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1981

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Editor

Albert Spillman

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Our Round Table
Is Happy To Report
These Valuable Proceedings
Covering Our
31st Annual Meeting
November 3-4-5, 1981

Tuesday, November 3, 1981

Morning Session
Moderators:

Frank P. Achorn
John L. Medbery

Introductory Remarks
Chairman Achorn

Welcome to Our 31st Annual Meeting. (Applause).

This meeting is an International Conference of Scientists that have come together to share their experiences so that Effective and Useful Changes can occur in the Vital Field of Food Production. In this conference we will discuss — New and Improved Fertilizer Processes, Products and Improved Methods of Using These Products. We will discuss many of the problems related to Pollution Control and Inplant Safety. We will have discussions on Latest Granulation Techniques, Fluid Fertilizer Technology, Bulk Blending, Latest in packaging Techniques, Ammonia Production, Production and use of Urea, Genetic Engineering, Energy Requirements and Updated Reports on Supply and Demand of N.P.K. and Sulphur.

The other day I observed an artist painting a picture that would never be changed until it was finally destroyed. It became apparent to me how different an artist must be than a scientist. It is a scientist's objective to create new discoveries and new technology and he is usually well recognized for these discoveries, however, immediately after the discovery is made, he and other scientists try to change and improve upon it until it can be utilized to profitably produce plant foods. Scientific discoveries are building blocks onto which others can build. Continuous improvement of old and new products has been the trademark of the fertilizer industry.

The purpose of this Meeting is to come together to discuss New Discoveries that will help us improve physical and monetary environment of our workplace. The wintering and sifting of this technical information, during and after this meeting, most certainly will result in increased food and fibre production throughout the world.

The success of the Meeting is dependent on active participation by the Conferees. It is the tradition of The Round Table that the speakers allow time for and welcome questions from the floor. Questions and answers are very important to the interchange of ideas and to the development of improved technology, therefore, each question and answer will be recorded in the printed proceedings. You can present your question, either in writing to the moderator, or we encourage you to use the microphone nearest to you. Please state your name, your organization and your question. I assure you all of us will be interested and respect your thoughts. I wish all of you a pleasant and interesting stay thruout our 3 day meeting. (Applause).

Our Keynote Speaker, Richard E. Lyng, is a little late and is expected shortly. Our Moderator, John L. Medbery, is outside waiting for Mr. Lyng's arrival to greet him. To save time I will introduce the first discussion of this morning's program — "Nitrogen Outlook", to be presented by J. W. Brown, Managing Director, Canadian Fertilizer Institute, Ottawa, Ontario, Canada.

Jim Brown is a native of Ontario. He received his education in Ontario and in 1953 he was granted the degree of Bachelor of Science in Agriculture by the University of Guelph. From 1953 to 1955 he was employed as a lecturer at the University of Guelph. In 1955, he joined Cyanamid of Canada Inc. as field sales representative for phosphate and nitrogen products. From 1958 to 1961, he was employed as a market analyst, Commercial Development Department, located in Montreal. For the period of 1962 to 1978 he was employed in various marketing management positions involving Cyanamid's pesticides and fertilizer products. These positions included Manager Wholesales Fertilizers, Pesticides Manager and Marketing Manager of Retail Fertilizers. In 1978, he was appointed Manager of Market Research, Plant Food Division, American Cyanamid Co. in Wayne, New Jersey.

He was a member of the Board of Directors of Cyanamid of Canada's Associated Fertilizer Companies.

In May 1981, he was appointed Managing Director of the Canadian Fertilizer Institute located in Ottawa.

He and his wife have 4 children. (Applause)

Nitrogen Outlook—1982

J. W. Brown

Thank you Chairman Achorn.

When I was asked to present the 'Nitrogen Outlook' at the Round Table, I quickly reviewed Dr. John Douglas' projections for the past two years. I found his forecasts to be highly accurate which makes one approach this year's task with considerable trepidation. I hope this year's projections have the same validity as those of the two previous forecasts. A recent survey on present and planned world ammonia capacities shows that capacities are substantially above the effective output to meet present and future nitrogen demand. North American ammonia plants operated close to 95% of designed capacity, whereas plants in the rest of the world operated on the average at 70% of capacity. The same survey shows that a substantial part of the ammonia capacity in West Europe and Japan still use naphtha or fuel as a feedstock. Many of these plants are inoperative or operating at greatly reduced rates. In the U.S., the high cost of natural gas, combined with low ammonia prices has resulted in the idling of three million tons of ammonia capacity. Idled plants in the U.S. and elsewhere will remain closed until natural gas prices approach the cost of other feedstock or ammonia selling prices rise substantially above current world levels.

The world is showing a relatively tight supply-demand balance for nitrogen products for the 1981 and 1982 fertilizer years. Current production statistics are not available but advances in world nitrogen prices during 1980 and the first half of 1981 add support to this tightly balanced position. Prices of ammonia last fall in Western Europe averaged $160 per tonne. Prices advanced through the year so that by the spring of 1981 they were over $200 per tonne. Prices of urea in bags likewise advanced from less than $200 in January 1980 to over $230 in May of 1981. Since May 1981, world prices of both urea and ammonia have declined.

1981

Despite the current level of interest rates, most evidence indicates that the U.S. economy is edging down but that a sharp decline like that of the spring of 1980 appears unlikely. Most of the weakness is concentrated in interest rate sensitive sectors such as housing, consumer durables and investment. Exports are also weakening in part due to the effects of high interest rates on the U.S. dollar and inventories which are building in recent months in several sectors.

The political embargo by the U.S. on grain and fertilizer shipments to the U.S.S.R. was removed early this spring as promised. The Soviets have purchased their entitled grain contracts and it is anticipated that they will purchase up to 20 million metric tonnes during the 1982 crop year.

Record wheat and corn crops have decreased grain prices and realized net farm income is down from estimates earlier this year. The financial markets are also hurting farmers. Record high interest rates, although coming down recently, are restricting farmers' purchases of fertilizers and other inputs.

An acreage set aside program has been announced for wheat. A feed grain and cotton acreage set aside program is also possible. Set aside programs will greatly reduce the government's exposure should grain prices fall below 'target' price levels.

Reduced grain prices, combined with relatively stable retail nitrogen material price make the corn and wheat fertilizer ratios less favourable than last fall and this spring. It now requires more bushels of corn and wheat to buy a ton of ammonia or urea than it did last fall. In contrast to the unfavourable crop fertilizer price ratios, farmers harvested higher average yields of corn per acre this year. Many farmers will obtain a higher dollar return per acre than last year.

World Nitrogen Supply-Demand Outlook

We can expect world demand for nitrogen fertilizer during 1981 to continue its increase at approximately three million tons per year. The continuing pressure on world food supplies is such as to ensure that additional nitrogen will be used in order to produce adequate supplies of grain.

Supply

Statistics on the number of plants coming on stream would indicate a significant world wide surplus of materials in 1982. Feedstocks for a significant part of the total world production capacity are from naphtha, fuel oil, and high cost natural gas. Current cost for these feedstocks put production costs well above the current world price for merchant ammonia. As long as this holds true, much of the production capacity will not be truly effective in producing nitrogen fertilizers.

In addition, most of the new nitrogen capacity coming into production in 1981 and 1982 will be in the U.S.S.R. and its eastern european satellites. Even if the Soviets are able to produce additinal ammonia, it is highly unlikely that it will move to world markets in time to fertilize 1982 crops. Indonesia and other relatively newcomers to ammonia production are experiencing operating difficulties that keep production levels well below the developed countries.

U.S. Nitrogen Situation — 1981-82

Demand

In contrast to the three previous years, demand prospects for the 1982 fertilizer year for nitrogen do not appear to be as bullish. Agriculture demand for nitrogen will increase a modest 2-4% over 1981 to around 12.6 million nutrient tons. Anhydrous ammonia and nitrogen solution shipments during the first quarter of the 1982 fertilizer year were about the same as a year ago. Urea and ammonium phosphate shipments were well below the previous year. There are signs that indicate shipments for the balance of the fall will be slow. Corn and wheat prices are currently depressed due to record productions for both crops. Interest rates, although coming down, are still high compared to historic levels. Realized net farm income is projected to be below earlier estimates. Both dealers and farmers are reluctant to replace depleted inventories until some of the uncertainties of the market place are cleaned up.

The agricultural economy is expected to improve during 1982. Improved growth in farm receipts combined with a slowdown inflation point to a modest increase in farm income next year. An improving agricultural economy during 1982 should put farmers in a buying frame of mind and record nitrogen consumption is expected during the 1982 spring planting season.

Supply

In 1981, U.S. ammonia production was 19.3 million tons, or approximately 400 thousand tons higher than the 18.9 million tons produced in 1980. This added production came about almost entirely by increasing the operation rate of the producing plants. Only one or two of the inoperative plants were brought back on stream. The net result was that U.S. plants operated at the highest rate of designed capacity in history.

The most often posed question at fertilizer meetings is 'How many of the idled ammonia plants will be reopened?' A comparison of average production costs to current sales prices provides the answer. According to a T.F.I. survey, the cost of production doubled between 1970 and 1975, and doubled again between 1975 and 1980. It is estimated that the weighted average production costs of ammonia is now approaching $120 per ton and $140 per ton for the 83% of the plants with gas costs in the $2-3 range or above. These costs do not include return on investment, storage and shipping costs, general administration and sales costs. We cannot expect many additional plants to open as long as the price of ammonia on the gulf coast hovers around $150 per ton.

In summary, U.S. ammonia production for this year may increase by another 3% or approximately half a million ton of product.

Exports

1981 was a banner year for U.S. nitrogen exports. 3.1 million tons of nitrogen were exported, up 17% from the previous year. Nitrogen exports exceeded imports by approximately 600 thousand tons of N. Although a record 816 thousand tons of ammonia were expected, most of the exported nitrogen was in upgraded products such as diammonium phosphates, nitrogen solutions, urea and ammonium sulphate. World demand as indicated by world prices softened in the second and third quarters of this year. Exports during the 1982 crop year are likely to be down for ammonia, urea, nitrogen solutions and DAP. Total nitrogen exports could decline by as much as half a million ton of ammonia equivalent. During the July-September period, U.S. nitrogen exports were down over 430 thousand tons of N, from the same period in 1980.

Imports

Nitrogen imports during the 1981 fertilizer year were 2.5 million tons of N, or 5% below the previous year. Approximately 90% of the imported nitrogen was two products — anhydrous ammonia (72%) and urea (17%). Ammonia imports were down 3% (2.16 million tons) and urea imports declined by 18% (.93 million tons). ammonia imports from the U.S.S.R. were approximately 200 thousand tons higher whereas imports from Canada, Trinidad and Mexico were lower than the previous years. With new ammonia capacity coming on stream in the second half of 1981 in Mexico and Trinidad, imports from these countries are likely to be higher. Canadian plants are working at capacity and imports from Canada are likely to be the same or slightly lower. Imports from the U.S.S.R. are expected to be higher for the July-December period, but for the fertilizer year, imports could be the same or lower than 1980-81.

Industrial use of ammonia was down in 1980 and early 1981. 1982 usage could be slightly above the 1981 crop year. With ammonia production up by over half a million tons and exports down by up to half a million ton, and imported ammonia or ammonia equivalent up by 200-300 thousand tons, the total supply available for fertilizer use could be up from 1 to 1.2 million tons.

Summary

The U.S. nitrogen supply-demand balance is expected to be in close equilibrium for the 1981-82 fertilizer year. Any major swing in consumption, production, exports or imports could change this delicate balance. Ammonia plants are expected to operate full out at better than 93% of designed capacity.

Supplies of nitrogen fertilizers should be adequate to meet anticipated demand during the 1982 fertilizer year. The year, as a whole, should experience no major problems. Thank you for your kind attention. (Applause).

CHAIRMAN ACHORN: Jim, we thank you for your excellent report covering "Nitrogen Outlook, 1982". We will hold the questions, Jim, for later.

I am very happy to see, coming down the aisle towards our podium, Keynote Speaker Richard E. Lyng and our Morning Moderator John Medbery. Here they are — thank you for your applause and your standing ovation.

I am sure most of you know John Medbery. He is the Director of Operations and Production for The Rainbow Division of IMC Corporation. He is an Active Director of Our Round Table. He is a leading Technologist in Granulation and General Fertilizer Processes. When you ask John to do anything he always gets the job done. John, please. (Applause).

MODERATOR MEDBERY: Thank you Frank. Our Chairman, Mr. Achorn, and our Secretary, Mr. Prosser, several months ago, notified me that I would be the Moderator for this morning's session. They jokingly inferred that I was "stuck" with the job because I failed to attend an early July Director's Meeting. Well, the joke backfired. First, I got to go fishing in Minnesota in July, rather than attend another boring planning meeting! I also have the distinct and pleasurable honor of introducing our Keynote Speaker.

Introduction - Keynote Speaker

Moderator - John L. Medbery

Richard E. Lyng has been the Deputy Secretary of the U.S. Department of Agriculture since February 1981. He was appointed to the position by President Ronald Reagan. He was the transition team leader for USDA from November 12, 1980 until his appointment.

Lyng was born in San Francisco, California. He graduated cum laude from the University of Notre Dame, in 1940. He spent 30 months in the South Pacific with the U.S. Army during World War II.

From 1945 to 1967 he was president of the Ed J. Lyng Company, Inc., a family seed an bean production and processing company. He was Deputy Director and Director of the California State Department of Agriculture in Sacramento from 1967 to 1969.

He was appointed Assistant Secretary of Agriculture for Marketing and consumer activities in 1969 and served for four years. From 1973 to 1979, he was President of the American Meat Institute.

He was Director of Tri-Valley Growers, San Francisco, California, from 1975 until January 1981; Chicago Mercantile Exchange, 1975 to 1979; Refrigeration Research Foundation, 1974-1979; and the Animal Health Committee, National Academy of Sciences, from 1976 to 1980.

Lyng received the Animal Agriculture Award from the American Meat Institute in 1979; and was made an Honorary National Member of Alpha Zeta Honorary Fraternity in 1974. He is an Honorary Member of Rotary International, Modesto Club.

Lyng is married to Bethyl Ball. They have two daughters.

It is with great pleausre that I present our keynote speaker, Richard E. Lyng. (Much Applause).

Keynote Speaker — The Honorable Richard E. Lyng

Deputy Secretary

U.S. Department of Agriculture

Thank you very much, John. It's a pleasure for me to be here and speak to this group this morning. I know very few of you. I haven't been close to the fertilizer business for a long, long time. Years ago, in that family business which later became a seed and bean business, in one stage we handled everything, including fertilizer. I can recall selling lots of superphosphates and ammonium nitrate. As a matter of fact, we used to import some Chilean nitrate of soda, so you know how long its been since I was involved in "N", as you were referring to it a moment ago. I never liked the fertilizer business. I figured that the only way to make a million dollars in the fertilizer business was to sell a million tons. The margins just weren't good enough for me, so we moved over to seeds and some other things. We didn't have to handle quite as much to make a dollar.

I thought maybe it would be interesting for you this morning if I would review what's happened, really, in the past year. It is almost a year to the day since the election took place. It was an election that dramatically changed the course of government in the United States. It promised to do so, and I think it has definitely done so. Just a few days after the election, I was asked by the President to come to the Department to serve as Transition Leader. We got busy right away and built a team and prepared for the coming of the new administration. We had excellent cooperation at the Department from then-Secretary Bob Bergland and Deputy Secretary Jim Williams and the people that we were actually going to move out of office. They couldn't have been more helpful, and being chairman of the transition was really pleasant. It was a full time, seven days a week job. It paid even worse than selling fertilizers — it didn't pay at all. However, it was exciting and thrilling. I figured that I would get that behind me and then I would go back to the kind of semi-retirement that I had been enjoying. That didn't quite work out.

The first chore, really, after the Inauguration, was to get the Department organized and to get a staff of people. At the Department of Agriculture, we had to make some substantial changes philosophically in the people who were placed in top spots. The President had promised during the campaign that the Department of Agriculture leadership would come from farmers and those who understood farmers. I am proud to be a part of this team headed by Secretary of Agriculture Jack Block, who is a farmer in Illinois — a successful one — and had been up until his appointment, Secretary of Agriculture in Illinois. He is a strong leader and is doing, I think, just a splendid job.

I think we put together a good team of top staff at the Department of Agriculture — people who understand not only farming, but agribusiness, have some geographical balance, a number of people with government experience, and so on. I think that we have a team that is working well together. I just came from our daily meeting. It's pleasant to work with them.

The second thing we had to do almost immediately was to put in a revised budget. You will recall that we cut very heavily in the Department's budget — actually cut, in the marked submission, $3.5 billion out of a $26 billion Department of Agriculture budget. A large part of that, of course, came from non-agricultural areas, because 70% of our budget is in food programs, such as food stamps, child nutrition programs and school lunches. That's where the biggest cuts were. There were some heavy cuts in Farmers Home Administration loans, REA loans, and in a number of other areas.

Almost immediately, on top of that, we had to come up with a Farm Bill. About every four years we have to get a new Farm Bill in Washington, and this is the year. The '77 Bill expired on September 30th and the congress has yet to pass the Farm Bill of 1981. The House has passed a bill, the Senate has passed a bill, and they're quite a bit different. They will be going to conference about that tomorrow and it will probably be well into next week before their work is completed. We are hoping that a bill will come out that the Administration will find acceptable. At this point, we are optimistic.

I will leave some time for questions. I don't know to what extent you people have interest in the specifics of the Farm Bill, but I will be happy to try to answer any questions you might have. We have been working on the Farm Bill since February and, I can tell you, we will be delighted to have it behind us. There are a number of goals that we have set out at the Department on which we have not been able to move as quickly as we would like, although we have been progressing on a number of fronts. We have worked at reducing spending and getting into key places the people that understand agriculture and the food systems of this country. We recognize that everything cannot be just totally producer-oriented. As a matter of fact, we have an obligation to consumers which we are not ignoring at all. We tried to get some people that understand the full system. We have begun a very active program of deregulation. It takes longer than we would have liked, but we are moving in the right direction and intend to continue.

In our reduction of spending, we would also improve productivity; not only productivity at the Department, but productivity throughout agriculture and agribusiness. If we are going to maintain our productivity, we must continue to invest money in research and development and education, and invest effort (less money but plenty of effort) in foreign market development.

The President is committed to and Secretary block and the rest of us firmly believe in a market-oriented farm program. Our Farm Bill proposals reflected that, and a Farm Bill that moves in the opposite direction from that will be unacceptable. Parts of the House version are unacceptable because they do move back in the direction of more government domination and less market orientation. The Senate Bill actually continues the movement that we have had since the '60's toward more market-oriented agriculture. That's important because it's absolutely essential for the nation and for the nation's farmers that we continue to expand our agriculture exports.

When I came to the Department, actually in 1969 the first time — our exports sales were less than $5 billion. This year, they will be $45 billion. The growth is far more that the infaltion would account for. It's a substantial difference, and we need to continue that growth. We need to expand exports in a number of directions. Toward that end, in spite of all these other activities during the first nine months, Secretary Block has made a trip to Europe and visited, I think, nine different countries there, meeting with the ministers of agriculture in that part of the world. I made a trip in May and June to China, Japan and Korea. Twenty-five percent of our export business is in those three countries. Then, Secretary Block headed a team that went to those same countries about two weeks ago. Seeley Lodwick, the Under Secretary for International Affairs and Commodity Programs, has just returned from a trip around the world. Later this week, the Secretary will be going, assuming that the foreign conference goes well, to Rome and giving a talk to the Food and Agricultural Organization and will be meeting there, again, with some of the European ministers. Europe is our number one customer. It's a problem area in many ways. We have been on a collision course with the European community for some time because of their Common Agricultural Policy which encourages their producers through high prices to produce a surplus, then increasingly adopting what seemed to be a permanent policy of dumping those surpluses on the world market. This not only blocks our sales of many commodities in the European community, but also interferes with the market to our other regular customers. We are hopeful that we are beginning to see some signs, perhaps, that the situation is changing, but we are going to keep pushing because otherwise, it's going to be such a problem for U.S. farmers and U.S. exporters that we will have to take some rather strong steps which we would much prefer not to do.

A few words about the state of agriculture: I don't need to tell you people we have had huge crops this year — the best corn crop ever, the best wheat crop ever, the best rice crop ever, big soybean crop, big cotton crop and, as a result, we have had low prices. Prices of most of these items have gone down most of the summer — some of them very sharply. This, coming at a time when interest rates are high and the economy is off, presents real problems for producing farmers. We believe that while having a big crop is a real blessing for the nation and the world, it's not very good sometimes for the farmers themselves and it certainly isn't much of a blessing for the Secretary of Agriculture.

The acceptance of Reaganomics by producing farmers is amazing to us. I think that most farmers are willing to go through a very difficult period. It's amazing. I spent last week in California. Secretary Block was in Kansas with Senator Dole. I talked to each of them separately. They both said that they were astonished at the friendly reception they received, considering the wheat problem — not that there wasn't some grumbling. There's a better acceptance because farm people understand that the major problems we're having are inflation and high interest rates. They recognize that interest rates cannot be low in a period of double digit inflation. We have seen the rate of inflation drop, and now we are beginning to see interest rates come down. One of the problems, of course, is the amount of Federal borrowing. Nearly 46% of the credit in the United States in 1981, the money that will be invested in credit instruments, will go to either U.S. government securities or to government guaranteed investments. So that leaves just a little over half for all the rest of the activities of the United States. That is up from 33% just three years ago.

The Federal budget this year is just over $700 billion. That's almost double the amount of five years ago. We are trying very hard to get that into balance. It's not easy. You can pick up any newspaper in this area (the Washington Post, the New York Times — any except the Wall Street Journal, and even that one sometimes) and find criticism of some budget cut that we are trying to put through. At the USDA, we are going to continue these very deep cuts. We will have big cuts in the 1983 budget which will be submitted to the Congress by the President in January, and even deeper cuts in 1984.

It's our goal to have a small department in a small government. Now, that's quite a change, but we think we can do this without harming agriculture. We think we can do it and help agriculture and the economy of the country. Our priorities will be in research and development, extension information, education, and market development. We have done quite a bit in terms of user fees. We are going to have a vigorous effort to get dairy support outlays under control. This is a major cost program.

I am optimistic about this administration. I served with Ronald Reagan when he was Governor of California. I was with him two years there before I came back here with President Nixon. I have been in Washington, in one job or another, since then. I campaigned for Ronald Reagan because I felt that he would be a good President, based on my service with him as Governor. In the job that I now have, I am fortunate that on occasion when Secretary Block is away, I have been able to watch Ronald Reagan and his top staff in operation. I must say that, in spite of all my optimism about what kind of President he would be, he's better than I thought he would be. I think he's just a super President. I think that the White House is well-managed and well-run. That's not to say they don't make mistakes, but I tell you — it's in good hands.

The economy presents a difficult problem and there's some impatience. We have been in office nine months. Most of you are in businesses. You have had some experience with businesses that were not in very good shape. You know how hard it is to turn them around. The Federal Government of the United States is gigantic beyond anything we can understand. The Department of Agriculture, with 118,000 employees and a budget of $25 or $26 billion, is hard to get your arms around, I'll tell you. It's going to take a little time to get this job done. I think we are going to do it.

I am optimistic for agriculture. If we can maintain the kind of economic society that most of you want, I think that we'll see that the last two decades of the 20th century will be the best two decades by far for U.S. agriculture. If you compare our agricultural productivity with that around the world, and you consider the amount of Federal Government money that's going in to build this, you realize our agriculture is market-oriented. We put very little money into subsidies. Even those are being cut back very, very sharply. Our farmers are equipped to compete in markets throughout the world. We have all kinds of problems keeping doors open, opening additional doors and all of that, but it can be, and will be done. This administration is going to posture themselves so that we will be able to do it with a great deal of vigor.

Again, it's a pleasure to be here. If you have questions, I will be happy to try to answer them. (Applause)

MODERATOR MEDBERY: Thank you Secretary Lyng for a most interesting and informative Talk. We are now ready for Questions you may have for Secretary Lyng. Please give your name, position and Company affiliation.

QUESTION FROM THE AUDIENCE: Do you think there will be "set asides" on feed and grains next spring?

DEPUTY SECRETARY LYNG: I would hope not, but with the size of the crop, it's a possibility. I think we may get some export sales and some increased domestic usage which would make that unnecessary. We would like to avoid set asides. We have announced our intention to have one on wheat, but we can't move any further on that until the Farm Bill is passed.

QUESTION FROM JOHN C. KRONSEDER, FLUOR CORPORATION: Would you like to comment on the sales of grain to Russia? We had a comment here this morning about 20 million tons. I think there's been all kinds of questions in the press about this.

DEPUTY SECRETARY LYNG: I think everyone knows that the Soviets had a dreadful crop. They had very bad luck for the third consecutive year. They had no reserves and they imported about as much as they could last year during the period when sales were limited by the embargo to about 8 million tons of grain. After we lifted the embargo they bought an additional 1.5 million tons beyond the 8 million tons they had already taken which was provided under the Long Term Agreement. About a month ago, we had a delegation in Moscow which indicated to the Soviets that they could buy as much as an additional 15 million tons which would make a total of 23. The factors that will determine what they will buy will be, first of all, their capacity to handle it. They will probably import at maximum capacity. They will buy as much from the Argentine crop as they can, I think. They will use us as a source of last resort because they aren't really happy about the embargo that we had, but they need our grain badly. They have been buying more wheat than we had anticipated and not quite as much corn. They bought, incidentally, a half million tons of soybeans which is the first they have purchased since the embargo in January 1980.

