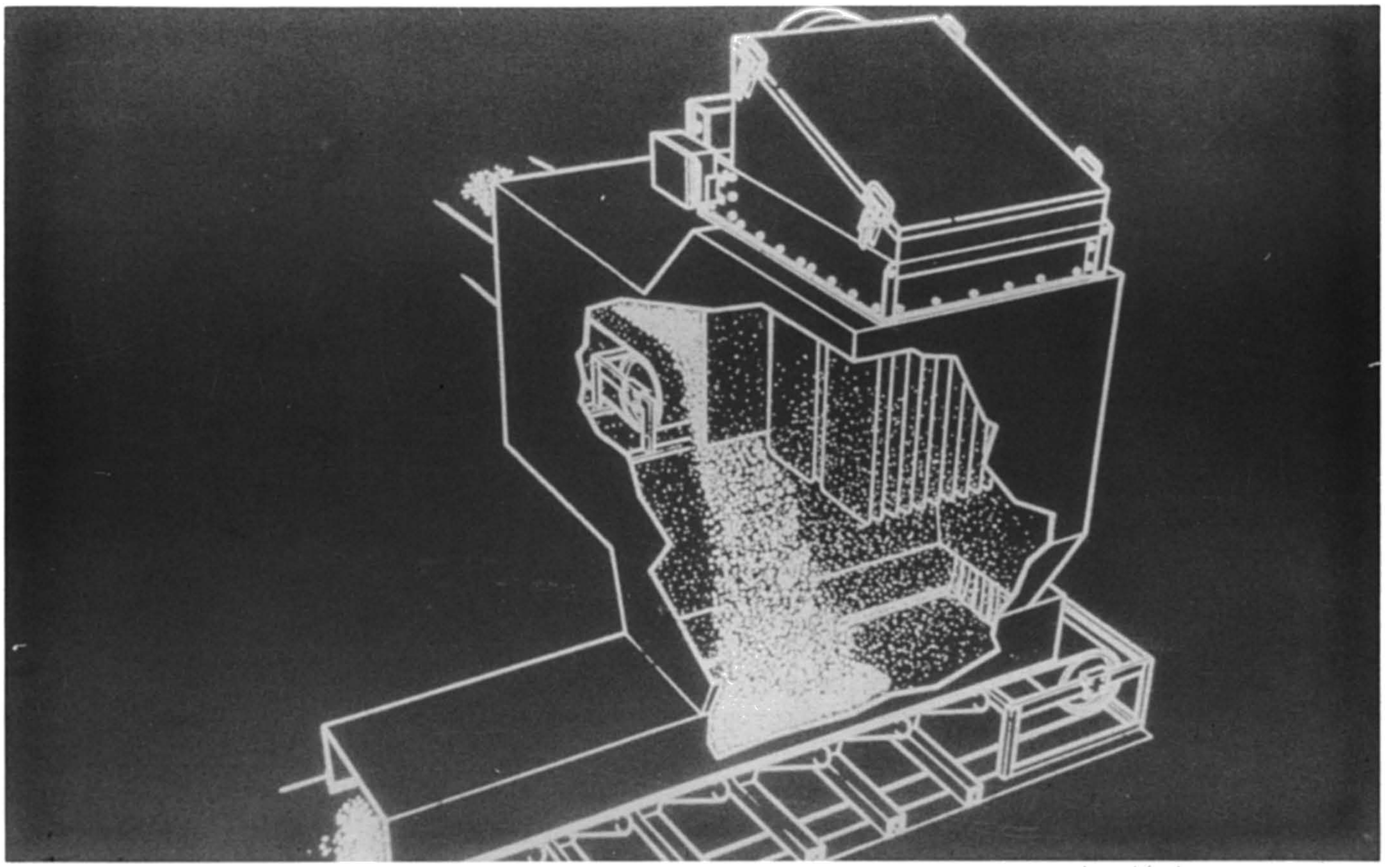
DR'N BY: JH
DATE: 10/16/78
SCALE: None

FEECO INTERNATIONAL, INC.
GREEN BAY, WISCONSIN

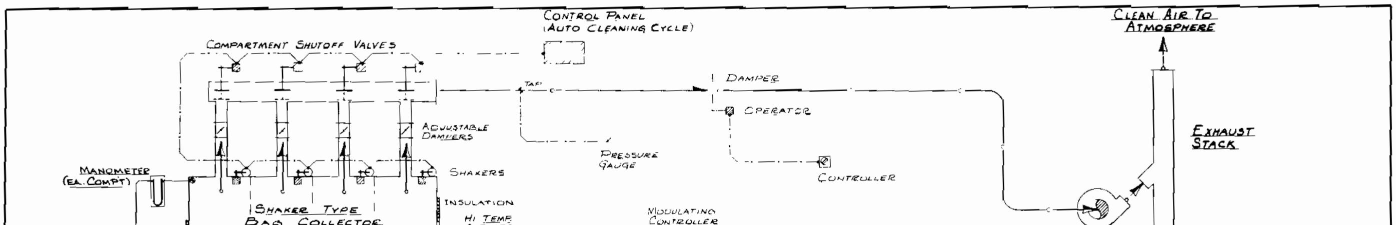
IN PLANT DUST CONTROL USING PRESSURE JET BAG COLLECTOR
FLOW DIA. & ILLUSTRATIONS

JOB OR CAT #: 208D
DWG NO.: 17970
REV. 0

Slide 18



Slide 19



Slide 20

Slide 21

MODERATOR COX: Thank you Glen. We have time for questions.

JOHN KRONSEDER, Fluor: If you have cyclons before the bag collector what particle size would you recommend going into the bag collector?

GLEN WESENBERG: The cyclones that we show going before the bag collector are between the cooler and dryer and that is done because of any turbulence that you have in the entrance to the air tempering or combustion chamber ring. We attempt to screen out the coarser particles so that any of the openings in the passage, coming into the combustion chamber, will keep the fine material in suspension in the air stream and we do not get drifting or falling out in the combustion chamber. Once it goes thru the dryer we do not have cyclone type collectors between the dryer and the bag collector. This is for obvious reasons because the larger particles are desirable in forming more porous and a better cake with higher permeability, I should say.

QUESTION: What is your particle size breakout of the cyclone?

GLEN WESENBERG: I cannot just answer that because the efficiency of the cyclones once you get below 10 microns, drops off quite rapidly. They will be about 90% efficient at that point.

ERIC SCHWEHR, Fisons: You were putting your ex-cooler dust into your combustion chamber. Since this would also contain fluoride is there any information on the damage to the furnace liner?

GLEN WESENBERG: I thought you were going to ask that question for another reason but there has not been any noticeable damage to the chamber or lining. I assume you are talking about the refractory lining?

GLEN WESENBERG: I would say not. That would be a minor deteriation compared to perhaps the life that you would get out of a good refractory lining.

ERIC SCHWEHR: Yes, and primarily the refractory lining, other than the brick, would be the plastic type material, which is quite resistant.

QUESTION FROM THE FLOOR: I would like to know the answer to the test plate question. Is there any ignition of the particles in the air stream causing air solids to be formed which are difficult to remove?

GLEN WESENBERG: This we had thought, and I know that others have, that this might be a problem, however, it does not seem to be. Because of the tempering air, the actual temperature of the air, and combustion gases when rapidly mixed with tempering air does not get that high. The actual combustion air comes in with the burner in a separate inner chamber let's say, in the fine ignition ring area and it has not been a problem. Theoretically it perhaps could melt in the air stream, just temporarily, as soon as the temperature dropped it would go right back to a solid dust state again. Keep in mind we are filtering out the basic coarse particles prior to going to it.

MODERATOR COX: Thanks a lot Glen. (Applause)

MODERATOR COX: Our next speaker is with New Wales Chemical, Inc. He received his Bachelors and Masters degrees in Chemical Engineering from Wayne State University and his Master of Business Administration from Central Michigan University. He is a Registered Professional Engineer in the State of Florida. He has worked in Process Engineering with Monsanto, Corning and for the last 6 years for New Wales Chemicals, Inc., where he is Plant Engineer responsible for all environmental duties at that facility. It is a pleasure to introduce to you Craig A. Pflaum who will speak to you on "Practical Design of Cross-Flaw Scrubbers in the Phosphate Industry". Mr. Pflaum. (Applause)

CRAIG A. PFAUM: I am going to try to cut this talk about in half so that we can pick up another fifteen minutes — hopefully! I brought about 120 copies of my paper and they are up front here and some are in the room in the back. Everything that I say is covered in the paper except some of our recent updated experience which I will talk about. (Applause)

Practical Design of Cross-Flow Scrubbers in the Phosphate Industry

Craig A. Pflaum

Introduction:

The IMC New Wales Plant is the largest phosphate chemical plant in the world, producing about 900,000 TPY P_2O_5, divided into such products as DAP, MAP, GTSP, MA, and AFI. We produce 7,800 TPD H_2SO_4 and up to 3,000 TPD P_2O_5. During construction of our facility in 1973-1975, we were required to meet all applicable emission and ambient air standards, and agree to zero-discharge of waste waters. We have met these criteria. To do this, we have spent approximately 15% of our capital, or $25 million for pollution control improvement.

In meeting these criteria, we have learned a lot about pollution control equipment, as it relates to emissions, costs, and imperability. We are still learning at a very high level.

As the Engineer of record for all permits and the Plant Engineer in charge of environmental function at this plant, I spent many hours inside tail-gas scrubbers, trying to find out how to make them work reliably. Most of the problems we solved were practical, rather than theoretical in nature. Therefore, this paper is entitled "Practical Design at Cross-Flow Scrubbers in the Phosphate Industry", rather than "Theoretical Design of Cross-Flow Scrubbers in the Phosphate Industry". I have brought about 90 copies of my paper for distribution at the end of this meeting.

Tail-gas scrubbers serve only one useful purpose— to reduce stack gas emissions from levels that were acceptable 10 years ago to levels that are acceptable *today.* On the other hand, they are a source of several problems— mostly associated with a simple phenomenon called plugging. Plugging causes downtime, and prior to shutdown, generally reduces the gas handling capability and hence the production capability of a plant.

On a practical basis, it is impossible to eliminate plugging completely, but it can be substantially reduced. The purpose of this paper is to discuss practical design techniques for tail-gas scrubbers, particularly cross-flow tail-gas scrubbers. The practical design should reduce stack gas emissions to acceptable levels and reduce plugging as much as possible.

Figure 1 is a typical cross-flow scrubber in the phosphate industry. It is versatile and can be used for tail-gas scrubbing of Phosphoric Acid, Diammonium Phosphate, Monoammonium Phosphate, Granular Triple Super Phosphate, GTSP Storage, and Animal Feed Ingredients Plant Exhaust Gases.

Tail-gas scrubbers in the fertilizer industry are generally designed to remove fluorine, traces of ammonia, particulate mist, and water vapor. Non-dusty air enters the scrubber at one end and discharges at the other end. The air is contacted stage-wise with acidic pond water from the fertilizer plant's gypsum pond. A series of sprays is used to condense water vapor and begin the scrubbing operation. The final scrubbing operation takes place in a packed section with pond water entering at the top and on the face. The air leaving the wet packed section is generally 90-120°F. saturated. A final dry packed section is used to reduce pond water mist entrainment to the atmosphere. The exhaust fan can be located either at the inlet or outlet of the tail-gas scrubber; however, at the IMC New Wales Plant, these fans are located at the outlet.

A variation of this design, used on Phos-Acid plant scrubbers, is to vent low fluorine gases into the scrubber after the spray section.

In order to eliminate dust from the gases prior to entering the tail-gas scrubber, a separate system is required. This generally includes cyclones or venturi scrubbers. In ammonium phosphate production, the venturi scrubbers, using weak phosphoric acid, also remove most of the ammonia emissions prior to the tail-gas scrubber.

In recent years, there has been a belief that the removal of fluorine from the air stream is difficult. *This is not so.* Reducing the gas temperature below 120° and intimately contacting the gas with a water stream will generally reduce the gaseous fluorine to acceptable levels. The key problem is to remove the fine water droplets, containing fluorine, from the cleaned gas stream. This, too, is very easy. A 2' deep packed section of 1" Tellerettes will usually accomplish this purpose if the gas velocities are kept in the range of 300-500 feet/min. Other demisting methods have also proven successful.

In this paper, I will discuss the following areas of design criteria:

1. Materials of construction
2. Scrubber shell design
3. Type of packing
4. Type and location of sprays
5. Quality of water
6. Air flows
7. Instrumentation
8. Update of recent experience

Materials of Construction

The materials of construction for a tail-gas scrubber *shell* can be rubber-lined steel, FRP, or stainless steel. At New Wales, we have had good experience with both rubber-lined steel and FRP. FRP has the advantage of being easily modified at a later date. However, recent pricing has indicated that FRP is considerably more expensive than rubber-lined steel. However, we are making all of our manhole covers out of FRP because of its light weight.

All internal piping and packing support grids should be made of stainless steel. We have had a tremendous number of failures with FRP pipe headers and packing support grids. A single day of lost production will more than offset any capital savings for FRP internals.

It should be remembered that scrubbers are cleaned by people who stand on the most convenient ledge they can reach, regardless of the material of construction of that ledge (or pipe header).

Scrubber Shell Design

If any unsaturated gas is fed to the tail-gas scrubber several duct sprays should be installed at the inlet to this scrubber. This cools the inlet gas stream to the point of saturation. The required water flow will be determined by the temperature of the inlet gas and its moisture content. It is not necessary to install Vee baffles in the scrubber inlet section if the scrubbing system, described in Figure 1, is utilized. However, if baffles are desired, we have found that large baffles are much more easily cleaned than small baffles. It is necessary to have a good flow of water on the facing of these baffles or they will plug off solid.

Often an integral venturi (Figure 2) is mounted on top of the tail-gas scrubber. This is an excellent cost saving design, and can be used if the effluent waters from the venturi are to be discarded. However, if the scrubber slurry is to be recycled back to the process. Many problems can develop. Using 30% P_2O_5 phosphoric acid as a scrubbing medium will result in significant losses of P_2O_5 to the gypsum pond; entrained scrubber slurry, to a large extent, follows the flow of air into the packed section of the tail-gas scrubber. We have attempted to capture this slurry using Vee baffles. However, the Vee baffles have plugged off with the entrained slurry. Using a slurry spray on the Vee baffles is not better either because the spray washes through the baffles and continues on to the packed section. If recycled pond water is used as a scrubber medium, a large amount of the P_2O_5 in the gas stream can be recovered. However, again, a significant P_2O_5 loss is experienced as entrained slurry is directed into the packed section.

Our own recommendation is to forego the use of an integral venturi if the recovered particulates are to be recycled back to the process. Several acceptable designs for a venturi scrubber have proven adequate for this service.

At the inlet to the scrubber we have had experience with what we call a ski slope. (See Figure 3) This ski slope was designed to help distribute the air prior to entering the packed section. Unfortunately, it was installed in a scrubber that utilized an integral venturi, the result being that the scrubbing medium, as it discharged through the venturi, followed the path of the ski slope and carried through to the packed section.

We have also had experience with a packed section. Inserted between the baffles and the pond water packed section. This section was designed to recover particulate mist and/or ammonia which carried past the baffles. This packed section invariably plugged up with slurry., causing considerable downtime. Operating with a separate venturi system will decrease the amount of entrainment carried through to the packed section: therefore, it is felt that this intermediate packed section is unnecessary. We have, in fact, eliminated these slurry packed sections at our plant. No increase in emissions has been noted as a result of this action.

Because of the potenial plugging problems in all tail-gas scrubbers, and because of the urgency of restarting a production facility, it is necessary that these scrubbers be manufactured with large clean-outs along the side and the top of the shell. These should be at least 2′ by 4′ on the side and full width of the scrubber along the top. As mentioned earlier, FRP is an excellent lightweight material of construction. Quick disconnects are preferred to bolts on these covers in order to reduce turn-around time.

Pond water scrubbers should not have integral sumps, since an upset in the level control can seriously affect the scrubber's operation. The pond water effluent should drain into a pond water trench, using several sealed drain lines, and then to a separate sump and pumping station.

Type of Packing

Several types of packing have been used in the New Wales tail-gas scrubbers. These include plastic Pall rings, Intalox saddles, and Tellerettes. Tellerettes tend to plug fast and are difficult to clean. Furthermore, they are extremely difficult to dump from a scrubber when they are plugged. Our experience has indicated that plastic 2″ Intalox saddles are adequate for wet packed sections in tail-gas scrubbers.

We have generally used 1″ Tellerettes for the dry packed demister sections of our scrubbers. In our DAP plant, it was necessary to install a Kimre mesh pad for the demisting operation.

I am personally not convinced that large amounts of packing are required for the applications in the fertilizer industry. Therefore, in the design of our Animal Feed Ingredients Facility tail-gas scrubbers, we have opted to install two wet packed sections back-to-back with the intention of removing one of these sections soon after startup. (See update section at end of paper)

Type and Location of Sprays

Several types of sprays have been tried in tail-gas scrubbers. The most trouble-free sprays have been the 2″ square pattern Bete sprays, which generated a full spray pattern. It is important to remember that the 4 corners of a square pattern spray must be turned in the right orientation, or the resulting square pattern will be incorrect. These sprays, although they use more water than the minimum required, remain generally free from plugging. A coarse strainer should be used in any case to remove such unwanted items as water beetles and twigs. Our experience with pig-tail nozzles has generally been poor as a result of pluggage with dead grass, leaves, and the like. With clean pond water, these pig-tail nozzles have been successful in tail-gas scrubbers at other plants.

Pond water sprays are located in the open chamber prior to the wet packed section. Generally, a wall of water is sprayed into the entering gases to cool the gas. The removal of gaseous fluorine in this step is quite good. Although the pond water is not used as efficiently as it otherwise might, the amount of packing required for fluorine removal is substantially decreased.

Mounted on the same down pipe with the previously mentioned sprays, are another set of sprays which continuously wash the wet packed section support grid. This operation has proven to be *extremely* critical to the successful operation of a tail-gas scrubber. This additional water acts as one more stage of cooling and fluorine removal. More importantly, however, it keeps the facing of the packing free from pluggage. If packing face sprays are not utilized, it would be necessary to slope the wet packed section downward and away from the incoming air in order to reduce the amount of packing which would otherwise not be irrigated. Inclination of the packed section, although it prolongs the period of operation, has not proven successful in *eliminating* pluggage of the facing.

As the air enters the packed section, it is further contacted with pond water entering at the top of the packing. This contact is the final stage of gaseous fluorine absorption into the pond water. The air stream leaving this section should be saturated at 90-120°F. Entrained mist will be excessive, and therefore the use of a dry packed section is necessary to reduce total fluorine emissionsa to the stack.

Quality of Water

There is often a reluctance to use gypsum pond water in tail-gas scrubbers because certain vapor-liquid equilibrium data tends to indicate that equilibrium fluorine concentration would exceed acceptable levels. If this data is used, it will lead to improper design of tail-gas scrubbers. Based on our stack sampling data at New Wales, we can only conclude that this data does not simulate the vapor-liquid equilibrium conditions which actually exist in the tail-gas scrubber using pond water. There is some speculation that fluorine in the gypsum pond doesn't exist in a completely soluble state, but may be largely suspended in the water phase. A suspended solid, of course, does not contribute to vapor pressure, although it will contribute to mist carryover. Stack sampling data at New Wales indicates that fluorine emissions at 100°F. *can* be less than 10 lbs/day for an air stream of 100,000 ACFM. This *appears* to be the lower limit of fluorine emissions for scrubbers with "infinite" stages of scrubbing and efficient demisting.

There has been a tendency to add an unnecessary fresh water section as the last stage of fluorine removal. At New Wales, this has invariably resulted in a silica pluggage in the fresh water section. Fresh water has been tried in our Phos-Acid, Clarification, and DAP scrubbers. We have discontinued the use of fresh water in these scrubbers.

As has been mentioned earlier, it is necessary to utilize a coarse strainer for the incoming pond water, even if large size spray nozzles are utilized. A plugged spray nozzle is as bad as no spray nozzle at all.

A point should be raised at this time concerning pond water temperature and fluorine concentration. Tail-gas scrubbers are generally designed for 90°F. pond water with less than 1% fluorine concentration. In the summertime, however, the pond water temperature can approach 95°F. The pond water concentration while generally holding below 1% fluorine, can also exceed that value.

As the pond water temperature and the fluorine concentration increase, the Equilibrium gaseous fluorine concentration in the exhaust air will increase. A well-designed and operated scrubber will achieve the acceptable emission standards, even at these elevated conditions. However, the design and operation of these scrubbers become critical at these conditions. Fluorine emissions are higher in the summer than they are in the winter, owing to the increased pond water temperature. (Surprisingly enough, *ambient* fluorine levels appear to be lower in the summer than they are in the winter.)

Air Flows

It has been our experience that fluorine emissions are more a function of air flow quantity than plant production rate or type of product being produced. Apparently, a well-designed and operated tail-gas scrubber will generally result in a near equilibrium concentration of gaseous fluorine in the exit gas as well as a specific pond water mist loading in that gas. If a plant is designed with an air flow adequate to produce 100 TPH of a given product, operating at a reduced rate of say, 50 TPH, will not result in 50% reduction in fluorine emissions. Allowable fluorine emissions are based on the maximum daily production rate produced in a given plant and not on day-to-day production rates.

It has been found convenient to install a damper on the suction of the exhaust fan to provide a constant air flow from the process as the scrubber gets plugged. If a fan is sized for a "dirty" pressure drop, its motor can overload in a clean condition. A constant air flow is often desired to maintain efficiencies in the cyclone/venturi scrubbing system.

Instrumentation

I have previously stated that a tail-gas scrubber should be properly designed and *operated.* However, a scrubber cannot be properly operated without adequate instrumentation, as we at New Wales are well aware. Flow and spray nozzle pressure indication should be available for all pond water streams. Temperature indication should be available at the scrubber inlet and outlet, with a high temperature alarm at the outlet. If an operator has to guess at the required pond water flow to operate a scrubber, he will invariably guess on the low side. This reduces potential overflow problems with the pond water return system; however, it also results in decreased operating time because of the impending pluggage which occurs.

Pressure taps should be installed at the inlet and outlet of the scrubber and between the two packed sections to determine if plugging has begun to occur. Generally, the pressure drop across a plugged packed section will begin to increase before any indication of a decrease in exhaust fan amps has occurred. Pressure taps should also be installed throughout the balance of the cyclon/scrubbing system.

Recent EPA regulations require that certain new tail-gas scrubbers be equipped with continuous pressure drop monitoring devices.

Update — Recent Experience

This section presents an update of our scrubbing experience over the last year. Scrubber changes have been experienced in our MAP and DAP plants.

During the initial design of our MAP Plant Scrubbing System, it was recommended that a venturi scrubber, using fresh make-up water, be installed, followed by a vent fan. This system was proposed to provide adequate assurance of meeting environmental emission standards.

As we proceeded through detailed design of the MAP scrubber system, it became apparant that we did not have enough confidence in the originally proposed simple scrubbing system; therefore, it was recommended that a complex tail-gas scrubber would be required to meet emission standards. The tail-gas scrubber consisted of irrigated Vee Baffles, an irrigated slurry packed section, a packed demister section, an irrigated pond water packed section, and a packed demister section. Emission levels were extremely good: fluorine emissiosns were approximately 4 lbs/day, and particulate emissions were approximately 10 lbs/day, well below all standards. However, it was impossible to maintain operation of this scrubber for more than two weeks.

Therefore, a series of improvements or simplifications were made. The ultimate simplification was made approximately one month ago. This was the complete de-gutting of the tail-gas scrubber. All packing and sprays have been eliminated, leaving only a large settling chamber behind. Emissions are currently 2 lbs/day fluorine and 30 lbs/day particulates, still considerably below all emission standards.

The DAP scrubbing system is more complex. In order to meet fluorine emission standards, it was necessary to increase the depth of the pond water pack section from 7′ to approximately 9′. Several additional preconditioning spray nozzles and packing face sprays were also required to meet fluorine standards and provide an operable tail-gas scrubber. It was also necessary to replace the dry demister section with a Kimre demister pad arrangement. Apparently the 1″ tellerettes were unable to demist the stream adequately at 500′ per minute exit velocity. With these modifications fluorine emission standards are being met.

We are continuing to evaluate the need for complex scrubbing systems in the GTSP and GTSP storage areas, as well as the Animal Feed Ingredients complex. Perhaps, in another six months, we will be able to provide more valuable information to the industry.

Conclusion

If the design and operating procedures recommended in this report are followed, a tail-gas scrubber will be able to adequately reduce stack gas emissions and avoid downtime caused by plugging.