QUESTION FROM THE AUDIENCE: Relating to the Outlook for Credit.

DEPUTY SECRETARY LYNG: I had mentioned the difficulty with credit and you have asked me for comments in more detail about the outlook for credit. I presume you are referring to credit for farmers and for agriculture. I am no expert in the overall credit business. However, farm credit will be cut as a part of the budget reduction plan. The Department of Agriculture will be reducing our farm capital loans far more than we will our farm operating loans. We will try increasingly to make that credit apply to what would be called "non-credit worthy" loans. In the past, too much has been going to people who could use private credit sources. We are vigorously collecting on outstanding loans, and I have been surprised at our success. We reduced the outstanding overdue loans from $2.5 billion to $1.5 billion just in recent months, collectigng a billion dollars. Part of that money will be available for loans. I would guess that we will have a credit crounch in the sense of there not being sufficient funds. I think the problem will continue to be the cost of it. People will be able to get loans, but it's going to cost them more than they would like to pay.

QUESTION FROM ALAN D. ANDREWS, CF INDUSTRIES, INC: What's the administration's position on agricultural embargoes as a political tool?

DEPUTY SECRETARY LYNG: The President made it very clear over and over again that he believes that agricultural embargoes, selective embargoes, should not be used. I think it's been abundantly clear that this one didn't even work. Our exports continued very good; the Soviets were able to import what they wanted. But it hurt our farm people dreadfully. If you look at the amount of grain that moved through The Netherlands in 1980-1981, you'll see a phenomenal increase in the amount of grain that was sold. Their usage could hardly have been that great, so it was an indication of the kinds of substitutions that take place. If international conditions were such that we would want to consider an embargo, the President has indicated it would have to be across the board. Further, in January 1980, our allies were not fully made aware of what we were intending to do. While some of them did support us, some did not. If we were required to impose an embargo again, it would be total and across the board. It would be done with the cooperation and full participation of our allies around the world. The purpose in reserving that possibility is that you can never say that no matter what adventurism someone like the Soviets might undertake you wouldn't cut them off. I tell people that the matter is in the hands of the Soviets. If an action on their part required it, there would be a total embargo, not just an embargo on agricultural products.

This has been a pleasure. Thank you very much. I hope you have a pleasant meeting. (Standing ovation, lots of Applause).

MODERATOR MEDBERY: We are now ready to continue our morning program. The Nitrogen Paper was given earlier this morning. Each Speaker, covering their discussions on Nitrogen, Phosphate, Potash and Sulphur, brought a supply of copies covering their respective papers. Those of you wishing copies can come to the platform here immediately at the conclusion of our meeting this morning. We will hold all questions until our discussions are completed.

Our next speaker is Eugene B. Graves, Vice President - Planning and Economics for the Agrico Chemical Company, a subsidiary of The Williams Companies. Gene joined Agrico in 1971 after having worked for 11 years with one of the major petroleum companies. He rose rapidly through many positions in the economics branch, and in 1974, he was elected vice president of information systems. He was elected to his present position in 1975.

Gene is a native of Kansas, obtained his bachelor's degree from Friends University in Wichita, and then acquired a master's degree in business administration from the University of Chicago.

He and his wife, Barbara, and two daughters reside in Tulsa.

May I present, Gene Graves. He will report on "The Phosphate Outlook". (Applause)

Phosphate Outlook

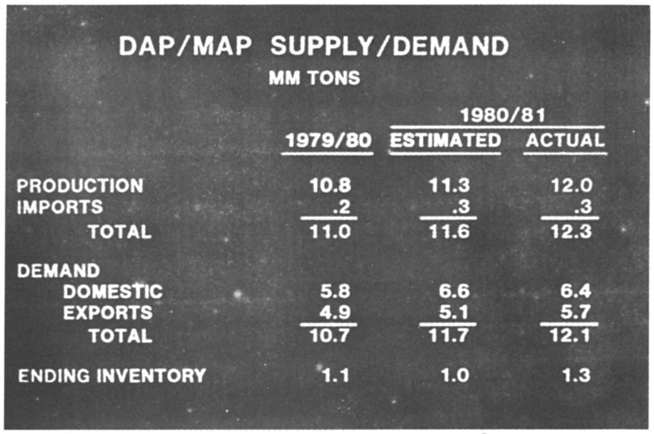
E. B. Graves

The phosphate industry has been undergoing significant changes over the past two decades. The types of product we make, and the way it is finally used by the farmer have all changed. Years ago normal superphosphate was the primary source of P_2O_5; today wet process acid is the principal raw material used in the production of phosphate fertilizers.

World trade has also changed. Up until the 1970's we, as a nation, supplied phosphate rock to other more developed areas, such as Western Europe and Japan who upgraded the phosphates for use in those areas as well as for trade around the world. They say that necessity is the mother of invention and, in the case of phosphates, this was certainly true. As we began building larger and larger phosphoric units in order to minimize the cost per ton of material, it became pretty obvious that we would also produce product for the export market as cheaply as anyone and, in fact, we began exporting our excess materials. At first this was simply the surplus but, as you will see later in my presentation, it has become big business and now represents nearly half of our total production.

In order to better understand the phosphate situation, I intend to cover in some detail the current status using DAP as a focal point for this discussion and then follow up with our outlook.

This slide summarizes what the industry had typically estimated versus what actually happened during the 1980-81 fertilizer year focusing in on the DAP/MAP Supply/Demand. For the most part, this represents what has happened to the total phosphate industry since DAP/MAP utilizes a lion's share of the wet process acid produced by the U.S. industry.



DAP/MAP SUPPLY/DEMAND
MM TONS

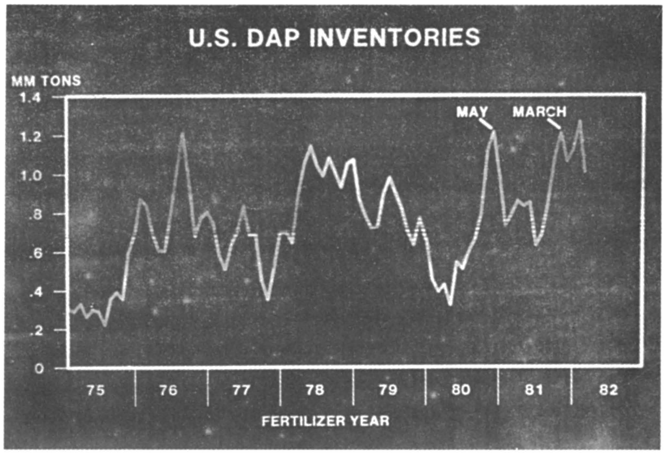
	1979/80	1980/81 ESTIMATED	1980/81 ACTUAL
PRODUCTION	10.8	11.3	12.0
IMPORTS	.2	.3	.3
TOTAL	11.0	11.6	12.3
DEMAND			
DOMESTIC	5.8	6.6	6.4
EXPORTS	4.9	5.1	5.7
TOTAL	10.7	11.7	12.1
ENDING INVENTORY	1.1	1.0	1.3

DAP/MAP Supply/Demand -
Estimated vs. Actual

Looking first at what was anticipated for the 1980-81 fertilizer year, the industry was looking at a 500,000 ton increase in production due in part to better operating rates. This would be used to meet an anticipated increase of 800,000 tons in the domestic market and a 200,000 ton increase in exports. Overall, this would have dropped ending inventory 100,000 tons. Neverless, this still left a relatively high ending inventory, much higher than what the industry would like to see.

Turning now to the actual situation, the industry produced 12 million tons, about 700,000 tons more than what had been anticipated. The increase in production was caused by incremental debottlenecking by various members of the industry, the re-activation of the DAP train by Oxy and some modifications by other members of the industry, such as Mobil's change at Pasadena, Texas. This is the facility they acquired from Olin earlier last year. As far as the demand is concerned, domestic demand was only 200,000 tons less than what we estimated and exports were much, much higher. Nevertheless, the ending inventory reached 1.3 million tons.

Let us now take a look at monthly inventories focusing in only on DAP. Incidentally, I should point out that DAP inventories account for only about 100,000 tons whereas MAP is by far the larger product.



U.S. DAP Inventories

This slide shows the DAP inventories on a monthly basis beginning in 1975. The key here is that they hit a maximum inventory level of about 1.2 million tons of DAP in the spring of 1976 and again in May of 1980. In 1981, industry inventories peaked in March and again in May.

The big difference between what happened this year versus last year is that last year, India came into the market with a demand for about 800,000 tons and, as you can see, inventory levels were substantially reduced from that May peak. In fact, inventories of DAP as of December 31, 1980, were just over 600,000 tons.

This spring, however, our exports slowed due in part to the higher value of the dollar. Coupled with that was a delay in take by the domestic market due to drought conditions which prevailed throughout a good part of the winter months. As a result, inventories this year peaked in March, 60 days earlier than they had in the prior year, and were not quickly drawn down as is usually the case. At that point, we began to have price pressures on our phosphate products.

Quite frankly, the industry was still attempting to run at 100% operating rate this spring even though demand did not call for product supply at that level. Had the industry reduced overall operating rates to a level of 95% this past spring, there would have been a substantial reduction in price pressures. The question is, why this did not occur.

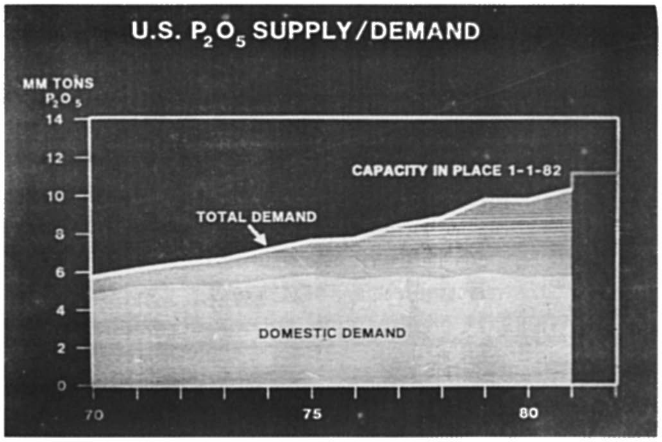
The fundamental reason why it is very difficult for an industry to curtail hinges on marginal costs. In the phosphate market, relatively small changes in demand, such as we have seen this year, can cause large decreases in prices. However, even when prices are below full costs, the real issue in considering curtailments is the relation of prices to *marginal* costs. In this case, it took a substantial decrease in prices before the marginal cost level was reached and curtailments began.

As I indicated a minute ago, the industry produced 12 million tons of DAP and MAP in 1980-81 fertilizer year. The fact is that the industry probably could not have produced much more than about 12.5 million tons; and thus, the price level that we experienced earlier this year caused no more than 1/2 million tons of curtailment from the maximum ability to produce.

Currently, the export demand has not rebounded to the same level which we experienced last fall. As a result, the industry is still in a curtailed mode. The question is, how long can we expect to be in the current situaltion and what is the near-term outlook?

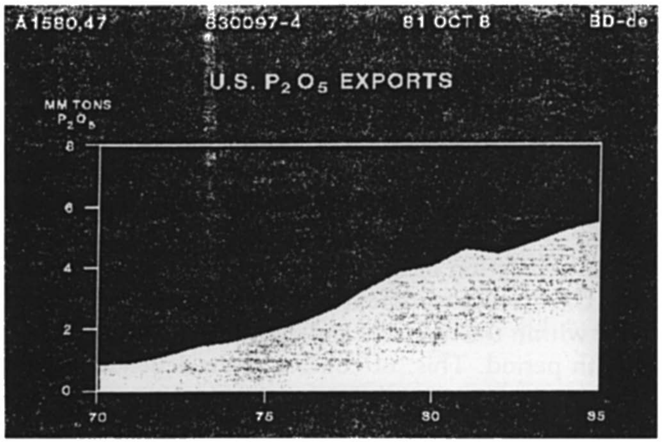
U.S. P_2O_5 Supply/Demand — 1970-81

This slide summarizes the U.S. P_2O_5 Supply/Demand since 1970 and shows what has happened. Basically, domestic demand has been relatively flat with all of the increase having come from the export market.



Further compounding the situation is the fact that new capacity will be in place as of the end of this year. IMC will be completing their 500,000 ton expansion and TG will do likewise. The W. R. Grace/USSAC joint venture will be coming on stream during the latter part of 1982.

There are a number of other increases, some of which are fairly slight. In total, we are looking at about a 1.5 million ton increase over the next 24-month period.

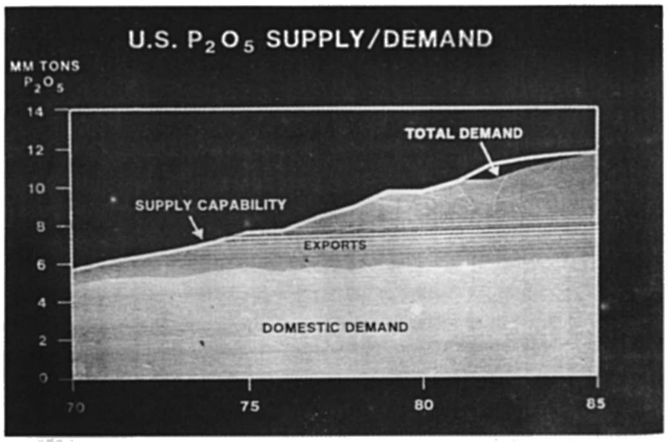


Exports 1970-1985

The dramatic effect of the increase in exports is shown on this slide. In 1970, we exported about 800,000 tons of P_2O_5; in 1981 this was 4.6 million tons, an increase of more than 5 times that of 1970. By 1985, we anticipate exports at about 5.5 and perhaps even 6 million tons.

This increase in exports is primarily the result of an increasing awareness by lesser developed countries of the need for a balanced nutrient program. As a result, many countries who have had access to relatively low-cost nitrogen are now finding that they need a comparable amount of phosphate in order to grow the crops which they need to feed their people. Another factor in this is the fact that the common size plant of today more than satisfied the demands of many of the countries around the world. As a result, it is to their advantage to buy smaller quantities of P_2O_5 from those that have surplus available, such as U.S. producers, as opposed to spending upwards from $300 million to build their own plant.

There is, however, a change in the customer mix and the product being used. As an example, where Brazil used to take large quantities of DAP and MAP and other finished materials, they, in recent years, have increased their use of phos acid and, in all probability, will eventually be able to satisfy most of their own demands. It is also to the country's advantage if they have at least one of the primary raw materials to attempt to build their own plant. As an example, if they have either sulfur or phyrites, then, from a balance of payments standpoint, it will be to their advantage to have their own production.



U.S. P_2O_5 Supply/Demand — 1970-1985

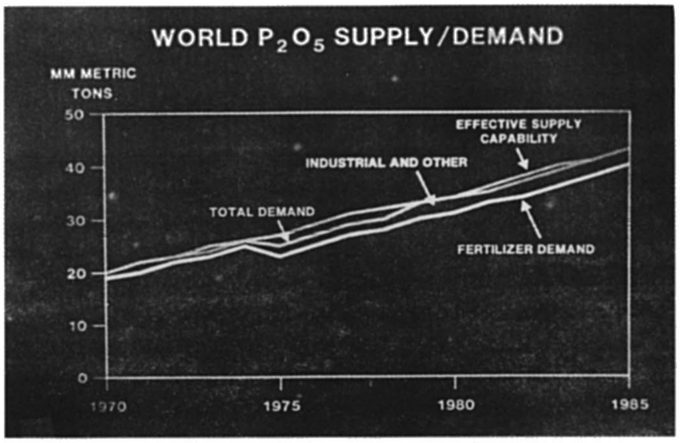
Our perception of the longer-term supply/demand for the U.S. indicates that it should be pretty much in balance within the next 24- and certainly no more than 36-month period. This, of course, again depends upon the export market since that is where the basic growth is. This means that the industry will have to run at about a 92% operating rate in 1981-82 and gradually increase the operating rate back up to an estimated 100% by 1984-85.

Several years ago, our estimate for a maximum sustainable operating rate was 92%, and you may recall that back in the middle 1970's the industry was experiencing operating rates near the 70% level. Today, the industry is facing a need to operate at approximately 90-92% and some feel that this is a disaster. This should not be the case; in fact, in some cases, we believe that companies have perhaps found that they actually did not change their unit cost of production by going to a lower rate.

Even if a unit were running at maximum efficiency at a 100% operating rate, the cost increase for reducing the operating rate to 90% would be no more than $4-6 per ton of DAP.

Curtailments have already occurred for the 1981-82 fertilizer year; in fact, for the July-September quarter the production of phosphoric acid was down by more than 400,000 tons, 17% below that of last year. DAP production was down 675,000 tons, 23%below that of last year. Thus, we believe that the industry will correct the current inbalance situation by running at a lower rate. Nevertheless, we must recognize that maximum operating rates are not likely for at least two years unless we have a rapid and substantial rebound in the export market.

Compounding this situation may be the fact that Russia still is not taking the total contracted quantities which would effectively remove 700,000 tons of P_2O_5 from the domestic market. This is a key factor, at least for the short-term outlook.



World P_2O_5 Supply / Demand

Turning now to the worldwide picture, we see a somewhat similar situation in that there is apparently a very slight surplus between total demand and effective supply capability. This surplus, if it can in fact be called that, is very slight and obviously any small change in demand or reduction in operating rate in some areas of the world could change that practically over night.

New capacity obviously will be built to meet demands of the middle 1980's and our view is that for the most part we expect a fairly balanced position between supply and demand. Thank you. (Applause)

MODERATOR MEDBERY: Thank you, Gene, for your very imformative paper covering The Phosphate Outlook.

MODERATOR MEDBERY: The next speaker will address us on the outlook for potash. He is D. E. (Doug) Logsdail, President and Chief Executive Officer of Sales for the Potash Corporation of Saskatchewan.

Mr. Logsdail holds a bachelor of science degree from McGill University, earned in 1953, and a M.S.A. degree from the University of Toronto, earned in 1957.

He held many positions including the following:

1953-1959 Assistant Professor, Department of

Soil Science, Ontario Agricultural College, University of Toronto.

1960-1965—Head of Department of Soils and Chemistry, College of Agriculture Technology, Kemptville, Ontario.

1965-1967—Executive Director, The Fertilizer Institute of Ontario.

1967-1973—Manager of Technical Services with Cyanamid Of Canada, Ltd.

From 1973 and into 1979, he held a number of important positions with Hudson Bay Mining and Smelting Co., Inc. and in 1979, he joined PCS as Sales Manager of National Accounts.

In 1981, he became Director of Sales and is currently President and Chief Executive Officer of PCS Sales.

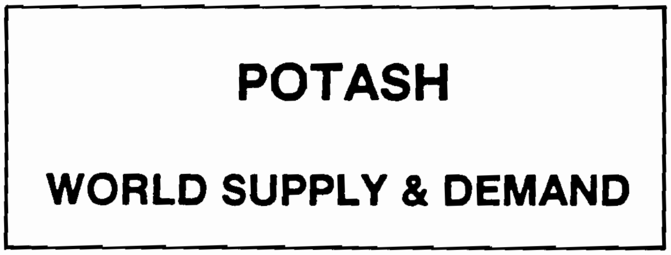
Mr. Logsdail is a member of the Potash and Phosphate Institute Board and the Canadian Fertilizer Institute Board.

I am most happy to present Mr. Doug Logsdail. (Applause)

Potash — World Supply and Demand

Douglas E. Logsdail

I am pleased to be here with you today as a representative of the Potash Corporation of Saskatchewan Sales Limited, and to share with you some of our views on what we see happening in the Potash industry in the 1980's.



POTASH

WORLD SUPPLY & DEMAND

Slide #1

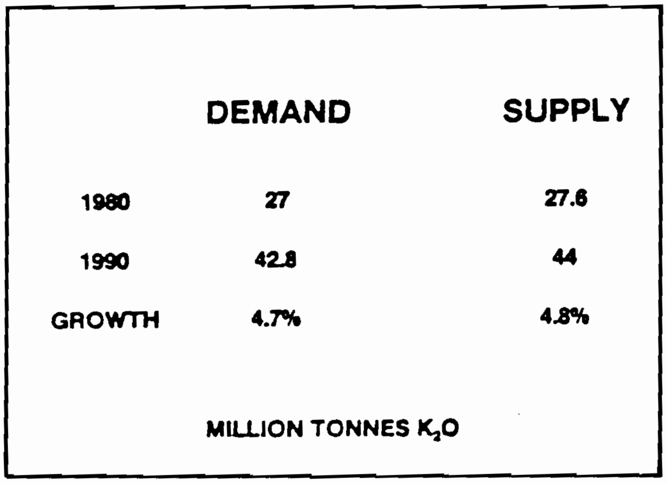
In preparaing this presentation we looked at announced production expansions throughout the world. We made our projections of North American supply based on the assumption that all announced expansions proceed as scheduled. The Soviet Union, the world's largest producer, has announced a number of projects as well. We are presently aware of two major mine expansions underway in the Soviet Union. The real question becomes one of estimating the rate at which Soviet production will come on stream and the amount of that production that will be available for export.

Potash demand is ultimately determined by the demand for the crops which it helps produce.

Our estimates of world potash demand are based on an appreciation of the need for the developing world to increase food self-sufficiency, and the recognition that the grain trade between the developing and centrally planned economies, and the major grain producing countries of the western world will continue to increase in magnitude over the 1980's. As population increases, combined with greater world affluence, we foresee a continuing widening of the spread between the demand for grain in the developing and centrally planned countries and their ability to produce these grains. The result of this rising demand will be increased efforts to achieve higher yields in all producing areas of the world.

After gathering all available information on expected production increases and likely demand in the various world regions, we conducted a careful analysis, did a little crystal ball gazing and, for some of the questions we had a little difficulty coming to grips with, tried a technique called a 'blue sky' estimate.

Having said that, here is our forecast. I would like to point out that the figures I will be using are in metric tons K_2O.



	DEMAND	SUPPLY
1980	27	27.6
1990	42.8	44
GROWTH	4.7%	4.8%

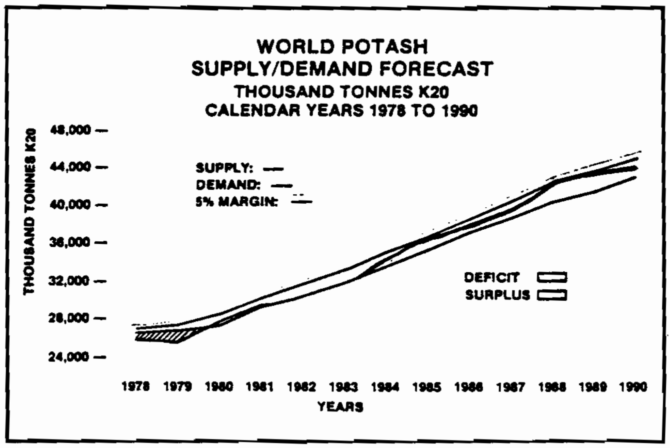
MILLION TONNES K_2O

Slide #2

We are forecasting world potash demand to reach 42.8 million tonnes K_2O by 1990. This is a 15.8 million tonne increase over the 1980 consumption of 27 million tonnes, and represents a compound annual growth rate of 4.7 percent. We forecast world production at 44 million tonnes K_2O by 1990. This is a 16.4 million tonne increase over the 1980 production of 27.6 million tonnes, and represents a compound annual growth rate of 4.8 percent.

This next Slide No. 3 compares PCS Sales' world potash supply and demand forecasts for the calendar years 1978 to 1990. In the early 1970's, world potash demand exceeded world supply.

The Mid-1970 softening in world grain markets suddenly reduced world potash demand and resulted in a surplus of supply. By the end of the 1970's demand had recovered along with the grain markets and we again experienced a deficit, as shown in the light green cross-hatched area at the lower left of this graph. This situation has resulted in new investments in production

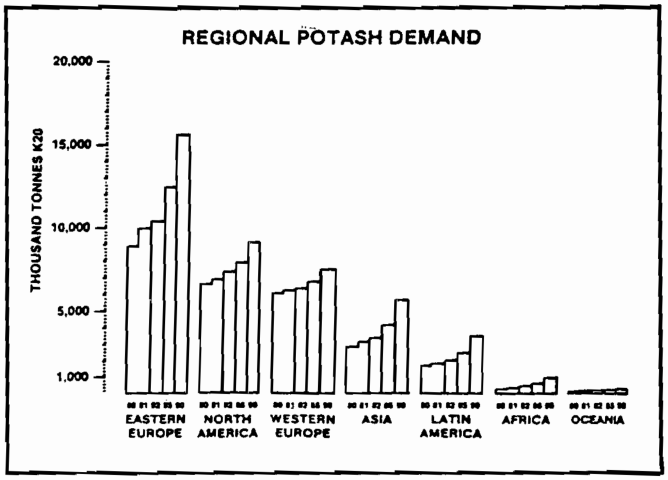


Slide #3

facilities in the 1980's. The graph shows a slight supply surplus in 1980-81, which will probably remain to the spring of 1982. From about 1983, we foresee a steady rise in supply relative to demand. The red line on the graph indicates a 5 percent margin surplus to forecast demand. We forecast that supply will briefly approach the 5 percent margin in 1985 and again in 1988-89, as scheduled expansions come on stream. This forecast surplus is partly held in inventory, and partly held in additional capacity to produce by operating mines at higher than normal levels of production.

As our forecast reflects the successful completion of all announced and probable expansions as scheduled, and assumes operation of all facilities at close to maximum capacity, it can be considered an optimistic supply side forecast. It can be seen from the graph that as forecast supply levels off by the end of the decade, and projected demand continues to increase into the 1990's, a new round of production capacity expansions could again be needed.

In this next Slide No. 4 we see a regional breakdown of the world potash demand picture. The first two bars, shown in dark green, represent actual demand in 1980 and 1981. The next three bars, shown in light green, represent our forecast for the years 1982, 1985, and 1990.

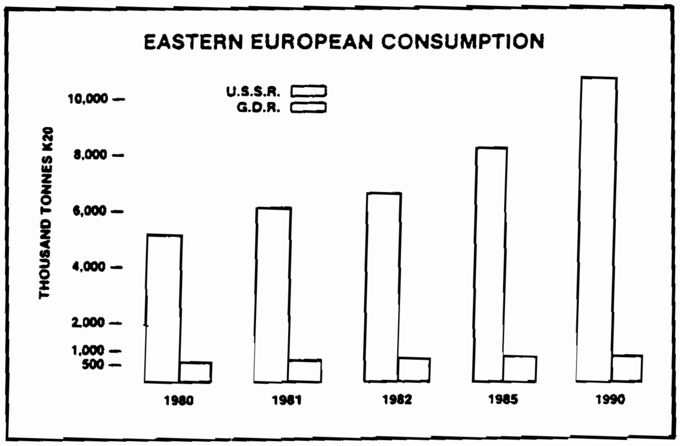


Slide #4

Potash demand in Eastern Europe is forecast to grow at a compound annual rate of 5.8 percent, reaching 15.7 million tonnes K_2O by 1990, up from 8.9 million tonnes in 1980. A more modest growth is forecast for the developed nations of North America and Western Europe. North American potash demand is forecast to grow at a yearly rate of 3.2 percent, reaching 9.2 million tonnes by 1990, up from 6.7 million tonnes in 1980. Western Europe, the most mature fertilizer region in the world, is projected to increase potash demand at a rate of 2.1 percent per year, reaching 7.5 million tonnes by 1980, up from 6.1 million tonnes in 1980. In total, the developed nations of the western world will account for 31 percent of world potash demand in 1990, down from 47 percent in 1980. This decline reflects the growing demand in the Third World.

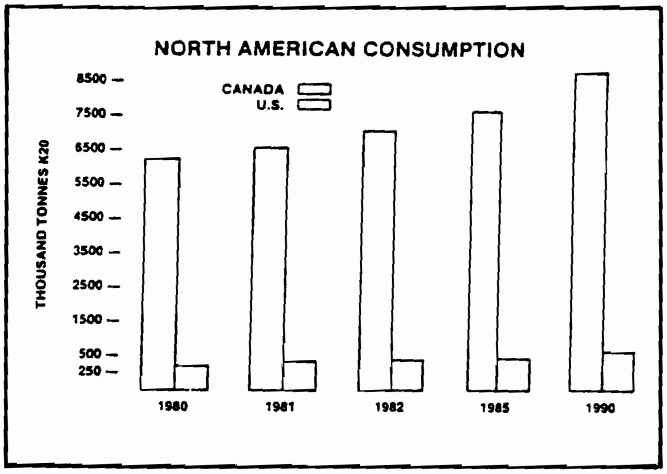
The developing nations of Asia, Latin America and Africa are each forecast to experience close to a 100 percent increase in total demand by 1990. Such an increase represents a compound annual growth between 7 and 8 percent for each region, over the decade. In total, these three developing regions of the world will account for 24 percent of world potash demand by 1990, up from 19 percent in 1980. Oceania is expected to post a modest growth of 2.9 percent per year, rising to 400 thousand tonnes by 1990, up from their 1980 demand of 300 thousand tonnes.

Looking at the demand forecast for the major countries in each region, we see in this next Slide No. 5 that Soviet demand, shown in dark green, is expected to increase along with their supply capability and is projected to double the 1980 consumption of 5.2 million tonnes K_2O reaching 10.8 million tonnes by 1990. This reflects a compound annual growth of 7.7 percent for the decade. East Germany, a more mature fertilizer region, is expected to increase potash demand the 631 thousand tonnes by 1990, up from 526 thousand tonnes in 1980. Consistent with its mature status, this represents a modest growth rate of 1.8 percent per year. The remaining countries in Eastern Europe will increase their aggregate consumption reaching 4.2 million tonnes by 1990, up from 3.2 million tonnes in 1980, a growth rate of 2.8 percent per year.



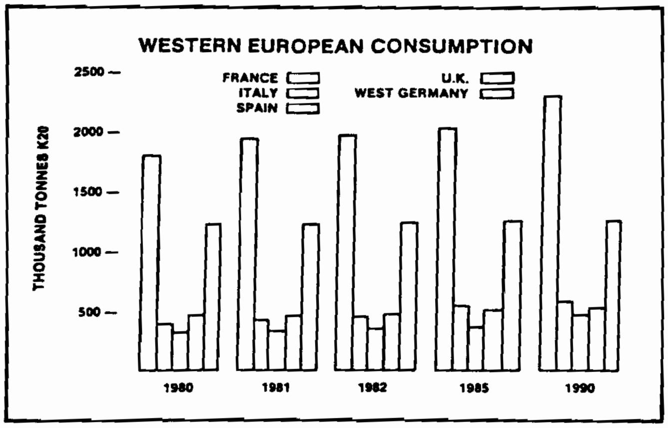
Slide #5

Turning to North America, we see that U.S. potash demand is forecast to reach 8.6 million tonnes K_2O by 1990, up from almost 6.3 million tonnes in 1980, a growth rate of 3.2 percent per year for the decade. Canadian potash demand will be growing at a higher rate of 4.4 percent, reaching 615 thousand tonnes by 1990, up from 400 thousand tonnes in 1980. (Slide No. 6)



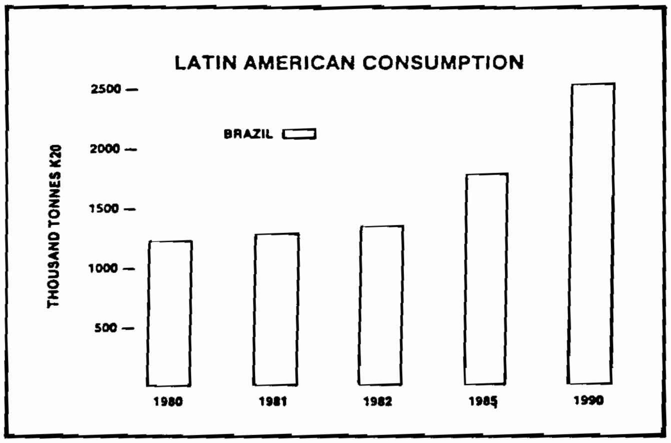
Slide #6

In Western Europe, Slide No. 7, we see that France, shown in dark green, is the largest potash consumer, followed by West Germany, shown in light green. Between them, France and West Germany accounted for 52 percent of total West European potash demand in 1980. France is projected to increase its demand by 2 percent per year over the 1980's, reaching 2.3 million tonnes K_2O by 1990, up from 1.9 million tonnes in 1980. West Germany, a very mature fertilizer market, is forecast to maintain an almost flat yearly demand between 1.2 and 1.3 million tonnes through the decade. By 1990, the combined French and West German share of total demand will decline to 48 percent, as other less mature markets continue to grow at higher rates.



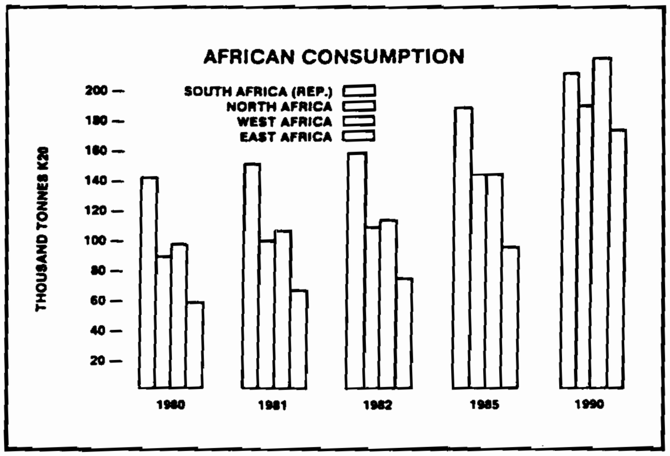
Slide #7

Brazil, shown her, Slide No. 8, is the largest potash consuming country in Latin America and will retain this position for the foreseeable future. Brazilian demand of 1.25 million tonnes K_2O in 1980, represented 70 percent of total Latin American potash demand. By 1990, we forecast Brazilian potash demand will double this 1980 level, reaching 2.5 million tonnes. This represents a compound annual growth of 7.3 percent.



Slide #8

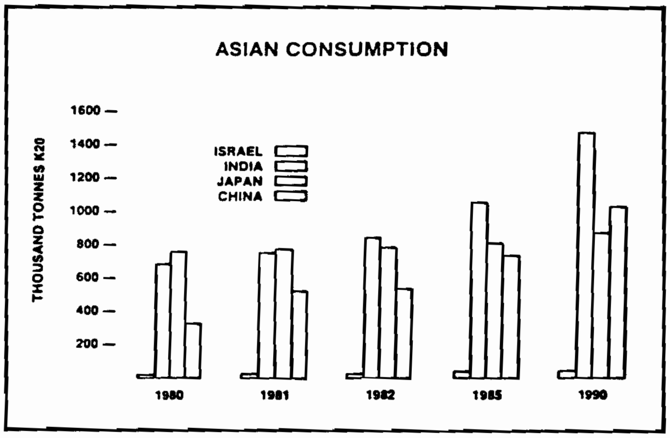
Moving along to Africa, Slide No. 9, where the Republic of South Africa is, and will remain, the largest consuming country, we are projecting South Africa to reach 210 thousand tonnes by 1990. The other countries have been aggregated into regions: North Africa, East Africa, and West Africa. We believe that these regions will all approach similar levels of potash demand by 1990. We forecast demand in North Africa at 189 thousand tonnes by 1990, East Africa at 173 thousand tonnes, and West Africa at 221 thousand tonnes. While total African potash demand will only account for about 2 percent of World demand by 1990, it will provide a growing market for Israel, Jordan, West Germany, and the USSR.



Slide #9

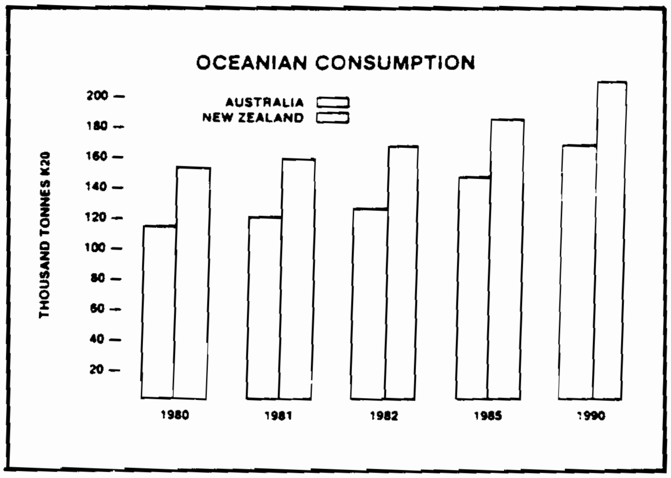
In Asia, Slide No. 10, we forecast that India will overtake Japan as Asia's largest potash consumer, reaching 1.5 million tonnes K_2O by 1990, slightly more than double the 683 thousand tonnes in 1980. This forcast assumes a continuation of aid programmes to India. China, too, is projected to overtake Japan, consuming

1.2 million tonnes by 1990, four times the 300 thousand tonne demand in 1980. While the ultimate demand for potash in China is very substantial, our forecast reflects our opinion on China's ability to pay and assumes a continued improvement in the development of china's infrastructure for transportation, handling and distribution. Japan, the most mature fertilizer market in Asia, is forecast to consume 841 thousand tonnes by 1990, up from 767 thousand tonnes in 1980.



Slide #10

Australia and New Zealand, Slide No. 11, are the two major potash consuming countries in Oceania. A continued slow increase in potash demand is forecast. due to the largely extensive versus intensive agriculture and relatively small agricultural land base. In total, Oceania will only account for two tenths of one percent (0.2•) of total world potash demand by 1990.



Slide #11

Turnging now to the other side of the world potash supply / demand picture, this next Slide No. 12 illustrates our projections for the five major potash producing regions in the world. Again, the dark green areas represent production for 1980 and 1981. The light green areas represent our forecast for the years 1982, 1985 and 1990.

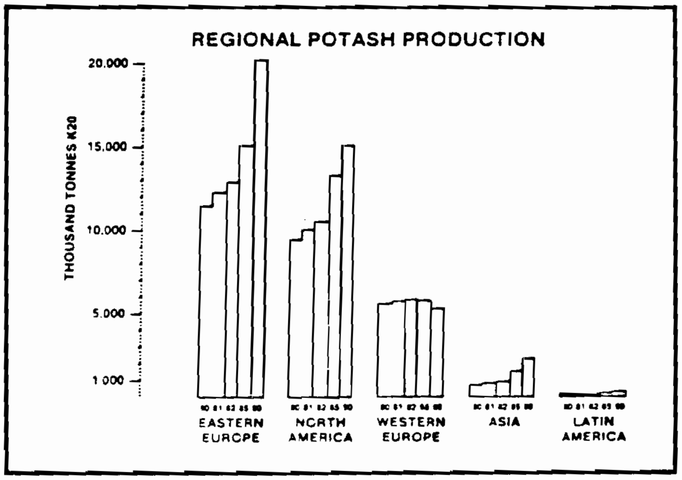
Eastern European potash production is forecast to reach 20.2 million tonnes K_2O by 1990, up from 11.5 million tonnes in 1980, a compound annual growth of 5.8 percent.

North American production will reach 15.9 million tonnes by 1990, up from 9.5 million tonnes in 1980, growing at a compound annual rate of 5.2 percent. Western Europe is the only region forecast to experience a decline in production. In absolute terms, we are expecting about a 300 thousand tonne decline in production over the decade. Western Europe's share of total world production will decline from 21 percent in 1980 to 12 percent by 1990. The decline is mainly due to the expected closing of French potash mines, long anticipated by the industry to start about mid-decade and continue into the 1990's.

Asia is expected to post a regionally significant increase in potash production in the 1980's. The majority of Asia's potash production is currently located in Israel but with Jordanian production due by mid-decade, and continued expansions in both Israel and Jordan throughout the latter part of the 1980's, total Asian production is forecast to reach 1.6 million tonnes K_2O by 1985, almost double the 1980 level of 800 thousand tonnes. By 1990, Asia production should triple this 1980 level, reaching 2.3 million tonnes. At this point, both Israel and Jordan will each be producing over one million tonnes K_2O annually.

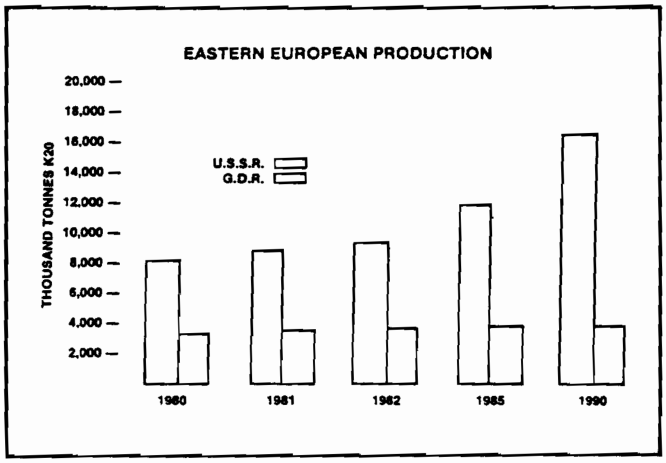
This growth represents a compound annual rate of 11.1 percent for the decade. Notwithstanding this very high growth rate, Asian production will represent only 5 percent of total world production by 1990.

Production increases in Latin America are not expected to exceed 300 thousand tonnes by 1990, and will not be a significant factor in total world production throughout the decade.



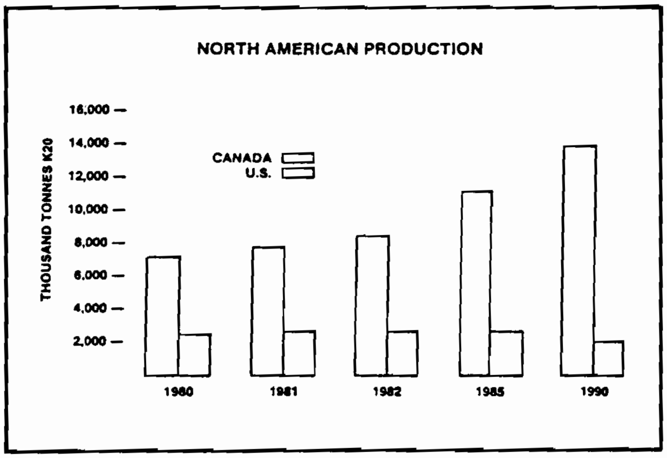
Slide #12

Looking at the production forecast for the major countries in each region, we see in this next Slide No. 13, that Soviet production is forecast to reach 16.6 million tonnes K_2O by 1990, slightly more than double their 1980 production of 8.1 million tonnes. This is a growth of 7 percent per year for the decade. East German production is rapidly approaching maximum capacity. East German is forecast to produce 3.6 million tonnes by 1985, up from 3.4 million tonnes in 1980, and to maintain this level for the rest of the decade.



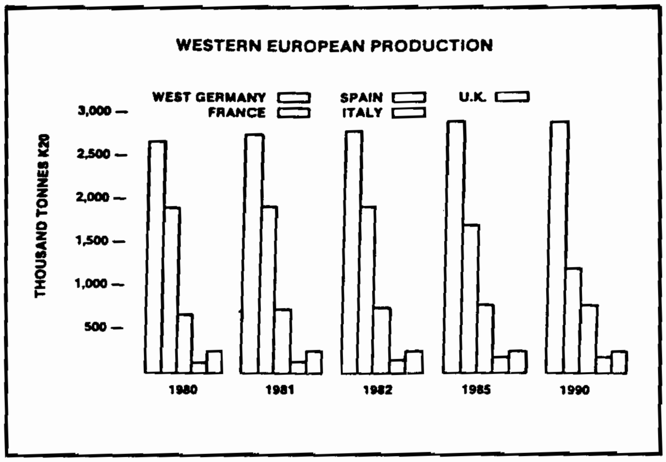
Slide #13

The next Slide No. 14, shows our North American production forecast, U.S. producers are expected to maintain their current production of about 2.2 million tonnes K_2O until mid-decade, after which production is expected to decline to around 2 million tonnes as economic reserves are depleted. Canada, on the other hand, is expected to produce 13.9 million tonnes by 1990, up from 7.3 million tonnes in 1980. This represents a compound annual growth of 6.7 percent.



Slide #14

Slide No. 15 — in Western Europe we forecast West German production increasing modestly to 2.9 million tonnes by 1985, up from 2.7 million tonnes in 1980, and maintaining this level to 1990. France will maintain production at the current level of about 1.9 million tonnes K_2O until mid-decade. French production will thereafter decline as uneconomic mines are phased out. We forecast that French production will fall to 1.7 million tonnes by 1985, and to 1.2 million tonnes by 1990. With the prospect of this decline in production leading to a growing shortfall relative to demand, the French industry has secured access to supplies from two new sources: Jordan and New Brunswick. The French have signed a 5-year contract with the Arab Potash Company of Jordan. In addition, France and West Germany will be marketing the entire output of the Denison-Potacan mine in New Brunswick. This mine is scheduled to be on stream in 1983-84.

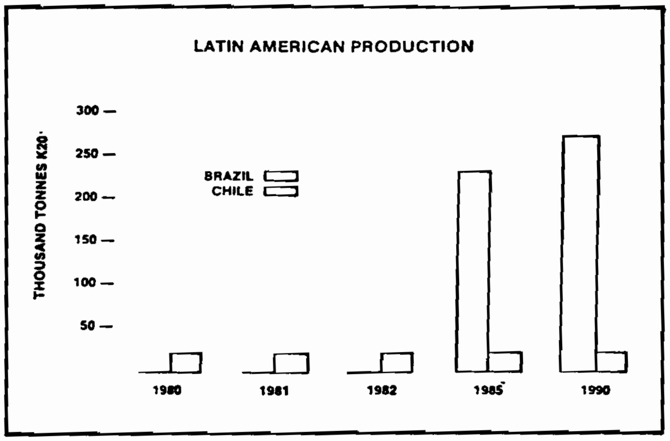


Slide #15

Spain and Italy are expected to show only modest growth in production.

The U.K., shown in red, has for the purpose of this forecast, been shown to maintain its current production of 240 thousand tonnes to the end of the decade. This does not represent the actual situation however, as sometime during the 1980's, probably fairly soon, U.K. producers will decide whether to increase their production or shut down the mine altogether. At this time the outcome of the decision is still uncertain.

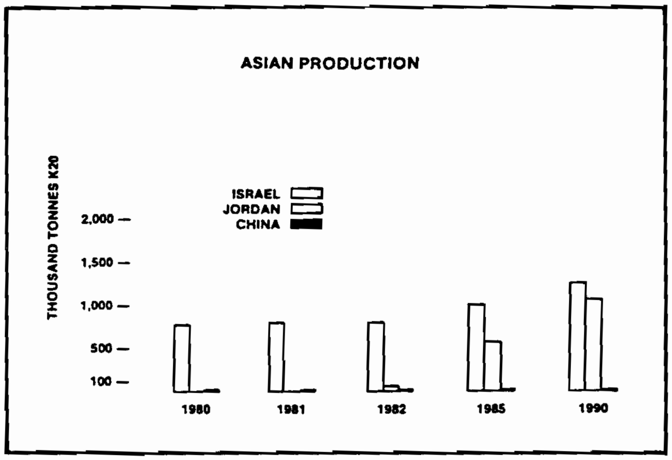
Slide No. 16 — in Latin America, we are expecting Chile to maintain its present production of 22 thousand tonnes throughout the decade. Brazil is scheduled to start producing potash domestically by 1985, at which time we are forecasting production at 230 thousand tonnes, rising to 270 thousand tonnes by 1990. Brazil will account for over 90 percent of Latin American potash production once their mine is on stream.



Slide #16

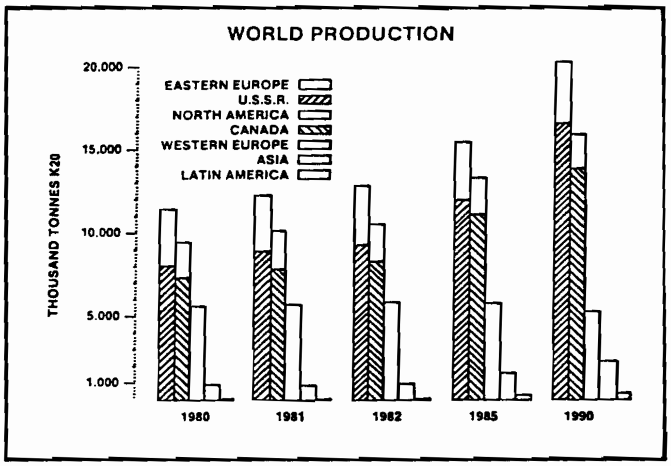
Slide No. 17 — turning to Asia, we forecast Israeli production at one million tonnes by 1985, rising to 1.26 million tonnes by 1990. Jordan is scheduled to come on stream in 1982 with 50 thousand tonnes, increasing to 575 thousand tonnes by 1985, and to just over one million tonnes by 1990.

China, a major potash consumer, is not expected to increase production beyond the current 20 thousand tonnes.



Slide #17

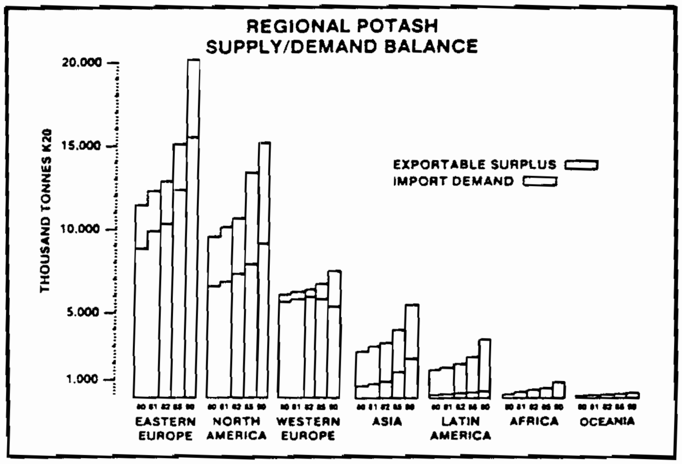
This next Slide No. 18, summarizes the production forecast by region from 1980 through 1990. Each region is represented by a different color. Eastern Europe, in dark green, and North America, in blue, will remain the world's largest producing regions. The importance of the USSR and Canadam are illustrated by the cross-hatched areas in these regions. It is apparent that the USSR and Canada will continue to dominate world potash production throughout the decade and beyond.



Slide #18

Slide No. 19 — combining our world regional potash supply and demand estimates in this next slide, we see that Eastern Europe, and North America will remain the world's net exporting regions as shown by the dark green areas on the graph. The relative size of these dark green areas indicates that North America will continue to be the world's largest exporting region. The Canadian potash industry is the second largest in the world, behind the Soviet Union, but Canada is the world's largest potash exporting country. The Potash Corporation of Saskatchewan, through its subsidiaries, is the largest Canadian potash producer and exporter.