Note: Figures 1, 2, and 3
on pages 149 and 150

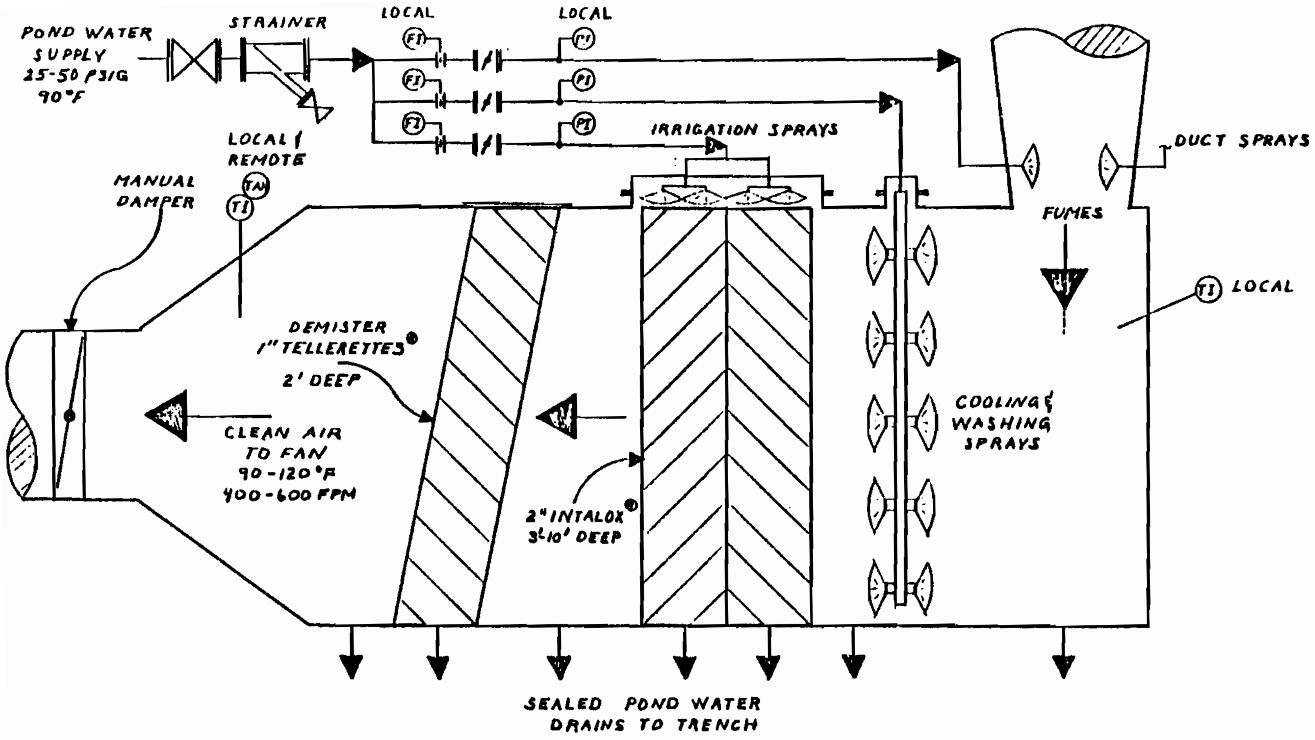


FIGURE 1-TYPICAL CROSS FLOW SCRUBBER

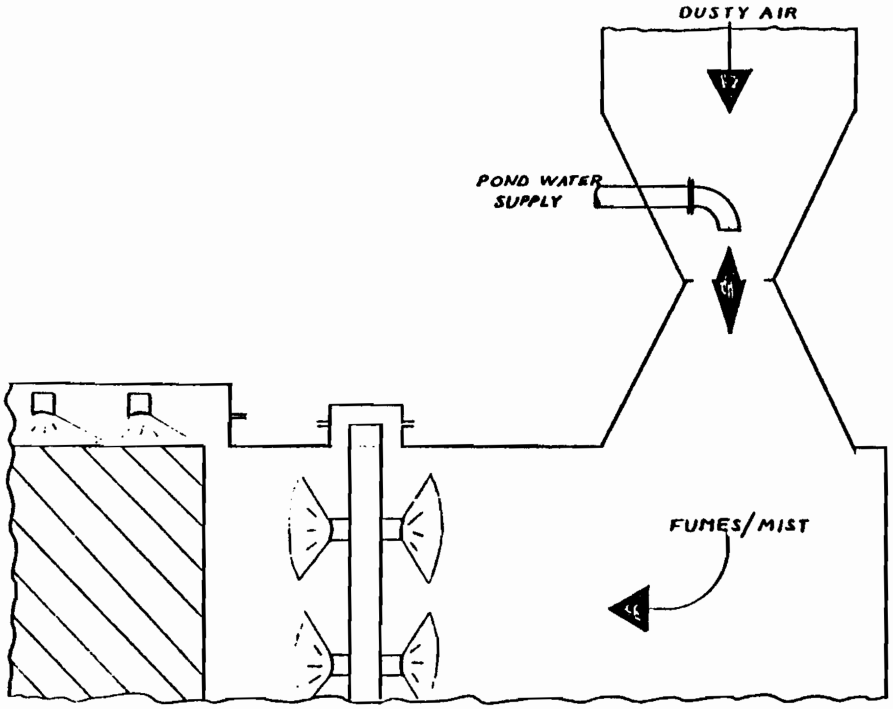


FIGURE 2- INTEGRAL VENTURI INSTALLATION

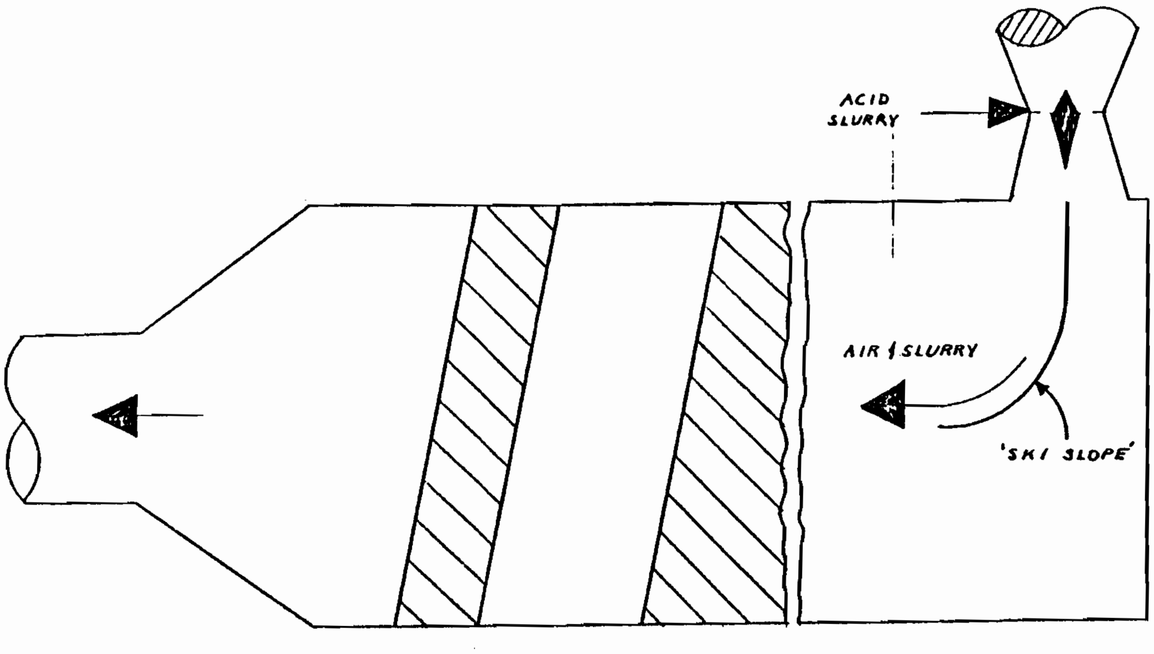


FIGURE 3-IMPROPER APPLICATION OF 'SKI SLOPE'

MODERATOR COX: Questions, please.

QUESTION FROM THE FLOOR: Sir, What type of flow indicator do you use?

CRAIG A. PFLAUM: On the pond water we just use orifice plates and they do have a fresh water purge on each one of the taps. We will be using mag meters on our slurry lines around our Venturi scrubbers. We are putting those in on the DAP Circuit.

MODERATOR COX: any other questions. I certainly do thank you Craig. Your discussion was most interesting and will be very useful.

MODERATOR COX: Our next speaker has a very distinguished educational career. He received his Bachelor of Chemical Engineering Degree from the University of Pittsburgh with a grade few of us ever see, 3.9 out of a possible 4.0. He went out to receive his Masters in Chemical Engineering from Syracuse University and has his Doctorate in Chemical Engineering from Cornell. He has also pursued Post Doctoral work at Purdue University. After serving with several engineering corporations, in 1974 he joined The Occidental Chemical Company. He is in Houston, Texas, and with them is a Senior Planner in charge of Marketing, Research and Planning, and is the Energy Conservation Coordinator. In addition to other things he does in our industry, he jotted down on a piece of paper a few notes about himself and I won't say he wanted me to mention them, but I thought it would be of interest. Starting with the premise that he is married, and he is, he wanted me to state that he has six children and be very careful to state that they are all boys, except for 5. Dr. H. Grey Verner will speak to us on "Sampling and Meeting State Guarantees". It is a pleasure to introduce to you, Dr. Verner. (Applause)

Sampling and Meeting State Guarantees

Dr. H. Grey Verner

Those of you who read the Ag-Chem Market Research Newsletter know of my fondness for puzzles. In the last issue I told you about the Pepsi Challenge, a giant demonstration involving a hundred gallons of Pepsi and a hundred gallons of another Kola.

You will recall that a deranged market researcher delighted in an opportunity to foul up the experiment. He stole into the demonstration area and took exactly 25 gallons of Pepsi and poured it into the Kola tank, mixed the contents thoroughly, and transferred 25 gallons of the mixture back into the Pepsi tank.

The problem; is there more Pepsi in the Kola or more Kola in the Pepsi? Are they the same?

Figure 1 is a schematic representation of the Pepsi Challenge after mixing. The equation under the Pepsi tank is a representation of that tank's contents before mixing and is equal to one hundred gallons.

The equation under the Kola tank represents the conditions in the Pepsi tank after mixing and is also equal to one hundred gallons. The two equations are, therefore, equal. If we subtract the quantity (100-P) from both sides of this equality, we observe that P equals K; they are indeed the same.

This particular quiz question was chosen because it has certain characteristics in common with the subject of my paper, "Sampling and Meeting State Guarantees." Observe that the P and K might also refer to phosphorus and potassium. The two tanks could be considered as containers for equal quantities of phosphate and potassium raw materials which might be blended to produce a two-component fertilizer.

The back-and-forth transfer of 25-gallon quantities represents a rather crude method of mixing which, when carried to the ultimate, would produce two tanks of mixed fertilizer each having the same composition.

If one stops short of perfect blending, he achieves a situation which might be shown schematically as in the Pepsi Challenge. For example, if one carries out only five pairs of the above back-and-forth transfers (25 gallons each time), we arrive at the following conditions:

Pepsi	**Kola**
(100-P) = 53.9	P = 46.1
K = 46.1	(100-K) = 53.9

This mixing experiment in a two-component system allows us to make a number of interesting observations:

1. The nutrient total remains a constant equal to the total of ingredients in the original system (considering both containers as the total system).

2. If a non-representative sample is taken from one place in the system (like the Pepsi container), a complementary sample with the numbers reversed exists in another place in the system (e.g. the Kola container).

3. The results of the analysis of one sample do not, therefore, necessarily represent the composition of the system. As a matter of fact, neither do two such analyses. Sampling theory has been developed which define the sampling procedure to be followed taking into account the variables involved.

4. This afternoon we will be looking at the official analyses of the fertilizer samples of the State of Louisiana. From the outset I want to emphasize that this study is in no way a special criticism of the State of Louisiana but is taken solely as an actual example to illustrate the principles which we will be discussing and which apply equally to all states where fertilizer analyses are carried out.

Since some of us have not been in school for some time, I would like to take a moment to review a few basic statistical principles. Figure 2 provides five examples dealing with average and standard deviation.

The bold-face characters across the top of the page are standard statistical symbols:

X_i = the values of the individual analyses
N = the number of analyses
EX_i = the sum of the analyses
$\overline{X}$ = the arithmetic average
O = the standard deviation

In Example 1, ten analyses having a value of 99 are added to 10 analyses with a value of 101 to give 20 analyses which have an average value of 100 and a standard deviation of 1. Example 2 is similar except the values are 95 and 105 to give the same average but a different standard deviation, that is, 5. Example 3 is the sum of examples 1 and 2, again the same average but a standard deviation of 3.6. Example 4 shows that you can have the same average, if you use one value of 50 and another of 150, but the standard deviation is 50. Example 5 is the sum of Example 3 and Example 4 and shows that a few values with a large deviation can radically affect the standard deviation.

We are all familiar with the arithmetic average. The standard deviation is a measure of the variability of a series of numbers. The smaller the standard deviation, the closer the numbers are to the population average. Figure 3 shows how the average and standard deviation may be used in evaluating a set of data. Six analyses of a 0-24-24 fertilizer were taken from the Louisiana data.

We divide the official analysis by the grade number to get the percent of nutrient indicated by the analyses shown under the Xi columns. To get the average, Xi, add the Xi values and divide by the number of analyses.

The State of Louisiana reports on only the deficient samples. Consequently, all of these numbers represent material which has been rejected.

The columns headed by a Delta represent the arithmetical difference between the analyzed value and the average. Thus, in line one for phosphorus, (99.2-92.9) equals 6.3. Likewise, for potash, (113.8-104.5) equals 9.3. The Delta-squared columns contain the square of the Delta number. The sigma delta-squared values were obtained by adding the numbers in the delta-squared column. We divide this sum by (N—1) because the number of samples is very small. The results, called the variance, are 75.36 and 170.76, respectively. The standard deviation is the square root of the varience, in this case, 8.68 and 13.07, respectively.

Figure 4 shows a normal distribution curve with $\overline{X}$, the population average, indicated by the heavy dashed line. Statistical theory indicates that approximately two-thirds of the numerical values in a normal distribution occur within plus-or-minus one standard deviation. About 95 percent of the values occur within plus-or-minus two standard deviations. The expression "95% confidence level" derives from this statistical concept. If the analysis of a fertilizer lies beyond the "two-sigma-limit", we can be 95% certain that the sample is deficient.

Normal distribution is a straight-forward concept. While the theorectical average is 100%, it is very, very rare for an actual analysis to be precisely 100%. Half the time it will be more than 100; the other half it will be less. The range and frequency of the variability from the population average ($\bar{X}$) is shown on the graph. The frequency of an occurence is indicated by the vertical distance, the variation from the population mean by the distance along the horizontal axis.

Figure 5 shows a similar distribution curve describing the basis that Louisiana and many other states use for rejecting samples. Note that only about one-fifth of a standard deviation on the left side of the population average is acceptable.

This could be a reasonable basis for rejecting these batches providing that an ample number of samples are taken to characterize the fertilizer so that the composited sample is truly representative of the material sampled.

The Association of American Plant Food Control Officials (AAPFCO) specify the methods of fertilizer analysis. This organization carried out an intensive round robin to determine the accuracy of their analytical procedures. They concluded their limit of accuracy was ±5%. It is this value that has been adopted by the many states as the negative limit. We should try to get AAPFCO to change their recommendations to the State legislature to include consideration for other sources of deviation besides the analytical error.

Note that in the situation where a single sample is used to characterize a fertilizer batch, the entire allowable variability in the fertilizer is used up by the inherent variability of the AAPFCO analytical method. There is no allowance for normal variability in raw materials, formulation, segregation in storage, improper and, therefore, non-representative sampling and less-than-perfect analytical procedures.

Figure 6 summarizes the Louisiana Fertilizer Data for the last three fertilizer years representing over 25,000 fertilizer samples. Over the period the nitrogen has average 103½ percent, the phosphorus nearly 104 percent and the potash over 102, with an overall average of 103 percent. Recall that these are the deficient samples which represent only about 15% of the total samples that they analyzed.

If the entire lot of samples had been included, the overall analysis would have been at least as high and probably higher. The 26% overall standard deviation means that about two-thirds of the analyses of the deficient samples fall in the range 75% to 125% of the guaranteed analysis. This is simply a restatement of basic statistical theory for normal distribution.

Since these are all deficient samples, you might ask why any of them are over 100%. We used all of the available data on the deficient samples. Hence, by one of our Pepsi principles, when one value is below the population mean, the others are likely to be above.

Figure 7 is a histogram of the Louisiana Data. The histogram shows the number of samples at each analytical value. For example, there were 136 samples that analyzed 93% of the grade analysis. This curve has been drawn with a standard deviation of 25% (essentially the same as the 26.4% actual). By inspection it appears probably that two thirds of the values lie in the range of 75%-125% (± 1. which characterizes a normal distribution).

A number of the samples were far-out. All of the samples analyzing 175% or more are shown at the plus-three-sigma point, about 76 such samples. Since 95% of the values should be within plus-or-minus two standard deviations, it was decided to look at the ones that were beyond the two-sigma limit.

Figure 8 summarizes this analysis. The bold-faced numbers show the method by which the analysis was carried out. Of the 480 nitrogen samples in 1974-1975, twenty of them were greater than plus-2 standard deviations, four of them were less than minus-2 standard deviation. If they are eliminated, 456 remain within two-standard deviations. Using this procedure we found that, of the 3,846 samples analyzed, 3,679 fell within two-standard deviations, or 95.7% of the samples. This value compares favorably with the theoretical value of 95.5%. Maybe those oddballs belong in our population afterall. However, we eliminated them and summarized the remaining data on Figure 9.

Observe the changed average analyses. The nitrogen at 101.7; the phosphorus, 101.4; and the potash, 99.6; for an overall average of 100.7. Note also the new standard deviation of 17.3 versus the previous 26.4. Please recognize that this was a statistical maneuver to observe the effect of eliminating those samples which were probably truly "bad" (beyond the 95% confidence level).

Once again it should be emphasized that we are not attempting to avoid proper monitoring of the fertilizer industry. Each farmer is entitled to the guaranteed quantity of every nutrient he purchases.

We are attempting to define a problem, to indicate the reasons the problem exists, to provide some ways for the industry to improve its performance, and to suggest ways in which the industry and the states may cooperate in achieving a more desirable evaluation program.

Figure 10 is a histogram of the same data except they are summarized at 5-percentile intervals. This chart shows the basic normal curve characteristics except that it is skewed to the left. This can be explained by the 95% lower limit of satisfactory samples. Had the good samples been included, the center of the distribution would be moved slightly to the right and the distribution would be taller and thinner than the one shown.

Figure 11 is a histogram of the rejected P_2O_5 fertilizer samples afor 1974-1975 fertilizer year. Once again this sample demonstrates dramatically the effects of the lower limit of acceptability on the departure from normal distribution.

It has been difficult to convince people that analyses falling between the population average $\bar{X}$ and a minus-one standard deviation just as validly represent the total population as the analyses that fall between $\bar{X}$ and plus-one standard deviation. We have not tried to explain that once in twenty times the analysis will vary by as much as two standard deviations and still represent the population.

Going back to our Pepsi principle, recall that every time there is a value to the right of the population average in a two-component system, there is another value to the left of the population average. If the value to the right falls in a reasonable part of the normal distribution, the complementary analysis falling to the left should not be rejected. Both results belong to the same population and normal distribution. Remember also that the lower limit may be based only on the AAPFCO determination of the accuracy of their analytical methods. They have disregarded the other factors that contribute to this deviation from the average.

Figure 12 lists some of the sources of the deviation which are observed. In the basic manufacture area we need to be concerned about the quality of raw materials and mistakes in formulation and labelling. Sampling procedures, I believe, represent the biggest single contribution of error. How do you take a sample and how many samples should you take? Getting a truly representative sample is difficult at best and probably impossible.

Consider, for example, the problem of sampling a bag of fertilizer. The bag is filled in an upright position with tendency toward segregation in the vertical direction during filling. It is then stored in a horizontal position on a pallet during storage and bounced around in this position during shipment, giving what we will call "horizontal segregation".

The usual sampling procedure involves the use of a cylindrical thief, inserted from the upper-left corner to the lower-right corner to get a "representative sample". But the vertical segregation during filling, followed by horizontal segregation during storage and/or shipment make it virtually impossible to get a truly representative sample.

For bagged material, one source recommends the number of samples to be taken should be equal to the square root of the number of bags, up to a maximum of 20. If there are more than 400 bags in a lot, 20 is considered an adequate sample.

In this situation multiple sampling improves the chances that the over-all sample will be representative. It is, however, not fool-proof by any means.

Let's return for a moment to our earlier example of the 0-24-24 fertilizer samples. (Figure 3). Let's assume that each of these rejected samples represents a ton of material in 50-pound bags. There are 40 fifty-pound bags per ton. The square root of 40 is slightly more than 6, the number of samples shown. These six samples of 0-24-24 material might then have represented the six samples which should have been taken from the same ton of 50-pound bags. If the six samples had been taken from one lot, properly composited, split, and analyzed, the analysis would have been 99.2 for phosphorus and 104.5 for the potash. The material would have been accepted.

It seems likely that many states are not taking enough samples to give a true representation of the fertilizer lots. They feel they can't afford to increase their sample load by analyzing more samples.

The rebuttal is either use a more accurate sampling procedure (both in number and technique) or broaden your specification to include those samples which in reality represent good material. A fair and equitable treatment should be worked out between the industry and the various state governments involved.

Returning to the previous slide (Figure 12), there are a number of sampling errors involving non-representative samples, mix-ups, improper techniques and etc. You are all aware of the possible errors involved in analytical procedures such as poor techniques in weighing, titrating, standardization, spilling and etc. These are the errors which were minimized in the AAPFCO study in which they obtained an ideal accuracy of plus-or-minus 5 percent. The State of Louisiana is not at fault in this area, but you might want to investigate the analytical techniques in your state.

In an effort to improve the quality of fertilizer sold to the farmers in the State of Louisiana, the state instituted a probation system. In 1975 a company was put on probation if more than 30% of the samples analyzed were rejected. In 1976 a manufacturer was allowed only 25% rejections before being put on probation and in 1977 only 20% rejected samples were allowed before probation.

Figure 13 summarizes the results of this approach. The vertical axis gives the percentage of mixed goods that were out of tolerance. Along the horizontal axis we have plotted average overall nutrient content for the three years involved. The three points reading from left to right are for 1975, 1977, and 1976, respectively. These points fall on a straight line with the material out of tolerance varying inversely with an increase in nutrient content.

Recall, however, that in 1975 the standard deviation was lowest of the three years involved and that standard deviation is a measure of the uniformity of the product. The lower the standard deviation the more nearly the materials involved approach the population mean.

The probation system has not reduced the standard deviation. We feel that the size of the standard deviation represents a better measure of improved performance by the industry. We should be cooperating with the states in an attempt to lower the standard deviation which *would represent an improvement for the farmers.*

We don't question the basic philosophy that fertilizer lots which are truly deficient in their nutrient content should not be marketed and should be subject to a fine. Our concerns lies with a system where insuffcient data are possibly being misinterpreted so that some satisfactory fertilizer materials may be called deficient. We feel that cooperative effort could produce a system which would be advantageous to farmer, state, and fertilizer suppliers.

One of the reasons for giving this paper is to enlist your aid in finding a way to convince the farmer and the various state agricultural commissions that three samples from a lot of 0-24-24 that analyze 22-26, 24-24, and 26-22, may all be representations of the same lot of good fertilizer. They all fall well within one standard deviation of the normal distribution. This is a difficult statistical concept for the layman to understand. Yet this situation frequently happens due to the use of non-representative samples.

People will usually agree with the basic principle that half of the analyses will be above and half below the population average. However, in actual practice the farmers and the fertilizer commissioners are reluctant to accept the thesis that a low value can be a satisfactory representation of a guaranteed-analysis fertilizer.

The graph illustrates dramatically what the industry has been doing to try to solve this problem. They have been overformulating in an effort to assure that minimum label levels are found in each bag. Not that overformulating by 4% reduces the amount of mixed goods out of tolerance by only 1 percent. Obviously this approach will never completely solve the problem. The manufacturer quickly reaches the point where the cost of overformulation exceeds the benefits.

We must convince the farmer and the agriculture commissioners of the problems inherent in the present system. Meanwhile, what else can we do?

1. First, we need to develop, and get state governments to accept, a better standardized procedure for taking and analyzing samples.

The biggest single factor working against us lies in the particle size distribution of the various fertilizer materials. When we mix a coarse fertilizer raw material with one which is extremely fine, it is almost impossible to achieve and maintain a mixed material of uniform composition. It's like trying to get a uniform mixture of small steel ball bearings with ping-pong balls; you just can't do it.

We must, therefore, attempt to establish manufacturing processes and inspection procedures which will provide us with materials having as nearly as possible the same particle size-distribution. This should reduce segregation to a minimum.

We would also recommend the use of statistical quality control procedures throughout the manufacturing process as an aid toward achieving product uniformity and quality.

We must cooperate with the various states in obtaining uniform and adequate sampling procedures. This involves the specification and utilization of the best possible sampling tools and the standardization of procedures to make certain that an adequate number of samples is taken to fully characterize a batch of fertilizer.

Note that this does not necessarily increase the load on the analytical laboratory in direct proportion to the number of samples taken. There are standard procedures available for compositing samples and obtaining a representative segment of the composite for use in the analysis.

For example, compositing the six samples given in our earlier example of the 0-24-24 fertilizer would have given analytical results on the composite equal to the arithmetic average of the six samples.

2. Second, industry has to recognize that each bag in each lot has to have a statistically acceptable probability of meeting guaranteed analysis levels. This doesn't mean averaging of nutrients; this doesn't mean even averaging results from samples of a single nutrient from a lot. It means that we have to have a confidence level that each nutrient in each bag meets the minimum level.

3. Third, if we are going to rely on sampling techniques and at the same time, meet the law's requirement of minimum guaranteed analysis in every package, we have to narrow the historical level of standard deviations, or else overformulate. Lowering the standard deviation will reduce the necessity for overformulating while simultaneously giving the farmer a fertilizer of improved quality.

4. Finally, we need to continue our educational process of the farmer and the Agricultural Commissioners. An even greater need, in many cases, is the education of the State Legislature. In many cases, the laws of the state need to be changed. They need to know that we are just as anxious as they are to maintain a system where the farmer gets a uniform high-quality fertilizer containing the ingredients that he needs in the amounts that he desires. We need their cooperation to achieve a proper interpretation of the law which, in turn, succeeds in helping the farmer without penalizing the fertilizer suppliers.