All other regions will continue to be net importers over the 1980's. The relative magnitude of these markets is indicated by the size of the light green cross-hatched areas on the graph. It is apparent that Latin America and Asia will continue to be the largest potash importing regions in the world throughout the 1980's.



Slide #19

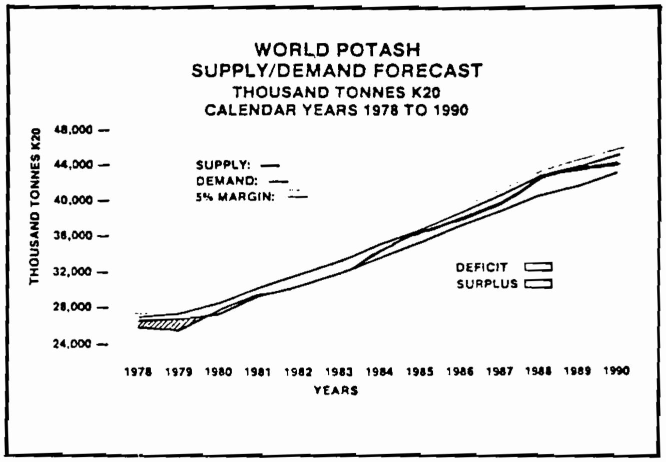
Slide No. 20 — this concludes my discussion of our supply / demand forecast. Here again is what we forsee. World potash supply will increase from 27.6 million tonnes K_2O in 1980 to 44 million tonnes by 1990, growing at a compound annual rate of 4.8 percent. World demand will grow to 42.8 million tonnes by 1990, up from 27 million tonnes in 1980. Annual growth in demand will be 4.7 percent.

	DEMAND	SUPPLY
1980	27	27.6
1990	42.8	44
GROWTH	4.7%	4.8%

MILLION TONNES K_2O

Slide #20

Slide 21 — graphically our forecast shows that potential supply will exceed demand from about 1983 onward. This supply surplus will be held in the form of inventory as well as surge capacity for production above normal operating rates.



Slide #21

Increased supply capability in the 1980's will serve to place stronger emphasis on marketing than has been the case for the last decade. The rising importance of the developing world as potash consumers will place increased emphasis on transportation and distribution in supplying these markets. Many of these countries do not enjoy the benefits of well developed internal transportation, handling, and distribution systems. Our Corporation intends to sell into these markets and we expect to become more directly involved in the development and maintenance of such systems to successfully meet the needs of the developing world.

MODERATOR MEDBERY: Thank you Doug for your most interesting discussion on the outlook for potash, World Supply and Demand, 1980-1990. (Applause)

Our next speaker is David Bixby of the Sulfur Institute, and as you probably have surmised, he will inform us on the outlook for sulfur.

Mr. Bixby is a graduate of Syracuse University. He is a chemical engineer. He has been with the Sulfur Institute since 1962 and serves as the Director of Fertilizer, Technology and Research.

Prior to joining the Sulfur Institute, Mr. Bixby had a number of important positions with the company now known as Agrico Chemical Company.

His background includes manufacturing, research and engineering in sulfur and phosphate processes and products.

He is the author of several technical papers and has served on many committees for industry and professional organizations.

May I now present David Bixby. (Applause)

Sulphur Status Report

D. W. Bixby

Fellow "knights" of the Fertilizer Round Table — for the last couple of years you have given me the privilege of saying a few words about sulphur. On those occasions, I thought about what I might say well in advance of our meeting. This time I didn't. I let it go until a couple of weeks ago, with the idea of making it an up-to-date as possible. My thinking was — maybe the Iraq/Iran war will have been settled, for a plus on the supply side; maybe Poland will have stabilized and been given a line of credit from the West to get a new mine going for another (eventual) plus on the supply side, maybe phosphates and the chemical industry generally will pick up with corresponding effects on the demand side, etc. I don't need to tell you that none of this happened and that the old axiom, "the more things change, the more they remain the same," wouldn't have been coined in the first place, if it didn't express a general truth.

We will talk about 1980 and 1981 at first, then have a look at what the future holds.

Let us look quickly at how the sulphur situation here at home is likely to compare with last year. (Slide 1) Estimated production figures for all of 1981 based upon data through July show a slight increase in Frasch material, and a slight decrease in brimstone from refinery operations, offset by a similar increase in sulphur from sour gas. This gives us a modest increase in brimstone. Smelter acid should be back to or above the 1979 level now that the strike is over. The expected total of approximately 11.8 million tons of sulphur in all forms in 3.1% over last year.

Slides No. 1 thru No. 12

all figures million metric tons

Slide 1. **U.S. PRODUCTION**

	1980	1981	%
Frasch	6.39	6.52	2.0
Petroleum	2.32	2.21	(4.9)
Natural Gas	1.73	1.86	7.5
	10.44	10.60	1.5
Smelter Acid	1.00	1.20	20.0
	11.44	11.80	3.1

On the supply side (slide 2), with estimated imports up more than exports are down, our available supply is seen to exceed that of 1980 by some .8 million tons.

Looking at apparent consumption, we anticipate a slight decrease. One thing this should do is free three or four hundred thousand tons for inventory increase and I am told some replenishing of stocks is indeed taking place. They had reached a level of less than 3 million tons or 3 months domestic supply, which is considered to be minimum.

So we seem to have, at the moment, some loosening up of sulphur supply within U.S. borders. I realize you would prefer it came from additional production. The fact that the sulphur supply may be less tight because of a slowdown in P_2O_5 or chemical output doesn't make me or you particularly ecstatic — it's like saying the flour supply is ample because no one is baking bread.

Slide 2 US—SUPPLY & CONSUMPTION

	1980	1981	%
US Supply	11.44	11.80	3.1
+ Imports (Br)	2.52	2.73	
+ Imports (Acid)	0.18	0.21	
	14.14	14.74	
— Exports (Br)	1.67	1.48	
	12.46	13.26	6.3
US Consumption	12.34	12.13	(1.7)

Today, everyone knows that the nations of the world and interdependent and this is certainly true for sulphur. Let us see what has happened since we last met in the other major sulphur producing areas. These are Canada, Mexico, Poland, U.S.S.R., Western Europe, Mid-East and Japan.

In Canada (Slide 3), sulphur production in Alberta and British Columbia this year is expected to total 6.05 million tons including output from two oil sands plants of about 200,000 tons. Net withdrawal from stockpiles would have been about 132,000 tons if expected sales volumes were met. Earlier, it was anticipated that remelting requirements could be on the order of 2 million tons, but now it appears it will be less than 1.5 million tons. Inventory is fairly high at Vancouver and remelting has stopped for the time being. Sales will probably be about 7.5 million with 5.1 million offshore, 1.6 million to the U.S. and 0.8 used within Canada. In addition there is an estimated 1.1 million tons of sulphur production from refineries and smelter acid.

Slide 3 CANADA—PRODUCTION & SALES

	1980	1981	%
Production			
Gas	6.18	6.05	
Petroleum	0.3	0.3	
Acid	0.8	0.8	
	7.28	7.15	(1.8)
Est. Sales			
Offshore		5.1	
US		1.6	
Canada		0.8	
		7.5	

In Mexico (Slide 4), this slide shows our estimate of production and sales for 1980 and 1981. Exports to the U.S. are off slightly, domestic requirements are begining to increase, a trend which will become much more pronounced in the near future.

Slide 4 MEXICO—PRODUCTION & SALES

	1980	1981
Production		
Frasch	1.7	1.7
Recovered	0.4	0.5
	2.1	2.2
Sales		
US	0.78	0.71
Mexico	0.82	0.95
Other	0.28	0.65
	1.88	2.31

(Slide 5) Although the U.S. does not import sulphur from Poland, they are one of the large sulphur producers, and the variations in the amount they export to the Western World have their effect on our sulphur export markets in West Europe and elsewhere and, in turn, on our local situation. In 1980, Polish exports to the West were slightly over 2 million tons, to the Communist countries 1.9 million tons of which Russia took 0.7 million tons. This year, Russia has increased its Polish imports and is buying from the West as well. This in turn has caused the rest of East Europe to turn to the West for some of its sulphur requirements. This may be a temporary situation in view of the huge sulphur producing facilities coming on stream within the Soviet Union, but it will have its effect over the short term. Polish production is expected to drop very soon as the Gryzbow mine winds down. Prospects of an often talked about new mine seem questionable at this time of political unrest with a poor outlook for any Western credits of assist in its construction.

Slide 5 POLAND—PRODUCTION & EXPORTS

	1980	1981
Production (Frasch)	4.98	4.90
World Exports	3.9	4.0
Western World	2.0	1.9
Communist	1.9	2.1
(Of which USSR)	0.7	1.0

Western Europe (Slide 6), will be producing about the same amount of sulphur as last year. The expected decline in output of the Lacq field in France has already began along with corresponding cuts in their export program. Notice the dramatic drop in estimated consumption due to economic difficulties, high prices and the strong dollar.

Slide 6 WESTERN EUROPE—PRODUCTION & CONSUMPTION

	1980	1981
Production		
France (Gas)	1.80	1.80
W. Germany (Gas)	0.85	0.85
W.E. Refineries	1.0	0.99
Total Brimstone	3.65	3.64
Pyrites, Smelter Acid	4.24	4.26
Total All Forms	7.89	7.90
Consumption	6.70	5.90

U.S.S.R. (Slide 7), we cannot say much about the Soviet Union except to note that they do have a couple of large Frasch complexes, which are expected to improve on a poor operating rate. The huge Orenbur gas complex is operational and another one is being planned for construction at Astrakhan. In addition there is a large open pit mine at Yavorov.

Mid-East — In the Mid-East (Slide 8), both Iran and Iraq are seen to have tapered off because of the war. Saudi Arabia's production is not yet available on the market. Thus the region as a whole has little if any exportable material.

Japan (slide 9), has some exportable sulphur as well as acid and their situation is not expected to change all that much in 1981.

Slide 7 USSR—PRODUCTION & CONSUMPTION

	1980	1981
Frasch	1.2	1.2
Refineries	2.0	2.5
Native	0.8	0.8
Total Brimstone	4.0	4.5
Pyrites Smelter Acid	5.9	6.3
Total all Forms	9.9	10.8
Consumption (Br)		5.7

Slide 8 MID-EAST—PRODUCTION & CONSUMPTION

	1980	1981
Supply		
Iran	0.13	0.05
Iraq	0.57	0.15
Saudi Arabia	—	—
Other	0.16	0.16
	0.86	0.31
Consumption	0.30	0.40
Surplus (Deficit)	0.56	(0.09)

Slide 9 JAPAN—PRODUCTION & CONSUMPTION

	1980	1981
Production		
Recovered	1.18	N
Smelter Acid	1.65	O
	2.83	
		C
Consumption — All Forms	2.10	H
Exports		A
Recovered	0.36	N
Acid	0.10	G
		E

On Slide 10, we compare the 1980 and 1981 world supply / demand balance. Demand will be down this year by half a million tons. We will later assume a recovery, but it will begin with a lower base. Sulphur production will be less than previously anticipated — 55 million tons, with a million or so tons frozen mainly in Saudi Arabia and Iraq. The two million ton deficite will need to be removed from inventory, but is 1.5 million tons less than last year.

Slide 10 WORLD SUPPLY/DEMAND

	1980	1981
Production	54.7	55.0
Supply	53.0	54.0
Demand	56.5	56.0
Surplus (Deficit)	(3.5)	(2.0)

Let us turn now to what the medium term future (till 1985) hold for these same regions, with emphasis on items that might have changed since last years Fertilizer Round Table. (Slide 11) This slide is a summary of the comments I am about to make.

For production in the U.S. Frasch sulphur will remain about the same, perhaps, declining slightly. Recovered sulphur should increase — new plants in the over thrust and Mississippi area are moving ahead on schedule. In the U.S., there are 30 odd sulphur producing facilities associated with gas plants or oil refineries expected to be constructed between now and 1983. Perhaps 1.5 million tons is a good guess as to expected actual tonnage. Another 200,000 tons should be coming out of the Duval Phillips Ranch property by that time. These new facilities may well give rise to some oversupply in 1982-1983 but this is likely to be temporary, with a return to a tight balance in 1985. The key to this balance will be our export P_2O_5.

Looking again at Canada, I am aware of six new gas processing plants expected to come on stream between now and 1983, totaling about 1.1 million tons / yr of new production. The largest is Gulf Canada Resources Hanalan-Robb plant with 400,000 tons/yr, followed by Amocos plant at Brown Creek with 300,000 tons/yr. The latter is only a maybe at this time. These will bring production to a peak of perhaps 7.3 million tons in 1985 after which it will decline, although partially offset to an increasing extent by new gas discoveries and oil sands operations. By the year 2000, oil sands and heavy oil should be contributing 30% of the total supply, and new discoveries about 20%.

As for remelting the Canadian stockpiles, if offshore exports continue at the present level of about 6 million tons / yr, it should continue at a level of between 1.5 and 2.5 million tons annually with depletion occuring about 1990. The way in which this is done is of course one of the most crucial elements in determining the world supply demand balance. These stockpiles are, in effect, "voluntary" capacity, independent of the production of sour gas. If the Canadians remelt and ship as much as possible there could be some market instability. If, on the other hand, they remelt and ship as needed, stable world supply balance could be promoted. Also the production of Canadian smelter acid is expected to nearly double in this decade, and may contribute additional 650 650,000 tons of sulphur equivalent by 1985.

Returning to Mexico, the revitalized Coachap mine should be contributing 600,000 tons/yr by 1985. In addition, Pemex has ten plants in various stages of construction which will also yield over 600,000 tons/yr. However, usage of sulphur within Mexico is expected to expand to the level of 1.9-2 million tons annualy by 1985. I understand their intention is to maintain export levels of 1.3 million tons/yr or so which may rise until 1985 but not thereafter, when their own needs will receive priority.

We have commented on the uncertain outlook in Poland and the guess of anyone who reads the newspapers is as good as mine. If they do in fact get a new mine at a place called Skepanie, they could have another million annual tons production in 1985, bringing then to a 6 million ton / yr level. A contemplated second new mine could increase this to 7.5 million tons in 1990. It seems unlikely to me.

We cannot add much to what has been said about the Soviet Union except to say that if the proposed complex at Astrakhan is built, recovered sulphur production in Russia could reach 5 million tons in 1985. Their goal is said to be self-sufficiency by 1985. If so, it *could* make more Polish tonnage available to the West, and lessen their present activity of the Soviets in the international market.

In Western Europe, output from Frances's Lacq field has begun its expected decline and will be down to 1.4 million tons by 1985, and to 700,000 tons in 1990. Production in Germany should remain at present levels, so the supply of brimstone will decline in Western Europe. On the other hand, production of pyrites in Spain, Portugal, Italy, Scandinavia and Germany should continue or even exceed present levels, which now account for about 25% of sulphuric acid production in those countries. I should remind you that much, but not all, pyrites is mined primarily for metal content, with sulphuric acid being an important co-product.

Slide 11 **ESTIMATED SULPHUR PRODUCTION SUMMARY**

	1981	1985
Western World		
Brimstone	25.1	28.0
Non-Brimstone	10.6	12.0
	35.7	40.0
Communist		
Brimstone	10.0	12.0
Non-Brimstone	9.3	10.5
	19.3	22.5
World		
Brimstone	35.1	40.0
Non-Brimstone	19.9	22.5
	55.0	62.5

Sulphuric production in the Mid-East should reach a level of over 2.5 million tons annually by 1985. Of this Iraq and Iran will be contributing about 1.2 million tons if peace breaks out this year. Saudi Arabia will be contributing about 1.3 million tons, and will be remelting from stockpiles after next year. Mid-East internal consumption will be on the order of 1.1 million tons, leaving 1.4 million tons available for export.

The situation in Japan is not expected to be greatly different than it is today.

The Communist data are certainly suspect but perhaps the uncertainty is not much greater than that from what we like to think of as our stable, predictable Western society. World wide we now look for an added 5 million tons of brimstone and about half that amount as non-brimstone.

From this Table, (Slide 12) it can be seen that supply is about a million tons less than production in 1981, half that in 1985. All surplus Communist production is assumed available to world markets, with the unavailable being confined to the West.

the 1981 Western World deficit of 3.6 million tons is assumed to be made up by imports of 2 million tons from Poland, 1.5 million tons Canadian remelt and about 300,000 tons from Mexican inventory.

The surplus shown for the Communist countries is not really accurate because they import some from the West. Our knowledge of the Communist sulphur situation is admittedly incomplete and thus adds an element of guess work to both the Communist and World figures.

We are still sticking with an annual increase in demand of 3%; 2.5% in the West and 4% in the Communist countries. This is certainly not true for 1980-1981, where demand has lessened by 1.2 million tons in the West and increased by 0.7 million tons for the Communist countries.

The large thrust in demand growth during the decade will come from the rapidly expanding phosphate fertilizer industry, particularly from new plants built in the developing nations of Latin America, Asia and Africa. Industrial dcemand in the developing nations should increase at a good rate although actual consumption is relatively small. Consumption in the developing nations should expand 6-7% per year and this accounts for perhaps 70% of the total tonnage gain in world usage during the remainder of the decade. In contrast, the use of sulphur in the industrialized nations will grow more slowly, perhaps 2% in the U.S. and only 1%, if that, in Western Europe and Japan.

Slide 12 **ESTIMATED SUPPLY/DEMAND SUMMARY**

	1981	1982
Western World		
Production	35.7	40.0
Supply	34.7	39.5
Demand	38.3	42.3
Surplus (Deficit)	(3.6)	(2.8)
Communist		
Production	19.3	22.5
Supply	19.3	22.5
Demand	17.7	20.7
Surplus (Deficit)	1.6	1.8
World		
Production	55.0	62.5
Supply	54.0	62.0
Demand	56.0	63.0
Surplus (Deficit)	(2.0)	(1.0)

In the U.S. we expect continued expansion of sulphur demand by phosphate fertilizers which will be called upon to supply increased quantities of fertilizer to those developing countries not yet capable of processing their own. However, I am one of those who think that domestic demand for P_2O_5 may well have plateaued and I see little growth in industrial demand for sulphur. Existing markets are mature and suffering from environmental pressures as well. Sulphur extended asphalt is a new use which will grow as fast as sulphur availability and the price relationship of sulphur and asphalt will permit. Sulphur concrete for special applications will grow because of its superior properties. Its use in ordinary construction will take longer.

For the Western World, then, the outlook is for some narrowing of the gap between supply and demand. Any gap must be closed of course, either by lowering consumption or increasing supply. In the latter case, as matters stand, it must be closed by Canadian inventory, Polish imports or later by Mid-East excess production. While these options can take care of us through 1985 or even 1990, after that additional new sources must be developed. As we have said, Canadian inventory will be gone by then, and existing U.S. Frasch only a few years after that.

As always, there are areas of "sensitivity," any one of which could and probably will throw a monkey wrench into our finely tuned forecast machinery. We have touched upon most of them. These question marks could have a 1-1.5 million ton effect on the supply side and a 1.5-2 million ton effect on the demand side by 1985. If they both work to these arbitrary limits in the direction of supply we could have a 2.5 million ton surplus, world wide, in 1985. If they work in the direction of the demand side the deficit could be 3.5 million tons more than we show here. You can let me know if I'm right at that time, but if not we'll talk about the weather.

Time does not permit us to touch upon other facets which will affect sulphur such as new uses of sulphur for example which are nearing commercialization, and eventually will have their effect on anticipated demand; the long term picture, in which sulphur from coal is expected to play a big part; but a field which is progressing much more slowly than anyone anticipated; the heavy oil fields of Venezuela which could be yielding 2 million tons annually by the turn of the century; The trend toward captive usage by sulphur producers which could remove a considerable tonnage from the marketplace. Coordination with the phosphate figures presented a while ago by Mr. Graves would certainly have made our sulphur demand estimates more accurate, since over half of world sulphur is used for that purpose. Nevertheless we trust our brief overview has been helpful and timely.

Thank you for your kind attention. (Applause)

MODERATOR MEDBERY: We are now ready for the question and answer portion of this morning's programs. Our four speakers will field questions from our audience. Those wishing to ask questions please use one of the microphones nearest to you. Now for the questions.

Question & Answer Session

QUESTION—FRANK ACHORN: My question is to Jim Brown. We keep hearing about bullseye drilling on all new gas supplies coming into the western part of the United States. Some predictions are that the gas supply now available is going to last 200 years into the future. We are seeing more gas supplies in Canada. Are we seeing any tendency for the price of natural gas to go down to the ammonia producers?

ANSWER—JIM BROWN, CANADIAN FERTILIZER INSTITUTE: I think you are right, Frank. There is a gas bubble in some of these areas. There is some conjecture as to how fast oil prices are going to rise. There has obviously been an oil glut in the market in the last few years. The OPEC people were together a few days ago trying to sort out that one the same way that we are trying to sort out some of our problems of the fertilizer business. Certainly any of the meetings I have attended, where they have projected the future prices of gas, the numbers that seem to come to the front in the mid 1980's, is $6.00 per MCF. I have heard prices at the end of the decade of a low of $11.50 per MCF up to $12.00 to $14.00. This certainly is not cheap. There is absolutely indecision about this when you look at the survey of what people's intensions are about expanding into Ammonia Production in the United States.

There are no plans between now and 1986 according to the latest T.F.I. survey. Obviously there is a lot of indecision on behalf of the customers. No one wants to comment on the type of money it takes to build a nitrogen complex today unless you are assured of the supply of gas and how it is going to equate with, not only the costs in the North American continent, but to some extent the costs worldwide. Nitrogen is, as we have found out, a very interchangeable product. We are importing a lot of ammonia and exporting a lot of downstream products. Somehow, I feel that gas prices may be a little more modest than some of these very high projections we see by the end of the decade ($12.00 - $14.00). If these projections are right, Frank, the price of corn is going to have to go up a long way and the price of wheat they will not be able to produce it.

QUESTION—JOHN KRONSEDER - FLUOR CORPORATION: How about the Neareast with their flared gas? Are they going to be a major factor in the future on ammonia?

JIM BROWN— CANADIAN FERTILIZER INSTITUTE: The Neareast really has not advancement to become a major factor in ammonia production. It is true that they have flared gas. Their capital costs, I understand, are very high. I think the other problem is that when you get in North America, Western Europe, Japan and the developed countries, they can run these plants at 95%, practically 100%. You look at these numbers for the rest of the world we show ammonia capacity of 105 million tons and when you look at the fertilizer production it is 57 million tons. There is obviously a big gap in between what can be produced in some of these areas and the capacity. It is due to varying reasons. I know in India it is their electrical supply. In other areas they do not have the experienced operators that we have here. I think they are going to have a problem building plants and becoming a bigger factor because, obviously, it is going to involve moving that ammonia to someplace else in the world to be consumed. The logistics problem in moving nitrogen is an important consideration as well. I see their sales worldwide are going up each year. they are obviously having lots of problems in moving the gas and ammonia to the places in the world where it is required. It is no use getting a cargo of ammonia the 2nd day in July when all of the DAP market is over the 1st day of May.

JOHN KRONSEDER: Nevertheless, there are plants being built now.

JIM BROWN: Yes they are. I think there is a about 7 million tons of capacity within the whole region and, obviously, they are going to be a bigger factor.

JOHN KRONSEDER: That is dependent upon ocean shipments of that ammonia to export and not for domestic consumption.

The ocean shipments put up quite a barrier. You need a cheaper unit cost of production in order to ship it. Most of the USSR ammonia, coming over here, is landing at coastal points and is being used for coversions. It is going into downstream products, DAP and other downstream products. If you put this thru the system, and bring it back to the mideast, it becomes very, very expensive. You have to put in a very large intra-structure to handle this in volume. You can possibly handle the 2 million tons well enough, however, we see various scenarios as to what the imports are liable to be by the mid-1980's. Some say 4½ million tons and some say 5 million tons. This is about 20% of the total usage at that time and compared with about 11% currently. It is going to require a lot of additional intra-structure to move ammonia from the Mideast to supply the North American market.

JOHN KRONSEDER: But you are practically comparing zero costs.

JIM BROWN: Yes I will grant you that. Currently, aout 75% of your processing is in the gas. It will be higher in the future, however, gas has good values for other use. You can liquify it and sell it to Japan. They have other options rather than putting it in downstream for fertilizer and other petro chemical products. It is certainly a possibility.

QUESTION—T. ZINGH - ZUARI FERTILIZER -INDIA: This is a question on the sulphur, potash and P_2O_5 status. What are the predictions for international prices, as predicted now, taking into consideration the fertilizer markets?

ANSWER—E. B. GRAVES: Agrico Chemical Co. We are not going to talk about prices. We simply do not project prices publicly. We obviously do it internally. Our General Counsel would absolutely get grey hair if we even talked about prices. So, I simply cannot do it.

D.E. LOGSDAIL—SASKATCHEWAN POTASH, LTD: I would have to take somewhat the same stance as E. R. Graves. Although we know, historically in the potash business, there have been definite inequalities regarding the North American price versus the world price, particularly in those developing countries, I think it is fair to say, we are going to eventually resolve it and more or less consider it as a world price. Granted, in some isolated cases, it may still continue. I think that most of you realize, that in the last decade or so you could consider the offshore market, I have to use this term, "A Dumping Market". Offshore prices were certainly lower than had been experienced in the North American domestic market. In the last few years it has been almost the reverse. The offshore market has been realizing a much stronger net back. From our viewpoint, we feel that this will tend to moderate, and we look at it speaking for ourselves, basically, people who are participating in the world market. We just do not see this will continue with as big a differential.

DAVID W. BIXBY—THE SULPHUR INSTITUTE: No, I am not going to touch the matter of prices with a ten foot pole! You are well aware it takes much more energy to make a ton of ammonia, and in the case of sulphur, it takes energy to mine it and to recover it. You can draw your own conclusions. Energy costs are going to rise. The cost of most commodities, using considerable amounts of energy to prepare them, are going to rise as well.

QUESTION—RODGER SMITH - AMAX CHEMICAL CORPORATION: David, can you expand a little further on your feeling as to sulphur recovery from coal in the distant future?

ANSWER—DAVID BIXBY: It is inevitible in the distant future we will get a lot of sulphur from coal gasification and liquification. It is just that the process has been made much more slowly than anyone would have anticipated. I was saying, five or ten years ago, that by 1985 we were going to have sulphur running out of our ears from coal processing plants. Obviously that has not happened and is not likely to happen for sometime. I understand there are approximately 5 semi-commercial operations underway in the United States recovering sulphur from coal. If the efforts towards using coal are not ultimately stymied by arguments that we are increasing the atmospheric carbon dioxide too much that will be the source of over 50% of all sulphur produced by the turn of the century.

JOHN KRENSEDER—FLUOR CORPORATION: Along those lines, there is considerable sulphur in shale oil. We are studying many particular units which have large productions of sulphur and ammonia. The Sosol Plant in South Africa, for example, is now moving into the fertilizer field based on its sulphur and ammonia recovery.

DAVID BIXBY: That is a Fisher Trepes operation?

JOHN KRONSEDER: Yes, but the sulphur and the nitrogen come from gasification, not the Fisher Trepes. So, the minute you go into gasification of coal, you are going to have nitrogen and sulphur. The same is true of shale oil. All of the nitrogen combined in these materials end up as ammonia in the operation. I think maybe that ought to have a little cosideration. I know it has not progressed as far as we all expected, however, there are awfully big plants in the offing.

DAVID BIXBY: No question about it, John.

QUESTION—BUD BALAY - T.V.A.: We heard this morning some talk of the potash market maturing in West Germany. Do you Gentlemen see any general maturing of the market or are they going to have increases in production and use?

ANSWER—D. E. LOGSDAIL - POTASH CORPORATION OF SASCATCHEWAN: My comments this morning on the maturing of the Western European market are - "We also look at other markets." Japan is becoming a more mature market and I think also North America. The rate of increase projected is at a much lower level percentagewise. I understand you are talking from a much bigger base. We do not think our projections basically are overly sky-balling. We look generally at somewhere in the magnitude of 3% to 3½% worldwide, recognizing that we think of some of the points I mentioned earlier. The infrastructure in some of these developing countries are developed to the point of being able to receive this material. Both the demand and the ultimate movement can be rather significant. We do look, quite consciously, at Western Europe, Japan and even North America as somewhat mature from potash.

QUESTION—BILL COATES - DECKER ROUCHLIN VENTURES, HOLLAND: From the discussion this morning it seems very clear that the cost of ammonia is going to rise much more rapidly than the cost of P_2O_5 though that too is going to rise. Is this likely to affect the production and marketing pattern of phosphates from the Florida area? Is there likely to be a decline in DAP?

ANSWER—GENE GRAVES - AGRICO CHEMICAL CO.: I would think that it will. I think historically DAP has been the big product at least during the last decade. In the future I would expect products which have a lower nitrogen content because of the high cost of nitrogen here. Of course it all depends on the countries it is going to. I would not even be willing to say that we would not see more products, such as triple, which has a lower sulphur content and no nitrogen, become a bigger factor into the market place. The key, of course, is the high cost of nitrogen which would be going to countries that could very well have some of their own nitrogen. From that standpoint, yes, I would probably see more MAP, or products of that type being produced here for the export market.

MODERATOR MEDBERY: Thanks to all of you for your excellent, interesting and up to date discussions on the subjects of Nitrogen, Phosphates, Potash and Sulphur. We have run out of time. Before I turn the meeting back to Chairman Frank Achorn, I wish to mention that copies of the "Outlook Papers" will be available immediately following adjournment. Chairman Achorn thanks again for the honor of moderating this morning's session. I will turn the meeting back to you. (Applause)

CHAIRMAN ACHORN: We had a fine morning. I appreciate our Speakers taking so much time in preparing their respective discussions. These projections into the future always become difficult because you can never tell what is going to really happen. We will start our afternoon session at 1:30 P.M. sharp. Thank you. (Much applause)

Tuesday, November 3, 1981

Afternoon Session
Moderator: William F. Sheldrick

MODERATOR SHELDRICK: My pleasure to be here to moderate Session Two of Our 31st Annual Meeting. (Applause)

Our first Speaker, Dr. Ralph W. F. Hardy, is very eminent in his field. He will discuss "Alternative Technologies For Nitrogen Fertilizers Including Genetic Engineering." This is a field, I think, many of us only touch superficially in our business, however, it comes up from time to time. I certainly come across this, quite often, when we have a "Bank Project" coming up for approval with "Our Board." Two questions are bound to be asked. One question is: "Why can't we use organic fertilizer" such as they did in China? that is quite easy to answer. If that is so: "Why are the Chinese building fifteen new, large Ammonia plants?" The other question is "Why don't we wait for Biological Fixation?" I must admit that I always find this question very difficult to answer. I am sure that Dr. Hardy will enlighten us on this. If I were to go thru all of "The Qualifications and Activities", Dr. Hardy has in this field, it would take longer than reading the paper itself.

Dr. Hardy is currently Director of "Life Sciences" in the Dupont Chemical Co. Central Research and Development Department. I understand from him, that this is possibly an "Activity" which shortly will be very much enlarged upon. Dr. Hardy is a native of Canada, has a Bachelors Degree from Ontario Agricultural College, of the University of Toronto, and received "The Governor General's Silver Medal". He has a Masters Degree and a Ph.D. from the University of Wisconsin. He is Editor of a multi-volume comprehensive treatise on "Nitrogen Fixation" and Co-Author of a monograph "Nitrogen Fixation in Bacteria in Higher Plants." I certainly come across Dr. Hardy's name everytime I look into this subject. We really are going to hear from an "authority in this field." Dr. Hardy, please. (Applause)

Alternative Technologies For Nitrogen Fertilizers Including Genetic Engineering

R. W. Hardy

A prophetic cartoon on the need for fixed nitrogen appeared in the *New Yorker* magazine in the 1960's. A small organism in a desert background was gasping not for water but for "ammonia, ammonia, ammonia." The importance of fixed nitrogen in world crop production portrayed by this cartoon preceded the rapid escalation in energy costs initiated in the early 1970's. In 1981, the continued importance of fixed nitrogen and the cost/availability of suitable energy to produce fertilizer nitrogen dictate the opportunity / need to discover and develop alternate technologies to meet the nitrogen input needs of crop production. My comments will survey our knowledge upon which alternate technologies may be based and the possible nature of these future technologies

The Nitrogen Need for Crop Production.

Cereal grains and grain legumes are the primary suppliers of world food and feed needs. Their nitrogen input systems differ. Cereal grains rely exclusively on fixed nitrogen endogenous to the soil or added as fertilizer nitrogen; grain legumes use both biologically fixed nitrogen contributed by their plant/Rhizobium symbiotic system and fixed nitrogen from the soil or fertilizer.

The increase in cereal grain production from about 1300 MM tons in 1975 to an estimated 2600 MM tons by 2000 A.D. will increase the nitrogen content in the harvested crop from 39 MM tons in 1975 to 78 MM tons in 2000. In general, this need may be met by increasing fertilizer nitrogen production from 50+ MM tons to 160 MM tons. Alternatively, the efficiency of fertilizer nitrogen use might be increased from an average of 50 to 75% thereby decreasing the absolute amount of fertilizer needed. In a futuristic chemical approach, a practical process for abiological nitrogen fixation with zero direct energy input would reduce the high energy input and the economic cost of the current Haber-Bosch-based process. In a futuristic biological approach, a biological nitrogen fixation system(s) compatible with high yield might be developed for cereal grains.

The need for grain legumes will grow from 130 MM tons in 1975 to an estimated 520 MM tons in 2000 with the accompanying harvested nitrogen content increasing from 10 MM to 39 MM tons. General approaches to provide this additional nitrogen may involve enhancement of the symbiotic biological nitrogen fixation system and/or nitrogen fertilizer responsive systems for legumes as well as the development of the futuristic chemical and biological systems suggested for cereals.

The Knowledge Base in Nitrogen Input.

The past 20 years have been most productive in terms of improved knowledge of nitrogen fixation processes especially those in the biological area. Table I summarizes the highlights of these advances grouped under the headings of mathematics and engineering, chemistry, biochemistry, genetics, biology and agronomy. The list of advances in almost all areas is impressive. In 1960 there was complete ignorance of the molecular aspects of biological nitrogen fixation; in 1981 molecular understanding of the chemical, biochemical and genetic areas is well advanced. There has been an accompanying significant improvement in our understanding of the biological and agronomic aspects of these processes. Engineering input has led to large nitrogen fertilizer synthesis plants and continuing input in this area is focused on improved efficiences and use of non-natural gas feedstocks.

These advances in understanding of the biological process have enabled the identification of many minor, moderate, and in several cases major limitations to the use of the biological system as a more extensive technology for provision of fixed nitrogen.

Biochemistry

At the biochemical level, about 34 specific limitations may be identified. The more important ones include the minimal variation in the structure of nitrogenase—the components of all N_2-fixing enzymes are very similar chemically. Moreover, these components are extremely sensitive to oxygen and this lability limits their location either within a living cell or their use as a catalyst in a chemical process. The nitrogenase system which catalyzes biological nitrogen fixation is a sluggish one with each molecule converting only about 50-100 molecules of N_2 to ammonia per minute. The biological process is a reductive one, e.g.,

$$N_2 + 3H_2 \rightarrow 2NH_3 + \text{Energy}$$

analogous to the Haber-Bosch system. A process that requires hydrogen is energy consumptive; an oxidative process would be preferable. Unfortunately, nature provided us with only a reductive process and no oxidative one, or if it did, man has yet to find it.

Furthermore, the enzyme is not absolutely specific for the substrate nitrogen and protons are reduced to hydrogen simulateneously with reduction of nitrogen to ammonia, e.g.,

$$N_2 + 3H_2 + 2H^+ + 2e + \rightarrow 2NH_3 + 1H_2$$

In addition to using energy in the form of hydrogen, the biological process also has a high direct requirement for biological energy, specifically ATP. Four ATP's are consumed for every two electrons transferred. The overall reaction of biological N_2 fixation follows:

$$N_2 + 3H_2 + 2H^+ + 2e + 16\ \text{ATP} \longrightarrow 2NH_3 + 1H_2 + 16\ \text{ADP} + 16\ \text{Pi} + \text{Wasted Energy}$$

Much energy is wasted in this reaction since the reaction of H and N_2 to produce ammonia is itself energy producing. The hydrogen that is produced in this reaction may be scavenged to recapture some of the energy used in its formation if an enzyme called an uptake hydrogenase is present.

Genetics

Molecular genetics research in nitrogen fixation is one of the most dynamic areas currently and is providing a key tool for new understanding of the process. Thus, we can in a molecular way define the structural genes of nitrogenase from several organisms. The recent observation in our laboratory that the early section of one of the structural genes for nitrogen from a blue-green algae is similar to the early sections of genes in higher plant chloroplasts provides experimental support that the chloroplast came from blue-green algae. Based on this hypothesis, algal genes may be preferred for movement to higher plant chloroplasts over genes from other sources such as bacteria.

At the genetic level, 19 specific limitations of biological nitrogen fixation can be identified based on current knowledge. Disappointingly, the genes for the proteins of the nitrogenase enzyme all are very similar — no useful variation. The total number of genes for the nitrogen fixation system are fairly large — 17 in the case of the most studied system from a facultative anaerobe called *Klebsiella.*

Biological organisms can be subdivided into lower forms like baceria and blue-green algae and into higher forms like yeast, plants and animals. The genes for nitrogen fixation are limited exclusively to lower forms—the reason, if any, for this limitation is unknown. Recently molecular geneticists have moved them up the evolutionary scale to yeast but the transver was unsuccessful since the genes failed to function. Undoubtedly, in time, scientists will learn how to move these genes in a functional form to higher forms such as plants and maybe even animals.

Of greatest near-term interest to agriculture is the symbiotic nitrogen fixation system of legumes. Very little information on the molecular genetics of these associations between the *Rhizobium* bacteria and the legume plants is yet known. The excess enthusiasm of some molecular geneticists has led them to make premature claims of the development of super mutants of *Rhizobium;* if such were the case in the laboratory, they were not substantiated by field trials.

The impact of molecular genetics research on nitrogen fixation, in general, may be threefold. It will be a key research technique for understanding the biological nitrogen fixation system and from this may produce products that are not directly the result of molecular genetics, e.g., agrichemicals that beneficially manipulate the system. One may use molecular genetics to construct microorganisms that produce a product, for example, ammonia, nitrate or urea. This does not appear to be an economically feasible opportunity especially in the reasonable future. Finally, one may genetically engineer microorganisms or plants, e.g., seed, that are the products. This rather than engineering microorganisms to produce products will possibly be the major use of molecular genetics research in nitrogen fixation. It is a long term not a short term possibility.

The general techniques for movement of nitrogen fixation (nif) genes into other organisms is reasonably straightforward. The steps are the following (Figure 1). The desired gene or genes, in this case those for N_2 fixation, are identified and isolated or alternatively synthesized. The desired gene is inserted into a carrier by enzymatic or chemical methods. Frequently this carrier is a plasmid, a small extrachromosomal circular piece of DNA. The desired gene in the carrier is then placed into the host cell which may be a plant cell, a microorganism or an organelle in a plant or animal cell. Manipulation of the inserted gene and carrier occurs so as to make them acceptable, stable, and copied in the host cell. Most importantly, the inserted gene must be expressed in an active form in the host cell at a rate that is appropriate with the desired activity. No one has yet succeeded to do this last step in a cell of a higher organism such as even a yeast. Further steps are required if the host cell is a plant cell. Obviously, the cell must be regenerated to a whole plant with the nitrogen fixing genes transmitted via the seed. Essentially no major crop plants can be regenerated at this time from their single cells—crops like tobacco and carrot can but not soybeans, wheat, and corn. A major technological advance must be made in regeneration to enable the production of the much publicized nitrogen fixing plants.

Biology and Agronomy

Limitations at the biological and agronomic level number at least 26. They include the limited occurrence of nitrogen fixation—only in microorganisms and only in a few microorganisms. Most comments will address the symbiotic system of *Rhizobium* and legumes because of its agronomic significance. Within the last few years *Rhizobium* in many cases have been manipulated so as to fix nitrogen independent of the symbiosis with legumes. However, the rates are low and the spectrum of organisms does not include all *Rhizobium.* This necessitates studies with the more complex plant microorganismal system than the more simple *Rhizobium* culture. Fixed nitrogen, nitrate, and ammonia produce multiple inhibitions of biological nitrogen fixation. They inhibit the infection process, the modulation process, and the quantity of nitrogen fixed by the system as well as promoting senescence of the symbiotic system.

The high requirement for energy, both electrons and ATP, discussed under biochemistry translates to biology and agronomy. Recent measurements in our laboratory and elsewhere of the efficiency of nitrogen fixation by the legume system—probably the most efficiently known nitrogen-fixing system—reveal the use (burning) of a minimum of 10 kg of carbohydrate for every kg of nitrogen fixed. This excessive energy consumption is the major concern about the feasibility pf broad extension of the nitrogen fixing system to crop plants. The concern can be states simply. Can the plant afford to spend 10 kg carbohydrate per kg N_2 fixed without decreasing its yield in an amount that would exceed the cost of an equivalent amount of fertilizer nitrogen? The answer will vary depending on a number of calculable factors as well as the possible ability of the plant to compensate through enhanced photosynthate production to meet the need.

The biological system in many cases evolves hydrogen during its fixation of nitrogen as discussed under biochemistry. The energy of this hydrogen is lost to the plant if it does not possess a hydrogen uptake system. Legumes and most cereals tend to be photosynthetically inefficient. They have the wasteful process of photorespiration that decreases their net dry matter accumulation by 25-50%. This photosynthetic inefficiency of legumes makes the cost of biological nitrogen fixation of even greater concern.

The symbiotic system undergoes premature senescence. Significant seed growth is still occurring in soybeans at the time that biological nitrogen fixation stops increasing and may even decline. The amount of nitrogen fixed will vary with the fixed nitrogen content of the soil. In high fertility soils, approximately 25% to a maximum of 50% of the nitrogen in legume plants arises from biological nitrogen fixation. There is an inadequate amount of nitrogen fixation for high yield soybeans.

The symbiotic biological nitrogen fixation system is difficult to optimize because of the multiplicity of the strains of *Rhizobia* that exists, the specificity of baterial strain-plant cultivar interactions, and the soil and climatic variables, and their impact on the biological component. Furthermore, conditions for use of biological systems are more demanding than inanimate ones. Manufacture, storage, handling, and application may all result in partial or complete loss of biological activity while an inanimate chemical additive is not similarly affected. In addition, there is competition between applied *Rhizobium* with improved N_2-fixing activities and endogenous *Rhizobium* already in the soil with the soil adapted endogenous *Rhizobium* often outcompeting the applied ones in module formation.

Policy, Proprietariness

Chemical solutions have an established base for proprietariness. Although an organism has now been patented as a composition of matter, it will be some time before the usefulness of microorganismal patents is established. In general, research and development investment in microorganismal solutions has not been well supported because of proprietary inadequacy.

Past, Current and Possible Future Alternate Technologies

The established importance of nitrogen input in plant agriculture is documented by the development of inputs for nitrogen that go back to biblical times. A summary of these past, current, and possible future technologies are tabulated in Table 2 grouped according to the past, current, near-term or long-term potential of their impacts. Eight technologies that span biblical times to the current are identified. The most significant current inputs are synthetic nitrogen fertilizer and nitrogen responsive crops. Newer technologies are slow release fertilizers, nitrogen transformation effectors, e.g., N-Serve, and foliar fertilization with NPKS mixtures.

A group of highly probable short term impact technologies are identified. They include highly effective *Rhizobium* inoculation technology, legumes that are more yield responsive to nitrogen fertilizers, an increased harvest index for nitrogen, *Rhizobium* with a gene or genes to enable effective uptake of the hydrogen produced and thereby recapture some of the energy that would be lost, and inoculation of cereals and grasses with the free-living nitrogen fixer *Azospirillum.* Recent field data from Israel show a consistent yield increase in wheat and other crops inoculated with *Azospirillum.* Experiments in our laboratory document the ability of plant *Azospirillum* associations to fix N_2 but of equal or greater significance was the observation that *Azospirillum* increases uptake of ions such as nitrate by crop plants. The impacts from these highly probable short term inputs may be significant but is doubtful that they will be highly significant in their total impact on the nitrogen input problem.

Less probable, mid-impact technologies include improved *Azolla-Anabaena* symbiosis for paddy rice and a promiscuous *Rhizobium* to simplify inoculation which could be important in developing countries where errors in inoculatin are probably even more prevalent than in developed countries. *Rhizobium* symbioses insensitive to fixed nitrogen also may provide mid-term impact.

The more speculative, long-term impact technologies will provide by far the greatest contribution to the nitrogen input problem. A major increase in photosynthate available to the module would have a strong benefit analagous to the multifold increase in N_2 fixation experimentally demonstrated by foliar CO_2 enrichment of field-grown soybeans. Improved efficiency of the nodule could be significant. Effective non-*Rhizobium* nitrogen-fixing associations for nonlegume crops could be important. Mycorrhizal associations are important in scavening ions for plants and one might suggest that mycorrhizal associations containing nitrogen fixing capabilities within them might be useful. Some have suggested that pathogens with the capability of nitrogen fixation but made nonpathogenic would provide effective systems for incorporation of nitrogen fixation capabilities in crops. Examples might include *Agrobacterium* currently being studied as a general system to deliver foreign genes to plants and *Erwinia.* Some hope that yet-to-be discovered N_2 fixing systems exist in nature that could be readily commercialized for nitrogen input. The discovery in the last decade of the *Rhizobium-Trema* association and the rediscovery of the *Azospirillum* grass association document the possibility of the existence of such systems.

Some suggest that the *Rhizobium* nitrogen-fixing symbiosis may be extended to noniegume crops. No doubt this will occur in time but it is becoming apparent that genes both in the plant and in the bacteria are critical to the formation of a symbiotic nitrogen-fixing system. This suggests that nonlegumes may need to have their genetic makeup augmented before they could form a symbolic relationship with *Rhizobium.*

One of the most significant breakthroughs would be the production of synthetic nitrogen fertilizer by a zero direct energy input process. Such a system would involve the catalytic conversion of nitrogen and oxygen to, for example, nitrate in an aqueous environment. In simple terms, a catalyst would be inserted into an irrigation stream and air pumped over this catalyst which would convert the air to nitrate. Such a process is theoretically possible on an thermodynamic basis although no chemistry is yet for the conversion. Clearly, significant additional exploratory chemical work on nitrogen fixation should focus on this aspect rather than continuing to explore reductive systems which became less attractive after the large increase in energy costs in the early 1970's.

The transfer of the genes for nitrogen fixation to crop plants including cereals and legumes was described earlier. There are significant technical problems yet to be solved. Success will be demonstrated in the laboratory within the next decade but it will probably be an additional decade or decades before such a transfer will result in an economically useful crop plant. Clearly, work in this area should be pursued but the expectations should be placed in a proper time perspective.

Finally, let me describe an even more futuristic solution—one that undoubtedly will occur within the next century. A synthetic gene will be made that codes for an enzyme with ideal N_2-fixing characteristics. This gene will code for a small, stable, high turnover, absolute substrate specificity, zero direct energy input nitrogen-fixing enzyme with appropriate regulation by fixed nitrogen. Such an accomplishment will clearly demonstrate man's superior capability over that of nature's stage of evolution. One would hope that such a system would code for a nitrogen-fixing enzyme with an oxidative rather than a reductive reaction, in other words, zero direct energy input.

Summary

I have given you an overview of the need for fixed nitrogen for crop production, the dynamic status of nitrogen fixation research, the many opportunities to improve especially the biological system, and the multiple solutions that may result from the development of technologies based on this knowledge. Some technologies will produce modest impact while others may completely alter the nitrogen input business. Both chemically and biologically based technologies have been described and in a area as quantitatively significant as nitrogen is, multiple solutions are not only feasible but appropriate. Both the chemical and biological basis of N_2 fixation is one of the major unsolved problems of science. The challenge is large and the opportunity for results of that science are not only fantastic but essential to feed the ever-increasing human population of the world. Thank you. (Applause)

FIGURE 1

SCHEMATIC FOR GENETIC ENGINEERING OF N_2 FIXATION

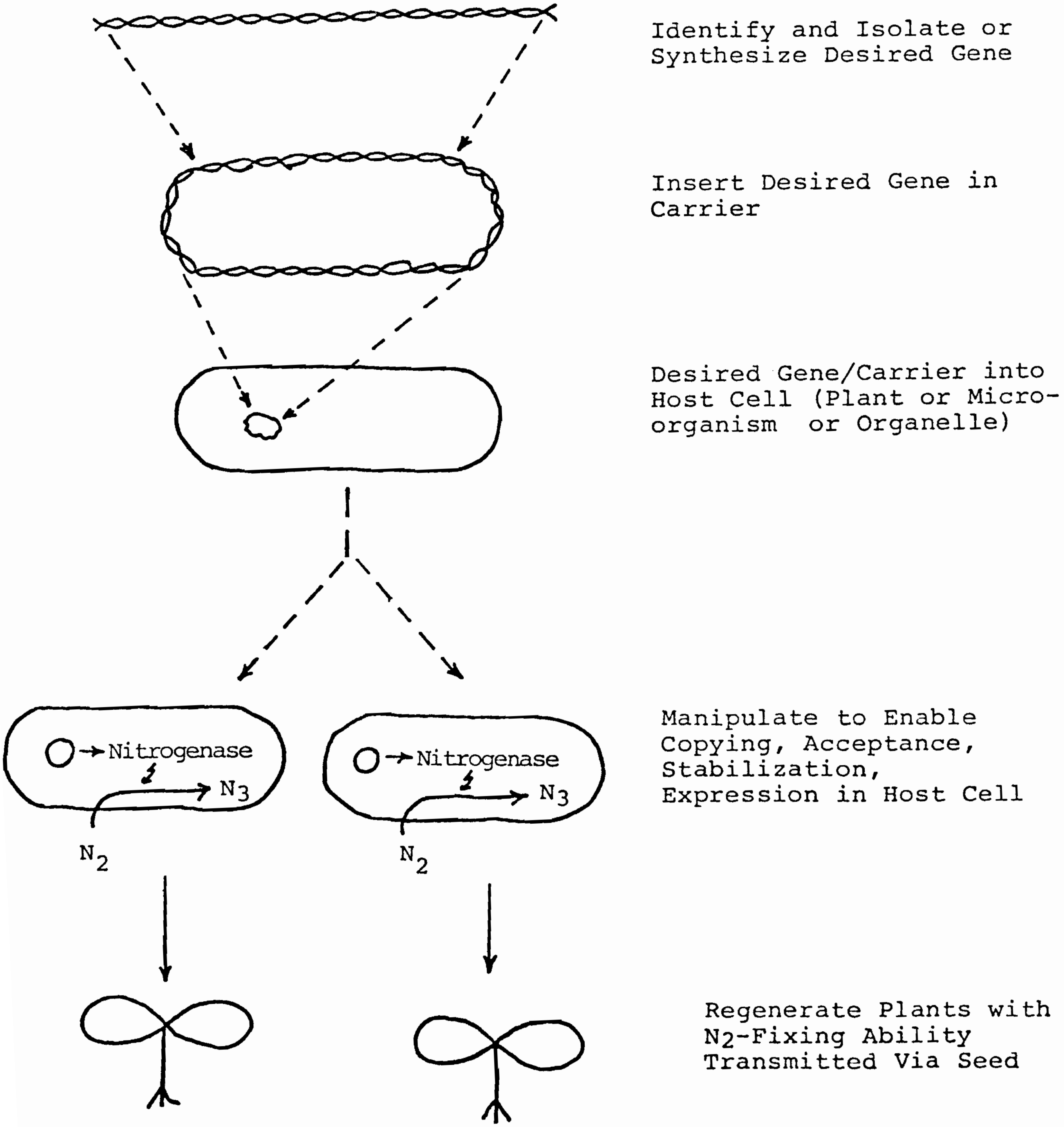


TABLE 1

RESEARCH ADVANCES IN NITROGEN INPUT RESEARCH

	MATHEMATICS & ENGINEERING	CHEMISTRY	BIOCHEMISTRY	GENETICS	BIOLOGY	AGRONOMY
1970		Molybdo-Thio Reductant	Mo-Fe Active Site			
			Crystallization of Mo-Fe Protein			
			C_2H_2-C_2H_4 Assay			
1965		M(N_2) Complexes	Substrate Versatility			Associative Symbioses
			ATP-Requirement of Nitrogenase			
	1000+ Ton/Day N_2 Fixation Plants	RMgBr + $(C_5H_5)_2$ $TiCl_2$				
						High-Lysine Corn
1960		Nitrification Inhibitor	Nitrogenase Extracted			

TABLE 1 (CONT'D.)