Note: Figures #1 to #13 on pages 155 through 158

FIGURE 1

PEPSI CHALLENGE

AFTER MIXING

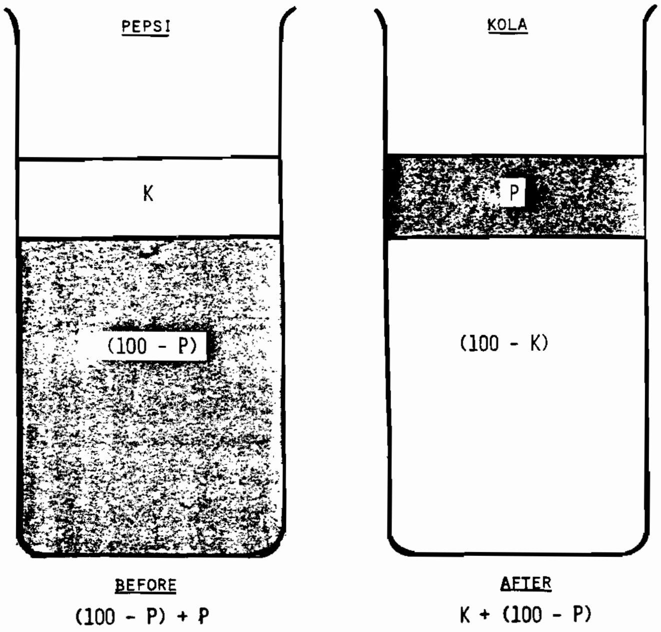


FIGURE 2

BASIC STATISTICS

AVERAGE AND STANDARD DEVIATION

	X_i	N	ΣX_i	$\bar{X}$	σ
EXAMPLE NO. 1	99	10	990		
	101	10	1010		
		20	2000	100	1.00
EXAMPLE NO. 2	95	10	950		
	105	10	1050		
		20	2000	100	5.00
EXAMPLE NO. 3		40	4000	100	3.61
EXAMPLE NO. 4	50	1	50		
	150	1	150		
		2	200	100	50.00
EXAMPLE NO. 5		42	4200	100	11.46

FIGURE 3

BASIC STATISTICS

AVERAGE AND STANDARD DEVIATION

TYPICAL EXAMPLE

SOURCE	GRADE N-P-K	OFFICIAL ANALYSIS P	 K	X_i %	P_2O_5 Δ	 Δ^2	X_i %	K_2O Δ	 Δ^2
ANNUAL REPORT:	0-24-24	22.3	27.3	92.9	6.3	39.7	113.8	9.3	86.5
ANALYSIS OF OFFICIAL		22.6	23.6	94.2	5.0	25.0	98.3	6.2	38.4
FERTILIZER SAMPLES		22.3	27.5	92.9	6.3	39.7	114.6	10.1	102.0
LA DEPT OF AGRICULTURE		26.6	21.5	110.8	11.6	134.6	89.6	14.9	222.0
7/1/76-6/30/77		26.4	21.9	110.0	10.8	116.6	91.2	13.3	176.9
		22.7	28.7	94.6	4.6	21.2	119.6	15.1	228.0
TOTAL	ΣX_i			595.4			627.1		
NUMBER	N			6			6		
AVERAGE	$\bar{X}$			99.2			104.5		
OVERALL AVERAGE					101.9				
	$\Sigma \Delta^2$					376.8			853.8
DIVIDED BY	$(N-1)$					5			5
VARIANCE	σ^2					75.36			170.76
STANDARD DEVIATION	σ					8.68			13.07

FIGURE 4

NORMAL DISTRIBUTION CURVE

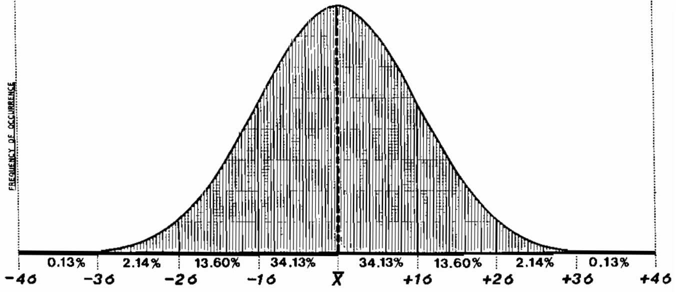


FIGURE 5

CURRENT BASIS

FOR

REJECTING FERTILIZER SAMPLES

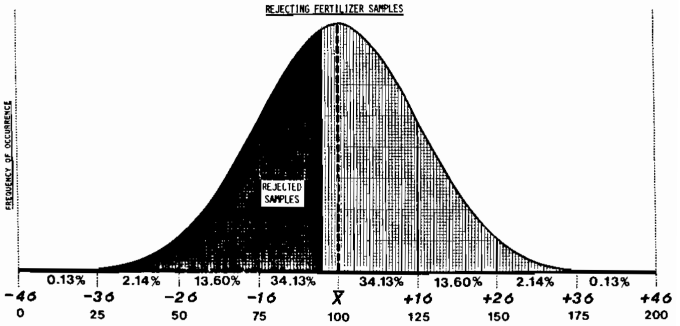


FIGURE 6

SUMMARY OF LOUISIANA DATA
ANALYSIS OF OFFICIAL FERTILIZER SAMPLES
(DEFICIENT SAMPLES ONLY)

NUMBER OF SAMPLES

YEAR	N	P	K	OVERALL
74/75	480	503	505	1488
75/76	451	488	491	1430
76/77	259	334	335	928
OVERALL	1190	1325	1331	3846

AVERAGE ANALYSIS

74/75	103.0	96.7	103.7	101.1
75/76	103.1	107.7	103.8	105.6
76/77	105.1	106.3	97.1	102.7
OVERALL	103.5	103.9	102.1	103.2

STANDARD DEVIATION

74/75	17.6	18.4	23.7	20.4
75/76	27.3	34.7	32.8	32.1
76/77	22.7	20.8	28.9	24.9
OVERALL	22.7	26.7	28.8	26.4

FIGURE 7

HISTOGRAM OF LOUISIANA FERTILIZER SAMPLES
(3860 ANALYSES TO THE NEAREST PERCENT)

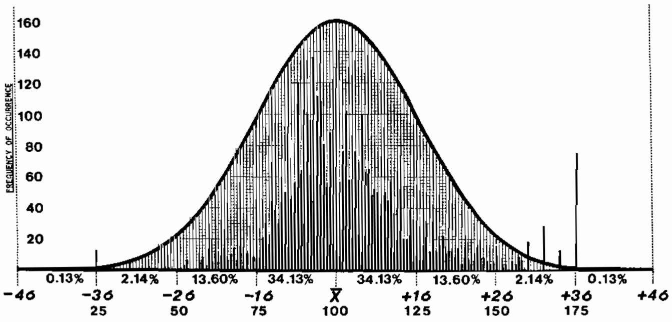


FIGURE 8

SUMMARY OF LOUISIANA DATA
ANALYSIS OF OFFICIAL FERTILIZER SAMPLES
DEFICIENT SAMPLES ONLY

TOTAL NUMBER OF SAMPLES

YEAR	N	P	K	TOTALS	% OF TOTALS
74/75	**480**	503	505	1488	
75/76	451	488	491	1430	
76/77	259	334	335	928	
TOTALS	1190	1325	1331	**3846**	

NUMBER GREATER THAN PLUS TWO STANDARD DEVIATIONS

74/75	**20**	12	22	54	
75/76	10	16	22	48	
76/77	10	10	12	32	
TOTALS	40	38	56	134	

NUMBER LESS THAN MINUS TWO STANDARD DEVIATIONS

74/75	**4**	4	3	11	
75/76	5	2	3	10	
76/77	6	2	4	12	
TOTALS	15	8	10	33	

NUMBER WITHIN TWO STANDARD DEVIATIONS

74/75	**456**	487	480	1423	95.6
75/76	436	470	466	1372	95.9
76/77	243	322	319	884	95.3
TOTALS	1135	1279	1265	**3679**	95.7
% OF TOTALS (OVERALL)	95.4	96.5	95.0	**95.7%**	

FIGURE 9

SUMMARY OF LOUISIANA DATA
ANALYSIS OF OFFICIAL FERTILIZER SAMPLES
DEFICIENT SAMPLES WITHIN ±2 STANDARD DEVIATIONS

NUMBER OF SAMPLES

YEAR	N	P	K	OVERALL
74/75	456	487	480	1423
75/76	436	470	466	1372
76/77	243	322	319	884
OVERALL	1135	1279	1265	3679

AVERAGE ANALYSIS

74/75	100.7	95.2	99.9	98.6
75/76	101.5	105.7	99.7	102.3
76/79	104.0	104.5	94.2	100.7
OVERALL	101.7	101.4	99.6	100.7

STANDARD DEVIATION

74/75	10.8	12.6	22.0	16.2
75/76	18.7	21.4	23.3	21.4
76/77	15.4	16.2	18.7	17.6
OVERALL	15.3	17.8	15.7	17.3

FIGURE 10

HISTOGRAM OF LOUISIANA FERTILIZER SAMPLES

(3860 ANALYSES AT FIVE PERCENT INTERVALS)

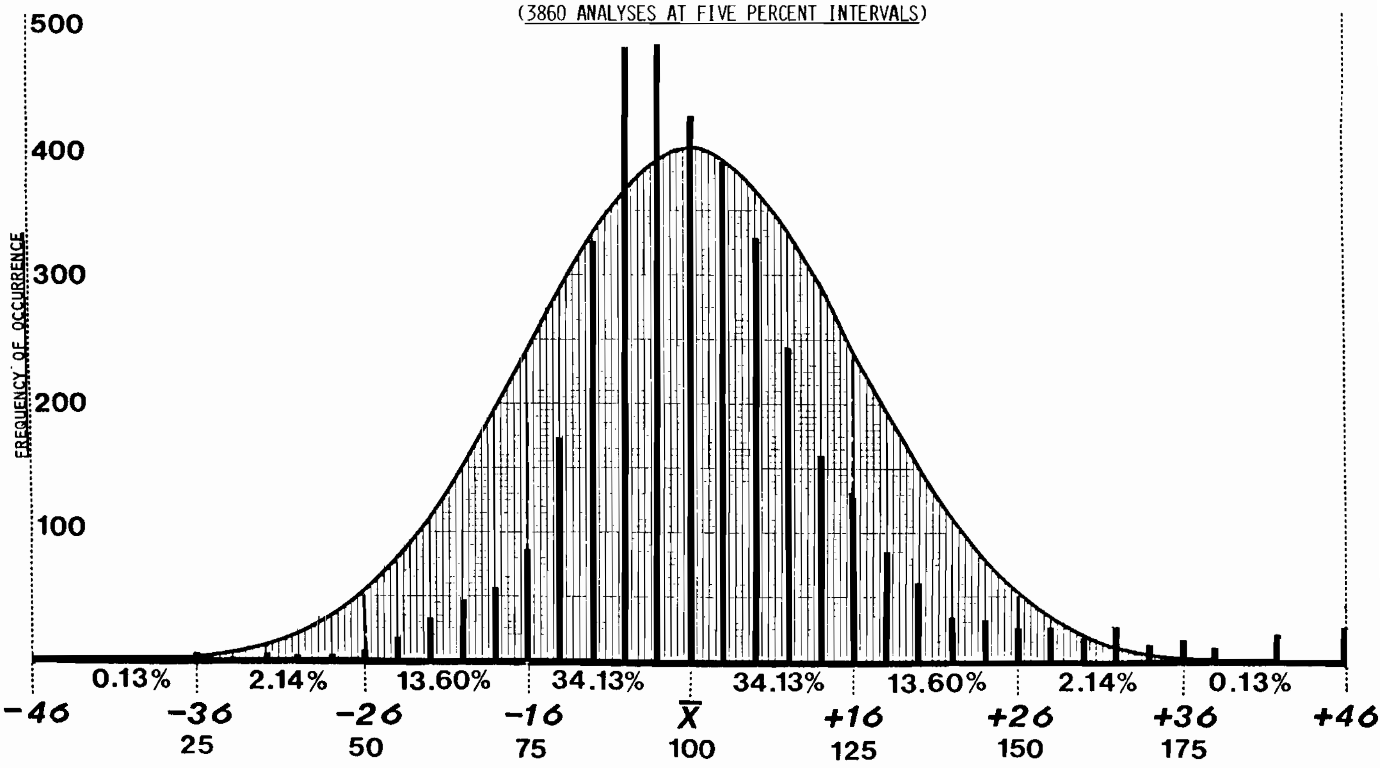


FIGURE 11

HISTOGRAM OF P_2O_5 REJECTED FERTILIZER SAMPLES FOR 1974/75 FY

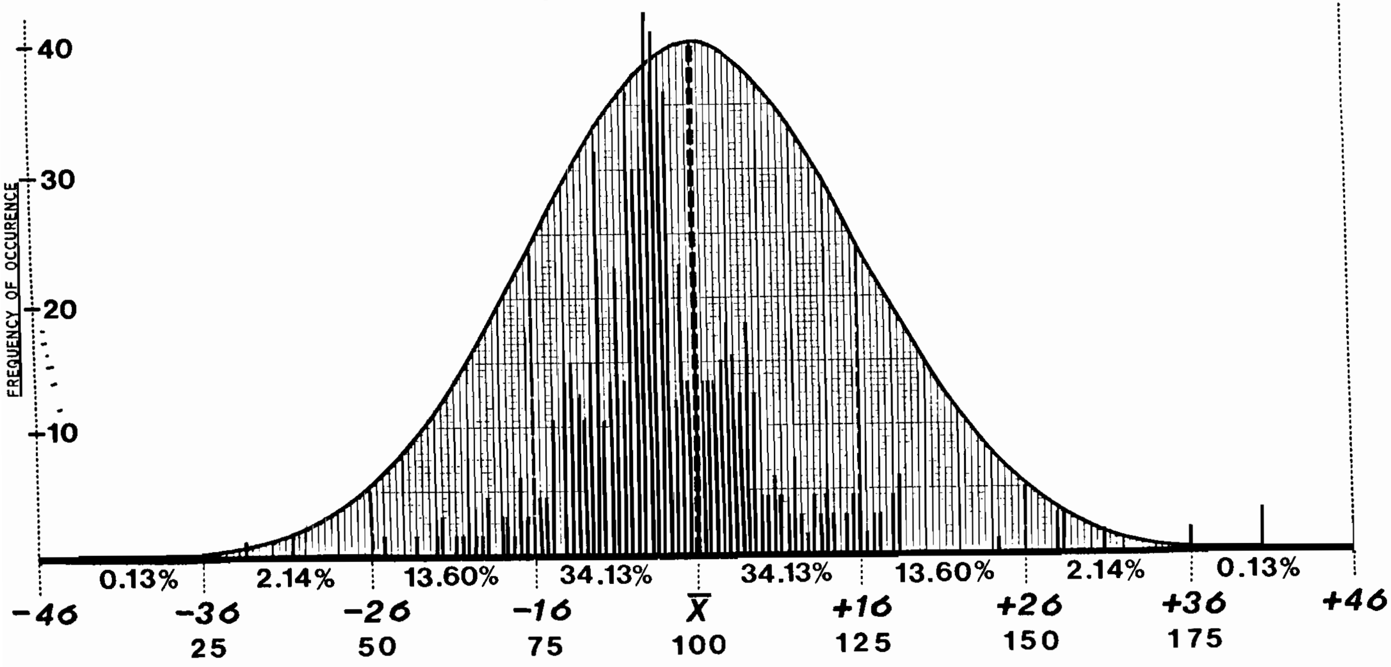


FIGURE 12

SOURCES OF DEVIATION FROM THE AVERAGE

BASIC MANUFACTURE

SAMPLING PROCEDURES

SAMPLING ERRORS

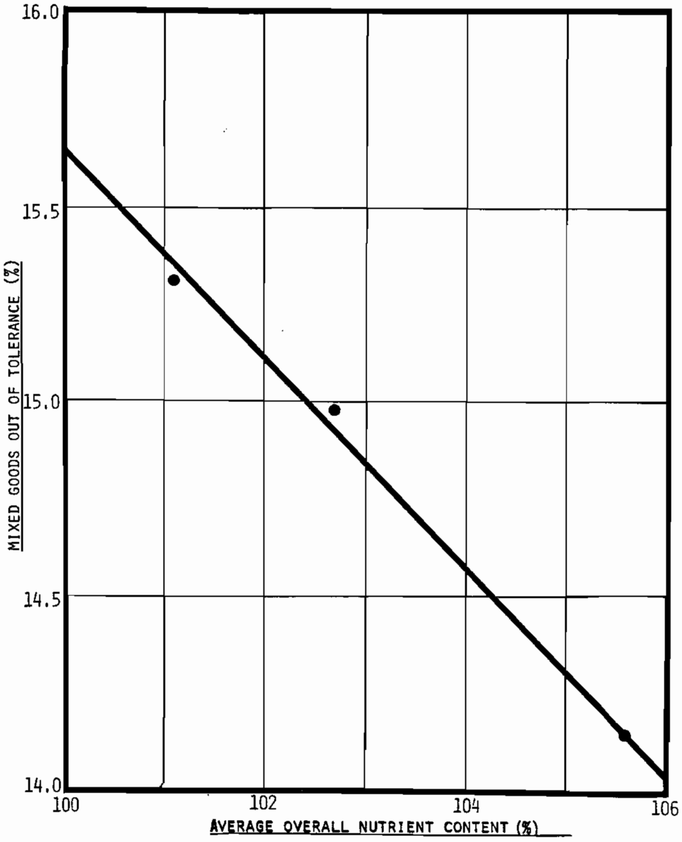
ANALYTICAL PROCEDURES

REPORTING PROCEDURE

TOTAL DEVIATION IS THE RESULT OF CUMULATIVE EFFECTS OF ALL THE FOREGOING VARIANCES AND PROBABLY OTHERS

FIGURE 13

REJECTED FERTILIZER SAMPLES VS NUTRIENT CONTENT



MODERATOR PETE COX: We have time for questions.

QUESTION FROM THE FLOOR: Do you have copies of your talk.

DR. VERNER: I have with me one more besides this one that I will be glad to give to you because you asked. I can make copies available to anyone who wants them. It is just a matter of reproducing.

MODERATOR PETE COX: Thank you Dr. Verner. You have given us a lot of food for thought on your most interesting discussion "Sampling and Meeting State Guarantees". (Applause)

MODERATOR COX: The final speaker on this afternoon's program is a Gentlemen to whom we are uniquely indebted and the reason for that is by us running late we caused him to change his plane schedule. His flight was due to have gone by now. When he saw what our schedule was, he changed it to fly later to get home, obviously very late this evening, for which we are most appreciative. He is a farmer, or was, born and raised on a farm in central Michigan. He received a B.S. degree from Michigan State University in Soil Science, and taught vocational agriculture for three years. In World War II he served with the Navy. He has worked in the Fertilizer Industry for 31 years and for the past 15 has been with the Andersons of Maumee, Ohio. He is Manager of Technical Services and Quality Control. It is a pleasure to introduce to you Wayne A. LeCureux who will speak to us on "Status of Particle Size of Fertilizer Materials. (Applause)

WAYNE A. LeCUREUX: Edwin, the time is getting on and I realize that the saying is — "The head can stand only as much as the bottom can bear". I am going to get right on here and talk about particle size because Dr. Werner gave me a wonderful introduction there on that thing. (Applause)

Status of Particle Size of Fertilizer Materials

Wayne A. LeCureux

The sizing of fertilizer materials has been an operating concern of ours now for several years. We know the affect that sizing has upon mixing compatability and prevention of segregation. To this end, we regularly sample and test inbound materials for analysis, screen size, density, moisture, and free acid; where that applies.

In our business, we operate a regional storage and distribution center. The larger percentage goes out as dry mixed bulk and bagged fertilizer. The smaller portion, we store and ship as dry straight materials mostly to other mixing plants in the region. We have storage capacity for about 200,000 tons of fertilizer material at the one location. All of the materials arrive by trainloads or by boatloads from the Great Lakes and St. Lawrence Seaway.

My topic "Status of Particle Sizing of Fertilizer Materials" implies a report of our findings and trends over the years. We find the results to date to be variable.

By way of improvements, we see the advent of Granular Urea and its advantages over Prilled Urea. We find the Granular Urea larger in size, harder and it has less tendency to crack upon impact. It is also less hydroscopic than Prilled Urea. We have experienced leaving it in an open bin over Winter without developing so much as a crust, or the taking on of any moisture.

Now, what do we see as continuing problems?

First, the question of particle size matching. Here is where the dilemma begins. While we see an increasing concern for particle sizing by individual product producers, on the other hand we still do not see a real development toward matching materials between n, p, and k products.

Standardization of particle sizes appears to be about as far off as ever. I thought a few years that D.A.P. particles would become the standard, when along came this granulated Urea; which ranges ½ —6+8 and ½ —8+10 mesh Tyler screens. These sizes are about one screen size larger than D.A.P.

When it comes to the matter of adopting product standards it seems to be a case of who is going to be the standard. It seems like each basic producer feels he should be the standard. Each do their thing in sizing without regard for the rest of the industry.

As of today, we still feel that D.A.P. should be the standard. To sum up the problem, we need more standardization between products such as Urea, Sulphate of Ammonia, D.A.P., T.S.P., and Potash. Add to this, the need for individual producers to develop more consistency of their individual products. For example, with D.A.P., we find the percentage of —6+8 mesh and the —10+14 sizes to range from 5 to 50% of the total; with the middle size of —8+10 mesh to range between 28 to 70% of the total. When we look at individual producers, the range can be almost that of the many producers as a whole. Some would say that this range of sizing is beneficial because it allows a greater opportunity to match other products.

Which brings us to the matter of uniformity predictability or as is sometimes said, "Send me another car like the one you sent me last week"! Such requests have become a joke in the industry, which admits that unpredictability is the going rule and we treat it without too much serious concern. Regardless, it is a real problem of the users at the other end of the line.

Potash sizing is another interesting phenomenon — not knowing which way to go. With the demand falling off for standard grade, the industry has had to turn more to compacting to get more of their output into larger particles.

The science of compacting and how to treat and handle the product needs more study. Some of the things we are seeing at the consumer end of the business are; too wide a range in particle sizing, and too many fines and breakdown into dust, and secondary hardening and lumping which results in fines when broken up.

This past year in 43 samples or lots of granular, they averaged 5% +6 mesh, with some individual samples running as much as 9% +6 mesh. At the other end of the screens, these same 43 samples of Granular Potash averaged nearly 7% —14 mesh, with some samples running more than 3% —28 mesh. How to treat and handle compacted Potash is still a question needing answers. Compacted Potash apparently can be made harder to breakdown than Crystal Potash. However, there is something occurring at the user end which results in too much fines, dust, and secondary set. These are Potash answers we still must search for.

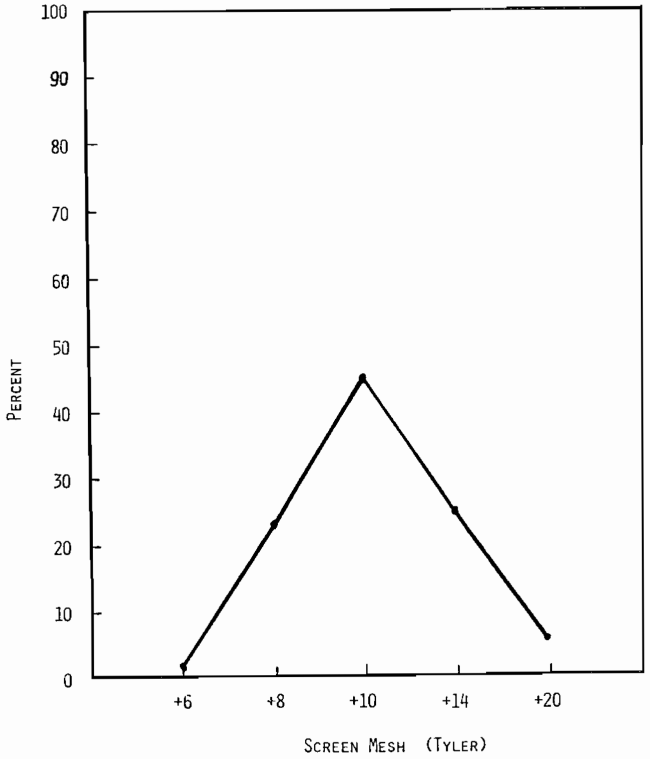
I must point out that the matter of material sizing and mixing campatability is at the top of the problem list of material users and state control officials alike.

To offer some idea of the extent to which control officials are viewing the matter is to note that at their annual meeting this past Summer, the Association of American Plant Food Control Officials (AAPFCO) had 7 main topics on their general session program, of which 5 dealt with the problem of better analysis control and particle sizing. The matter of particle separation or segregation is generally held to be the chief culprit.

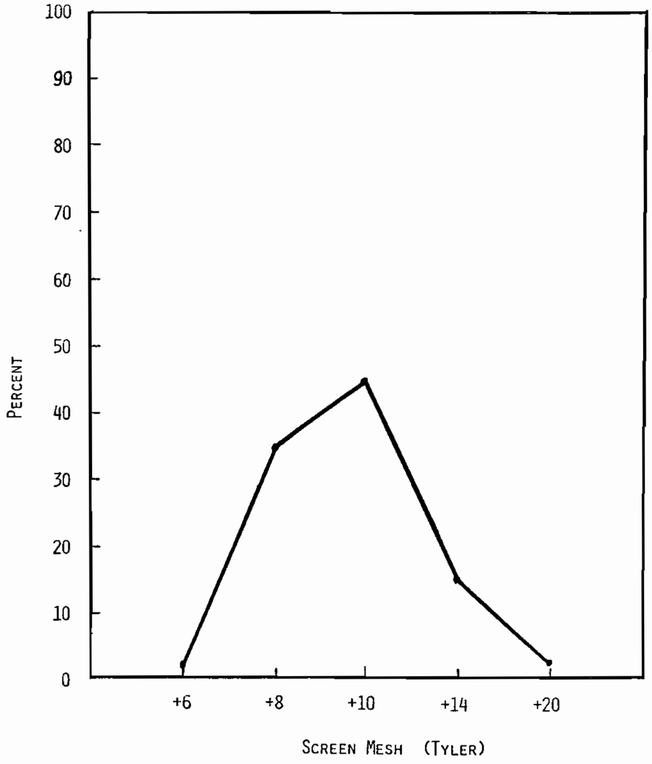
Two years ago at a meeting with a Mid-West state control official, he reported to us that he had recently been called before his state legislative committee and asked what was wrong that his reported rate of fertilizer analysis deficiencies were running so high and what was he doing about it.

The official told us at the meeting that if the rate of deficiencies continue as they were, he could forsee the possibility of more strigent laws being passed by states to bring analysis more into compliance. It was two years ago that this Mid-West state official made that statement. It is now a matter of record that Pennsylvania, this past Spring, did put into effect a revised fertilizer law with deficiency penalties unlike that of any other state to date. Such laws are not the answer. They create too many ill side effects, which are unfavorable for good control regulation, farmers, and industry.

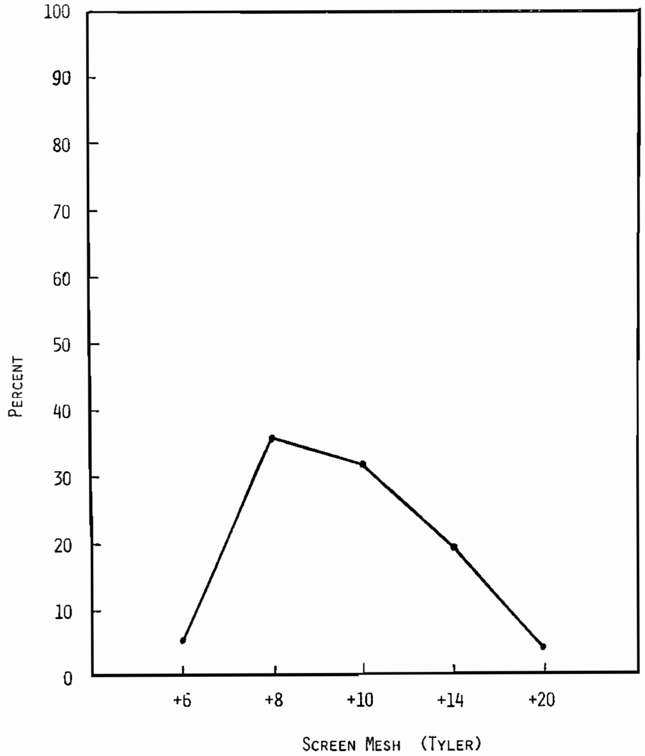
To help correct the problem, we see the state control officials now addressing the matter thru education and training. They are training their inspectors not only to be sample takers, but to be observers and advisors to local plant managers. To bring a heavier impact, I would like to suggest that the fertilizer production industry get more active — first, to produce more compatable uniform products and second, do more in training and education of people who are serving farmers with their products. Regulation is one thing we do not wish more of. To head it off, we as fertilizer industry must show more concern for the users and end use of our products if we are going to avoid more undesirable government interference into our businesses.