RESEARCH ADVANCES IN NITROGEN INPUT RESEARCH

	MATHEMATICS & ENGINEERING	CHEMISTRY	BIOCHEMISTRY	GENETICS	BIOLOGY	AGRONOMY
1985				*nif* Transferred to Yeast		
				Sequences of *nif* Structural Genes of Several Organisms	*Azospirillum* Inoculation Fixes N_2 and Enhances Ion Uptake	
		EXAFS of Nitrogenase		*nif* in Plasmid in *Rhizobium*		*Azospirillum* Increases Yield in Field
1980	*Rhizobium*-Cereal Lagmuir Adsorption Isotherm			H_2 Uptake Plasmid	Ureides & Asparagine Assimilate	
				Mapping 14 *nif* Genes	CH_2O Cost for Legume N_2 Fixation	*Azolla*-*Anabaena* Rediscovery
		$N_2 \xrightarrow[TiO_2]{h\nu} NH_3$			H_2 Uptake Hydrogenase	"A" Value Method
			N_2H_2 Intermediate	Cloning *nif* Genes	Plant Lectin Rhizobia Interaction	
1975		$M(N_2)_2 \rightarrow N_2H_4$ or NH_3	Fe-Mo Cofactor		N_2 Fixation by Cultured Rhizobia	Soybean Foliar Fertilization
				nif Regulation Glutamine Synthetase		Photosynthate Limitation for Legume N_2 Fixation
			Fe-Protein-ATP-e Mo-Fe Protein Interaction	*nif* Transfer		

TABLE 2

PAST, CURRENT AND POSSIBLE FUTURE ALTERNATE TECHNOLOGIES

Past to Current

• Legumes as Green Manures	Biblical Times
• Recycling of N-Containing Wastes	" "
• Mined Nitrates as N Fertilizers	19th Century
• Inoculation of Legumes with Rhizobium	4th Quarter 19th Century
• Synthetic Nitrogen Fertilizer	1st Quarter 20th Century
• Nitrogen-Responsive Crops	2nd & 3rd Quarter 20th Centur
• Multiple-Cropping and Inter-Cropping of Legumes and Nonlegume Crops	3rd & 4th Quarter 20 Century
• High Efficiency of Fixed N Use by Crops, e.g., Slow Release, Cultivars, Nitrogen Transformation Effectors	4th Quarter 20th Century
• Foliar Fertilization, e.g., NPKS	4th Quarter 20th Century

Highly Probable Short-Term Impact Technologies

- Highly Effective *Rhizobium* Inoculation Technology
- Nitrogen Fertilizer Responsive Legumes--Chemical or Genetic Solutions
- Increased Harvest Index for Nitrogen
- *Rhizobium* with H_2 Uptake Gene
- *Azospirillum* Inoculation

Less Probable Mid-Term Impact Technologies

- Improved *Azolla-Anabaena* Symbiosis for Paddy Rice
- Promiscuous *Rhizobium* to Simplify Inoculation
- Symbioses Insensitive to Fixed N Including Derepressed Microsymbionts

More Speculative Long-Term Impact Technologies

- Increased Photosynthate Available to Nodule and/or Improved Efficiency of Nodule
- Non-*Rhizobium* N_2-Fixing Associations for Nonlegume Crops
- Mycorrhizal Associations Containing Endosymbiotic N_2 Fixers
- N_2-Fixing Infective but Nonpathogenic Pathogens, e.g., *Agrobacterium*, *Erwinia*
- Naturally Occurring but Undiscovered N_2-Fixing Systems, e.g., *Rhizobium-Trema*
- Synthetic Nitrogen Fertilizers by Zero-Direct Energy Input Process
- Extension of Rhizobial N_2-Fixing Symbioses to Nonlegume Crops
- Transfer of Genetic Information for N_2 Fixation and Associated Genes to Crop Plants Including Legumes
- Synthetic Gene that Codes for Small, Stable (Oxygen and Temperature), High Turnover, Absolute Substrate Specificity (No H_2 Production), Zero-Direct Energy Requiring (No ATP) N_2 Fixing Enzyme with Appropriate Repression by Fixed N

MODERATOR SHELDRICK: Thank you, Dr. Hardy, for that overwelming presentation. I had no idea there were so many operations and so many considerations to be looked at in this subject. I did explain to Dr. Hardy that we are basically practical people from the plant level and it may be difficult for us to raise some questions on the level of his presentations. He has to leave shortly, therefore, I will appreciate any questions you may have for Dr. Hardy.

QUESTION—MODERATOR SHELDRICK: Sometime ago I went to a lecture in Washington, at The Academy of Sciences, where Dr. Dobenheimer was giving a talk about some of her work in Brazil. I got the feeling from her lecture, in an elementary part of way, that there is a limit to the amount of nitrogen that can be fixed and that this limit may be beyond the economic limit that you could apply directly to the soil. There comes a point of nitrogen concentration in the soil that kills this activity. A well informed soil chemist with me at the time did not deny this.

Sorry, due to microphone difficulties, we could not clearly read the answer.

QUESTION—RUSSEL JAMES: Maybe, I do not understand Dr. Hardy very well. I am thinking about what "Raw Material" we start with? I wonder if there are processes which take a material like hydrocarbon or methanol, and with enzymes, can produce Nitrogen Fertilizer?

ANSWER—DR. HARDY: The material of most nitrogen fixing bacteria is a carbon-hydrate material. There is no reason that any material could not, be coupled to a nitrogen fixing system. You can take a bacteria which would consume methonol or would consume hydrocarbon and then you would put in that bacteria the hydrogen gene. I would give you fairly high assurances today of being able to do this. The economics of doing that are not such that would appeal to me. We obviously are interested in making some of our chemical feed stock by fermentation. Prior to 1940, in fact, almost all of the chemical feed stock did come via fermentation, acetones, butanols and so on. Clearly, these do represent interesting opportunities. Ammonia, as a product, with that huge inefficiency of nitrogenate, I do not think represents an attractive fermentation to go.

MODERATOR SHELDRICK: Dr. Hardy we thank you very much for your most interesting discussion. (Applause)

MODERATOR SHELDRICK: Our next Speaker needs no introduction to people in the ammonia field. Russ James is a well known international Chemical Engineer in this business. He is certainly known to us at "World Bank" because he has participated in many of our international projects. Russ has a degree, in Chemical Engineering from Yale University. For 15 years he worked in the chemical industry. since 1964 he has been running James Chemical Engineering, Inc. He has been involved in over thirty major ammonia/urea projects. He has very closely worked with U.S.I.D., World Bank and many other companies in many parts of the world. I do not think we could have anyone more qualified today to tell us about what is going on in this "Subject of Ammonia and Energy". Russ, please (Applause)

How Ammonia Processes May Change To Suit The Energy Available

G. Russel James

Ammonia manufacture in the U.S. in the past thirty years has been based on availability of large quantities of natural gas at low price. When the current design of 1000 STD plants was developed, it was possible to build a plant that could sell ammonia profitably at $20 per short ton. That was only sixteen years ago.

Since then, energy prices have changed dramatically. Figure 1 shows what has happened to the energy costs for oil, gas and coal since the early 70's. Oil price has increased by seven times, coal by three times and gas by ten times. Predictions are for an increase in 1990 of forty times for gas, fourteen times for oil and six times for coal.

Energy cost per short ton of ammonia in 1990, if the curves in Figure 1 hold, will be:

Gas	$380
Oil	$414
Coal	$ 74

At the same time, capital costs for ammonia plants will increase. Our predictions for erected costs of 1000 STD plants versus the same time period are given as:

	Erected Cost — $MM		
	1973	1982	1990
Gas	25	98	210
Oil	31	123	252
Coal	50	200	420

These costs are approximate, but they allow us to produce (in Figure 2) the feed plus capital-associated costs for the three energy sources. As can be seen, even with the higher capital-associated costs in coal and oil plants, the sum of feed plus capital costs for ammonia from gas is expected to move from the low side to the high side between 1975 and 1985.

The curves in Figure 2 ignore differences in labor and power which will relatively increase manufacturing costs for oil and particularly coal considerably. They also are based on feed energy consumptions of 31.5, 34.2 and 40.5 MM BTU.ST for gas, oil and coal respectively.

Figure 2 does illustrate the problem, i.e., energy costs for gas are predicted to rise at a higher rate than those for other energy sources. A breakdown point for gas cost versus coal in 1990 is some $9.00 at 26 MM BTU/ST and $7.50 at 31.5 MM BTU/ST

The difference of 5.5 MM BTU/ST is the subject of this review. Realizing such an energy reduction may mean the difference between an operable gas-based plant and one that must be shut down.

Tabulations have been made of possible process changes that can be made in order to achieve the increased efficiency. The changes are shown in the figures as follows:

Figure 3A—Reforming
Figure 3B—CO_2 Removal & Final Purification
Figure 3C—Compression & Purge Gas Recovery
Figure 3D—Synthesis & Refrigeration

Possibilities are generally listed in descending order of current status of process, equipment and engineering realization. Costs given are, of course, not specific, but for illustration only.

Notes of (N) and (R) under applicatins indicate either new plant (N) or retrofit (R) as suggested application.

Possible changes listed in Figures 3A, B, C and D are briefly discussed below by section:

Figure 3A — Reforming

Combustion air preheat is accepted and proved with almost all reformers now on the market. Retrofit is much more complicated, but given adequate time will pay out in many cases.

Process air preheat has been going up steadily. Retrofit is relatively easy, but may not allow use of an efficient source of heat.

Higher superheat and/or reheat of steam in new plants is common. Pressure of steam is also increasing toward 1900 psig. Efficiency in steam drives can be thus markedly increased; however, changes in existing plants are difficult and limited.

Reformer pressure of 600 psig have long been possible. Until the current round of energy hikes, payout has been limited. A new round of pressure increase may be expected.

Inertia in the industry seems to limit S/G ratio to three. A reduction to 2.5 seems to be reasonable, but may not happen immediately.

Use of high level heat exit the secondary and from reformer flue gas to supply part of the reformer duty can bring marked fuel reductions. Practical experience with workable designs is lacking.

Removal of nitrogen by low temperature or other means later in the process will allow addition of higher than 3:1 air ratio to the secondary reformer. Alternatively, availability of an oxygen stream would allow its introduction into the secondary. In either case, raising of the total oxygen to the secondary will increase reforming efficiency although somewhat, at the expense of the CO conversion and CO_2 removal systems.

Figure 3B — CO_2 Removal

Efficiency of MEA or carbonate systems may be improved by adding equipment, changing solution strengths, adding activators or inhibitors or licensing a different process. Provided the heat source can be reduced or used elsewhere, this change is probably worthwhile in existing plants. New plants are being designed to use minimum heat.

Switch from reaction (MEA, carbonate) to physical absorption systems essentially eliminates the CO_2 removal heat requirement. There may be other problems if full recovery of CO_2 is required. This change is more suited to a new plant where an aqua system or absorption refrigeration can use the liberated heat to advantage.

Some old plants can gain capacity and operating efficiency by adding a stage of CO conversion and CO_2 removal. The result is less hydrogen reacted in the methanator and lower inerts in the loop for a small increase in production with the same gas throughput.

Figure 3B — Final Purification

Absorbent for H_2O, NH_3, CO and N_2 removal is covered further under Figure 3B. The absorbent system may be on the makeup gas or on the gas entering the converter, depending upon whether it is necessary to purify just the makeup or the gases after ammonia removal.

Selective oxidation of CO: It is understood that there are several plants now operating using oxygen or air for selective oxidation of CO. over a catalyst at low temperatures. The result of this step is a reduced loss of hydrogen in the methanator, reduced inerts in makeup gas and corresponding increase in capacity.

Cryogenic purification: Drying and subjecting the makeup gas to a low temperature step after methanation can remove impurities such as methane, argon and some nitrogen. The resulting process has very pure makeup gas and can tolerate additional air to the secondary reformer. As covered under 3A above, another result is an increase in reformer efficiency.

Figure 3C — Compression & Purge Gas Recovery

Centrifugal compressors were proved more economical when the large (600-1000 TPD) plants were first introduced. Energy costs were less then, and now the differential cost favoring centrifugals is eroding. Reciprocating compressors may again come back, particularly in small plants.

Gas turbine drive for the process air compressor using tail gas as primary reformer burner air is a known application that saves energy. In large complexes it is possible that tail gas to a boiler or other furnace might make drive of other compressors economical.

Superheat of steam gives almost direct conversion of heat to power.

Purge gas recovery systems may not be needed in a new, well-designed plant. They seem to find application in retrofits and provide a good payout.

Figure 3D — Synthesis & Refrigeration

Low pressure drop converters pay out in higher conversion and lower recirculation costs. Several are available. They are usually limited to new plants, although installation of a parallel converter can do the same thing in existing plants.

Lower pressure loops may pay out if ammonia recovery is via aqua under which there is no ammonia in the recycle stream and very low level refrigeration is not required.

Steam generation has been used more in European plants. It may be expected in the U.S. as energy costs rise.

LT catalyst for ammonia is still a dream which would allow low pressure operation at higher conversions.

Ammonia Recovery

Use of absorbents to remove water and carbon oxides from makeup gas and recycle gas before gases enter the converter permits removal of ammonia to low levels. The result is higher conversion per pass on synthesis catalyst and less pressure drop through refrigeration equipment.

In an existing system, addition of an absorbent on the makeup gas stream eliminates the need of a final scrub with ammonia before entering the synthesis catalyst. Makeup gas therefore need not be admitted until after ammonia removal, resulting in higher ammonia partial pressure and higher removal at the same refrigeration temperature.

Aqua systems and absorption refrigeration provide good sinks for low level heat available from other sources as plant efficiencies increase. Absorption refrigeration might replace a compression refrigeration system, or part of it, if CO_2 removal heat became available from a process change in that area.

There are possibilities for increased efficiency other than those involving process changes. Listed in Figure 4, they are briefly discussed below:

Figure 4A — Operating Considerations

Debottlenecking may result in capacity increase of ten percent for relatively less increase in energy. The result is an increased efficiency and a decrease in capital-associated costs per ton.

Onstream time analysis and improvement may result in more production for the same amount of energy. Shutdown and startup or low capacity operation directly increases energy costs per ton.

Figure 4B — Design Considerations

Improving or refining process may result in an increase of ancillaries, instruments, piping, etc. to a point where capital costs offset decreases in energy consumption.

Erection time and starting time play an important role in the economic outcome of an installation. Complicated or new equipment may upset the payout if the plant does not start up easily and on time.

Figure 4C — Process Combinations

An ammonia plant and a methanol plant may be combined to allow stoichiometric feed to the methanol plant and economy of large-scale operation to ammonia.

An ammonia plant and a urea plant may be effectively combined so that the urea plant becomes the CO_2 removal system for ammonia. This system has been designed and built on a small scale. Independence of operation may be sacrificed for efficiency; however, a saving of some ten percent in energy and capital cost is predicted by advocates of this combination.

Conclusion

Natural-gas-based plants can reduce consumption to perhaps 26 MM BTU per short ton of ammonia. Such a reduction in energy usage will be necessary in order for U.S. gas-based plants to compete with coal plants and with ammonia plants based on cheaper foreign sources of natural gas.

Developments in both oil- and coal-based plants are not covered here. They will occur, particularly in coal processes where production at relatively high level may be just in its infancy. Even so, coal plants will be capital-intensive, ponderous monsters requiring much more labor and maintenance per unit of production than the current gas-based units.

Credits

Much of the data contained herein was assembled by my colleagues: Dr. K. T. Lee, K. J. Stokes and T. E. Gilbert. Their assistance made this review possible. Also, reference to the literature below provided valuable information.

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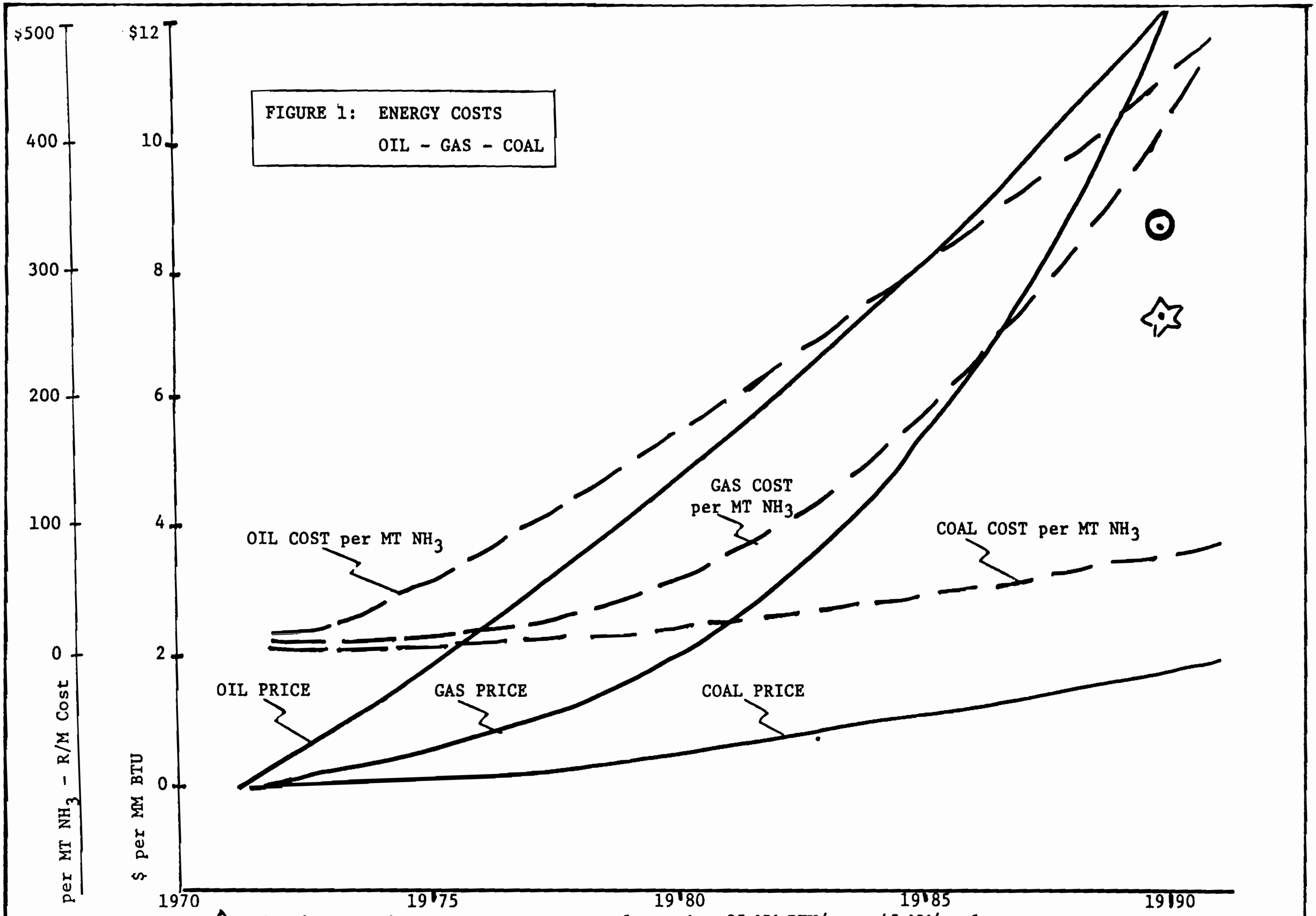
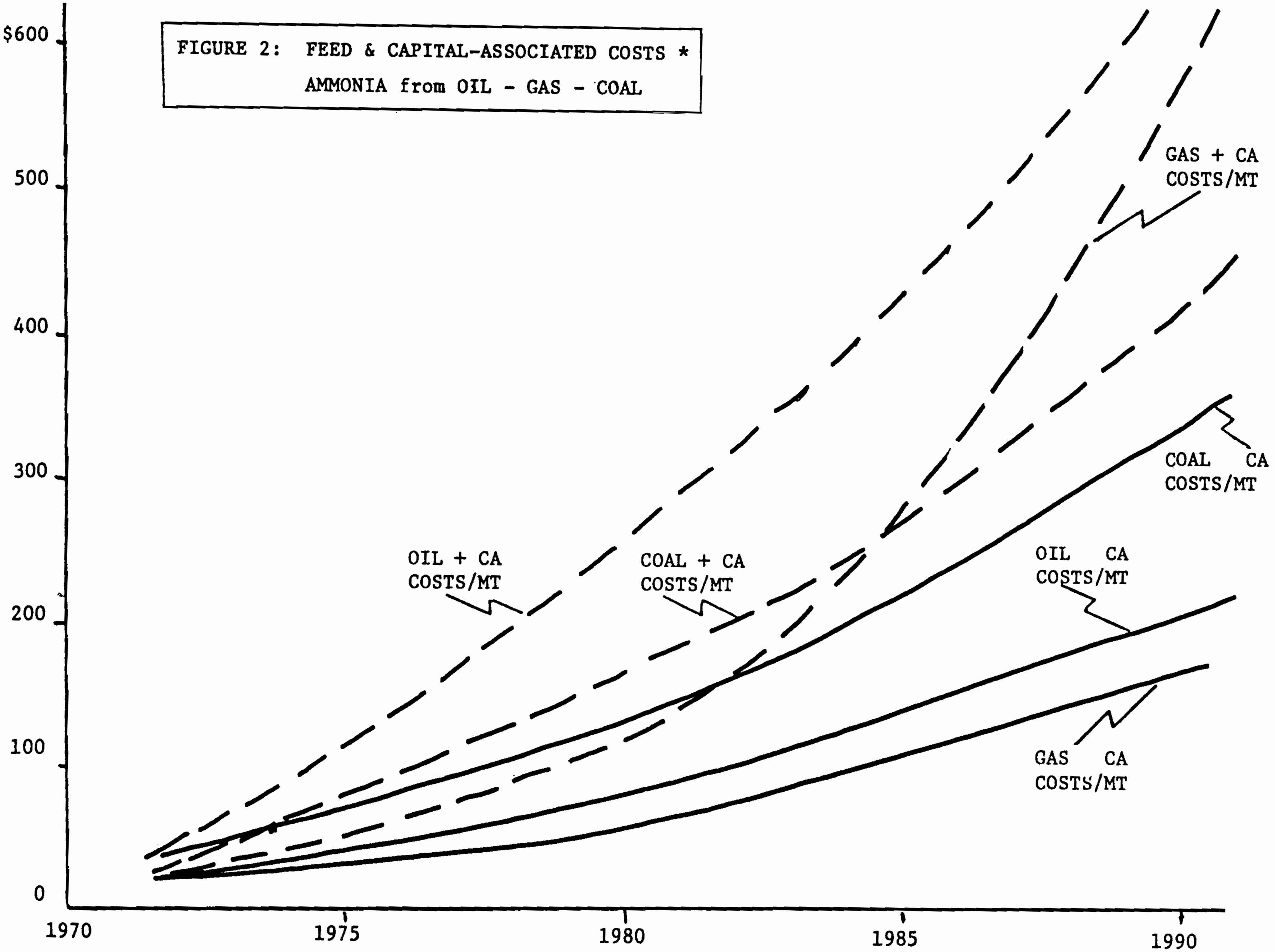


FIGURE 1: ENERGY COSTS
OIL - GAS - COAL

☆ Breakeven point on gas cost vs. coal - using 35 MM BTU/gas, 45 MM/coal.

⊙ Breakeven point on gas cost vs. coal - using 29 MM BTU/gas, 44 MM/coal.

FIGURE 2: FEED & CAPITAL-ASSOCIATED COSTS *
AMMONIA from OIL - GAS - COAL



* Capital-associated costs - 25% per year for depreciation, taxes, maintenance and insurance.

ITEM	APPLICATION(1)	SAVING MM BTU/ST	ESTIMATED COST - $MM	COMMENTS
Combustion Air Preheat	N + R to 500°F	0.7	1.0 (N)	Costs for (R) higher.
Process Air Preheat & Higher Feed Preheat	N + R to 1500°F	0.6	0.5	Costs for (R) higher.
Superheat and/or Reheat Steam	N + R	1.0	1.5	Costs for (R) higher and changes limited.
Increase Reformer Pressure	N	*	*	Saves compression and raises partial pressure of steam.
Lower Steam Ratio	N + R	*	*	Combine with other changes, minimum ratio 2.5
Use High Level Heat for Reforming, Secondary Exit and Stack	N	*	*	Depends on heat used but available heat is perhaps 4.0 MM BTU/ST.
Use more O_2 in Secondary Reforming	N + R	*	*	Depends on purification and purge gas treatment as well as possibility of O_2 available. Results in decrease in primary heat load but increase in CO_2 removal duty.

FIGURE 3 A: POSSIBLE PROCESS CHANGES REFORMING

* Figures not available.

(1) N = New plant
R = Retrofit

ITEM	APPLICATION	SAVING MM BTU/ST	ESTIMATED COST, 1000 STD	COMMENTS
CO_2 REMOVAL				
- Improve efficiency of existing system	N + R	1 to 3	*	May be largely license fee changes & operating changes.
- Change from reaction-type to physical-type absorption	N + R	1 to 3	*	Costs for (R) higher.
- Use low level heat for: -absorption refrigeration -feed stream saturation -power	N + R	→	→	May be combined with other heat-saving changes.
- Use two-stage CO_2 removal	R		*	Largely for capacity increase.
FINAL PURIFICATION				
- Absorbent for H_2O, NH_3, CO and N_2 removal	N + R	0.4	0.5	Costs different for (R) and may result in capacity increase.
- Selective oxidation of CO	N + R	*	*	Has been discussed for many years.
- Cryogenic purification	N	*	*	

FIGURE 3 B: POSSIBLE PROCESS CHANGES CO_2 REMOVAL & FINAL PURIFICATION

* Figures not available.

ITEM	APPLICATION	SAVING MM BTU/ST	ESTIMATED COST, 1000 STD	COMMENTS
COMPRESSION				
- Centrifugal vs. reciprocal	N	1.0	*	- △ cost on reciprocating vs. centrifigal shrinking and power costs rising. -Possibility of power recovery with recips as with centrifugals.
- Gas turbine drives	N	1.0	2.0	-Known application. Could expand in larger plant where boilers or power generation combination possible.
- Superheat steam or reheat steam	N + R	*	*	-Increase of turbine steam temperature may be the best application for moderate to high level heat where turbines are able to take it.
PURGE GAS RECOVERY				
- Low temperature system	N + R	0.5	1.5	
- Semi-permeable membrane	N + R	0.5	1.5	All probably more applicable to (R).
- Absorbent system	N + R	0.5	2.0	

FIGURE 3 C: POSSIBLE PROCESS CHANGES
COMPRESSION & PURGE GAS RECOVERY

* Figures not available.

ITEM	APPLICATION	SAVING MM BTU/ST	ESTIMATED COST, 1000 STD	COMMENTS
SYNTHESIS				
- Low Δ P converter	N	0.6	0.5	
- Pressure change	N	*	*	May fit well with aqua system.
- Steam generation	N	1.0	*	
- LT catalyst	wait	*	*	
NH_3 RECOVERY				
- Combination of absorbant with refrigeration or other	N + R	0.4	0.4	May result in capacity & efficiency increase.
- Aqua system	N	*	*	Good combination with available low level heat.
- Absorption refrigeration	N + R	*	*	Good combination with available low level heat.

FIGURE 3 D: POSSIBLE PROCESS CHANGES SYNTHESIS & REFRIGERATION

* Figures not available.

ITEM	APPLICATION	SAVING MM BTU/ST	ESTIMATED COST, 1000 STD	COMMENTS
A. OPERATING CONSIDERATIONS				
- Increase capacity 10%	N + R	to 3.0	minimum	
- Increase onstream time	N + R	to 2.0	minimum	
B. DESIGN CONSIDERATIONS				
- Cost of ancillaries - piping, concrete, steel instruments, offsites	N	*	*	
- Erection time	N	*	*	
- Startup time	N	*	*	
C. PROCESS COMBINATIONS				
- Methanol/ammonia	N	*	*	
- Urea/ammonia	N	3.0	10% saving	Limited to urea combination operation.

FIGURE 4: OTHER POSSIBILITIES

* Figures not available.

MODERATOR SHELDRICK: We thank you Russ. Your discussion was very comprehensive. (Applause) Questions please:

QUESTION—JOHN KRONSEDER - FLUOR CORPORATION: With the projections that they have made of Ammonia are you thinking of retrofitting to get these energy improvements rather than new plants?

RUSS JAMES: The new plant will necessarily adapt themselves and they are already. I think in this country there is a large effort towards increasing the efficiency of plants. So, there will be an effort in the retrofitting area.

QUESTION—JOHN KRONSEDER: The new plants are getting towards the 26 million BTU's per ton. The new C.I.L. plant in Canada is projected for that rate.

RUSS JAMES: That is correct. It will be difficult for an old plant to get that far now without spending a lot of money.

MODERATOR SHELDRICK: On this particular subject I am a little confused myself, at the moment, between these engineering figures of 26 and 27 thousand BTU's and I look at the T.F.I. energy survey it says the average energy consumption per ton of ammonia in the U.S.A. is well over 40,000 BTU's. Where is all of this energy going? Are we really misleading the people to quote figures of 27 thousand BTU's? Perhaps the figures are given under equilibrium conditions. However, there is a very big difference between actual figures and quoted figures. Would anyone else like to comment on that.

RUSS JAMES: That is right. That is what happens.

JOHN KRONSEDER: Russ how many plants in the U.S. would you say pre-heat their gas going into the reformer?

RUSS JAMES: The combustion air? How about 20? I am just guessing. I know that most of the mid-recent plants did not use pre-heaters. The new plants are all using air preheaters. Some of the old plants are putting air pre-heaters in, based on the new gas contracts. It pays off directly. It is a very easy change.

MODERATOR SHELDRICK: Are there any further questions? Thank you Russ for giving us a very comprehensive review "How Ammonia Processes May Change To Suit The Energy Available". This information is going to be a very useful reference into the future. (Applause)

MODERATOR SHELDRICK: At our several meetings in Baltimore, this past March and July, our Board of Directors thoroughly discussed possible discussions for our five Session, 31st Annual Meeting, today, Wednesday and Thursday. There was a great deal of interest shown by our Directors to cover the subject "Granulation Compounds Incorporating Urea." I stated that I thought one of the most experienced regions in the world was India who have built and are operating a number of these plants. Our Chairman commissioned me to invite the speaker I thought could best handle this subject.

I am very happy that Mr. T. Singh, Vice President (Technical) at Zuar Agro Chemicals, Goa, India, answered my call agreeing to discuss "Urea Based Granular N.P.K. Fertilizers - experience at Zuari Agro Chemicals Ltd. Plant". Mr. Singh is closely associated with the operations of this Company. He possesses a M.S.E. (Chemical Engineering) from University of Michigan, Ann Arbor (U.S.A.) in 1959. He has 20 years experience with the Fertilizer Industry in India. His plant at Nagar produces ammonia, urea, urea based phosphate fertilizer. I should add that perhaps many of you are unaware that India now has one of the largest fertilizer industries in the world. For anyone who has attended the F.A.I. meetings has seen, perhaps, 700 very experienced and well-informed participants, they know that India is really now coming very much to the forefront in much of our "technical know-how". Mr. Singh, please. (Applause)

Urea-Based Granular N.P.K. Fertilizers Experience at Zuari Agro. Chemicals Ltd. Goa, India

T. Singh

Abstract

In this article an effort has been made to highlight the problems experienced during the production of urea-based high analysis grades at Zuari Agro Chemicals. Steps taken to tackle these problems have also been clearly mentioned. The article covers major aspects including production, quality control, storage as well as pollution control.

Introduction

The technique of granulation of compound fertilizers has been known for a long time. Granular product is homogeneous and results in better distribution of nutrients to the plant. In addition it has good physical and storage properties.

The process of granulation and the properties of product depend upon many factors like type of raw materials, mode of feeding of raw materials, their size distribution, type of granulation equipment i.e. pan granulator, blunger, rotary drum granulator or a combination of these, operating conditions, etc.

Various methods for producing granular compound fertilizers of varying concentrations have been described in literature based on both pilot plant study and actual plant data. They include water granulation, steam granulation or combination of both (water and steam); wet kneading process in which a part or all of the raw materials are made in the form of slurry and sprayed over a rolling bed of recycle fines; neutralization process in which a slurry is obtained by reaction of ammonia with phosphoric acid, sulphuric acid, nitric acid or a combination of these acids which is then fed into a granulating system; and a melt granulating process which involves heating a mixture of urea, ammonia phosphate and potassium chloride to obtain a fluid melted mixture which is either sprayed over a rolling bed of recycle fines in a granulator or is prilled in a cooling medium. A new technique for the production of granular compound fertilizers by spraying the melt of raw materials in a stationary fluidized-dryer-granulator has also been developed.

Need for Urea-based Fertilizers

In earlier days of development of complex fertilizers, low analysis formulation were produced using Ammonium sulfate and other such sources of nitrogen. However, the use of Urea as a source of nitrogen made it possible to produce high analysis grades. The popularity of high analysis balanced NP and NPK fertilizers increased rapidly because higher total plant food content can be achieved. Considerations such as soil characteristics, climatic conditions, cropping pattern, etc. determine the type of formulations required. In most cases, the required $N:P_2O_5:K_2O$ ratios in NP and NPK grades are preferably 1:1 or 1:1:1. Based on market demand, the high analysis grades required are 28-28-0; 19-19-19; 26-13-13, etc. For the production of such high-nitrogen balanced fertilizers, urea is required. Any other source of nitrogen such as ammonium sulfate (21% N) or ammonium nitrate (35% N) cannot produce grades like 28-28-0, 19-19-19, 26-13-13, etc. For example, in the case of 1:1 formulation, ammoniation of merchant grade phosphoric acid to a mole ration of 1.8 would 26-26-0 if ammonium nitrate is used and 28.5:28.5:0 if urea is used. For a product of 1:1:1 formulation, it is possible to make 17-17-17 with ammonium nitrate, 19-19-19 with urea compared with 14-14-14 obtainable with ammonium sulfate. For 2:1:1 formulation the grades obtainable are 22-11-11 with ammonium nitrate, 26-13-13 with urea and only 16-8-8 with ammonium sulfate.

Some of the advantages in the production of high-analysis urea-based NPK fertilizers are:—

i) Savings in distribution cost.

ii) Lower cost of production because urea is a cheaper source of nitrogen as compared to ammonium sulfate or nitrate.

iii) Urea is generally available at site for most of the compound fertilizer manufacturers.

iv) In countries like India where no natural sulfur is available, use of Urea instead of ammonium sulfate in the production of complex fertilizers results in saving of precious foreign exchange.

v) It is safer to use Urea instead of ammonium nitrate in view of possibility of formation of explosive mixtures due to decomposition of the latter.

vi) The formulations produced by the use of ammonium nitrate have a lower critical relative humidity as compared to those produced by the use of urea. This affects the storage and handling properties of the material.

vii) The interaction between ammonium nitrate and KCL continues in the bulk storage. This causes caking and other related problems in handling operation which are minimized by the use of urea.

viii) The product of ammonium nitrate should be dried to 0.2 - 0.5% for easy subsequent operations whereas the product of urea grades need not be dried to lower than 1.0% moisture.

ix) Handling of bulk ammonium nitrate is considerably more difficult as compared to handling of bulk urea due to difference in their critical relative humidities.

x) The fines and oversize inevitably produced in a Urea plant can be consumed in urea-based formulations. This considerably helps in the storage properties of bulk urea in addition to solving the problem of disposal of fines and oversize.

However, every rose has a thorn and production of high nitrogen grades is no exception. The problems encountered in their production are:

1) Over granulation with lumps and balls due to high solubility of urea and ammonium nitrate.

2) Low drying rate and low melting point especially of urea based grades needs high retention time in dryer and limits the allowable drying temperature.

3) Handling of fertilizer containing urea or ammonium nitrate poses difficult problems of blockage of equipment due to their sticky nature if proper drying is not achieved.

4) Foaming in preneutralizer due to higher urea concentration in scrubber liquor adversely affecting the pumping rate of a slurry which in turn affects production.

Technology of Urea-based Fertilizers

Urea is used in the formulation of granulated compound fertilizers in one of the following ways:—

1) Urea — superphosphate-based: using ordinary superphosphate or triple superphosphate along with muriate of potash.

2) Urea — ammonium phosphate-based: either using solid MAP/DAP or ammoniation of wet process phosphoric acid.

At Zuari Agro Chemicals, we manufacture urea-ammonium phosphate-based fertilizers using conventional neutralization process. The plant was commissioned in 1976. Process description along with our experience of the production of such high analysis grades is given below.

Process Description — CUM-ZAC Experience

Zuari NPK plant has been designed and built by MTC/TEC, Japan, to produce 535 metric tons per day of 28-28-0. However, the plant is equipped for the production of other grades like 19-19-19, 14-35-14, 18-46-0, etc.

Neutralization Section

Merchant grade imported phosphoric acid is neutralized in a preneutralizer (PN) with gaseous ammonia. The mole ratio of ammonium phosphate slurry is adjusted to 1.40-1.45 in the PN as at this range it has maximum fluidity at all the operating temperatures (Ref. Fig. 1). It can be seen from Fig. 1 that at higher temperature, solubility of ammonium phosphate increases. Although it is possible to obtain slurry of high concentration but it tends to block the spray nozzles faster than slurry having 80 - 82% solids obtained at a termperature of 115°-118°C. This condition is considered optimum from operational point of view. The slurry is pumped to ammoniator granulator (AG) where further ammoniation is carried out to a mole ratio of 1.68 to 1.7 for 28-28-0 and 19-19-19 and to a mole ratio of 1.8-1.85 for 14-35-14 and 18-46-0. The extent of ammoniation in AG depends upon the requirement of ammoniacal nitrogen in the final product. Since ammonia is the cheapest form of nitrogen it would be desirable to maximise its use in AG for high analysis product. Another advantage of usage of more ammonia in AG is reduction in dryer load due to more evaporation of water in AG as a result of additional heat of reaction. However, it has been observed that ammonia loss in fume scrubber increases with higher ammoniation in AG. For example, ammonia loss through fume scrubber could be as high as 1500 ppm during the production of 18-46-0 grade as compared to 500 ppm for 19-19-19.

Since the phosphoric acid used by us contains only 1-2% suspended solids and has a very low level of other inpurities the problems faced in some other plants due to acid quality have not been faced by us. The only major problems experienced in the operation of PN has been foaming caused by excessive urea concentration in scrubber liquor (above 5%). This problem is more prominent during the production of 28-28-0 which needs large quantity of urea. This problem has been tackled by us to some extent by minimising dust generation in the dryers and a close watch on the efficiency of dust cyclones. Antifoamer is also used in PN. It has been our experience that excessive foaming reduces the rate of slurry pumping consequently reducing production. Low pumping rate is caused by the necessity to keep low liquid level in PN to avoid overflow due to foaming which would not only make operation around PN difficult and unsafe but also create a serious pollution problem.

Ammoniator — Granulator Section

TVA type drum granulator is used in our plant. In the AG the recycle fines, urea and potash is added. Slurry is sprayed over the rolling mass. Ammoniation is carried out by injection of vapour ammonia at pressure of 3.5 - 4.0 Kg/cm2g through nozzles which dip into the rolling mass. The heat of reaction in AG evaporates part of free water of the slurry depending upon the extent of ammoniation and also increases the temperature of material. The rate of recycle material is adjusted to obtain a moisture content of A.G. outlet material 3.0 -3.5% and temperature about 60°C. As per our experience these conditions result in good granulation having 40-60% product size granules. Since urea based grades have higher solubilities (Fig. 2) granulation is very sensitive to liquid phase. Even a slight variation in slurry condition, slurry flow rate, or the flow rate of solids disturbs granulation resulting in the formation of excessive lumps and balls.

The design recycle ratio for 28-28-0 is 6.7 and for 19-19-19 is 5.6 based on a moisture content of 2.5 and 1.9% respectively at A.G. outlet. However, by experience it has been possible for us to reduce these recycle ratios and maintain a moisture content 3-3.5% at A.G. outlet for both grades. It has been possible to do so in our case because of liberal drying capacity available. Addition of water or steam in A.G. is normally avoided because it softens the granules resulting in exdessive dust in driers.

In order to control the condition in A.G. at potimum level it is desirable to vary only the recycle fines while keeping the slurry rate and feed rate of urea and potash constant. In order to achieve this our plant had a bin and weigh feeder for recycle fines. However, due to the production of high nitrogen grades it was found by experience that recycle fines would not flow uniformly from the bin despite provision of vibrators. Thus this system became a hindrance rather than a help to maintain desired conditions in A.G. We, therefore, had no choice but to remove recycle bin and feeder. It was felt necessary to install an NPK auto analyser to keep the control on product quality. With the help of auto analyzer it is possible to obtain complete analysis in a short time of 30 minutes thus making it possible for the operating staff to keep a tight control on product quality.

Another problem experienced was frequent jamming of urea and potash crushers resulting in frequent shut downs. Both these crushers were bypassed and uncrushed urea prills and potash were added to A.G. We have not experienced any problem in granulation or in homogeneity of product granules because of this modification.

Drying Section

The moist granules from A.G. are fed to the first rotary dryer and dried by a cocurrent stream of hot air to a moisture level of 1.0-1.2%. This material then enters the second dryer in which further drying is achieved by a counter-current stream of hot air to a moisture level of less than 1.0%.

The rate of drying depends upon the product temperature, its moisture content as well as temperature of hot air and its humidity. Urea-based fertilizers having a low melting point pose limitation on the allowable drying temperature to avoid fusing of material.

The hot air temperature used by us is 120-130°C at I dryer inlet and 70-80°C at II dryer inlet for all the grades.

The operation of drying is very critical in the sense that excessive dust is produced if material is over-dried and remains sticky if it is under-dried. In order to maintain proper conditions of the drying operation, dehumidified air is used as dilution air in the dryer furnaces to control inlet air temperature. This helps drying of material at low temperature.

Product of moisture content less than 1.0% even when the moisture level at A.G. outlet becomes high due to any operational upset is possible in our plant because of availability of two dryers in series. In actual practice it was observed that excessive breakage of granules took place in II dryer resulting in high amount of dust in exhaust gases. This created problems in scrubbing system and severe foaming in PN especially during production of 28-28-0.

This problem was studied in depth and successfully tackled to a major extent by cutting off the II dryer furnace and introducing only dehumidified air counter current to the flow of material. It was observed that the moisture content dropped by 0.1 to 0.2% in the II dryer thereby resulting in a product having moisture 0.9-1.0%. This also enabled us to discontinue the use of cooler because the material at the exit of II dryer was already cooled. The cooler was therefore bypassed. The step mentioned above not only resulted in saving of fuel oil and power but also solved the problem of excessive dust in the exhaust gases of II dryer.

An interesting thought which emerged due to availability of cooler was the possibility of using it as a dryer for a parallel stream of smaller capacity. Thus a revamping scheme was formulated in which the spare capacity of the neutralization section would be fully utilized. A new smaller ammoniator granulator would be installed with its independent scrubbing system. A new wet scrubber would also be installed after the existing cooler cyclones. A new furnace would be added to use cooler as dryer. It is expected that with these relatively minor additions, it would be possible to increase the production capacity by 25-30%. The available dry section appears to be adequate to handle the additional material. This scheme is being further scrutinized before finalization.

Screening Section

The material is further handled through the usual steps of screening, coating etc. The problems faced in screening section were mainly confined to vibrators and tearing of screen mesh. The fines and oversize (after crushing) and dust recovered from cyclones is recycled to A.G. Mechanical problems like twisting/shearing of the flights of recycle flight conveyor were initially experienced. However this was tackled by proper strengthening.

Scrubbing Section

The scrubbing system comprises of a fume scrubber for recovery of unreacted ammonia from PN and A.G., a scrubber for exhaust gases from I dryer and independent scrubber for gases from II dryer. About 12-15% of the total acid consumed and required process water is added to the fume scrubber liquor tank. The same liquor is pumped to both dryer scrubbers. The final liquor from dust scrubber tank is pumped to PN. As per design the P_2O_5 content in this liquor going to PN is 17% for 19-19-19 and 14% for 28-28-0. We have also made a provision for steam injection in dust scrubber liquor tank for partial removal of CO_2 whenever urea concentration in this liquor is beyond 5%. It has been observed that foaming in PN gets somewhat reduced in this manner.

One problem which was being faced frequently was excessive dust blow out from chimney, thereby creating muisance in the neighborhood. This was happening due to blockage of dust cyclones resulting in considerable overloading of wet scrubbers. Since the scrubbers could not handle sudden increase in load, large quantity of dust used to escape to the chimney through the exhaust fan. It also resulted in problems in the exhaust fan itself. In case such a situation arose at night quite sometime may lapse before it is noticed by the plant operators. In order to overcome this problem, manometers were installed at different locations along the route of the dust handling duct. The base manometer readings were established when the system has been thoroughly cleaned. The maximum manometer readings were established by deliberate blowout from the chimney. With the help of these observations limiting values were fixed for manometer readings as a guideline. The plant is shutdown when the limiting values are reached, ducts and cyclones cleaned and plant restarted. This system has helped to practically eliminate the problem. In fact the exhaust from dust chimney is not even visible under normal operation and some times gives an erroneous impression as if plant is stopped.

Quality Control

As mentioned earlier we use an auto analyzer for speedy analysis of nutrients. The system followed is to take hourly samples of product which are analysed with the help of auto analyser and results make available to the shift officer within 30 minutes. Based on these results corrective action is immediately taken as felt necessary. The frequency of analysis is increased at the descretion of the shift officer depending upon plant condition. In case the product quality is not within specified control limit bleading of the product stopped.

It is extremely essential that product quality of different grades conforms to the specifications laid down in

Fertilizer Control Order instituted by the Government of India. In order to maintain product quality a sample is collected every thirty minutes from the belt conveyor leading to bulk storage. A composite sample is prepared for one shift production. Production of each shift of eight hours is stored in a separate bin in NPK bulk storage. An independent sample is taken from different parts of the heap and a composite sample is prepared. Thus there are two composite samples the results of which should match within normal tolerance limits. Only after this is ensured, the bin is released for bagging and despatch. As a further safeguard random samples are taken from a few bags while bagging as a cross check.

With the help of this system described above it has been possible to minimise the generation of off-spec material. There is a provision of returning off-spec. material from the off-spec. bins in NPK bulk storage area to the NPK plant for reprocessing.

Storage

For the sake of comparison, the critical relative humidity of various fertilizers at a temperature of 30°C is given below:

MAP	91%
KC1	84%
DAP	82%
Urea	75%
14-35-14	70%
28-28-0	57%
19-19-19	45%

The problem of low critical relative humidity of the grades manufactured by us is further aggravated by the local climatic conditions where rainfall is as high as 2500 - 3000 mm and atmospheric relative humidity remains high the year around. The NPK bulk storage building has therefore been dehumidifed to minimize caking problem during storage.

Polution Control

Liquid Effluent

The limit of phosphate specified by Pollution Control Authority is 50 ppm as PO_4.

The major sources of liquid effluent in NPK plant are gland leakages, overflow/draining of scrubbers/preneutralizer and any emergency plant washings. Spillage of dry material at different transfer points of conveying equipments are collected round the clock and fed back into the recycle system at designated points at different floors. Thus no accumulation is allowed. The washing points for cleaning of floors have been sealed and only sweeping is done. The liquid effluent emanating from different points is taken to a waterproof R.C.C. tank having compartment. The decanter liquor is collected in one of the compartments from where it is pumped to dust scrubber liquor tank. The sludge which settles down in the compartments is removed periodically, mixed with filler or dry spillage and fed back into the plant. With the help of this system it has been possible to achieve practically zero liquid/sludge discharge from the plant.

Gaseous/Dust Effluent

The design limits for gaseous/dust effluent from the fume scrubber chimney and dust scrubber chimney are as follows:

Fume Scrubber Chimney	**19-19-19**	**28-28-0**	**18-46-0**
Ammonia	500 ppm	600 ppm	1500 ppm
Dust	—	—	—
Dust Scrubber Chimney			
Ammonia	—	100 ppm	100 ppm
Dust mg/Nm3	20	8	14

It has been possible for us to stay within the design limits most of the time. However, during plant upset conditions these values are exceeded once a while for a short duration.

At regular intervals, the fume and dust scrubbers are inspected and cleaned. Emission of dust has been brought under control with the help of manometers and regular inspection and cleaning of dust cyclones. Some dust within the plant is inevitable but it can be minimized with the help of efficient dust collection system from various locations of dust emission like transfer points and screens.

Conclusion

The experience of operation of our plant presented above as gained during the last five years has convinced us that despite difficulties in the production of urea-based high analysis complex fertilizers, it is possible to maintain a high level of production with constant vigilance of operational conditions and with proper predictive and preventive maintenance.