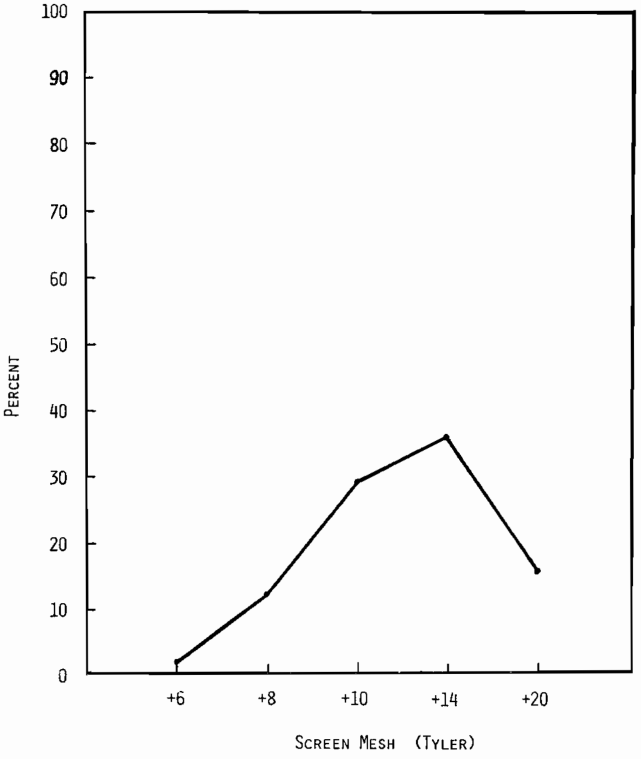
Diammonium Phosphate



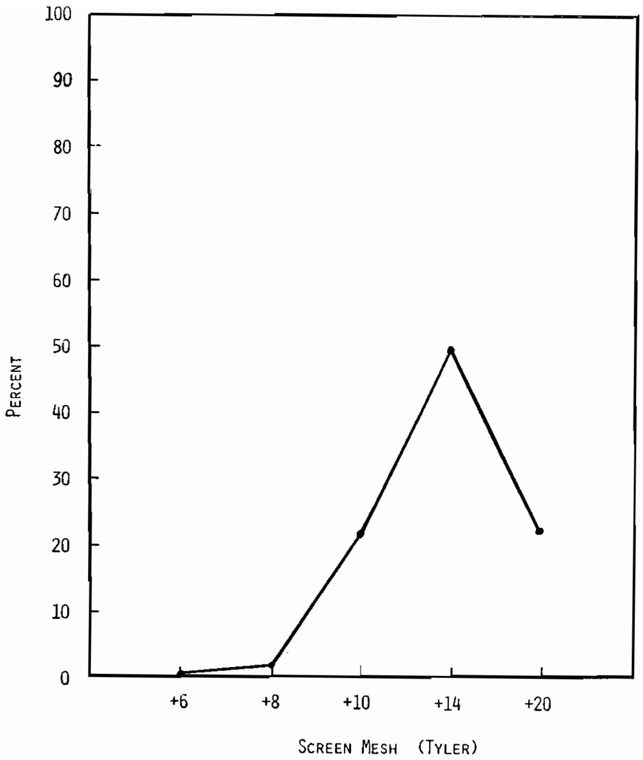
Triple Superphosphate



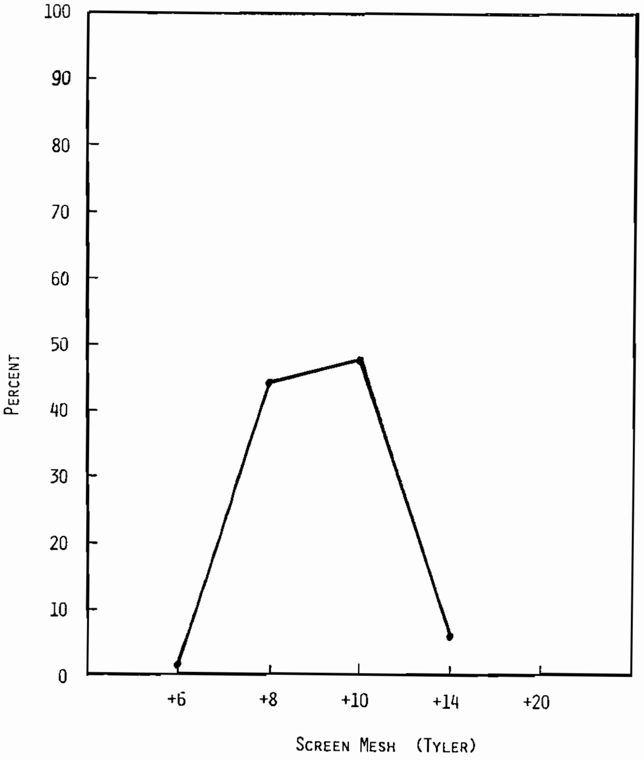
Granular Potash



Coarse Potash
1



Coarse Potash
2



Granular Urea

DAP - 49 Samples - 7 Producers

	Range			Average
+6 Mesh	0.0%	-	3.0%	.7%
+8 "	5.0%	-	49.5%	23.1%
+10 "	27.8%	-	70.5%	45.0%
+14 "	5.4%	-	41.9%	24.5%
+20 "	.1%	-	21.9%	5.4%
-20 "	0.0%	-	5.3%	.9%

DAP - 23 Samples - 1 Producer

	Range			Average
+6 Mesh	0.0%	-	1.6%	.4%
+8 "	8.0%	-	27.8%	16.8%
+10 "	27.8%	-	48.8%	36.3%
+14 "	23.4%	-	41.9%	33.4%
+20 "	1.9%	-	21.9%	8.4%
-20 "	0.0%	-	4.5%	3.7%

TSP - 17 Samples - 1 Producer

	Range			Average
+6 Mesh	.7%	-	2.0%	1.4%
+8 "	18.8%	-	46.2%	35.1%
+10 "	35.4%	-	54.0%	44.5%
+14 "	8.3%	-	30.7%	15.7%
+20 "	.4%	-	4.2%	1.7%
-20 "	0.0%	-	.8%	.4%

Granualr Urea - 20 Samples - 1 Producer

	Range			Average
+6 Mesh	.1%	-	2.1%	1.1%
+8 "	40.8%	-	62.5%	52.4%
+10 "	33.7%	-	54.1%	42.5%
+14 "	.1%	-	6.0%	3.6%
+20 "	0.0%	-	.4%	.2%
-20 "	0.0%	-	.4%	.2%

Coarse Potash - 25 Samples

	Range	Average
+6 Mesh	.2% - 2.9%	.7%
+8 "	4.2% - 31.0%	13.0%
+10 "	18.1% - 35.5%	29.0%
+14 "	25.1% - 43.7%	35.8%
+20 "	6.2% - 26.6%	16.3%
-20 "	1.5% - 12.2%	5.1%

Granular Potash - 43 Samples

	Range	Average
+6 Mesh	.3% - 9.1%	5.1%
+8 "	27.9% - 48.3%	36.7%
+10 "	26.7% - 44.1%	32.0%
+14 "	9.4% - 28.3%	18.9%
+20 "	.9% - 8.2%	4.0%
-20 "	1.2% - 6.1%	2.7%

Part 1

DAP

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

Company	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %		DENSITY (lb/cu.ft.)
								N	P_2O_5	
G	.2	15.8	51.8	26.8	3.8	1.0	.6	18.01	47.28	54.0
G	.2	19.6	45.0	21.8	8.1	3.0	2.3	17.88	45.11	56.4
G								18.43	45.68	
G	.4	37.7	53.6	7.4	.7	.1	.1	17.8	46.2	56.4
G	.4	32.4	53.7	11.8	1.3	.2	.2	18.3	47.2	56.8
C	2.1	33.9	42.4	17.1	3.6	.6	.3	18.04	46.05	56.0
C	1.8	26.8	39.5	22.5	6.6	1.5	1.3	18.32	46.29	56.0
C	2.3	41.8	44.6	10.1	.8	.2	.2	18.28	46.11	55.0
C	.9	22.3	40.3	24.5	9.1	2.1	.8	17.87	46.26	55.2
C	3.0	42.9	39.5	11.0	2.5	.6	.5			56.0
E	0	27.5	66.8	5.4	.1	.1	.1	18.0	46.7	58.0
E	.2	21.6	51.4	20.3	4.3	1.1	1.1	17.7	46.1	56.0
E	0	13.5	67.8	16.3	1.9	.2	.3	18.2	46.2	59.0
V	.2	17.3	55.7	22.8	3.2	.5	.3	17.88	46.03	55.2
V	.3	14.4	53.9	27.0	3.6	.5	.3	18.23	46.70	55.0
V	.2	17.4	70.5	11.4	.2	.1	.2			54.0
V	.2	15.7	61.2	20.3	2.0	.4	.2	18.38	46.77	54.0
B	.1	35.3	45.9	15.7	2.6	.3	.1			59.0
B	.5	49.5	42.0	7.0	.8	.1	.1	18.31	43.55	58.0
B								17.98	45.60	58.0
B	.3	38.0	40.8	16.4	3.7	.5	.3	18.20	45.86	58.5
B	.3	31.2	50.8	14.6	2.3	.5	.3	17.83	45.45	59.0
B	.4	41.2	47.8	9.2	1.0	.2	.2	18.70	44.54	58.0

DAP continued
Page 2

CO.	+6	+8	+10	+14	+20	+28	-28	ANALYSIS % N	ANALYSIS % P_2O_5	DENSITY
A	.9	40.5	44.0	13.0	1.0	0	.6	18.67	44.49	58.8
D	1.5	31.3	48.0	16.6	2.3	.2	.1	18.06	46.38	60.8
D	1.5	27.2	47.4	19.3	3.7	.8	.1	17.2	46.0	60.0
D	1.1	23.9	48.7	22.1	3.8	.4	–			60.2
D	2.1	28.8	47.5	19.5	.2	.1	–	18.03	46.13	60.0
F	.3	19.6	39.0	33.1	7.0	.8	.2	17.25	45.91	61.5
F	.2	19.4	39.2	28.4	10.0	2.3	.5	17.30	45.86	60.2
F	1.6	26.8	35.0	31.6	4.5	.3	.2	17.9	45.35	60.8
F	.6	20.7	38.8	31.1	7.5	1.0	.3	17.89	46.15	61.2
F	.6	20.7	38.8	31.1	7.5	1.0	.3	17.72	45.94	61.2
F	0	9.0	36.8	40.6	11.5	1.6	.5			
F	.7	27.8	36.9	25.7	6.4	1.6	.9	17.5	42.79	59.8
F	.5	22.3	39.1	30.3	7.1	.6	.1	17.98	46.09	62.2
F	.2	17.4	38.8	34.2	8.4	.9	.1	18.03	45.81	62.0
F	.2	8.0	35.5	41.7	11.4	1.9	.8	18.27	46.05	61.8
F	.2	10.8	43.5	38.0	6.6	.7	.2	18.27	45.94	62.0
F	.5	16.8	32.9	33.9	12.5	2.7	.7			60.0
F	1.2	29.6	38.7	23.4	5.7	1.0	.4			60.0
F	.3	14.3	41.7	32.5	9.3	1.6	.3			60.2
F	.3	16.9	43.1	31.8	6.7	.9	.3			60.4
F	0	5.5	27.8	40.8	21.9	3.5	.5	17.43	44.33	59.4
F	.2	9.1	37.4	39.8		1.4	.1	17.95	46.60	62.0
F	.1	8.8	35.2	41.9	12.0	1.8	.2	17.7	45.9	59.0
F	.3	19.9	48.8	28.9	1.9	.1	.1	17.9	44.1	60.0
F	.1	9.4	37.3	40.0	11.4	1.6	.2	18.1	46.1	58.2
F	.2	18.8	51.3	27.5	2.0	.1	.1	18.2	45.6	60.0
F	.1	16.7	42.9	31.5	7.7	1.0	.1	17.9	45.5	60.8
F	.2	18.6	42.8	31.5	6.3	.5	.1	17.5	44.7	61.0

· Part 2

TSP

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
D	1.3	38.3	45.3	13.0	1.5	.3	.3	46.59	64.0
	1.9	42.0	43.2	11.7	.8	.2	.2	45.96	63.8
	1.4	38.2	47.2	12.0	.9	.1	.2	46.14	64.0
	1.7	44.1	43.8	9.7	.5	.1	.1	46.54	63.8
	1.9	42.0	43.2	11.7	.8	.2	.2	46.61	63.8
	1.8	44.9	44.2	8.3	.5	.1	.2		64.2
	2.0	46.2	38.3	11.4	1.7	.2	.2	46.39	63.2
	1.4	41.7	43.5	12.0	1.2	.1	.1	45.73	63.4
	1.3	45.8	35.4	15.8	1.6	.1	TR	45.43	63.4
	.7	18.8	45.3	30.7	3.9	.4	.2	44.94	65.2
	1.3	34.8	48.0	14.2	1.3	.2	.2		
	.5	31.6	54.0	13.5	.4	0	0	45.6	
	1.5	29.1	43.2	21.2	4.2	.6	.2	46.8	65.0
	1.0	31.1	45.4	19.6	2.6	.2	.1	46.3	65.0
	1.0	24.4	44.2	26.2	3.6	.4	.2	46.8	64.0
	.7	28.4	49.9	19.4	1.5	.1	0	47.0	64.8
	1.7	35.1	42.2	17.5	2.9	.5	.1	43.03	65.0

Part 3

GRANULAR POTASH

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
A	2.8	34.4	32.6	23.7	4.7	.8	1.0	0-0-61.92	65.0
	5.1	36.9	33.2	18.5	3.4	.9	2.0		65.4
	5.8	31.1	27.9	23.5	7.3	1.8	2.6	59.4	66.2
	3.5	32.8	35.2	23.2	4.0	.6	.7		65.4
	3.0	30.7	34.9	25.8	3.9	.7	1.0		65.0
	6.5	41.8	31.1	16.4	2.4	.6	1.2	0-0-60.87	66.4
	2.7	38.5	39.0	16.0	1.8	.7	1.3		66.0
	7.1	41.3	29.9	16.4	2.8	.8	1.7		66.0
	6.3	38.1	31.3	17.9	3.1	1.0	2.3	59.7	65.8
	3.7	38.7	35.1	18.0	2.3	.7	1.5		65.2
	5.3	39.1	33.7	17.2	2.4	.8	1.5	60.45	65.0
	8.2	47.1	29.1	12.7	1.4	.5	1.0	60.60	66.0
	6.2	43.5	34.1	13.4	1.6	.5	.7	59.66	65.4
	.3	42.2	36.2	17.8	1.8	.6	1.1	60.55	66.2
	5.9	34.4	30.9	19.7	3.0	1.5	4.6		67.2
								60.5	66.6
	4.9	34.9	33.8	19.7	2.7	1.1	2.9		67.2
	4.6	28.6	30.4	25.4	6.0	1.7	3.3		67.0
	7.0	39.1	31.5	17.5	2.8	.7	1.4	60.1	67.0
	6.3	43.0	34.2	14.0	1.3	.4	.8	59.7	66.8
	8.5	48.3	30.4	10.3	.9	.4	1.2		66.2
	8.4	45.5	31.6	11.6	1.7	.4	.8	60.74	66.2
	6.7	37.9	31.2	16.8	3.9	1.2	2.3	60.26	67.2
	3.8	33.2	34.2	21.4	4.0	1.4	2.0	60.80	66.0
	2.5	27.9	31.8	28.1	8.2	.9	.6	59.7	65.2
	4.0	29.4	28.4	28.3	6.6	1.3	2.0		66.0

Granular Potash (continued)
Page 2

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
A	7.0	33.9	26.7	23.3	5.4	1.2	2.8	58.2	66.8
	7.6	39.2	28.4	17.7	4.2	1.0	1.9	60.57	
	9.1	42.5	27.1	15.4	3.4	.8	1.7	60.41	
	4.1	32.5	32.5	23.1	5.9	.8	1.1	61.3	64.8
	5.7	40.6	29.1	17.9	4.7	.7	1.3	59.2	65.0
	4.0	34.5	31.9	21.1	6.0	.9	1.6		65.0
	6.8	42.6	29.2	14.9	3.9	1.0	1.6	60.3	65.2
	6.6	44.7	30.5	13.5	3.4	.4	.8	61.1	65.0
	3.6	32.2	32.1	23.9	6.4	.7	1.1	59.7	64.8
	5.9	38.0	30.0	19.0	4.1	1.0	2.0	62.1	66.0
	5.3	34.2	29.3	21.8	5.6	1.2	2.6	61.7	65.4
	5.1	36.0	31.5	20.8	3.9	.9	1.8	58.8	65.0
	3.4	29.6	31.7	24.8	6.8	1.5	2.2	60.3	65.0
	3.7	38.1	30.3	19.5	6.5	1.1	.8	60.1	65.8
	3.6	32.4	30.9	21.3	7.7	1.8	2.3	60.2	66.4
	3.9	34.6	30.9	19.5	6.7	1.9	2.5	60.3	66.5
W	3.2	39.9	44.1	9.4	1.9	.7	.8	60.71	65.8
	2.8	40.5	38.3	11.7	2.8	1.3	2.6	61.36	65.0

COARSE POTASH

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
A	.7	12.5	28.3	36.1	18.6	2.8	1.0	61.22	66.2
	.5	9.9	31.7	38.7	15.7	2.1	1.4		65.4
	.5	11.9	33.5	37.8	13.4	1.5	1.4		65.4
	.6	11.1	28.7	31.5	15.9	5.2	7.0	62.36	66.4
	.3	9.6	32.0	37.5	15.1	2.9	2.6		66.4
	.4	12.4	35.5	36.2	11.6	1.9	2.0	61.63	66.4
	.4	13.4	33.0	33.2	12.7	3.8	3.5		64.6
	.4	9.7	29.8	36.4	17.7	3.9	2.1	61.43	64.6
	.3	6.3	23.3	38.1	22.7	5.3	4.0	61.29	66.0
	.7	14.0	31.9	31.3	12.9	4.0	5.2	61.26	66.2
	2.9	31.0	33.3	25.1	6.2	.6	.9	61.30	68.6
	1.3	22.0	28.6	33.4	12.3	1.3	1.1		67.2
	2.4	26.2	30.4	26.8	10.4	2.0	1.8	60.95	68.0
	1.7	19.8	28.8	32.1	13.9	2.1	1.6		67.8
	.4	12.9	32.3	35.7	15.0	2.1	1.6	61.43	63.0
	.6	13.0	29.0	36.5	16.7	2.6	1.6		66.2
	.7	12.3	29.2	38.2	16.1	2.1	1.4	60.3	67.2
	.6	13.3	30.6	35.5	15.7	2.6	1.7	61.13	67.0
	.8	15.7	32.6	34.1	12.6	2.3	1.9	62.0	66.2
	.9	21.7	34.9	29.2	11.0	1.5	.8	62.21	66.4
	.3	6.2	25.0	42.9	20.9	3.0	1.7	61.6	65.6
	.2	7.2	23.9	39.6	23.3	4.0	1.8	60.8	64.6
	.3	4.2	18.1	41.8	26.5	5.1	4.0	61.5	64.4
	.4	4.3	19.5	43.7	26.6	3.8	1.7	62.0	64.0

Coarse Potash (continued)
Page 2

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
A	.4	4.9	21.7	42.9	24.9	3.8	1.4	62.0	62.5
D	0	1.7	23.2	49.6	20.2	2.9	2.4		64.4
D	0	2.4	26.4	48.6	18.2	2.6	1.8	61.5	64.6
D	0	1.6	18.9	48.6	24.2	4.0	2.7	60.52	65.0
D	0	1.5	21.6	47.9	23.7	3.2	2.1		65.2
D	0	1.7	23.2	46.8	21.6	3.4	3.3	61.05	65.2
D	0	1.5	20.2	49.2	22.9	3.5	2.7		65.0
D	TR	1.6	23.5	50.2	20.1	2.5	2.1	61.07	66.2
D	TR	1.4	22.8	50.6	19.3	3.1	2.8	60.97	65.2
D	0	1.7	20.8	51.4	21.4	2.8	1.9		66.2
D	0	1.2	23.9	49.6	20.9	2.6	1.8	61.50	66.0
D	0	1.0	22.4	47.3	22.4	3.3	3.6		65.8
D	0	1.8	23.9	49.5	20.9	2.4	1.5		65.4
D	0	1.3	20.0	50.2	23.4	3.1	2.0		65.8

Part 5

GRANULAR UREA

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
U	0	40.9	56.1	2.8	.2	-	V.LT.TR.	46.03	47.0
U	.2	39.1	56.1	3.9	.3	.1	TR	44.6	47.8
U	.3	26.3	60.6	11.6	1.1	.1	-	45.96	47.0
U	.6	48.4	43.2	6.6	1.1	.1	-		46.2
U	1.3	58.8	38.0	1.5	.3	.1	-	46.2	45.0
U	1.3	43.7	50.6	3.9	.4	.1	-	46.0	45.4
S	.2	11.6	45.2	35.5	3.1	1.6	2.8		45.8
S	.1	23.0	67.7	7.3	.8	.4	.7	46.08	44.8
S	0	8.5	71.1	15.0	2.4	1.4	1.6	46.04	-
S	.1	8.8	59.3	24.7	4.0	1.4	1.7	45.95	45.4
S	.2	12.2	60.4	20.3	3.5	1.3	2.1	45.79	45.0
K	1.2	53.7	43.2	1.5	.1	.1	.2		47.0
K	.6	44.2	51.7	2.8	.3	.2	.2	46.35	47.0
K	.6	38.1	58.4	2.5	.2	.1	.1		46.2
K	.4	37.8	57.5	3.9	.2	.1	.1		47.0
K	.6	38.8	55.8	4.3	.3	.1	.1	46.2	47.2
K	.6	42.1	51.9	4.7	.3	.2	.2	46.30	46.5
K	.8	44.5	49.0	5.1	.4	.1	.1		47.0
K	1.2	42.7	49.7	5.5	.5	.2	.2		46.2
K	.8	43.7	50.3	4.3	.5	.3	.1	46.4	46.5
K	1.3	41.7	53.0	3.2	.4	.2	.2	46.03	46.4
K	.8	39.5	56.2	2.9	.3	.1	.2		46.5

Part 5
Granular Urea (continued)
Page 2

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
K	1.4	53.8	40.9	3.5	.3	.1	TR		46.2
	1.1	50.6	43.5	4.4	.2	.1	.1	45.48	47.1
	1.0	48.6	43.9	5.9	.4	.1	.1		47.0
	1.5	53.5	39.7	4.8	.4	.1	TR	45.7	46.6
	.5	41.7	51.6	6.0	.2	TR	TR		47.4
	.4	45.9	48.5	5.0	.2	.1	.1	46.05	47.2
	1.6	59.4	36.1	2.6	.2	-	.1	45.4	48.2
	.4	40.8	54.1	4.1	.3	.1	.2	45.5	
	.4	45.6	49.6	4.1	.2	0	.1	46.34	
	.7	46.2	46.7	6.0	.3	0	.1	45.92	
	1.8	58.2	37.4	2.1	.1	.1	.3	46.6	45.8
	1.2	56.8	39.0	2.6	.2	.1	.1	45.7	45.4
	1.4	51.5	43.8	3.0	.2	0	.1	46.5	45.4
	1.2	57.0	37.8	3.5	.2	.1	.2	46.0	46.0
	1.9	61.0	33.7	3.1	.1	.1	.1	46.4	
	1.2	57.0	37.8	3.5	.2	.1	.2	46.0	46.0
	1.2	51.5	44.7	2.4	.1	.1	0	46.4	46.0
	2.1	55.2	39.7	2.5	.2	.1	.2	46.4	46.2
	1.0	51.9	44.2	2.6	.1	0	.1	46.6	46.0
	.1	62.5	37.3	.1	0	0	0		45.0

PRILLED UREA

SCREEN, CHEMICAL ANALYSIS AND DENSITY 1977 - 1978

Screen Profile (Tyler Screens)

COMPANY	+6	+8	+10	+14	+20	+28	-28	ANALYSIS %	DENSITY (lb/cu ft)
P	.1	12.0	50.2	33.9	1.9	.8	1.1	46.17	45.2
	.1	12.0	50.2	33.9	1.9	.8	1.1	45.5	45.2
	0	10.0	52.0	36.5	1.1	.2	.2	46.1	45.8
	0	9.4	52.1	37.3	1.0	.1	.1	46.6	45.0
	0	8.6	48.1	40.6	1.6	.5	.6	46.4	45.2
	.2	11.3	49.6	35.9	1.6	.7	.7	45.69	46.0
	0	11.0	46.5	35.2	2.9	1.7	2.7		45.2
	.3	17.0	55.8	23.5	1.1	.6	1.7		45.2
	.2	1.9	46.6	41.0	3.8	2.1	4.4		45.2
	.1	11.8	50.4	34.1	1.8	.9	1.1		45.0
	.2	11.5	47.5	34.9	2.5	1.2	2.2	46.16	45.4

MODERATOR COX: Thank you Wayne. Another good interesting discussion. Are there any questions for Wayne. I thank you for finishing up this afternoon Session with a roaring start.

CHAIRMAN RODGER SMITH: My thanks to Moderators David Leyshon and Pete Cox, all of our speakers and an attentive audience for a most interesting meeting this afternoon. Our Thursday morning session will start promptly at 9 A.M.

All of you are invited to our Cocktail Party — 6 p.m. — room location shown on Bulletin Board at Registration Counter.

MODERATOR COX: I apologize for the lateness of the hour and I appreciate your courtesy. Meeting is adjourned.

Thursday, November 2, 1978

Final Session

Moderators

Rodger C. Smith

Glen Wesenberg

Business Meeting

CHAIRMAN SMITH: Okay Folkes. The 1978 Business Meeting, of The Fertilizer Industry Round Table, can now come to order. We will follow the Program as printed. Our Secretary-Treasurer, Paul Prosser, will give us his report at this time. Paul please.

Secretary-Treasurer Report

Paul J. Prosser, Jr.

Good Morning. I would like to take one minute to mention again that all of the support of this Round Table comes from registrations at the Annual Meetings and to some extent from the sale of additional copies of the Proceedings. We have, therefore, asked in the past, and we continue to request, that all of the people who attend this meeting please register and pay the fee. We have even asked the "Speakers", who make a very big effort to help us here, also to make that contribution provided they come from an "Industry" or a "Company" that is associated with the "Fertilizer Group". We have had only slight problems with that in the past. I just mention, however, that it is the only source of revenue and that is what we depend on.

CHAIRMAN SMITH: Thank you Paul. I think we will all agree that the Round Table is the best buy that any of us incur, and this is only possible, because everybody contributes much time and effort to the "Program" in addition to performing many other duties required. Please let me make a "Special Mention" of the Contribution that "Paul Prosser and his Office make". In effect they become "The Executive Secretary Equivalent" to what you have in many "Organizations". It is a tremendous "Contribution" both in "Cost and Performance" and it is really great to have them. (Applause)

Financial Statement
on page 169

CHAIRMAN SMITH: The next subject is Nominations. Before calling on the Chairman, of our Nominating Committee, I would like to say that our Board of Directors have been studying, during the past year, the makeup of the Round Table, the type of Organizations that are represented, the Geographic Representation, other Cross Cuts of the Organization and considering what modification might be needed in the membership of The Board, through time, in order to perhaps get a little more representation of the total membership and also The Board to be progressively representative people that have been loyal in both attendance and contribution of time. We do not have anything specific to suggest at this time but possibly will in another year. (Applause)

I now call on Wayne King, Chairman of The Nominating Committee.

Nominating Committee Report

Wayne W. King, Chairman

Good Morning. Thank you Rodger. I would like to handle our "Recommendations for Nominations" in two easy steps.

The First Step: We place two names in nomination for "Chairman and Vice-Chairman." The Period of Time is TWO YEARS. For Chairman, to replace Rodger, will be Frank T. Nielsson of IMC: And for Vice-Chairman we have Frank P. Achorn of TVA. I would like to get a second for these two Gentlemen and please let Rodger have your vote.

Financial Statement

Secretary—Treasurer

Paul J. Prosser, Jr.

October 24, 1977 to October 25, 1978

CASH BALANCE— October 24, 1977		$ 7,273.13
Income October 24, 1977 — October 25, 1978		
Registration Fees — 1977 Meeting	$12,977.00	
Sale of Proceedings	2,542.45	
Total Receipts October 24, 1977 — October 25, 1978		15,519.45
Total Funds Available October 24, 1977 — October 25, 1978		$22,792.58
Disbursements October 24, 1977 — October 25, 1978		
1977 Meeting Expenses	$ 1,157.30	
1977 Proceedings Including Printing, Postage, etc.	9,570.73	
Miscellaneous Expenses Including Postage, Stationary, etc.	484.30	
Reimbursement for Cocktail Party	120.86	
Membership Letters, Including Postage	600.25	
Directors Meetings	898.48	
1978 Meeting — Preliminary Expenses	276.56	
Total Disbursements October 24, 1977 — October 25, 1978		13,108.48
CASH BALANCE — October 25, 1978		$ 9,684.10
Less Reserve for Cocktail Party Fund		653.46
Total Cash Available October 25, 1978		$ 9,030.64

Respectively submitted,

PAUL J. PROSSER, JR.
Secretary-Treasurer

CHAIRMAN SMITH: Do we have a second? Yes we have several in the room. Any discussions? Frank Nielsson and Frank Achorn have performed so many times, at our Round Table Special Board Meetings during the year and at our Annual Meetings, that I am sure most of you know them for their many contributions and time they give the Round Table from year to year.

Please stand up Frank and Frank. (Much Applause)

All those in favor to elect both, please say "Aye" and those against "Nay" — There were no "Nays".

CHAIRMAN SMITH: It is a vote. Congratulations Frank Nielsson and Frank Achorn. (Lots of Applause)

WAYNE KING: For our second step: We place in Nominations four names to add to our Board of Directors now. We have more names and they will come up at the next meeting. We are trying everything we can to get "our Board" geographically properly represented. Here are the four names—

Tom Howe, Howe, Inc. Minneapolis, Minn.	Ralph Hughes, Land Mark, Inc. Columbus, Ohio
John H. Surber, New Whales Chem. Inc. Mulberry, Fla.	Barney Tucker, Burley Belt Chem. Co., Lexington, Ky.

CHAIRMAN SMITH: Thank you Wayne. Do I hear a second? Yes, many.

Hopefully, Wayne and I explained the effort that is going on to attempt to develop something further in the way of rotation in the future. Will the Nominees stand up please? Thank you. (Applause) The Nominees are our regular attendees at these meetings.

Those in favor of the Nominations please say "Aye" and against "Nay" Lots of "Ayes".— No "Nays". The vote is unanimous and we congratulate our "New Board Members". (Applause)

WAYNE KING: It is now our pleasure to have Walter Sackett come up here with a little something that we give to "Past Chairmen". Here you are Walter.

Presentation Of Plaque

Walter Sackett

To

Rodger C. Smith

It takes a lot of dedication and selflessness to represent our Round Table as Chairman over a period of two years and we had no shortage of these qualities in Rodger.

Rodger— I would like to present this "Plaque" to you with "Affection" of all the "Membership". Plaque reads—

FERTILIZER INDUSTRY
ROUND TABLE
RODGER C. SMITH
CHAIRMAN
1977—1978

CHAIRMAN SMITH: Thank you "Walter" and thank you "All". Having attended the first one of these Round Tables, 28 years ago at Atlantic City, and all but one since, I have gained a lot of information from the meetings over the years and on accasions I tried to contribute a little bit. I have known a lot of people among you, and others that have attended the Round Table over the years, as friends. This is much appreciated and I assure you this beautiful "Plaque" will be displayed very prominently. Again I thank all of you. (Much applause)

CHAIRMAN SMITH: Our next subject for discussion:

Meeting Place and Dates Committee

Tom Athey - Chairman

Our Board voted, a year and half ago on "Odd Years" we would meet in Washington, D.C. Arrangements have been made to hold our "29th Annual Meeting" at The Shoreham-American Hotel, Washington, Tuesday, October 30th, Wednesday, October 31st, and Thursday, November 1st, 1979. Letters with complete information, will be mailed in plenty of time for making your reservations. Hope to see you all there.

CHAIRMAN SMITH: We certainly are fortunate in having Tom Athey handling this important phase so "professionally" and we thank you Tom. (Applause)

There just seems to be a general acceptance of rotating our Annual Meetings between Atlanta and Washington. It seems to work out well as far as "Arrangements and Transportation". Geographically it seems to be a good "center" for the part of "United States Fertilizer Industry" our program appeals to. It is also a convenient "location" for "our overseas people."

Tom also is Chairman of our "Entertainment Committee" and has a message of thanks to our hosts and to our hotel management.

Entertainment Committee Report

Tom Athey

On behalf of "our Members", "our Board of Directors" and "our Officers" I wish to thank our "Hosts" for that "Beautiful" Cocktail Party last night. Needless to tell you the Hotel Management did a magnificient job and that all of us enjoyed all of it. (Applause)

Hosts

ATLANTA UTILITY WORKS
C&I / GIRDLER INCORPORATED
COMMONWEALTH LABORATORY INCORPORATED
DAVY POWERGAS INC.
FEECO INTERNATIONAL, INC.
FESCO, INC.
HOWE RICHARDSON SCALE COMPANY
J&H EQUIPMENT, INC.
JACOBS ENGINEERING GROUP, INC.
KIERNAN-GREGORY CORP.
PETROCHEMICALS COMPANY, N.C.
THE PROSSER COMPANY, INC.
EDW. RENNEBURG & SONS CO.

ST. REGIS PAPER COMPANY, BAG PACKAGING DIVISION
THE A. J. SACKETT & SONS CO.
STEDMAN FOUNDRY AND MACHINE CO., INC.
UREA TECHNOLOGIES, INC.
WEBSTER INDUSTRIES, INC.
WHEELABRATOR-FRYE INC.

CHAIRMAN SMITH: Another important aspect of any meeting of course is Public Relations and Walter Sackett does a fine job in this respect. Walter, come up here, please. (Applause)

Public Relations

Chairman

Walter J. Sackett, Jr.

We have expanded the number of publications this past year, covering our "Press Releases" highlighting our Program and Meeting Dates. We are going to try to do a better job this year. I show the following "Publications" we work with.

Agri-Chemical Age—San Francisco, California
Chemical & Engineering News—Washington, D.C.
Fertilizer Progress—Washington, D.C.
Sulfur Institute—Washington, D.C.
Potash Institute of Noirth America—Atlanta, Georgia
Chemical Processing—Chicago, Illinois
Farm Supplier—Mt. Morris, Illinois
Fertilizer Solutions—Peoria, Illinois
Farm Store Merchandising—Minneapolis, Minnesota
Chemical Engineering—New York, New York
Chemical Engineering Progress—New York, New York
Chemical Marketing Reporter—New York, New York
Chemical Week—New York, New York
Chemical Week Southeastern News Bureau—New York
The New Agriculture—White Plains, New York
Farm Chemicals—Willoughby, Ohio
Custom Applicator—Memphis, Tennessee
Ag-Chem Newsletter—Houston, Texas
The Plant Food Council of Ontario—Mississaugua, Ontario
Fertilizer News—India, New Delhi
The British Sulphur Corp. Ltd.—London, England
Fertilizer International—London, England
The Fertilizer Society—London, England

If you have any publication that I have not mentioned that I should be contacting, please let me know. Thank you. (Applause)

CHAIRMAN SMITH: Thank you Walter. I think we all can make ourselves a part of "One" to advise people in our industry, interested in "our Programs" to encourage "their attendance".

Is there any other subject that anyone wishes to bring up at this time? This is an opportunity to express any viewpoint you wish to bring up before we start our morning "Program discussions".

QUESTION FROM THE AUDIENCE: I would like to know what the procedure is for presenting "Papers"?

CHAIRMAN SMITH: If you or anyone has any "Suggestions" on something you would like to present on "A Subject" that you would like to have someone present, experienced in that particular area, please drop a note to Paul Prosser or Frank Nielsson, our new "Chairmen" or mention it to someone else on "The Board" that you know. You can be assured your suggestions will be considered. Our procedure is very simple. We have a Board Meeting in March. Our Board members come in with whatever "Ideas" they have on suggested "Subject Matter". We spend a full day sorting and discussing and finally determining which suggested topics are really "Pertinent" and "Timely". The subjects agreed upon for our "Session - 3 day Annual Meeting" are "assigned" to our Directors to find suitable "Speakers" for each "Subject". We have another "Meeting" in July when "each" reports on "Speakers" for their respective "Subjects". We finalize the "Program" and I can say that we have a 95% "Acceptance".

Our Committee Reports are now completed. It is my pleasure to call on our Director, Glen Wesenberg of FEECO International, Green Bay, Wisconsin to moderate the remainder of our final session this morning. Glen resides in Wisconsin where they have a "Little Football Team". He was introduced to you yesterday so I will not go into detail. Glen, will you proceed. (Applause)

Moderator

Glen Wesenberg

Thank you Rodger. Good Morning Ladies and Gentlemen. It is my pleasure to "Moderate" the remainder of our program this morning. We have very"Interesting Presentations" Process Innovations and Developments. These discussion, I know, will be "new to many of us and very interesting." I am pleased to introduce our first speaker who is from France. He has a degree in Chemical Engineering and a Masters in Science from "Lilly". He is also a Pharmacist. He has been with the French Potash Mines Group since 1942 and has had considerable experience in Process Work. He was on The Round Table Program in 1968. He is currently the Manager of Developments of PEC Engineering in France. We are very pleased to have Ives Berquin give us his presentation on the "Spouted Bed Granulation". (Applause)

Spouting Beds — General Considerations

Y. F. Berquin

A relatively recent concept, the spouting bed technique (as described in the theoretical work of the Wisconsin Alumni Research Foundation in 1959) has been the subject of many studies and laboratory trials, but up to the present day it has found little application at the industrial level. Still, it is a simple process which, when applied to granulation in pilot plants or full-scale installations, has already achieved quite outstanding results.

The spouting bed is a varient of the fluidized bed. Like the latter, it involves setting a more or less granular mass of raw material inside a vertical cylinder and causing a stream of gases (air, for example) to flow through it. It should be noted, however, that in the fluidized bed process this granular mass rests on the flat bottom of the cylindrical vessel— in fact, on a grid through which the gaseous fluid is to flow— wheras in the spouting bed technique the mass of raw materials, which forms the bed, is contained in an inverted cone. The gaseous fluid is introduced at high speed at the throat of the venturi located just at the apex of this inverted cone. Under these conditions, no supporting grid is required. The stream of air— or more generally, gas— flows upwards through the bed of raw materials, creating a narrow whirlwind or geyser, through which all the grains come successively in contact with the jet.

Plotting a curve to register the various pressure drop values throughout the spouting bed process operation gives a typical illustration of its flow pattern. As the air velocity at the throat of the vessel is gradually increased, starting from the minimum pressure required to keep the bed within the inverted cone, the following phases of its operation may be noted:

1. To begin with, the unit works in a manner resembling a fluidized-bed. Air bubbles flowing through the bed set up a boiling movement at the level of its free surface.

2. Then, all of sudden, the spouting bed pattern sets in, with a corresponding drop in pressure. There is no more bubbling throughout the mass of material; only a vertical air stream in the centre, pushing drains upwards to form a geyser.

3. Within the whole operating range corresponding to spouting bed operation (around 50 m per sec., as a rule), the pressure drop remains virtually constant.

4. At a certain gas velocity, grains are drawn out of the vessel by the air stream, and a sharp reduction in pressure drop value takes place. The "spouting bed" disappears suddenly.

In other words, there are sharply defined limits on the air velocity, at the throat within which it is possible to maintain a spouting bed. This velocity depends, among other things, on the average size distribution of the grains and also on their specific weight.

Another characteristic of the spouting bed process is the effectiveness of the heat transfer that takes place, whether the heat is being supplied in hot air for drying or results from crystallization and is being removed.

It is also valuable to recall that a spouted bed is a very good blender. All these qualities can be used for industrial operations.

Granulation In A Spouting Bed

When applying the spouting bed principle to granulation, it should be borne in mind that granules obtained through this technique are gradually built up by a succession of thin layers over an initial core (onion-skin structure). Each one of these thin layers must dry up and solidify very rapidly. To achieve this, the slurry (which is sprayed into the Venturi throat) must harden speedily (at the rate of 1 grain-cycle inside the unit) if the entire contents are not to lock into a solid mass. It should, furthermore, be well understood that the more suddenly each layer solidifies— without having to undergo a transitory "pasty" stage — the better granulation will be.

there are three different ways in which this may be brought about.

Evaporation

In this case, the spray consists of a hot solution, usually saturated, sometimes (depending on circumstances) with some product in suspension. The carrier fluid is a hot gas which, in a first step, vaporizes, through a "flash" effect, part of the water contained in the droplets before they come into contact with the bouncing granules, and, afterwards, dries up the fresh layer thus deposited.

Crystallization

In this case, the product sprayed is in a molten state, with little or no water content, depending on its nature. The carrier gas in this case is cold, and the thin layer of melt deposited on the particles hardens as a result of crystallization.

The strength of the granules made in this way is much higher than that of conventional prills. In actual fact, the sensible heat from the sprayed liquid brings about a superficial fusion of the receiving granule, which, through the subsequent re-crystallization process, results in close welding of the new coating to the core of the granule.

Chemical Reaction

There is also the possibility of bringing about the necessary solidification by means of a chemical reaction between two components not in a solid state, as— for instance— one gaseous component and one in liquid form, which together form a solid compound. In the case of an exothermic reaction, the heat given out may be adequate to vaporize some water, thus allowing one of the components to be introduced in the form of a concentrated solution.

Application In The Fertilizer Field

In fact, each of the schemes outlined above has been the object of actual tests on a pilot scale, many of them oriented towards the manufacture of fertilizers.

Evaporation Process

One of the first uses of the spouting bed concept was in the production of a granulated potassium chloride, compatible with other granular fertilizers, intended particularly for bulk blending. To start with, a hot and saturated KC1 solution was sprayed in at the venturi throat of the spouting bed unit, while air, heated by a direct-flame process, was introduced at the same time. The inlet air temperature could, in this way, be brought up to 500°C. As the air left the vessel at about 80°C., the thermal efficiency was very good.

Crystallization Process

The first use of the crystallization form of the spouting bed process was in forming molten sulfur to conform with antipollution regulations, which demanded that the solid sulfur should be capable of being handled without giving rise to dust.

As a consequence of this experimental operation, an outlet for this type of product was eventually found as a direct application sulfur fertilizer. Pure sulfur is no longer used for this purpose. Instead, the composition used holds a certain quantity of a moisture-swelling clay, of the bentonite type. Granulation of such a molten mixture by means of the spouting bed is easy. Once in contact with the ground moisture, they break down easily and give out a sulfur milk, which is easily absorbed by the crops.

Later on the crystallization process was applied to the preparation of ammonium nitrate or urea granules for bulk-blending (2-4 mm) or for some special uses in forestry (for instance, 7-12 mm granules).

In the pilot plant, the main operating parameters have been determined, including the optimum concentration value for the basic solutions, bed temperature during operation and residual moisture content.

Neverless, to our knowledge, development up to a full-scale operation remains to be done.

Chemical Reaction Process

This idea has been studied and developed by several parties. The initial application was in the direct production of MAP granules, using phosphoric acid as the liquid-phse component and ammonia as a gaseous component.

As mentioned, it is, furthermore, possible to combine the evaporative and chemical process schemes — in other words, to vaporize the water from the components (or water which may result from the reaction) by means of either reaction heat or hot gases. In the production of MAP, this permits the use of phosphoric acid of not very high concentration, but, when using this method in the pilot plant, it was found that it was mandatory, to avoid very high losses of ammonia, to keep the MAP nitrogen content lower than expected.

Full-Scale Practical Application In Fertilizer Production

In spite of the promise of the pilot-plant trials, these systems have not been realized in industrial units to any great extent.

General Remarks

It is possible, whatever the solidification process type selected, to obtain the benefit of a quite close grain-size distribution pattern by control of the spraying, flow-rates and temperatures at air inlet and outlet (therefore, of granule discharge temperature). In such conditions, the recycle ratio is around 2:1.

Results Obtained

Using the evaporation scheme, full-scale operations have been carried out on a number of different fertilizers, as listed hereafter:

MAP (monoammonium phosphate)	(12-52-0)
DAP (diammonium phosphate)	(18-47-0)
TSP	(0-48-0)
Sulfo-nitrate	(26-0-0)
NPK	(17-17-17)
NP	(16-20-0)

These formulations were prepared by spraying slurries into a hot air stream at the venturi throat of the vessel.

When dealing with fertilizers where the P_2O_5 is highly ammoniated, any volume of ammonia that may have been lost during drying can be recovered by scrubbing the gases leaving the cyclone downstream of the granulation unit with phosphoric acid.

As regards the crystallization scheme, the granulation of sulfur has been and is still currently carried out.

Main Feataures Of Installations On Stream

Some information has been gathered on existing full-scale or semi-industrial units that have been erected. As a rule, it appears that the following ratios are being more or less kept to:

$$\frac{\text{Diameter at venturi throat}}{\text{Diameter of the free surface of bed}} \approx \frac{1}{5}$$

$$\frac{\text{Height of the granulation unit}}{\text{Diameter of the free surface of bed}} \approx \frac{5}{1}$$

The maximum gas temperature in the case of drying-type granulation is about 450°C. Above this temperature, a hugh proportion of fines is frequently noticed.

As regards dimensions, industrial-size units are found with rather comparable features. Their diameter, at the bed free surface level, varies around 2.5 m.

An expansion chamber is often to be found above the granulation unit. Its purpose is to limit air entrainments.

Concerning electric power consumption, it depends essentially on the type of process put in use and on the nature of the materials to be granulated. For sulfur granulation, for instance (crystallization process), it amounts to 16 kWh per ton of sulfur.

Using the crystallization scheme, a recent use, that is being developed at Columbia British University (Canada) : it is the sulfur coating of urea.

The present trials, in batch, are very encouraging : the sulfur film is much more regular than in other processes and on that account, urea temporary insolubility is better ensured. If one wants still better results, only a very slight quantity of wax is necessary.

Of course, batch technique is valid, it ensures great film regularity.

However, it would be very interesting to carry out some continuous trials from high quality granulated urea, in order to make sure that in this case the sulfur film is sufficiently constant on the whole of the granules.

We may wonder whether this particular case might not be related to beds-in-series technique, for the undermentioned reason : the hope of greater regularity.

Other Potential Uses Of The Spouting Bed Technique In The Fertilizer Industry

Another use of the spouting bed technique in the fertilizer industry, besides granulation, is in phosphoric acid concentration. The same type of spouting bed unit is used, with only the addition of a flap at the lower part of the cone. Concentration is effected by contact with hot gases.

Compared with other hot-gas processes, the spouting-bed concentration technique offers the following advantages :

Thermal Efficiency

This is excellent, as has already mentioned in respect of granulation. For instance, the temperature of gases at the inlet nozzle which is required for concentration up to 63% is 590°-600°C. Under these conditions, gases leave the unit at a temperature of 140°-150°C.

De-Mist Operation

In actual fact, the spouting bed unit, through its design, belongs to the family of spray-type mist separators such as the venturi scrubber. Thanks to the high velocity of incoming gases, a large amount of energy is brought in, which ensures the coalescence of droplets. Losses are minimal, and cleaning gaseous effluents is much simplified.

Cost

Heavy corrosion, owing to a combination of high temperatures and acidity, affects only a small portion of the spouting-bed unit, where the use of costly, corrosion-resistant steel is unavoidable.

Immediately above the bed level, the temperature of gases and liquids is low enough to allow the use of cheap, anti-corrosion synthetic materials or paints. As a consequence, it can be said that the spouting-bed unit, owing to its plainness of design, is not a costly piece of equipment.

This unit can handle 28-30% acids and concentrate them up to 70-72%, if required. If a high level of concentration is desired, however, it would be beneficial to use several stages in the process.

Indeed concentration up to 54% or even 60% is very easy and can be obtained at a rather low temperature, that means low corrosion. Only high concentration, higher than this point is cause of severe corrosion.

Another use of spouted beds has also been signalized in industry and is applied to fertilizers.

An English Company would have set up and used a spouted-bed as a cooler. It would concern an important appliance of about a 3 meter diameter and from six to nine meter depth.

To finish this enumeration, it would appear convenient that a certain number of spouted beds possible uses be studied.

1°/ At present time the stress is put on uranium extraction from green phosphoric acid manufacture. This extraction is generally carried out by means of liquid and not miscible solvent. How, liquid/liquid extractors have been set up with success on spouted beds principle. Maybe they might be applied to this case.

2°/ Physical qualities of granules got in spouted beds are such that it would probably be worth carrying out some researches as regards manufacture of some catalysts used in fertilizer industry, for instance that used in the various stages of ammonia manufacture, by means of this method.

3°/ Besides these spouted beds have already been used for some catalytic reactions on gaseous stage, the bed being constituted by catalysts. The steam reforming for instance might perhaps derive from this technique. It has besides been considered to regenerate also some catalysts in spouted-beds.

Summary

The spouting bed technique is a relatively recent accomplishment— in contrast with many other processes used in the fertilizer industry, which have long since proved their practical value. And, being new, its implementation appears to be taking a long time. However, it presents a series of advantageous features which should be brought to the attention of researchers and industrialists. They are :

1. very simple construction,
2. no important rotating parts,
3. gaseous effluents easily collected for any subsequent processing (washing, filtration, recycling),
4. granulated end-product with exceptional qualities (sphericity, strength,
5. large field of possible uses (it has even been possible to use this equipment for the granulation of products, such as potassium acetate or sodium pentachlorophenate, which are hard to prill).

On the other hand, it should be mentioned that there are two unfavourable factors against its use in large fertilizer production plants :

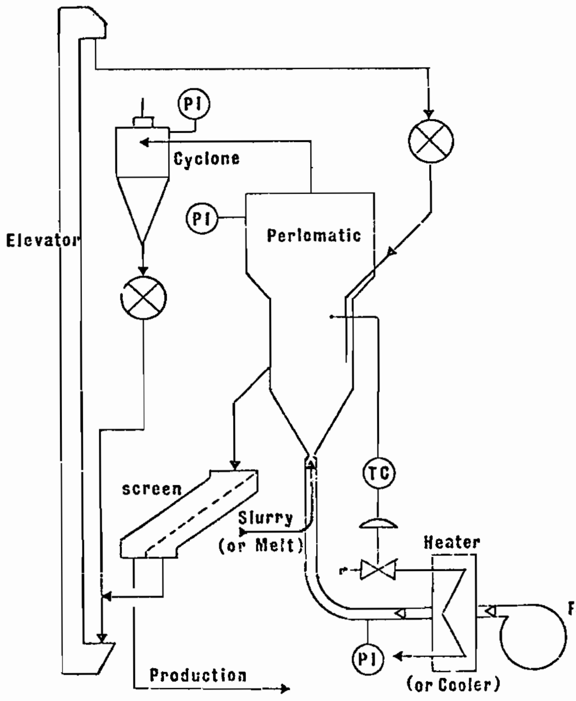
a. Where the granulation procedure entails evaporation, high temperatures are necessary in order to secure a satisfactory throughput. To obtain these temperatures, only direct-combustion gases can be used. This precludes the use of steam for this purpose, whereas in other processes spare steam may be used as the heating medium.

b. It is known fact that the unit capacity of the production units in fertilizer plants is continually increasing. In the case of spouting beds, extrapolating would be the only means through which this unit capacity increase could be secured. This would mean a proportional increase in the height of the bed through which the air stream is to flow and, consequently, of the corresponding pressure drop. In other words, the specific electric power consumption per ton of end product would grow in proportion to the dimensions of the unit concerned. For the time being, this factor may be a disadvantage which tends to restrain the use of spouting bed units to medium-capacity plants (200-300 tpd).

This point draws the attention of workers who tried to avoid the difficulty.

Two ways are studied at present time :

1. The multiplicastion of cells in parallel in a same general containing vessel : the bed height is, in this case, lower than the one of a single bed of the same capacity : the pressure drop is therefore inferior. However, some air balance problems between cells are raised. It is obviated to them :
    a/ by displaying some partition baffles between cells, covering a part of the bed height.
    b/ by adding individual air-flow controllers under each cell. This represents a certain pressure drop. However, with using a six triple spouter, PETERSON was in a position to show that the power consumption was reduced by more than 50% in comparison with a single spout bed of equal production.
2. Another technic consists in displaying the cells in series : the over-flow of each one of them pours out into the next one. The seeds growth is therefore progressive from a cell to the next one. One may esteem that the screen analysis of final product will be more narrow than in the case of the single appliance.


"PERLOMATIC" granulation system

These two ways, if they are developed, leave the hope that the spouted beds, at least for some uses, will prove to be some competitive instruments from the economical point of view, considering once for all that the physical quality of granules is of the highest level : sphericity, hardness, resistance to erosion, absence of creeks.

MODERATOR WESENBERG: Thank you Ives. Any questions on this Innovation of Process?

QUESTION, Frank Achorn: Have you injected ammonia into the gas stream to see if you can ammoniate in this bed?

IVES BERQUIN: This was made, not by my Company. Of course, as you know you cannot go up to diammoniation (DAP). You have to stop in the range of (MAP).

QUESTION, Frank Achorn: Do you put acid in?

IVES BERQUIN: Yes, acid. Concerning the Fertilizer Industry one deviation of the spouted bed facilities can be used and has been used in long term tests for concentration of phosphoric acid. You have about the same pattern, the same shape of vessel and so on. This was quite efficient, however, this was very good when "energy" was not so expensive. "steam" evaporation is cheaper than "hot air". Maybe this could be considered again in some cases. This is very efficient and you can go up to 64 and even 69% P_2O_5 with only the down part of the vessel in corrosion resistant material.

QUESTION FROM THE AUDIENCE: At the lower scale what was your air velocity.

IVES BERQUIN: This was expressed in commercial units. One, means the right speed, the right velocity for a certain product because the velocity changes with the product. Myself, I have worked with products having a specific weight around one and another with a specific quantity around 8. Of course, the velocity is not the same. Generally speaking, when you are on this flat part you are under 50 meters per second. This gives you means of calculation for the configeration of the equipment.

QUESTION FROM THE AUDIENCE: Could you really granulate NPK by triple 15, triple 17?

IVES BERQUIN: I said regrading NPK granulation that the tests were made by another company. Myself, I did not succeed with the products that I had to granulate. I consider, myself, that this concept is valuable only when you have a really acute point for solidification. If you have to pass through a thickly state you have risk of plugging. More exactly you are sure to plug. So we have to find a grade which crystallizes quite instantaneously so that the granules falling down on the bed are hard enough to avoid the caking.

QUESTION FROM THE AUDIENCE: Do you think for a much simpler material, like MAP or DAP, that the combination is a Pipe Reactor. You could use a spouted bed, for granulated MAP and DAP by injecting the mole ration of 1.3 and ammoniate in the spout.

IVES BERQUIN: From what I know you cannot go up to 1.3. You have to stay under the monoammonium. The ammonia losses would be too high.

Thank you Ives for your most valuable paper and your excellent discussions. (Applause)

Our next speaker is well-known to all of us. He was a Moderator in the previous sessions. He is the Manager of the Chemical Fertilizers Projects for Jacobs Engineering. He is a graduate Chemical Engineer from the University of Michigan and he has been in the workings of fertilizer activities for over 25 years. He is on the Board of Directors of the Fertilizer Industry Round Table. It is my pleasure to introduce to you David W. Leyshon. (Applause)

Innovation In Commercial TS—, DAP and NKP Granulation

R. J. Danos and D. W. Leyshon

Presented by D. W. Leyshon

TABLE OF CONTENTS

I. *INTRODUCTION*

We would like to present, in this paper, some innovations in the slurry process granulation of TSP, DAP, and NPK. Some of these techniques can be used in existing plants and some are only applicable to new installations.

II. *AGING BELT*

The first innovation we would like to cover is the use of an aging or stabilization conveyor and the improved equipment arrangement it makes possible. The application of a belt conveyor between the granulation and dryer has some unique properties. It has been used successfully in at least two commercial designs with the objective of eliminating drag flight conveyors and to reduce dryer feed chute buildup and dryer flight scaling, especially when producing slurry process TSP. The belt conveyor provides enough aging time, to allow surface drying of the granules being discharged from the granulator. The result is less spill back from the dryer feed end, especially slurry process TSP.

With less dryer scaling and washing, the dryer lasts longer and the knockers and chains formerly used are eliminated.

The aging belt plus a unique screening arrangement eliminate the need for drag flight conveyors, which have to be conceded to be among the highest maintenance items in a granulation plant.

In Slide 1, you see an isometric view of the equipment arrangement showing the relationship of the granulator, aging belt, dryer and screening system. The hot damp granules discharing from the granulator are conveyed on a wide belt conveyor at a slow speed allowing enough time to surface dry the material. The enclosed belt conveyor is vented.

Slide 2

STABILIZATION CONVEYOR ADVANTAGES

(1) Elimination of excessive chute rodding

(2) Layout advantages — one high portion — minimum building at dryer/cooler feed end

(3) No fines drag flight conveyors

(4) Reduces frequency dryer cleanup or washing

Slide 2 lists the advantages of the stabilization conveyor. The belt itself stays remarkably clean and no cleaning brushes or the like are required.

For plants in moderate or dry climates the dryer may be partly outside the building or covered by a minimum canopy shelter. The size of the building can be minimized and construction of the major structure can proceed before erection of the dryer.

No drag flight conveyors are used and all the screening equipment is compact in a vertical stack arrangement.

The control room elevation is on the same level as the granulator and product belt. The controls for the product screens and feeders are also located nearby.

This new arrangement fits compactly into the tall part of the granulation building permitting the remainder of the equipment to fit into a relatiavely low level building structure, thus offering significant cost saving in structural steel, siding, etc.

III. *SCREENING AND RECYCLE CONTROL*

An improved screening and recycle control system is shown in Slide 3. For even very large capacities up to 500 TPH or more, only two screen lines are required so that a screen feed conveyor or multiple splits are not required.

In most slurry process granulation plants the screen analysis of the recycle falls within the following range.

Oversize	10%—30%	(+6 mesh)
Product	55%—70%	(—6 +14)
Fines	10%—25%	(—14 mesh)

The theory of this screen system is that only as much recycle is screened on the product screen as required to produce the desired plant output. It is useless and unproductive to screen the whole recycle and then use only a fraction as product.

This system features single deck oversize screens.

For single deck screens, the oversize screen area is no longer dependent on the product screen as for double deck screens. Therefore, the area required is considerably smaller. Single deck oversize screens have capacity for at least 2.5 tons of feed/sq. ft.

The product screening also ues single deck screens, again for maintenance and performance advantages. However, product screening efficiency is greatly improved by using the take-out feeders to feed the product screens. Therefore, only the amount of feed required to give the desired product rate is screened.

Automatic recycle control is incorporated in the design. The product take-out feeders are controlled by the load in the primary elevators as measured by recording the amperage or wattage or by a recycle weigh scale, shown in Slide 3.

Continuous Recycle Screen Analysis

Calibration of the product screen feeders which are variable speed weigh belts gives the operator a running screen analysis of the fine fraction of the recycle since both the weight of screen feed and weight of product out is known. Conceivably this signal can be incorporated into automatic process control. It gives the operator a continuous screen analysis of the recycle, a new tool to help in plant process control.

Another piece of data that heretofore was impossible to obtain is the product screen efficiency. Knowing the product screen analysis, the feed rate, and product rate, it is possible to calculate a very accurate screen efficiency. This will be extremely helpful in screen evaluations and for vibrator adjustments.

The advantages of this screening and recycle control system are summarized in Slide 5.

Slide 5

ADVANTAGES FOR JACOBS-DORRCO SCREENING SYSTEM

(1) Single deck screens
(2) Screen area equipment is low
(3) Product screeens not overloaded
(4) Automatic recycle control
(5) No screen feed or fines drag flight conveyors
(6) Dust collection dusts are short

A second stage of product screening (polishing) may be provided, where the last 5%—10% of oversize and fines are removed. The combination of single deck screens, the product screen feed control feature and the polishing screen means that less overall area for screening is required to make a closer sized product than previously possible.

IV. *VENTING AND DUST CONTROL*

Another unique feature of the new arrangement is a simplified dust collection system, as shown in Slide 6. This layout permits one to vent all of the equipment in the screening system to a single vertical header. The close proximity of the equipment to the vertical header permits relatively short runs of duct work. The vertical header extends upward above the elevators where it makes a 90° turn into a short horizontal run before entering the vent gas cyclone. The dust collected in both the dryer cyclone and vent gas cyclone discharges into a screw conveyor which is located high enough to feed into the granulator recycle chute. Few granulation plants are arranged to permit cyclone dust to go directly into the granulator. Most plants return the extremely fine dust to other equipment such as recycle conveyors or elevators. As a result, this fine dust is for the most part, reentrained with the vent air and recycles indefinitely or it becomes a permanent part of the duct work.

V. *PIPE REACTOR*

We have studied the pipe reactor particularly as it applies to large slurry process plants. Our work goes back some time. We believe patent #3,310,371, slide 7, which was issued to Dorr-Oliver and now owned by Jacobs, is probably the grand-daddy of pipe reactor patents.

We have concluded that in most cases the fuel savings making MAP based grades in a pipe reactor compared with making the same ratios as DAP and using fuel, favors DAP because the cost of the fuel saved is more than offset by the use of the higher cost nitrogen in the form of ammonium nitrate or urea or the cost of sulfuric acid if ammonium sulfate is used. It should also be noted that a lot of the economic comparisons that have been circulated to not take into account that DAP based grades take less fuel than MAP grades because of the drying effect of ammoniation in the granulator. Generally the advantage of DAP grades using fuel, over MAP based products and no fuel is in the range of $1 to $2 per ton of product using 45¢/gal. fuel and $1 per unit for the incremental nitrogen cost of urea or ammonium nitrate.

In our opinion, the real advantage of the pipe reactor lies in the DAP processing.

A number of processors have described the making of DAP in pipe reactors, TVA, Consolidated Fertilizers of Australia, and Cros of Spain. Rates of production described, however, have been in the 20 TPH range except that in a paper given at the recent ISMA meeting in Orlando, it was indicated that designs are available for 70 to 100 TPH DAP systems using the pipe reactor. It is also known that some large scale plant tests have taken place.

Two pipe reactor configurations should be considered.

Jacobs-Dorrco DAP Process

This system is shown on Slide 8 and described in a recent article by R. J. Danos of Jacobs engineering in CHEMICAL ENGINEERING, October 9, 1978.

In that system a fuel fired dryer is not used and the granulator product is instead cooled and the residual moisture evaporated by the initial heat present.

The pipe reactor itself, operating on liquid ammonia, will generate a substantial amount of heat, about 475,000 BTU/ton of DAP, which must be utilized and dissipated properly. In the conventional DAP process additional heat of about 160,000 BTU/ton of DAP is evolved in the ammoniation in the granulator. In the pipe reactor process this heat is also present plus at least part of the 475,000 BTU/ton in the pipe reactor slurry. Cooled recycle will absorb a great deal of the heat, but unless very high recycle rates are used some overheating in the granulator can occur. In the Jacobs pipe reactor process, cooling and evaporation is assisted by blowing cooling air into the granulator.

In a new plant, it will be possible to design a system to provide adequate temperature control and drying, bu the conversion of existing plants at higher output rates may be difficult because of lack of cooling and inadequate separation of the steam generated in the pipe reactor.

Alternate Pipe Reactor Process

The pipe reactor can be used to supplement the normal preneutralizer slurry of a conventional DAP plant. In this mode of operation fuel is used in the dryer as formerly but the benefits of the pipe reactor would be taken in the form of increased capacity and reduced fuel requirements per ton of product.

For instance, a supplemental Tee reactor may be utilized to increase the capacity of a 60 TPH plant by about 20 TPH. At the same time less recycle per ton of product is used and effectively a higher strength of composite feed acid is employed. Fuel requirements are about 25% lower per ton of product than using the conventional DAP process.

Two material balance block diagrams follow, Slide 9 and 10, the first indicating a conventional 50 TPH DAP granulation plant and the second indicating a granulation plant producing 50 TPH of DAP which incorporates a supplemental pipe reactor.

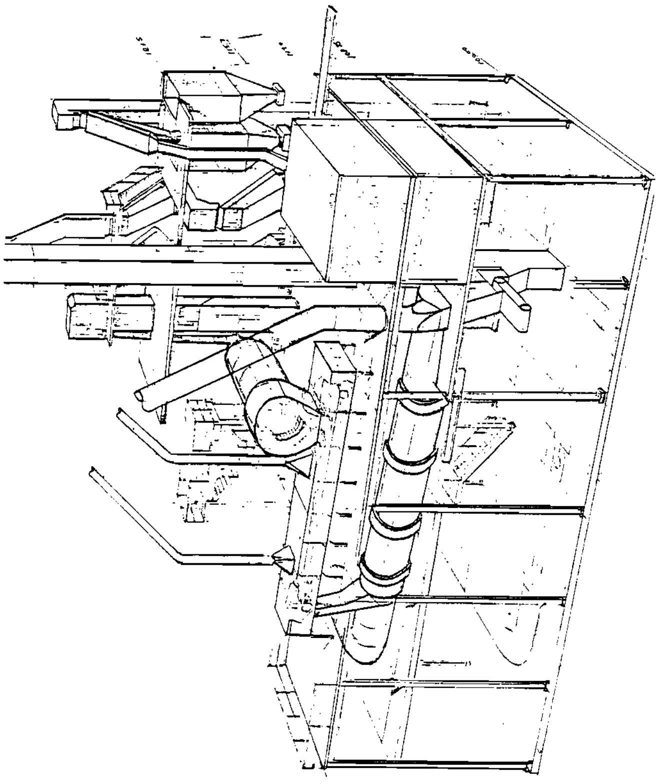
A study of the two diagrams shows that the use of the supplemental pipe reactor has the effect of being able to use higher strength feed acid, having less water to evaporate, and therefore make more product-per-ton of recycle.

Wherever recycle is a bottleneck in a DAP plant, the use of a supplemental pipe reactor could increase the capacity remarkably. Looking at the two block diagrams, for example, the capacity of the conventional 50 TPH plant could be raised by a factor of 275/190 (the ratio of the recycle), to about 72 TPH. Not all of this increase might be realized because the amount of ammoniation in the granulator has to increase as capacity goes up. Reducing the dryer outlet temperature would be helpful to allow for the increased heat load in the granulator.

This technique would eliminate the use of 30% acid in the preneutralizer allowing the use of the meter for this stream to be used for the 54% acid going to the supplemental pipe reactor.

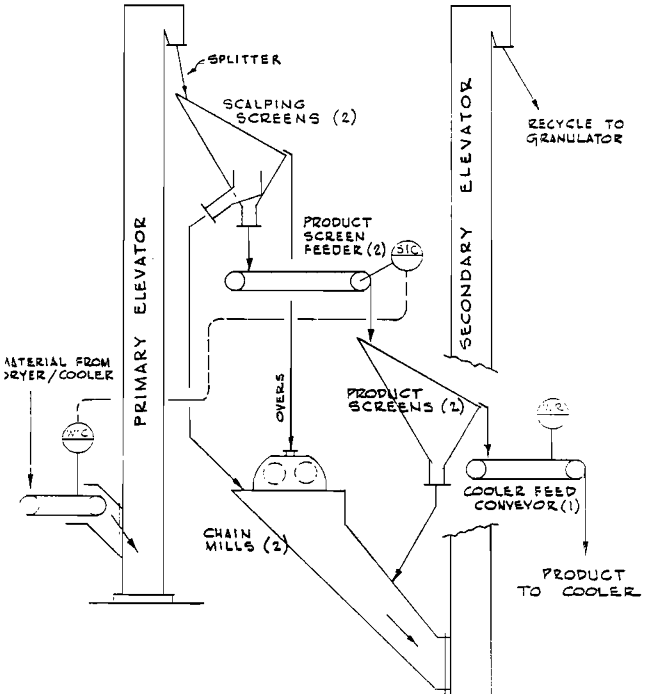
SLIDE 1

ARTIST'S RENDITION - GRANULATION PLANT

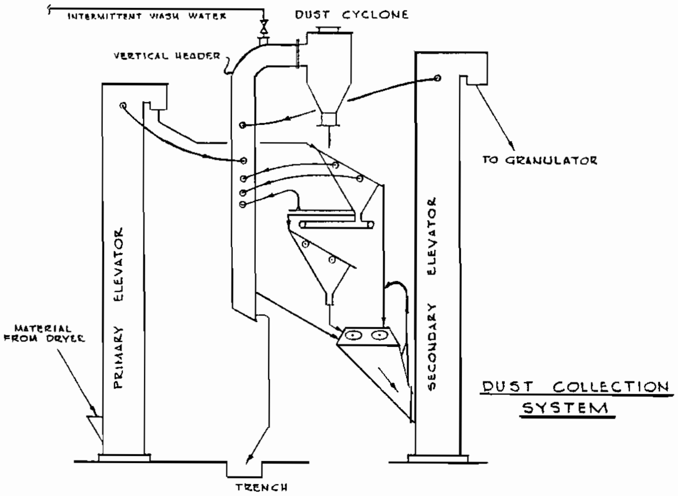


SLIDE 3

SCREENING SYSTEM



SLIDE 6



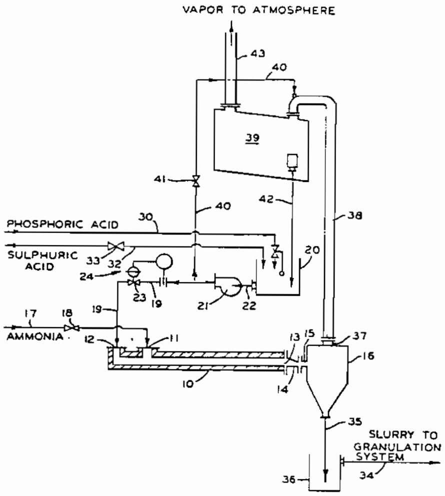
DUST COLLECTION SYSTEM

SLIDE 7

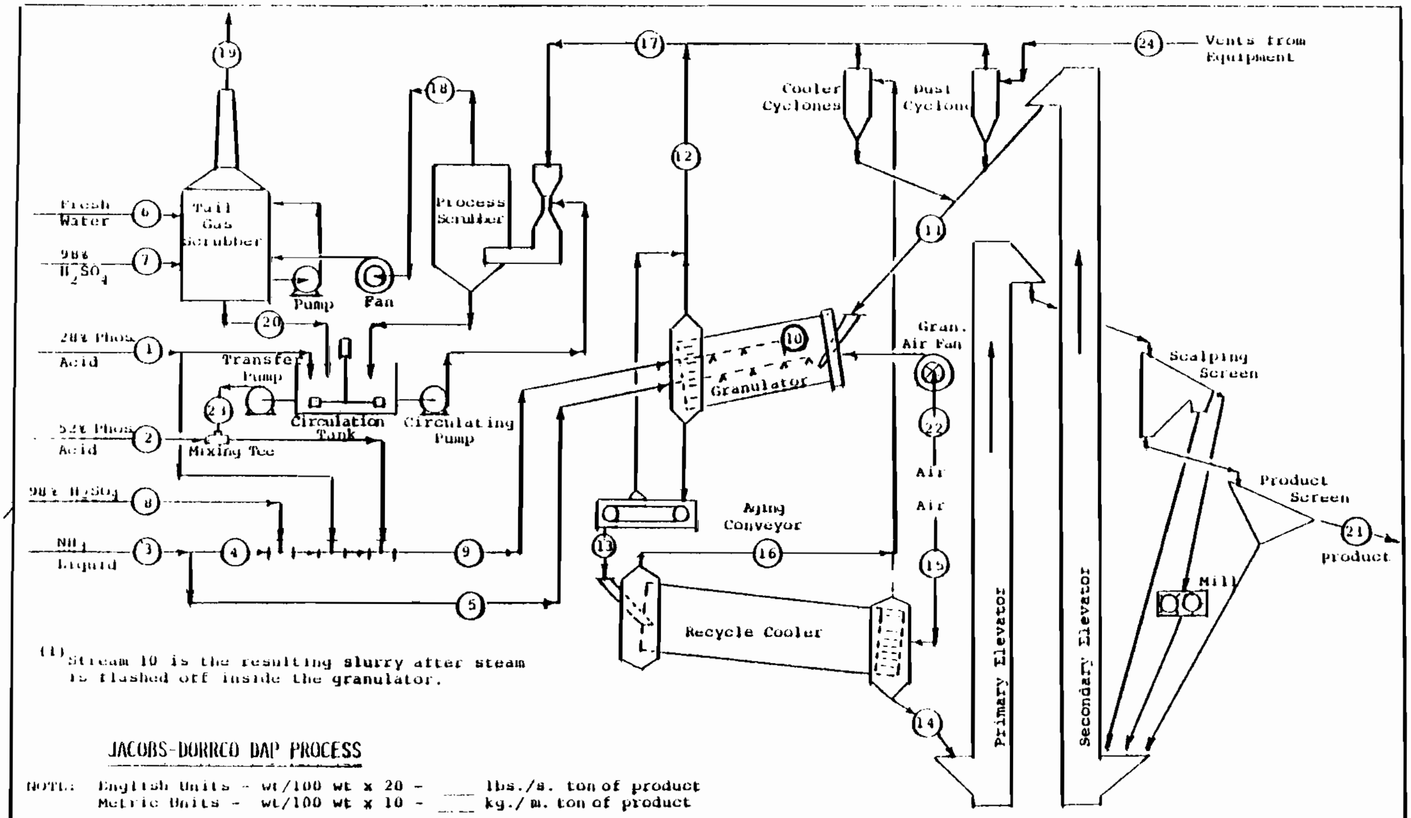
March 21, 1967 W. A. LUTZ 3,310,371

PRODUCTION OF AMMONIUM PHOSPHATE

Filed Oct. 30, 1962



INVENTOR.
WILLIAM A. LUTZ



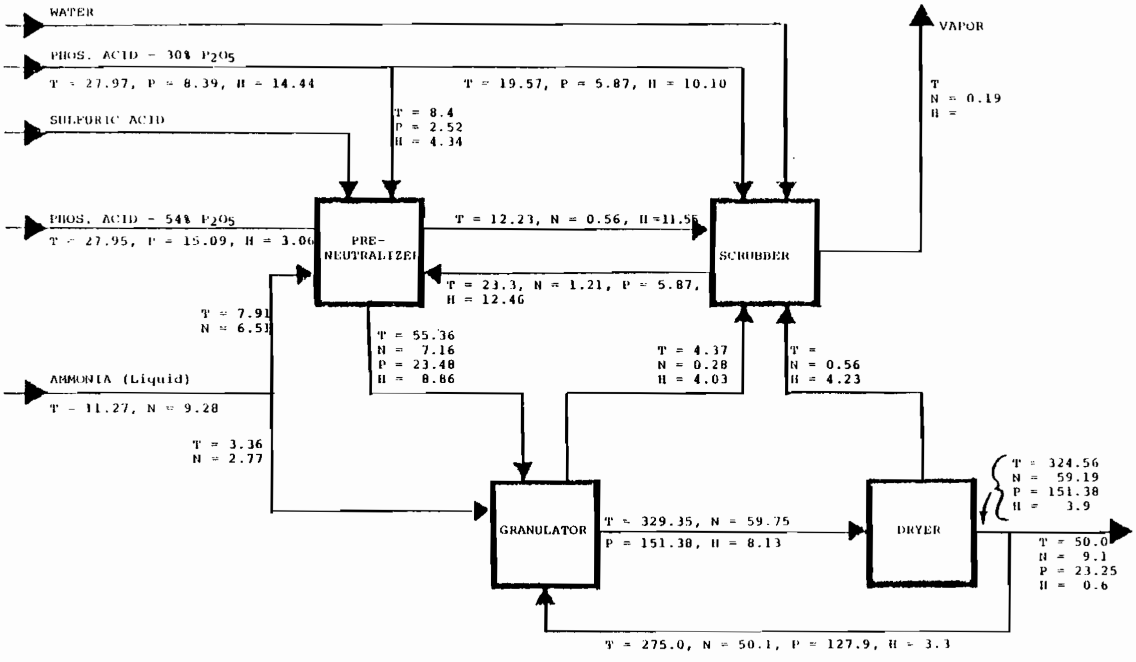
(1) Stream 10 is the resulting slurry after steam is flashed off inside the granulator.

JACOBS-DORRCO DAP PROCESS

NOTE: English Units - wt/100 wt x 20 - ___ lbs./s. ton of product
Metric Units - wt/100 wt x 10 - ___ kg./m. ton of product

Stream No.	1	2	3	4	5	6	7	8	9	(1) 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Flowrate (wt/100 wt)	32.8	72.2	22.3	14.5	7.8	2.29	0.065	1.67	125.9	103.9	250	80.5	353.6	350.4	270.9	274.0	427.6	425.2	425.1	2.4	100	25.2	32.2	73.2	
Temperature °C	49	65	28	28	28	29	38	38	150	108	52	82	98	52	29	84	76	60	53	50	52	29	55	38	
% P_2O_5	28	52	-	-	-	-	-	-	47.1	45	-	-	46	-	-	-	-	-	-	-	46.5	-	23.9	-	
% N	-	-	81.9	81.9	81.9	-	-		11.0	13	-	-	18.1	-	-	-	0.49	0.02	0.02	-	18.2	-	6.3	-	
% H_2O	54.8	16.3	0.5	0.5	0.5	100	2	2	25.6	10	1.2	35.6	2	1.2	-	-	9.17	9.3	9.3	96.9	1.2	-	53.9	-	
N:P Mol Ratio									1.3	1.3			1.79										1.2		

SLIDE 8



WATER

PHOS. ACID - 30% P_2O_5

T = 27.97, P = 8.39, H = 14.44

T = 19.57, P = 5.87, H = 10.10

T = 8.4
P = 2.52
H = 4.34

VAPOR

T
N = 0.19
H =

SULFURIC ACID

PHOS. ACID - 54% P_2O_5

T = 27.95, P = 15.09, H = 3.06

PRE-
NEUTRALIZER

T = 12.23, N = 0.56, H =11.55

SCRUBBER

T = 23.3, N = 1.21, P = 5.87,
H = 12.46

T = 7.91
N = 6.51

T = 55.36
N = 7.16
P = 23.48
H = 8.86

T = 4.37
N = 0.28
H = 4.03

T =
N = 0.56
H = 4.23

AMMONIA (Liquid)

T - 11.27, N = 9.28

T = 3.36
N = 2.77

T = 324.56
N = 59.19
P = 151.38
H = 3.9

GRANULATOR

T = 329.35, N = 59.75
P = 151.38, H = 8.13

DRYER

T = 50.0
N = 9.1
P = 23.25
H = 0.6

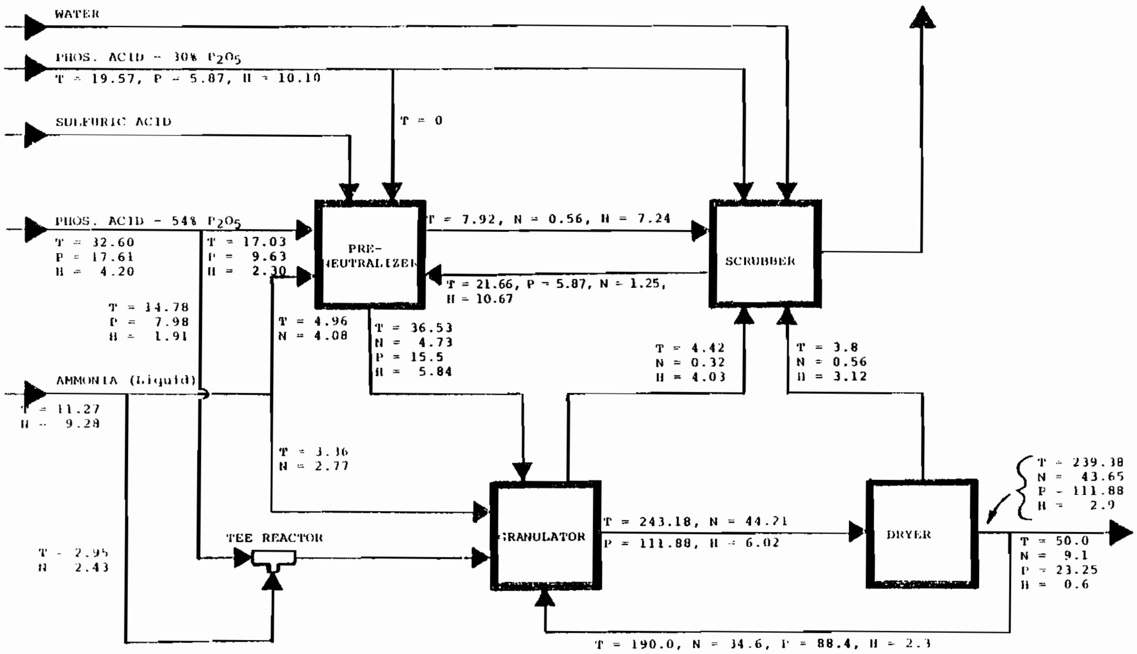
T = 275.0, N = 50.1, P = 127.9, H = 3.3

SLIDE 9

LEGEND: A = Air, H = Water, N = Nitrogen
P = P_2O_5, T = Total

ALL UNITS EXPRESSED AS TONS PER HOUR

50 t/h GRANULATION PLANT - BLOCK FLOW DIAGRAM
CONVENTIONAL PROCESS GRADE = 18-46-0
JACOBS ENGINEERING GROUP INC. LAKELAND, FLA.



WATER

PHOS. ACID - 30% P_2O_5

T = 19.57, P = 5.87, H = 10.10

SULFURIC ACID

T = 0

PHOS. ACID - 54% P_2O_5

T = 32.60
P = 17.61
H = 4.20

T = 17.03
P = 9.63
H = 2.30

PRE-
NEUTRALIZER

T = 7.92, N = 0.56, H = 7.24

SCRUBBER

T = 21.66, P = 5.87, N = 1.25,
H = 10.67

T = 14.78
P = 7.98
H = 1.91

T = 4.96
N = 4.08

T = 36.53
N = 4.73
P = 15.5
H = 5.84

T = 4.42
N = 0.32
H = 4.03

T = 3.8
N = 0.56
H = 3.12

AMMONIA (Liquid)

T = 11.27
H - 9.28

T = 3.36
N = 2.77

T = 239.38
N = 43.65
P - 111.88
H = 2.9

T - 2.95
N 2.43

TEE REACTOR

GRANULATOR

T = 243.18, N = 44.71
P = 111.88, H = 6.02

DRYER

T = 50.0
N = 9.1
P = 23.25
H = 0.6

T = 190.0, N = 34.6, P = 88.4, H = 2.3

SLIDE 10

LEGEND: A - Air, H - Water, N = Nitrogen,
P - P_2O_5, T - Total

ALL UNITS EXPRESSED AS TONS PER HOUR

50 t/h GRANULATION PLANT - BLOCK FLOW DIAGRAM
SUPPLEMENTAL PIPE REACTOR GRADE = 18-46-0
JACOBS ENGINEERING GROUP INC. LAKELAND, FLA.

MODERATOR WESENBERG: Thank you Dave. That was a very interesting presentation. Do we have any questions for Dave at this time?

QUESTION BY CRAIG PFLAUM, New Wales Chemical Co.: You said there was some commercial testing making DAP into a pipe cross reactor. What is the largest production rate and where?

DAVE LEYSHON: I do not really have the details of that. There is at least one company represented here, if they wish to discuss this. I think it is up to them. I will say that there have been some tests. That is all I can say. The gentleman I was looking at has left.

QUESTION FROM THE AUDIENCE: Is that plant riding on DAP now?

DAVE LEYSHON: No.

MODERATOR WESENBERG: Any other questions for Dave Leyshon. Thank you Dave. (Applause)

We shall proceed with our next speaker who has a Doctorate in Chemical Engineering from the University of Florida. He is the Past Head of the Chemical Engineering Department of Auburn University. He worked as a Consulting Engineer for sometime. He is currently Vice President of FRIT Industries. It is my pleasure to introduce Dr. Lowel Taylor who will give us a good presentation on the manufacture of micronutrients.

Production Of Micronutrients

Dr. Z. L. Taylor, Jr.

Definition and Introduction

During recent years, the role of micronutrients in plant nutrition has received increased attention. The necessity of providing an adequate source of these elements as part of a balanced fertilization program is now well recognized and accepted.

For the purpose of this paper, the term micronutrient is used to define mixtures or compounds containing the elements:

Copper
Iron
Manganese
Zinc
Magnesium
Boron
Molybdenum
Cobalt

The so-called secondary elements, calcium, magnesium (as linestone or sulfate of potash magnesium), and sulfur are not included in this discussion. These elements are derived from numerous sources (often part of the major element mix) and their manufacture and application normally are distinctly different from that of the micronutrients.

Physical Forms

The physical form of a micronutrient product is usually dictated by the method by which it is to be incorporated into the major nutrient mix. Most micronutrients are incorporated into mixed fertilizers and applied with the fertilizer mix. Therefore, most of the micronutrient products are either granular or powdered. The granular product is used in blend plants where it is mixed with the granular forms of the mixed fertilizer. Specifically, the product should be a firm granule in the 6 x 16 mesh range.

Where the mixed fertilizer is produced by granulation, the cicronutrient package is blended with the raw materials prior to introduction to the granulation process. The micronutrient product usually provided for this application is a powdered product with a particle size of minus 20 mesh.

Other special applications require liquids, fine powders, and coated products. Liquid products are normally soluble salts that may or may not contain chelating agents. These are normally incorporated into liquid nutrient mixes; however, some manufacturers prefer to add micronutrients in the liquid form to granular products. Fine powders in the size range of 100 to 200 mesh are required for suspensions and for the coating of granular product.

Mixes

Micronutrient packages may be a single element product or a mix of several elements. Typical single element products are the 18% and 36% granular zinc. A typical multielement mix would be F 503.

Element	%	Element	%
B	3.0	Mn	7.5
Cu	3.0	Mo	.07
Fe	18.0	Zn	7.0

Custom mixes of any or all elements can be produced in both powdered or granular forms.

Chemical Considerations

Micronutrients normally fall into one of the following categories:

1. Metallic Oxides
    a. Zinc Oxide
    b. Copper Oxide
    c. Manganese Oxide
2. Metallic Salts
    a. Zinc Sulfate
    b. Zinc Chloride
    c. Manganese Sulfate
    d. Sodium Borate
    e. Copper Sulfate
3. Metallic Oxide-Salt Mixture
    a. Zinc Oxide-Zinc Sulfate
    b. Manganese Oxide-Manganese Sulfate

4. Fritted Products
    a. Glasses of Metallic Salts or Oxides

The particular chemical form of a given product is a function of the raw materials and manufacturing process. The end use factors that dictate the chemical nature are:

1. Solubility
2. Release characteristics
3. Analysis

Generally speaking, the frits and oxides exhibit slow release characteristics dependent upon soil chemistry and moisture, whereas the salts are more readily soluble and exhibit quick release characteristics. Conversely, the salts are more susceptible to leaching and washout than are the oxides.

Raw Material Processing

There is a wide range of raw materials used in the manufacture of micronutrients. They include mineral ores and various by-product streams from the metals industries. A major technical and economic consideration in micronutrient manufacture must be given to the processing and conditioning of these materials prior to the main manufacturing operation.

These materials usually can be classified into the following categories:

- Sludges
- Slags
- Ores
- Powders

Sludges are usually finely divided materials such as filter cakes or scrubber residues which contain from 40 to 90% moisture. Slags are solid materials such as glass fluxes used in metals refining, and are usually received in particle size of 12″ x 12″ down. The slags usually contain little or no free moisture. The ores are usually mixtures of fine and larger materials of varying hardness. The ores will contain moisture in the range of 0 to 30%. Powdered or fine materials may range in particle size of 6 mesh down to 200 mesh range. The moisture content of these materials usually range from 0 to 8%.

These materials must be processed to a dry state with a particle size of minus 6 mesh before they can be utilized in manufacturing.

At Frit Industries two central processing plants are operated for raw material preparation. In general these plants provide for the following operations:

Drying.................. (rotary, direct fired)
Primary crushing............... (jaw crushers)
Secondary crushing............. (roll crushers)
Fine grinding.......... (ball mill, hammer mill)
Screening

Each plant is designed and built so that any number of operations can be conducted in any sequence depending upon the material which is to be processed. Considerable care has to be given to preliminary scalping and magnetic separation to remove any foreign matter and tramp metal.

Granular Products

The granular products are usually mixtures of metallic oxide and salt, usually the sulfate. The ratio of oxide and sulfate are dependent upon solubility and analysis requirements. The manufacture is normally accomplished in equipment similar to the classical fertilizer granulation plant. Special requirements do exist for raw material handling and batching. Also due to the unusually high bulk densities, heavy duty materials handling equipment is normally required.

The most common method of granulation is to utilize sulfuric acid to granulate the metallic oxides. Water and steam can also be used to aid the granulation process. The exact formulation depends upon the solubility requirements and granulating characterisitics of the raw materials. Usually an acid feed of 150-500 lbs. H_2SO_4/ton dry product is required for micronutrient granulation.

The granulation of metallics salts are a special case, and will be discussed later as part of the manufacture of metallic salts.

Manufacture of Powders

The manufacture of powders consists of grinding, classification, batching, blending, and bagging. Major considerations in the operations are uniformity of analysis and physical form and environmental control. Powders are produced by Frit at the Ozark, Alabama location. All raw materials are stored in 100 ton silos after processing. Materials are then conveyed to batching vessel pneumatically.

The flow of materials is controlled automatically by computer and preselected formulation cards. The operator has continuous CRT display of the batch status. After the batching is complete, the materials are dumped into a pneumatic blender. After blending is complete, the materials are pneumatically transported to the storage silo for bagging and shipment. For those products which carry a fine particle specification (100mesh), the batch is diverted after the blender to a feed hopper for further grinding. The materials are then fed to Allis Chalmers vibratory ball mills before bagging.

Manufacture Of Soluble Salts

Three major soluble metal salts are produced for the micronutrient market. These are zinc sulfate monohydrate, copper sulfate pentahydrate, and iron sulfate monohydrate. Zinc sulfate and copper sulfate are produced by reacting the metallic oxide with sulfuric acid. The resulting hot liquor is filtered and crystallized. The magma is then centrifuged to produce the zinc sulfate heptahydrate or copper sulfate pentahydrate.

The mother liquor is recycled back to the reactor to be combined with fresh raw material and acid. Ferrous sulfate heptahydrate is readily available and is introduced into the granulation drying system directly.

Both zinc sulfate heptahydrate and ferrous sulfate heptahydrate must be dried to the monohydrate form and granulated to obtain the usual article of commerce. This operation is complicated by the fact that both of these compounds release six of their seven waters of hydration at approximately 140-160°F. When this occurs, the material dissolves in its own water and becomes liquid. A pug mill and high recycle are used to overcome this problem. Temperature and recycle control to the pug mill are essential. The pug mill is discharged to a rotary dryer and typical granulation process followed. The extremely high recycle rate and bulk densities dictates that large and heavy duty conveying equipment be used.

Copper sulfate can be utilized with only air drying. Screening is performed as required.

Manufacture Of Frits

A totally fritted micronutrient is produced by smelting the oxides with proper fluxes at temperatures ranging from 1800-2200°F. The resulting liquid is then quenched to produce a glass or frit. This material must then be dried, ground, and screened. Fritted elements such as boron may be used in powdered or granular products to obtain the desired release characteristics.

Manufacture Of Liquids

Micronutrients are provided in various mixtures for liquid applications. Since zinc reacts with annonia to produce a fairly insoluble complex salts, care must be taken to isolate the zinc if the micronutrient mix is to be added to ammonia solutions. A wide range of chelating agents are used to accomplish this. These include EDTA and lignin sulfonates. In addition, prereacted zinc and ammonia solutions (Frit's NITRAZINC) are also produced. The manufacture of these products requires tankage and mixing. Both dry salts and liquid side streams from the manufacture of soluble salts are mixed with the selected additives to obtain the final product.

Special Problems

A comprehensive quality control and analytical program is essential for the successful production of micronutrients. This program must include all departments beginning with the screening of potential raw material through the final followup with product delivered to the customer. A multitude of raw materials are utilized which may contain multiple elements and vary widely in physical state. Sampling must be extensive, and can often be satisfactorily conducted only after the material is processed. In any event, the following sampling program is considered minimal: prospective raw materials, delivered raw materials, processed raw materials, production samples, and shipping samples.

The following tests are conducted routinely: total elemental, soluble elemental (EDTA and Water), and moisture. Most analysis are conducted by digestion and atomic absorption spectrometry.

Special environmental considerations are required in the manufacture of micronutrients. Regulations for emissions and in-plant fugitive dust dictate the use of extensive control equipment. The relative high cost of materials also requires that losses be kept at a minimal level. For the transport and handling of powdered products we have found that totally enclosed systems with pneumatic transport are required to meet the existing regulations. In the future, these types of systems will be utilized in the raw materials handling and batching systems of the granulation facilities. We have found that the granulation and finished product handling portions of these facilities can be controlled with extensive dust pick up and baghouses. Extraordinary maintenance and supervisory effort is required to support these systems.

Conclusion

A brief summary has been presented of the various types of micronutrient products and methods of manufacture employed to produce them. The range and type of products is continually changing and innovations appear constantly. The problems associated with a wide range of raw materials and a large product line present a constant challenge to the production manager. For example, at our Ozark plant we will produce over 100 different micronutrient mixes employing at least 50 different raw materials during a production season.

MODERATOR WESENBERG: Thank you Lowell. (Applause)

QUESTION FROM THE AUDIENCE: Did I understand that the granulation with sulfphuric acid was in the pug mill only, or, have you used other types of granulations?

DR. LOWELL TAYLOR: We use both types of granulators at different plants. We use both the TVA ammoniator type granulation and the pug mill. No pan granulator.

MODERATOR WESENBERG: We shall proceed with our next discussion — Basis for selection of granulators at TVA. The authors are Gordon Hicks, Isaac McCamy, Byron Parker and Mel Norton. This discussion will be presented by Byron Parker. Byron is actually a farm boy from Elba, Ala. He was a Coop. Student at TVA, while attending Auburn University where he received "The Bachelors" and "Masters of Science Degrees" in Chemical Engineering. He worked 3 years in the textile industry and than 4 years in the Process Engineering Branch of TVA. He worked with the "Granulation Groups." Byron is presently Senior Project Leader.

Basis For Selection Of Granulation AT TVA

By

G. C. Hicks, I. W. McCamy,
B. R. Parker and M. M. Norton
Presented by B. R. Parker

The Tennessee Valley Authority's National Fertilizer Development Center at Muscle Shoals, Alabama, being a research organization for the development of new fertilizer processes and materials, has has many years of experience in testing various equipment and processes. Granulation of fertilizer has been one major area of technology investigated by TVA. In its investigations, TVA has developed only one type of granulator, the TVA ammoniator-granulator drum. However, TVA has used previously developed pan granulators and pug mills in its development of new fertilizer processes. Although there are several types of very successful fertilizer granulation processes used throughout the world, this paper is limited principally to processes which use the above three granulators.

TVA has been developing granulation processes since about 1950 when a nitroic phosphate melt was granulated in a pug mill. The drum granulator was developed at TVA in the early 1950's during studies of continuous ammoniation of superphosphate. Actually, TVA produced granular fertilizer as far back as early 1942 when ammonium nitrate was grained (or granulated) in steam-heated kettles for munitions use.

TVA selects its granulators on the basis of the functions they must perform in the process under development. Years of study of fertilizer processes have taught TVA engineers the functions each type granulator can perform better than the other types. The drum granulator is best for processes in which ammoniation or other chemical reactions are involved during granulation. Pug mills are best for granulation processes requiring thorough mixing of plastic and solid masses or vigorous working for physical conditioning. The pan granulator is best suited for granulation of melts, fine powders, or highly concentrated solutions of highly soluble salts. Although the spray drum ("Spherodizer") has not been studied at TVA, it has also been used successfully for melts and highly concentrated solutions.

Rotary Drum Granulators

The rotary drum is the most widely used and the most versatile granulator in the fertilizer industry. When a chemical reaction is involved during granulation, a drum granulator is usually selected for the process. An example of a typical continuous TVA-type ammoniator-granulator is shown in Figure 1. The rotary drums vary in size from 6 feet in diameter by 12 feet long to about 12 feet in diameter by 24 feet long. The drums are usually sized to allow a shell area of about 12 to 15 square feet per ton of product per hour[1]. The drums are usually equipped with mechanical scrapers to remove solids that stick to the shell. Some used fixed scraper blades, but a reciprocating scraper (Fig. 1) is more commonly used. Some drums are kept clean by the use of a flexible liner; rubber sheet or belting supported by metal strips (Fig. 2) has been used quite successfully.

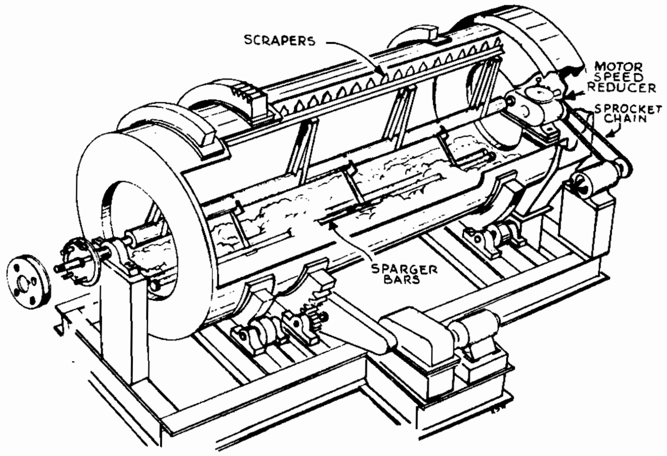


FIGURE 1

Continuous Ammoniator-Granulator

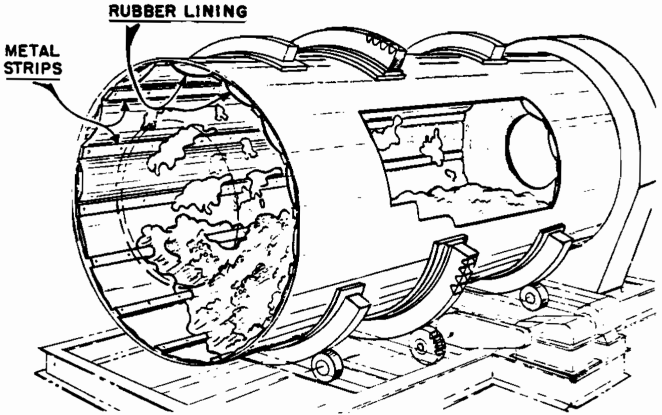
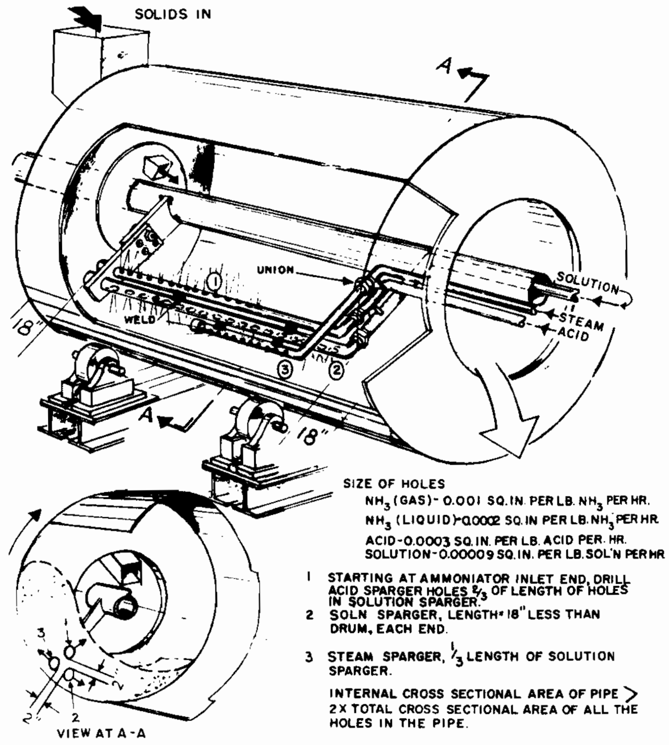


FIGURE 2

Rubber-Lined Ammoniator-Granulator

The spargers for introducing fluid feeds to the ammoniator-granulator are critical features of the unit. With the exception of phosphoric acid, preneutralized slurries, and melts, fluid feeds are normally introduced through perforated pipes submerged beneath the bed of rolling solids. Figure 3 shows suggested positions for three spargers, one for ammonia or ammoniating solution, one for acid, and one for steam and water. The ammonia sparger usually extends the length of the drum except for 6 to 18 inches at each retaining ring; larger drums require the most space between the sparger and the retaining ring. The ammonia and steam spargers usually are made of Type 316 stainless steel pipe with holes drilled in a single or double row, usually on 1-inch centers. For feeding vaporized ammonia, experience has shown that a total of 0.001 square inch of hole area or less is required for each pound of ammonia fed per hour. For liquid ammonia, only 0.0002 of a square inch is needed per pound of ammonia fed per hour. The holes in these spargers are usually no smaller than 1/16 inch in diameter[2][3]. The acid sparger has 1/8-inch-diameter holes drilled along only two-thirds of its length, starting near the feed end of the drum. The acid sparger is usually made of Hastelly C. The spargers should be located in the deepest part of the bed under about three-fourths of the bed depth[4]. Normally, they would be spaced 4 to 6 inches from the shell of the drum. When a pipe-cross reactor is used with a drum granulator, the spargers are located as shown in Figure 4[5].



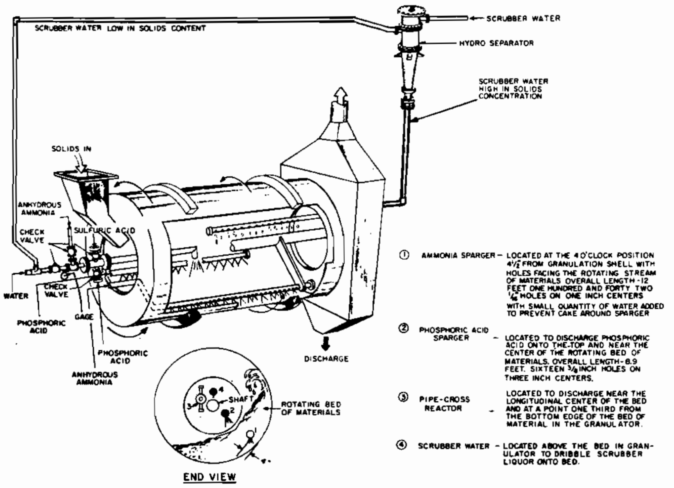
SIZE OF HOLES
NH_3 (GAS)- 0.001 SQ.IN. PER LB. NH_3 PER HR.
NH_3 (LIQUID)-0.0002 SQ.IN PER LB. NH_3 PER HR.
ACID-0.0003 SQ.IN. PER LB. ACID PER. HR.
SOLUTION-0.00009 SQ.IN. PER LB. SOL'N PER HR

1 STARTING AT AMMONIATOR INLET END, DRILL ACID SPARGER HOLES 2/3 OF LENGTH OF HOLES IN SOLUTION SPARGER.
2 SOLN SPARGER, LENGTH = 18" LESS THAN DRUM, EACH END.
3 STEAM SPARGER, 1/3 LENGTH OF SOLUTION SPARGER.

INTERNAL CROSS SECTIONAL AREA OF PIPE > 2X TOTAL CROSS SECTIONAL AREA OF ALL THE HOLES IN THE PIPE.

FIGURE 3

Sparger Location for Continuous Ammoniator-Granulator



① AMMONIA SPARGER – LOCATED AT THE 4 O'CLOCK POSITION 4½" FROM GRANULATION SHELL WITH HOLES FACING THE ROTATING STREAM OF MATERIALS OVERALL LENGTH - 12 FEET ONE HUNDRED AND FORTY TWO 1/16" HOLES ON ONE INCH CENTERS WITH SMALL QUANTITY OF WATER ADDED TO PREVENT CAKE AROUND SPARGER

② PHOSPHORIC ACID SPARGER – LOCATED TO DISCHARGE PHOSPHORIC ACID ONTO THE TOP AND NEAR THE CENTER OF THE ROTATING BED OF MATERIALS. OVERALL LENGTH - 8.9 FEET. SIXTEEN 3/8 INCH HOLES ON THREE INCH CENTERS.

③ PIPE-CROSS REACTOR – LOCATED TO DISCHARGE NEAR THE LONGITUDINAL CENTER OF THE BED AND AT A POINT ONE THIRD FROM THE BOTTOM EDGE OF THE BED OF MATERIAL IN THE GRANULATOR.

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

FIGURE 4

TVA Pipe-Cross Reactor in Rotary Ammoniator-Granulator

Drum granulators are usually installed with a slope, but they can be installed without a slope if the retaining ring on the discharge end is low enough to allow good feed-through of the materials. The speed of rotation of the drum is of considerable importance. The preferred rotational speed is 30 to 40% of the critical speed; however, some of the drums in diammonium phosphate (18-46-0) plants turn even faster, up to 50% of the critical speed. Critical speed is defined as that speed at which material would be carried around the drum by centrifugal force and thus would no longer have the desired cascading action. The critical speed in revolutions per minute is calculated by the formula

$$\text{critical speed} = \frac{76.5}{\sqrt{D}}$$

where D is the diameter of the drum in feet.

The TVA drum granulator has been widely used in production of superphosphate-based NPK grades of granular fertilizer (conventional granulation)[6][7]. Within 5 years of its introduction, there were over 100 U.S. plants using the drum granulator. Within another 10 years, this figure had doubled to 200 plants (Fig. 5)[1].

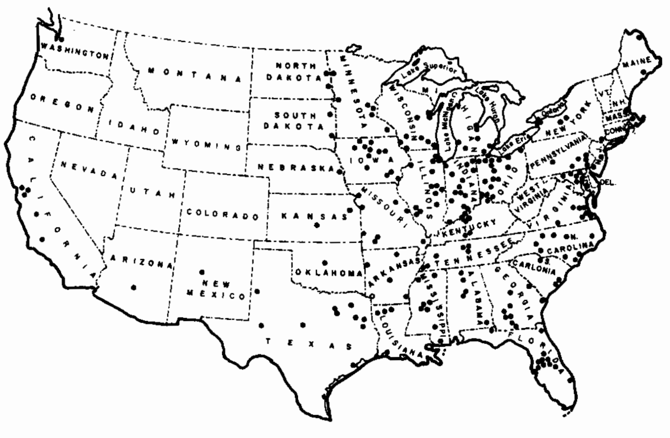


FIGURE 5

Location of Plants Licensed to Use TVA-Developed Continuous Ammoniator

In the course of its research and development work in fertilizer granulation, TVA has used the rotary drum granulator in conventional granulation processes, a granular diammonium phosphate process, and a nitric phosphate process.

Drum Granulation of Diammonium Phosphate

Because of the need to ammoniate during granulation, TVA chose the drum granulator for use in developmental work on the granular diammonium phosphate process. this choice has been widely accepted by the fertilizer industry. Pilot-plant studies of this TVA process were begun in early 1960[8]. At least one commercial plant designed on the basis of the TVA process was in operation as early as 1961. The feed phosphoric acid, after having been used to recover ammonia in the scrubbers, is ammoniated in a reaction tank to about 1.4 moles of ammonia per mole of acid. The resulting slurry is then fed to the ammoniator-granulator drum where additional ammonia is added to increase the mole ratio to nearly 2. In the drum, the ammonia is introduced through a single perforated pipe submerged beneath the cascading bed of solids. The ammonia is usually fed as an anhydrous liquid, although vaporized ammonia is sometimes used. A detailed description of a commercial diammonium phosphate plant is given by Heck[9]. Figure 6 is a simplified flowsheet of this process. Drums of 10 feet by 20 feet and 11 feet by 25 feet are common. Rotational speed of the drum ranges widely but is usually from 30 to 50% of the critical speed. The length of the submerged ammonia spargers is usually about 75% of the length of the drum. The distributor for the partically neutralized ammonium phosphate slurry is located above the bed and may be a simple open-end pipe, a perforated pipe, a spray manifold, a saw-tooth sparger, or four to five pipes with pinched ends. Granulation occurs in the drum and is regulated primarily by proportion of recycle fed to the drum.

Drum Granulation of Nitric Phosphate

After pilot-plant tests[10][11] spanning about 8 years, TVA built a demonstration-scale plant using a mixed acid process and a drum granulator to produce nitric phosphate fertilizer. The pilot-plant tests showed that the ammoniator-granulator could serve to simultaneously ammoniate and granulate the nitric phosphate slurry; whereas, in previously tested nitric phosphate processes, the ammoniation step was carried out in a fluid state prior to granulation. The demonstration-scale plant was operated about 7 years beginning in 1966[12]. The grades of nitric phosphate fertilizer made were 20-20-0 and 26-13-0. Figure 7 is a flow diagram of the nitric phosphate process. Nitric acid and phosphate rock were fed to the first of two acidulators in series. The acidulant flowed by gravity to a preneutralizer or reaction tank. Here the phosphoric acid and about three-fourths of the required ammonia were added. The slurry from the preneutralizer was fed by controlled gravity flow onto a bed of recycle in the drum granulator. About one-fourth of the ammonia in the formula was introduced into the drum as vapor through a submerged perforated pipe. Recycle-to-product ratios for granulation control were about 6 to 8 pounds of recycle per pound of product. The 10- by 20-foot drum granulator was rotated at 10 rpm by a 150-horsepower motor. The drive was reversible and was linked with a fluid coupling. An unusual shell cleaner used in the drum granulator is shown in Figure 8. It is a rotary scraper driven at 13 rpm by a 7.5-horsepower motor. It was designed so that only two of the individual teeth contacted the shell at one time. This scraper gave very good service. Off-gases from the drum were exhausted through impingement-type wet scrubbers.

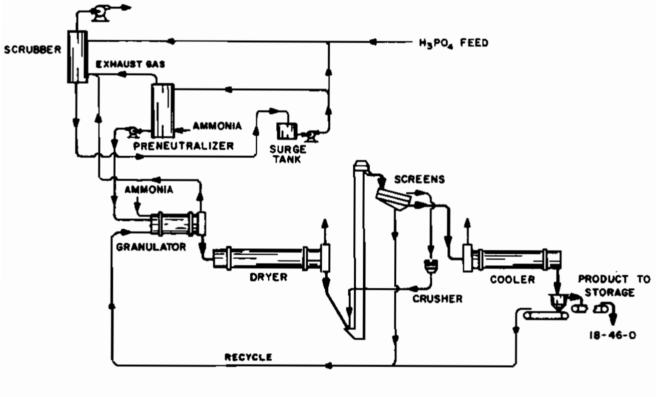


FIGURE 6

Flowsheet for Drum Granulation of Diammonium Phosphate

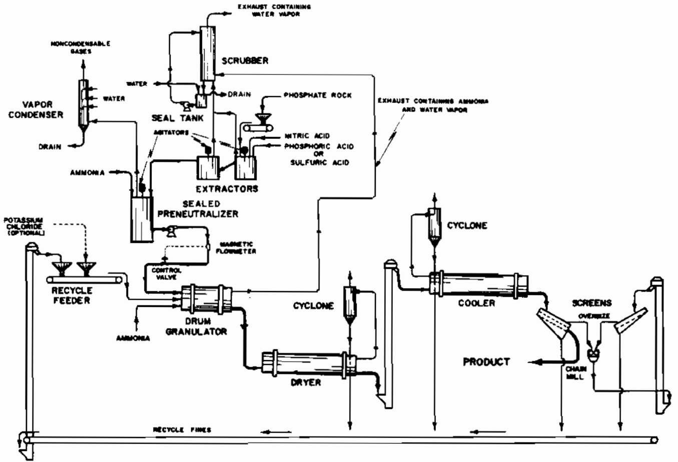


FIGURE 7

Flowsheet of Modified Nitric Phosphate Process

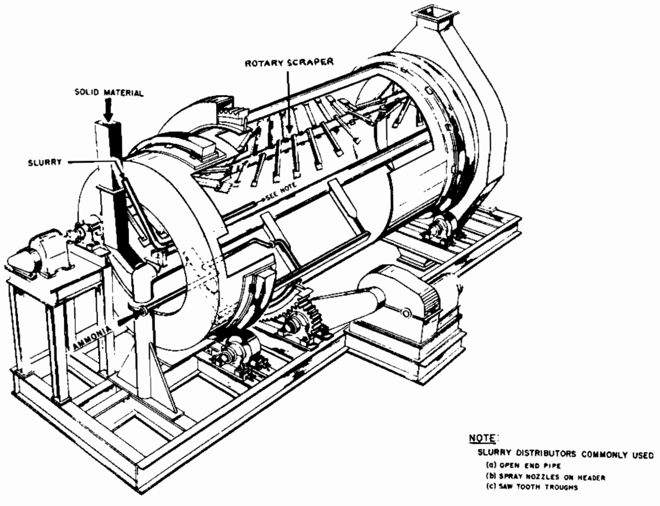


FIGURE 8

Continuous Ammoniator-Granulator with Rotary Scraper

Pug Mill Granulators

TVA uses pug mills for granulating ammonium phosphate melts or slurries in its demonstration-scale plant. These pug mills have two shafts with blades or paddles attached. The action of the paddles is mixing and kneading. Pug mills are commonly used by industry for mixing phosphate rock and acid in the manufacture of run-of-pile superphosphate.

Dorr-Oliver[13] has developed the blunger (a modified pug mill) for use in ammoniation-granulation processes. One major difference in the blunger and pug mill is the action of the blades or paddles. The blades of the blunger turn at such speed that a fluidized bed is created. The bed actually bounces violently and resembles a boiling liquid. Two outboard turning shafts drive the paddles. This differs from the kneading action that results in a pug mill. The blunger has a tremendous conveying capacity not characteristic of pug mills. The slope of a blunger is much greater than that of a pug mill. Particle growth is by layering of the slurry feed on bouncing seed particles and to a lesser extent by agglomeration of fine particles.

Blungers are used widely in the slurry process for granular triple superphosphate. Several producers of granular diammonium phosphate use blungers in their processes[9][13][14]. In the original process, all of the ammoniation was done in three slurry tanks[15], but currently many of these plants have been adapted for the addition of ammonia using submerged spargers in the blungers[16].

Although ammoniation during granulation in a pugmill has been carried out commercially in production of mixed fertilizer[17] and diammonium phosphate[13], drum granulator installations probably outnumber pug mills four to one. However, the pug mill process has unique advantages that keep it an important segement of granular fertilizer operations.

The pug mill generally gives a harder, more dense, and more homogeneous granule, but particle shape is more angular or irregular than that produced by the drum granulator. Particle size is easily controlled in the pug mill granulator, but more recycle may be required. Formulation cost should generally be lower using the pug mill. Since it can operate in a slurry or near-slurry state, a greater proportion of nitrogen from nitrogen solutions can be incorporated into the formulation. Maintenance and construction costs, however, are higher and more drying and cooling would be required when higher moisture contents are maintained in the pug mill. Control of liquid raw materials is usually easier in the pug mill because of the better mixing action and greater flexibility in the recycle feed location, but sparger placement and sparger hole plugging can be a problem with either granulator.

The horsepower required to drive a pug mill is considerably higher than for a drum or pan granulator. For fa 30-ton-er-hour unit, Reynolds[18] listed 100 horsepower for a pug mill and only 40 horsepower for a drum granulator. Additional data from Feeco International, Inc., on power requirements of pug mills are given in Table I.

Both the drum granulator and pug mill can be operated economically and satisfactorily with a wide range of products if attention is given to sound formulating and processing fundamentals. The choice of granulator should be made after the relative merits of each is considered.

Pug Mill Granulation of Ammonium Polyphosphate Melts

In early pilot-plant studies of granulating ammonium polyphosphate melt made from anhydrous ammonia and thermal superphosphoric acid, the use of a drum granulator resulted in the need for twice the proportion of recycle required when using a pug mill[19]. The vigorous mechanical working of the melt by the pug mill blades resulted in more rapid crystallization of the melt than when the drum was used. TVA first demonstrated the use of a large-scale pug mill in melt-type granulation in 1966 in the granular combination fertilizer unit at the National Fertilizer Development Center[20]. No ammonia was added in the pug mill. The melt produced from thermal superphosphoric acid and ammonia combined in a pressure reactor gave a 15-61-0 grade of product with about half of the P_2O_5 in the polyphosphate form. Production rate was 8 tons per hour with ammonia vapor and 10 tons per hour with liquid ammonia. Granulation was in a 5- by 16-foot pug mill which was driven by a 200-horsepower motor. After 10 years, operation was discontinued when TVA stopped producing thermal acid.

In December 1973, after about 10 years of pilot-plant development work[21][22][23], TVA began operation of another melt-type granulation plant using a pug mill. This pug mill is 6 feet wide, 4 feet 10 inches deep, and 17 feet 6 inches long. The 6-inch diameter shafts are driven at 40 rpm by a 300-horsepower motor. Changes in the new plant include the use of wet-process orthophosphoric acid and a pipe reactor. As with the earlier pug mill, no ammonia is added in the pug mill. The ammonium polyphosphate, which contains about 20% of its P_2O_5 as polychosphate, has a grade of 11-55-0 and is purchased at a rate of 400 tons per day. Molten urea is added to this 11-55-0 melt in the pug mill to produce urea-ammonium phosphate grades of 28-28-0 (400 tons per day) and 35-17-0 (300 tons per day). A simplified flow-sheet of the process is shown in Figure 9.

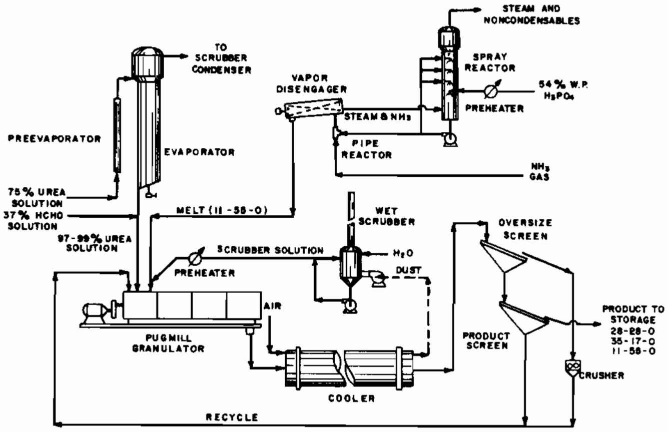


FIGURE 9

Flowsheet of Pipe-Reactor/Pug Mill Process

Raw materials fed to the process are urea solution (75% by wt.), wet-process phosphoric acid (52% P_2O_5), and ammonia vapor. The 75% urea solution from the urea synthesis unit is converted to a 99% urea melt in an air-swept rotary-disk evaporator. The ammonium phosphate melt is produced in a pipe reactor from partially ammoniated acid and ammonia vapor. The heat of reaction is supplemented by preheating the feed acid to about 150°F. to provide the extra heat necessary to increase the polyphosphate level of resulting melt at about 20 to 25%. The amount of preheating required varies considerably with the water content of the feed phosphoric acid. There are also provisions for preheating the ammonia vapor, but they are seldom used.

The feed streams to the pug mill granulator are ammonium polyphosphate and urea melts, recycle, and heated (concentrated) scrubber liquor returned from recovery of dust in a wet-scrubbing system. The pug mill product is cooled and screened. The onsize fraction (—6 +16 mesh) is further cooled and conveyed to bulk storage. No conditioning is required for the 28-28-0 and 11-55-0 grades; the 35-17-0 grade may not require conditioning if the moisture content is below 1%. The undersize and oversize fractions are transforred to the recycle cooler and recycle screens. The oversize is crushed and fed with the undersize to the pug mill. The primary granulation controls are the recycle ratio, rate of scrubber solution return, and the polyphosphate content of the ammonium polyphosphate melt. These govern the readiness with which the melt crystallizes. It is important to note that solid urea instead of urea melt can also be used in this melt-type granulation process[24].

Pan Granulators

The first use of the pan granulator was for pelletizing materials, such as iron ore concentrate, and for processing fines in cement and ceramic manufacture. When feeding fine solids such as these, it is usually necessary to add either a binder or some means of wetting or both. Particle size of the pelletized product generally was considerably larger than is desired for granular fertilizers. However, the good conditions for agglomeration and its classifying action have led to the use of the pan for granulating fertilizers. The first reported use for fertilizer was in Germany for granulation of ordinary superphosphate[16]. This use of the pan granulator now is practiced quite widely in other parts of the world including Australia, Japan, Greece, and Formosa[25]. Another use of the pan is to produce granules from hot concentrated solutions, such as those of ammonium nitrate or urea. Still the pan granulator has seen very limited use in the fertilizer industry in the United States. However, TVA has shown in its demonstration-scale facilities that the pan granulator can be successfully used in production of granular ammonium nitrate-based products and granular urea. It has been used successfully in pilot-plant studies at TVA to produce urea-based NP and NPK products.

A very favorable feature of the pan granulator, which results in closely sized granules, is its self-classifying action which allows melts or concentrated solutions to be selectively sprayed on undersize particles which, with the proper slope and rotational speed of the pan, collect in the upper quadrant of the pan. Figure 10 illustrates the operation of the pan.

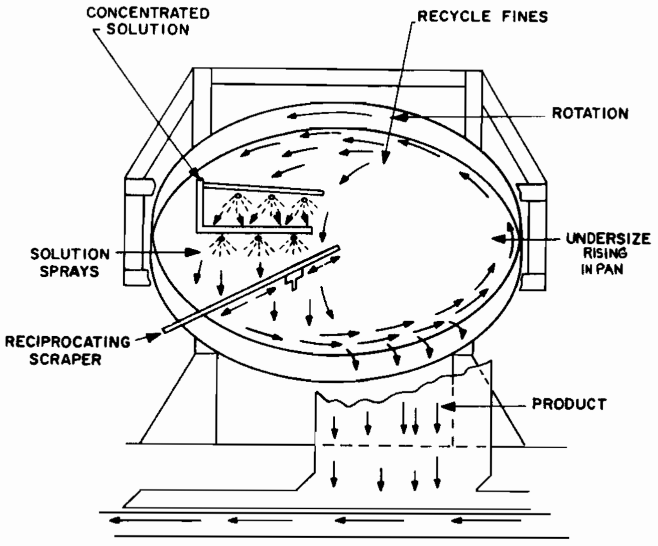


FIGURE 10

Sketch of Pan Operation

For solution granulation, critical features for best operation of the pan granulator include slope; rotational speed; location of sprays; concentration and temperature of the feed solution; and the amount, particle size, and temperature of the recycle material. For best operation there is a definite relationship between the pan diameter, pan depth, slope, and rotational speed. The approximate rotational speed for best results can be estimated from the following relationship[26][27].

$$\text{speed of rotation (rpm)} = K_1 [1 - \cos \theta] \frac{(76.5)}{\sqrt{D}}$$

where θ = slope of pan
D = pan diameter in feet
K_1 = constant derived from experimental data, usually 1.0 to 1.6

The depth required for a pan granulator of a given diameter can be estimated by the following relationship[27].

$$\text{depth of pan (in.)} = K_2 (\sqrt{D})$$

where K_2 = constant obtained from dimensions of experimental pan, usually 1.3 to 1.6
D = pan diameter in inches

Best operation is with a pan slope of 60 to 65 degrees.

Several advantages of the pan granulator in proper application have been established:

- The inherently good classifying action in the pan allows solutions to be sprayed selectively onto undersize particles, thus producing a very low percentage of oversize.
- Recycle requirement is considerably lower than for the same type of product in a rotary drum or pug mill system.
- The granulation operation can be readily observed by the operator, and the effects of operating changes on granulation are quickly detected.

There are some disadvantages of the pan as compared with the rotary drum:

- The pan granulator is not well adapted to efficient ammoniation.
- Fumes and dust are not easily controlled and collected.
- For good results, production is restricted to $N:P_2O_5$ ratios of 1:1 or higher. Best results are obtained when the $N:P_2O_5$ ratios are 2:1 and higher

Pan Granulation of Ammonium Nitrate-Based Products

TVA first tested the pan granulator for granulation of ammonium nitrate in 1956 in a pilot plant using a 3-foot-diameter pan[1][26]. Limited tests did not convince management to install a pan granulator in the demonstration-scale plant. However, pilot-plant studies of the pan process were renewed in 1958 to obtain design data for a demonstration-scale plant because products made in the pan granulator using concentrated solutions were found to be far superior to products made by granulating crystalline ammonium nitrate in a drum. In the early sixties, TVA began the design and installation of a demonstration-scale plant using the TVA pan-granulation process. A simplified flowsheet of the process is shown in Figure 11. The process utilizes a conventional solution or melt preparation system; conventional equipment for drying, cooling, and sizing the granular product; and a pan granulator. The pan granulators installed in this unit were 14 feet in diameter with a 20-inch side wall. They were driven by 50-horsepower motors. The rotational speed (which was variable) was usually about 18 rpm.

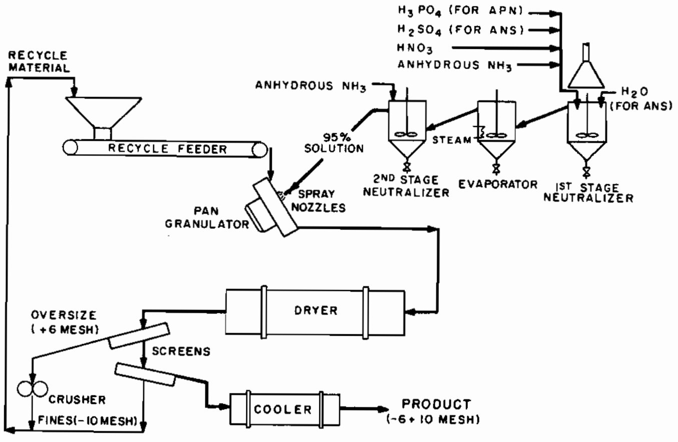


FIGURE 11

Flowsheet of Pan-Granulation Process for Ammonium Nitrate-Based Products

The process as developed by TVA for making granular ammonium nitrate-based products is quite simple and inexpensive. Hot concentrated solution (92-97% dissolved salts) is prepared by ammoniation of acids in two reaction tanks with an evaporation vessel follwing the first reaction tank. Granulation is accomplished by spraying the hot solution of fertilizer salts onto a cascading bed of recycle material in a pan granulator. The sprays are directed to fall on the area in the pan in which the smaller particles are rolling. The granulator product is either cooled, or dried and cooled, and sized in conventional equipment. The oversize fraction from the screening process is crushed and returned to the pan granulator with the undersize fraction as recycled material; the onsize product is treated with an appropriate conditioning agent and sent to storage. Critical variables for best operation of the pan granulator include slope; rotational speed; location of sprays; concentration and temperature of the feed solution; and the amount particle size, and temperature of the recycle material.

A demonstration-scale plant with a design capacity of 20 tons per hour was operated by TVA at Muscle Shoals, Alabama, from 1965 to 1973. During this period, the following granular fertilizers were produced at rates up to 23 tons per hour in one 14-foot pan granulator:

Ammonium nitrate (33.5-0-0)
Ammonium nitrate sulfate (30-0-0-5S)
Ammonium phosphate nitrate (30-10-0 and 25-25-0)

The TVA pan-granulation process for ammonium nitrate-based products was fully developed and amply demonstrated during the operational period. Later the process was adapted to production of granular urea and urea-based products[26].

The N-Ren Corporation of Pryor, Oklahoma, has a pan-granulation unit for ammonium nitrate which began operation in December 1975. This unit, which uses the TVA process, replaced a prill tower that was shut down because of particulate pollution problems. The design rate of this unit is 400 tons per day. The operation at the N-Ren plant demonstrated that a dryer is not needed for the process when the feed to the pan is essentially anhydrous ammonium nitrate melt.

Pan Granulation of Urea

TVA began pilot-plant studies of pan granulation of urea in 1963. Operating procedures and conditions similar to those for pan granulation of ammonium were used in the beginning for these studies. Granulation generally was good when 96 to 98% urea solutions were fed to the pan. The products were of good quality, but drying was required for satisfactory storage properties. In later pilot-plant studies, the use of urea solutions of 99.3 to 99.8% concentration was tested. The highly concentrated urea solution was prepared for the pilot-plant test by melting prilled urea. The temperature of the urea solution was maintained at 20° to 30°F. above the melting point to prevent premature crystallization during spraying. Good granulation was obtained and the granules were of good quality and well rounded when the correct operating conditions were maintained. No drying was required.

A demonstration-scale plant for granular urea has been operated by TVA since late 1973[1][24][27][28]. Much of the equipment formerly used for granulation of ammonium nitrate-based products was reused for production of granular urea. The capacity of the urea solution plant is only about 9 tons per hour. Therefore, it was considered necessary to decrease the effective pan diameter from 14 feet to 12 feet. The pan granulator rotates at about 18 rpm, and it has a variable slope. It is usually operated at 60 degrees from the horizontal. Operation of the demonstration-scale plant has established the feasibility of the TVA pan-granulation process for producing granular urea. A simplified flowsheet of this process is shown in Figure 12.

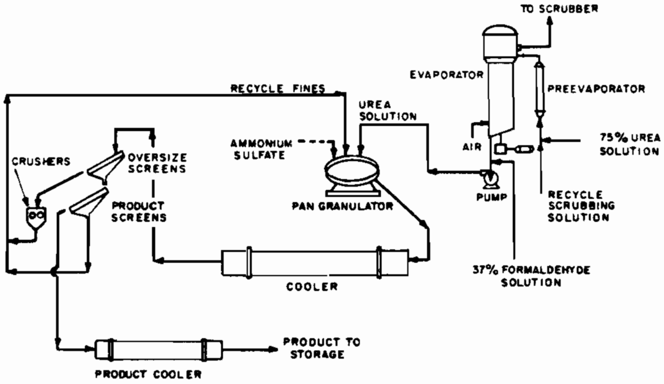


FIGURE 12

Flowsheet of Pan-Granulation Process

for Urea and Urea-Ammonium Sulfate

Other Types of Granulators

Other and lesser used granulators include pin mills, which are similar to pug mills; fluidized bed granulators; spouted bed granulators; spray drums ("Spherodizers"); and graining kettles. Prilling towers can be considered equipment for producing granules. Except for the graining kettle mentioned previously, none of these granulators have been used to any extent by TVA.

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TABLE I

Approximate Power Requirements for Pug Mill

Granulation of Mixed-Grade Fertilizer

Pug mill housing dimensions, ft	Approximate maximum throughput,[a] tons/hr.	Recommended horsepower[b]
1.8 x 8	12	20
1.8 x 10	15	25
1.8 x 12	20	30
3 x 10	40	50
3 x 12	50	60
4 x 10	80	75
4 x 12	100	100

---

[a] Performance characteristics and capacities with respect to sizes can be varied for specific requirements by changing one or more of the following:

1. Speed (rpm)
2. Paddle pitch, size, or shape
3. Slope
4. Retention volume

[b] Based on approximate 60-second retention time, loaded to shaft centerline, and 25% safety factor for starting overload and process upsets.

MODERATOR WESENBERG: Thank you Byron, and your associates at TVA, Messrs Hicks, McCamay and Norton, for that most interesting discussion on selection of "Granulators" at TVA. Your Presentation was excellent. (Applause)

Our next speaker has a Bachelor of Science Degree in Chemical Engineering from Mississippi State University. He is a registered Professional Engineer. He is currently Chairman of the Fertilizer Institute Manufacturing Environmental Committee. He is Project Manager, Mississippi Chemical Corporation, Wauchula, Florida. Carey Stark, please.

Cost Of Environmental Control In The Fertilizer Industry

Carey Stark

The economics of pollution control is a contradiction in terms. If pollution control were economic, it would not have to be forced upon industry by powerful bureaucracies like EPA. Admittedly, industry and muncipalities have in the past discharged pollutants in harmful amounts. This practice needed correction, but the pendulum has swung far too much to the other extreme.

Presently, a significant part of industry's operating costs are due to pollution control and much of the available capital for industrial investment goes for new and ever increasingly sophisticated pollution control equipment. And the available capital for industrial investment is limited by our governments' "spend ourselves rich" policies which absorb 80% of all available capital.

Since pollution control does cost some money in our industry, let us see what all is involved. Our industry is affected most directly by these five laws as amended:

Clean Air Act
Federal Water Pollution Control Act
Toxic Substances Control Act
Resosurce Conservation and Recovery Act
Safe Drinking Water Act

These first two laws caused us to install the equipment and facilities that have cost us the most money. They require extensive monitoring and reporting, as do the other three. These last three are still early in the formative stages as far as implementing regulations are concerned, but they have potential for costing us a lot of money.

As far as the present costs of pollution control are concerned, I want to show you some industry-wide figures. Then we will look at the specifics of what our company has had to spend to comply.

Lets look at five common products — Ammonia, Urea, Ammonium Nitrate, Phosphoric Acid, and Diammonium Phosphate:

Urea

BAT Controls — Air and Water
Capital Cost/Ton—$1.64
Operating Cost/Ton—$1.35

Ammonia

BAT Controls — Air and Water
Capital Cost/Ton—$3.69
Plant Operating Cost/Ton—$2.55
Total Operating Cost/Ton—$3.68
(includes ammonia plant control costs)

Ammonium Nitrate

BAT control Cost — Air and Water
Capital Cost/Ton—$3.56
Plant Operating Cost/Ton—$2.20
Total Operating Cost/Ton—$4.96
(includes ammonia and nitric acid plant control costs)

Phosphoric Acid

BAT Control Cost — Air and Water
Capital Cost/Ton—$2.08
Plant Operating Cost/Ton—$1.11
Total Operating Cost/Ton—$1.61
(includes suslfuric acid plant control costs)

Diammonium Phosphate

BAT Control Cost — Air and Water
Capital Cost/Ton—$3.12
Plant Operating Cost/Ton—$3.92
Total Operating Cost/Ton—$4.96
(includes ammonia and phosphoric acid
plant control costs)

Well, these figures show the impact of control on each unit of fertilizer; the impact on the farmer as he buys each ton of fertilizer, but what about the total impact on the economy?

Ammonia

Production—17,902,000 tons
Control Cost—$24,200,000

Urea

Production—4,256,000 tons
Control Costs—$15,700,000

Ammonium Nitrate

Production—5,970,000 tons
Control Cost—$29,600,000

Phosphoric Acid

Production—8,289,000 tons P_2O_5
Control Cost—$13,300,000

Diammonium Phosphate

Production—8,629,000 tons
Control Cost—$42,800,000

Total — Urea, AN, DAP

Control Cost — $88,100,000

Mississippi Chemical Corporation operates a Nitrogen Fertilizer complex at Yazoo City, Mississippi and an NPK fertilizer complex at Pascaguola, Mississippi.

Each of these facilities produce about one million tons per year of product. Because both of these facilities are located such that they discharge into water quality limited receiving streams, we were required to install the best available control technology. This means Ion-exchange at our Nitrogen Plant and cross-flow scrubbers with double lime treatment for waste water at our NPK plant. To control air emissions and other areas, some very sophisticated equipment was installed.

Altogether, this equipment cost about $52,000,000. The Ion-exchange system cost $8,500,000 and the NPK control facility cost $23,000,000. The operation of these and other control facilities costs about $6,500,000 annually. This increases our cost of producing fertilizer about 4%. There is no return on this investment to our company nor is there any return on this increase in cost to our farmer-customers.

And the situation is getting worse. More regulations are coming and more monitoring and reporting will be required as TSCA, RCRA, and the amendments to the Air and Water Acts are implemented. In addition, the standards for new sources are constantly being reviewed and each advance in technology is seen as license for the regulators to turn the screws a little tighter.

The only relief is what we do for ourselves. We must cajole our lawmakers into limiting the power of the bureaucracies and reducing the number of new laws controlling our operations. We must comment and object individually and collectively on new regulations. We must be willing to go into court to beat back bad regulations and expansive tendencies by the agencies. It can be done. MCA, along with TFI and others, won an impressive victory over EPA on Hazardous Spill Regulations. EPA was forced to return to Congress, hat-in-hand, to ask for a law on which they could write regulations.

You've seen how much regulations cost all of us, and how much it costs one particular company, so you see why we should reduce it. I've tried to show you some ways to do it, now it's up to all of us to get the job done.

MODERATOR WESENBERG: Thank you Carey. That was very interesting. I am susre we all appreciate the valuable information you left with us. (Applause)

We thank all of you die-hards that stayed to the end. I shall return the program back to Rodger or Frank. (Much Applause)

FRANK NIELSSON: It has been a long morning. I want to thank all of the people who have been here. I want to thank all of the participants. We have had a fantastic 3 day - 5 session meeting — one of the best in years. Thank you and so-long.
(Applause — Applause — Applause)

Comments By Albert Spillman

Editing Chairman

It has been my pleasure to "Ready, Assemble and Edit" our 1978 Proceedings, covering Our Round Table — 28th Annual Meeting held in Atlanta, Georgia, Tuesday, Wednesday and Thursday, October 31st, November 1st and November 2nd, 1978.

We had a very good "Registration". Our "Audience" seemed to be very much interested in "Our Programs". Each of our "Five Sessions" had an excellent "Attendance".

Our "Speakers", covered their "respective, updated discussions" very "clearly and most interestingly".

I am sure you will enjoy reading the "timely, interesting and valuable information" covering the many "phases of your daily fertilizer and chemical operations."

It takes much time and effort, assembling, proof reading, corresponding, telephoning, etc. to be sure this important project is finally put in print as correctly as is humanly possible. This I have done gladly and I hope you enjoy it.

I take this opportunity to thank all of you, our Chairman, Directors, Moderators, Speakers, Secretary-Treasurer Paul Prosser and his most accommodating "helpful Secretaries", also those in "Our Audience" asking questions and giving answers, for helping me promptly when I called on them to clear-up many of the details necessary to complete "our valuable printed proceedings."

Hope to see you at our 29th Annual Meeting to be held at:

The Shoreham-American Hotel
Washington, D.C.
Tuesday—Wednesday—Thursday
October 30-31 and November 1st, 1979

Most of our attendance will be arriving in the afternoon and evening — Monday, October 29th.