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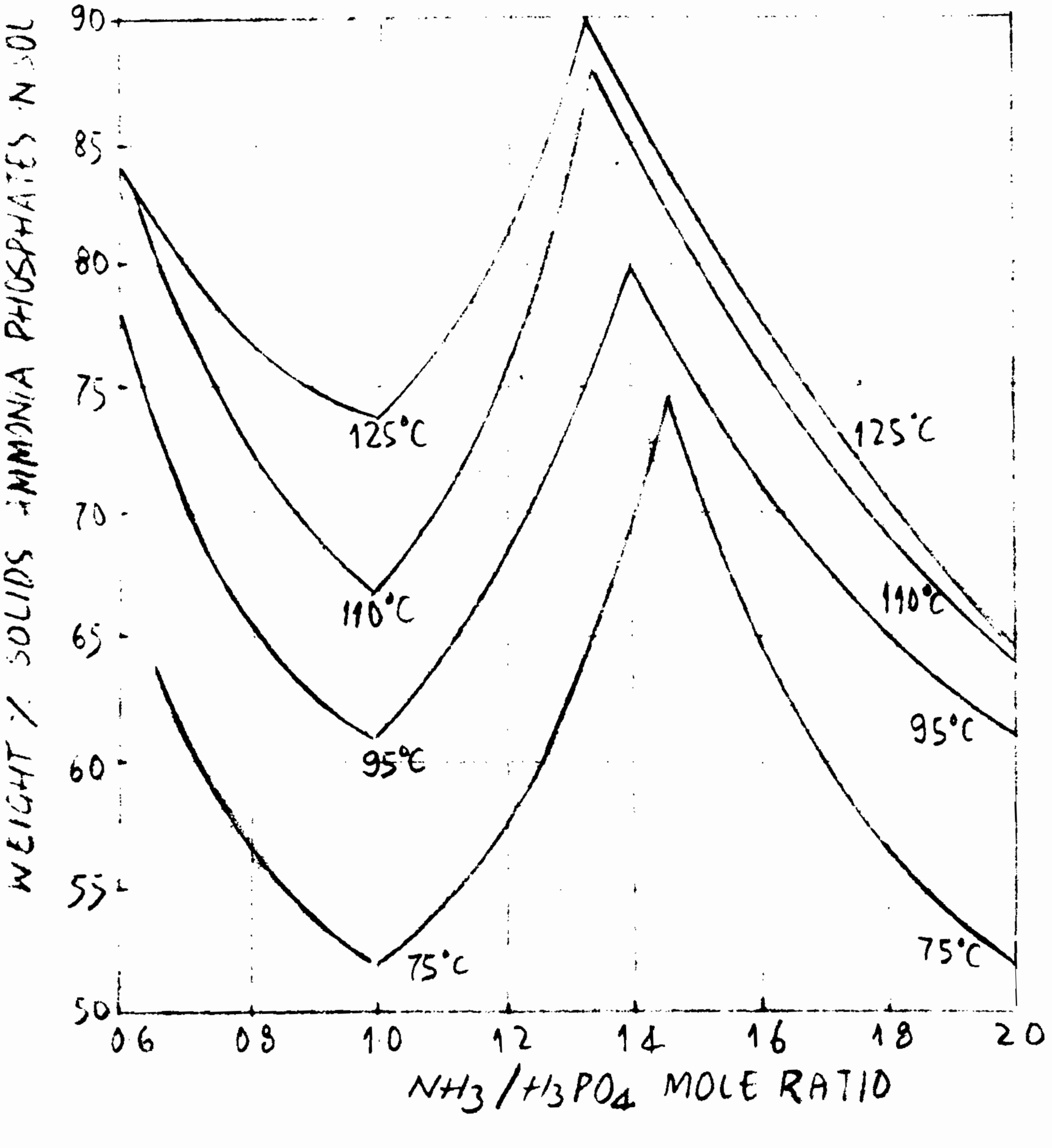

WEIGHT % SOLIDS AMMONIA PHOSPHATES IN SOL
90
85
80
75
70
65
60
55
50
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
NH3/H3PO4 MOLE RATIO
125°C
110°C
95°C
75°C
125°C
110°C
95°C
75°C

Fig. 1

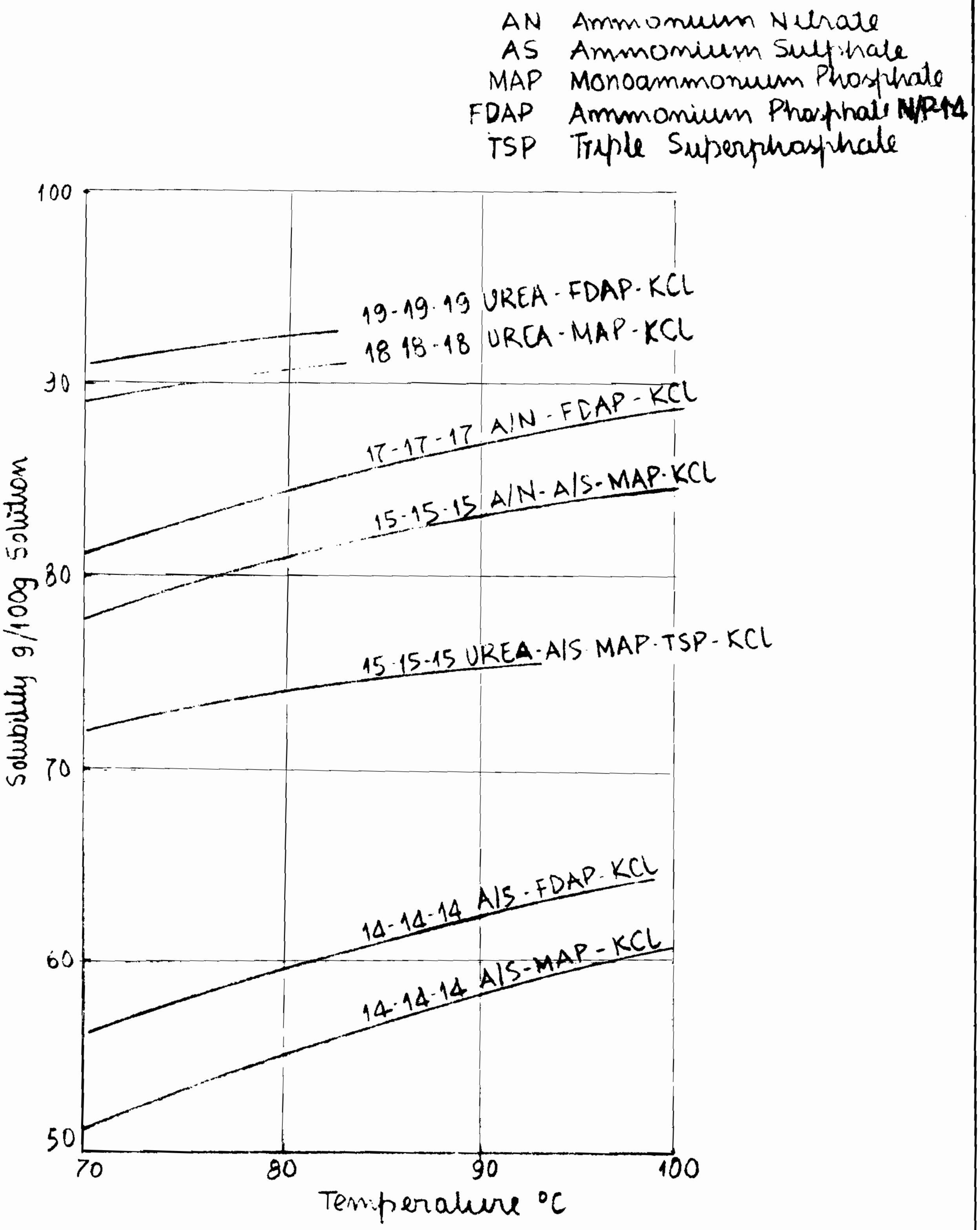
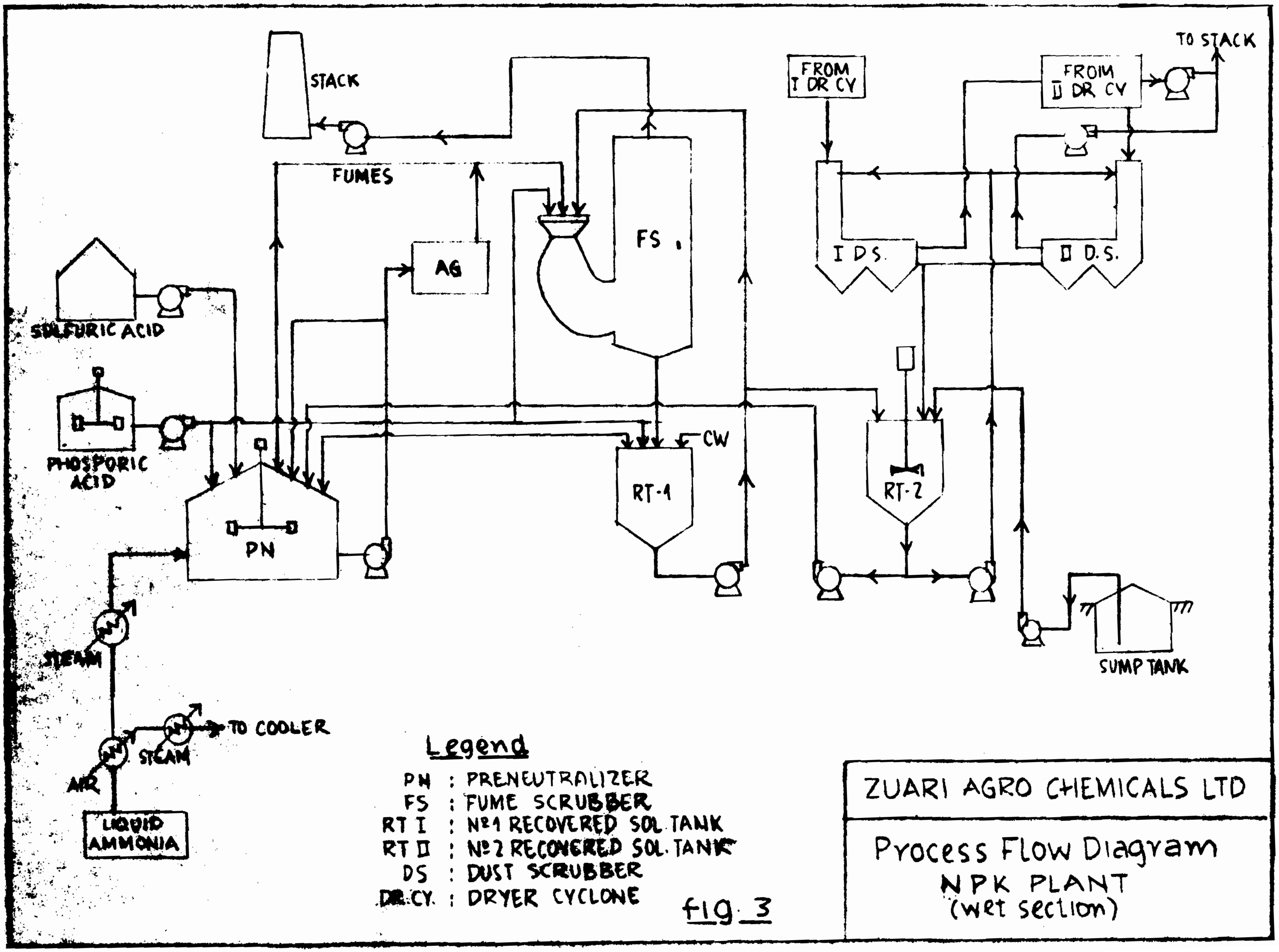

AN Ammonium Nitrate
AS Ammonium Sulphate
MAP Monoammonium Phosphate
FDAP Ammonium Phosphate N/P14
TSP Triple Superphosphate
100
90
80
70
60
50
Solubility g/100g Solution
70
80
90
100
Temperature °C
19-19-19 UREA-FDAP-KCL
18-18-18 UREA-MAP-KCL
17-17-17 A/N-FDAP-KCL
15-15-15 A/N-A/S-MAP-KCL
15-15-15 UREA-A/S MAP-TSP-KCL
14-14-14 A/S-FDAP-KCL
14-14-14 A/S-MAP-KCL

Fig. 2



Legend

PN : PRENEUTRALIZER
FS : FUME SCRUBBER
RT I : No 1 RECOVERED SOL. TANK
RT II : No 2 RECOVERED SOL. TANK
DS : DUST SCRUBBER
DR.CY. : DRYER CYCLONE

fig. 3

ZUARI AGRO CHEMICALS LTD

Process Flow Diagram
NPK PLANT
(wet section)

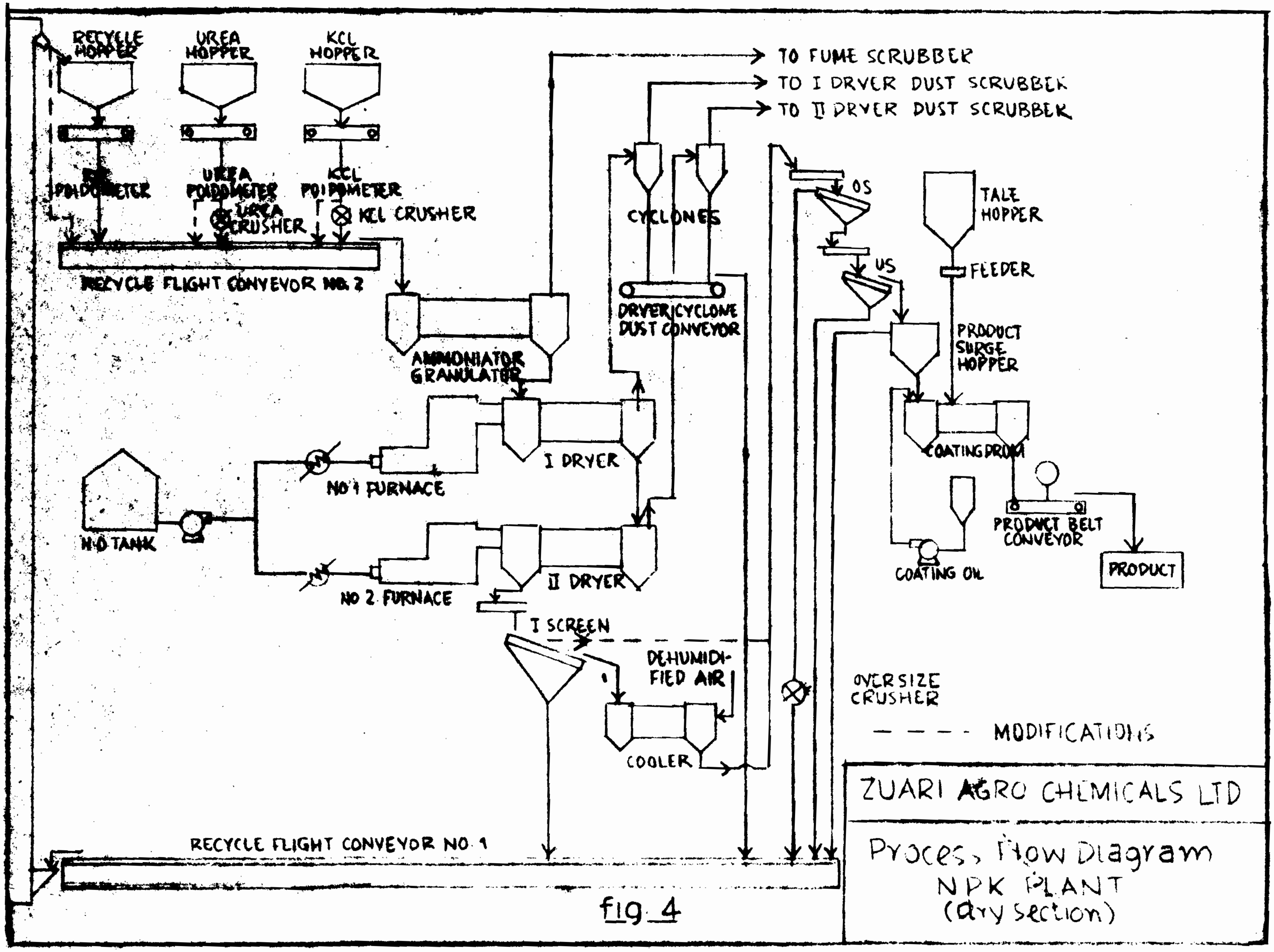

RECYCLE HOPPER
UREA HOPPER
KCL HOPPER
POIDOMETER
UREA POIDOMETER
UREA CRUSHER
KCL POIDOMETER
KCL CRUSHER
RECYCLE FLIGHT CONVEYOR NO. 2
TO FUME SCRUBBER
TO I DRYER DUST SCRUBBER
TO II DRYER DUST SCRUBBER
CYCLONES
DRYER CYCLONE DUST CONVEYOR
OS
US
TALC HOPPER
FEEDER
PRODUCT SURGE HOPPER
AMMONIATOR GRANULATOR
I DRYER
NO 1 FURNACE
NO 2 FURNACE
II DRYER
NO TANK
COATING DRUM
PRODUCT BELT CONVEYOR
COATING OIL
PRODUCT
I SCREEN
DEHUMIDIFIED AIR
COOLER
OVERSIZE CRUSHER
- - - - MODIFICATIONS
RECYCLE FLIGHT CONVEYOR NO 1
ZUARI AGRO CHEMICALS LTD
Process Flow Diagram
NPK PLANT
(dry section)

fig 4

MODERATOR SHELDRICK: Thank you Mr. Singh. Your discussion was an extremely useful contribution. We have had a lot of pracitical information shared with us. I am sure that for many of you, at has whetted your appetite to have some more discussions with Mr. Singh. Thank you again Mr. Singh. (Applause)

MODERATOR SHELDRICK: Our next presentation by M.M. Norton, is going to talk on a very similar subject. We shall have this discussion and then we will have Messrs. Singh and Norton come to the platform to answer questions. Melvin is employed by T.V.A. where he has worked since 1950 in the "field of Chemical Development." He has a degree in Chemistry from the University of North Alabama. He has worked on just about every operation in the fertilizer business —"Granulation, Nitrophosphates, DAP, MAP, Urea, Ammonium Phosphate." He co-authored many technical papers on these subjects. Without any further ado I will ask Mr. Norton to make his presentation. (Applause)

An Update of TVA's Experience in Production of High-Analysis Granular N.P.K. Fertilizers Containing Urea

B. R. Parker, M. M. Norton
and T. R. Stump
Presented by M. M. Norton

For about 20 years, work at TVA has included research and development programs to demonstrate the use of urea as a source of supplemental nitrogen for the production of granular fertilizers. In 1964, TVA demonstrated a process for production of granular urea-ammonium phosphate fertilizer based on diammonium phosphate with the addition of urea as supplemental nitrogen[1]. When solid urea is used, it is metered into the recycle stream in a typical diammonium phosphate plant, and when urea solution is used, it is added directly to the granulator. This process now is being used successfully in several large commercial operations in India and other parts of the world to produce such grades as 28-28-0, 35-14-0, 15-15-15, and 19-19-19[2][3][4]. Other processes that are similar, but which use nongranular monoammonium phosphate as the basic source of phosphate with urea as supplemental nitrogen, also have been quite successful in commercial operations for many years[5][5]. Quite often small amounts of either phosphoric or sulfuric acid and ammonia are required to enhance granulation. This process has been used in Spain, Turkey, and the United Kingdom.

TVA also has shown the use of urea in combination with both single and triple superphosphate to produce granular NP and NPK fertilizers[7,8]. This process has been very popular in the United Kingdom for production of a 20-10-10 grade.

The presence of urea in all these granular products makes drying difficult, because high temperatures cannot be used without melting the product. Therefore, because of the drying problems associated with these products, TVA's more recent research and development programs on urea-based fertilizers have been concentrated on melt-granulation processes. In these processes, all or part of the fertilizer ingredients are fed to the granulator in the form of melts of low moisture content, and because of the low moisture content, little or no drying is required.

Pipe-reactor processes, in which ammonium phosphate melts are formed by reation of ammonia with phosphoric acid in a pipe and then fed to a granulator, are particularly adaptable to the production of urea-based products. In this connection, TVA has for the past 8 years been operating a demonstration-scale melt-granulation plant for the production of 28-28-0 and 35-17-0 grades of urea-ammonium phosphate. A flowsheet of the process employed is shown in Figure 1, and typical operating data for the production of each grade are shown in Table I. This process, which employs a spray reactor, pipe reactor, vapor disengager, and pug mill granulator, has been described previously[9,10,11,12]. This plant now has a production capacity of about 450 tons per day of 28-28-0 or about 340 tons per day of 35-17-0 urea-ammonium phosphate fertilizers. Plant operation is routine. The products have good handling properties and are well accepted as solid fertilizers and as intermediates for suspension preparation. Polyphosphate level in these products is 20 to 35%, which is considered an advantage for use in suspension preparation.

Another melt granulation process developed by TVA was shown to the fertilizer industry during the TVA Tenth Demonstration of Fertilizer Technology in 1974[9]. A flowsheet of the process is shown in Figure 2. In this process, an ammonium phosphate melt produced with a preneutralizer followed by a pipe reactor is introduced into a drum granulator. Urea and other solid feed materials are added to the recycle stream. At the time these tests were made, it was thought that preneutralization prevented scaling in the pipe reactor. Typical grades produced were 19-19-19, 12-24-24, and 15-30-15. Their formulations and operating conditions are shown in Table II. Later tests indicated that the preneutralizer could be omitted.

More recent TVA pilot-plant development work with granular fertilizers has been with melt granulation processes that use either a pipe reactor or pipe-cross reactor without a preneutralizer. These processes offer energy savings and produce fertilizers that contain polyphosphate, which also makes the products more suitable as intermediates for producing fluid fertilizers. In the process using a pipe reactor and drum granulator without a preneutralizer, operation is simplified and investment and pollution control costs are lower. Also, a dryer is not required. Most pilot-plant work with this process has been in production of granular 11-55-0 monoammonium phosphate fertilizer[12,13,14]; however, urea-ammonium phosphate grades 28-28-0 and 35-17-0 also have been made. These grades are granulated mixtures of urea and ammonium phosphate melts in ratios of about 1:1 and 2:1, respectively. Granulation was good with both grades, and the products compared very favorably with the same grades produced in TVA's demonstration-scale plant with the pipe-reactorpug mill process that used a spray reactor and vapor disengager. Also, in production of these grades, less oversize was produced and lower recycle ratios were needed with the pipe-reactor/drum-granulator process than with the pug mill process. However, the polyphosphate content of the products was lower (6-8% vs 25-35% of P_2O_5).

In 1974 TVA, in cooperation with the Missouri Farmers Association at their fertilizer plant in Palmyra, Missouri, began experimental tests of a modified pipe reactor in which sulfuric acid was added in addition to phosphoric acid and ammonia. This reactor, known as the pipe-cross reactor[13,14,15,16,17,18,19,20,21,22], now is utilized by commercial companies throughout the world in the production of granular fertilizers both with and without inclusion of urea; there are about 27 installations in the United States. A flowsheet of this process is shown in Figure 3. The pipe-cross reactor melt usually is granulated in a rotary drum-type granulaor. TVA has used this process in pilot-plant tests since late 1975. Many NP and NPK grades, some of them containing urea, have been produced in this pilot plant, and many of these products have been produced under operating conditions that formed a portion of the P_2O_5 into polyphosphate. This makes the products more useful as intermediates for fluid fertilizers. Most products made in commercial plants by this and other granulation processes are based on an orthophosphate system and contain very little or no polyphosphate. Pilot-plant production of various grades, such as 33-11-O-XS, 32-16-0-3S, 20-10-10-XS, 17-17-17-9S, and 15-15-15-4S, by the pipe-cross reactor/drum-granulator process has been described previously[12]. Formulations and typical operating conditions for these grades are included in Tables III and IV. In that work, overall granulation was good for the 33-11-0-XS using urea melt and for the 15-15-15-4S using solid urea prills. Some difficulties were encountered in producing homogeneous granules of some of the other grades when using solid urea. Some drying was required for the 32-16-0-3S grade because more moisture was required to agglomerate the solid feed of urea.

[Figure #3 - Table #3 and Table #4] In recent TVA work, additional tests have been made of the production of a 17-17-17-XS grade fertilizer using the pipe-cross reactor/drum-granulator system. Formulations and operating conditions for this and several other grades are shown in Table IV. These tests were performed using merchant-grade wet-process phosphoric acid. This work was reported and demonstrated to the fertilizer industry during the TVA Thirteenth Demonstration of Fertilizer Technology in 1980[23]. Several process modifications have been tested, but thus far the recycle ratio required has been somewhat high (4 and above) in tests in which all the sulfur was furnished as sulfuric acid. Lower recycle rations may be obtained by substituting solid ammonium sulfate for some of the sulfuric acid. Under some operating conditions, a small amount of drying might be required.

In other recent pilot-plant tests, a granular 25-25-0-XS urea-ammonium phosphate sulfate has been produced by the same route. Formulations and operating data are included in Table III. Various sulfate levels and pipe-cross reactor NH_3:H_3PO_4 mole ratios have been tested. Granulation in these tests also was considered marginal because of high recycle ratios (> 4:1) required when all the sulfur was furnished as sulfuric acid. The recycle ratios could be lowered in this grade also by (1) decreasing the amount of sulfuric acid in the formulation, (2) substituting solid ammonium sulfate for sulfuric acid, (3) using urea microprills instead of urea melt, or (4) using a lower ammoniation rate in the pipe-cross reactor with additional ammonia added in the granulator. However, even with these changes, the lower recycle ratio obtained was still above 4. Some drying might be required to reduce the product moisture to 1% or less, which is considered desirable for good storage properties[24].

One problem encountered with production of urea-based granular products is dust collection in the off-gas system and from miscellaneous pickup points. Wet scrubbers, although efficient, are not well adapted for use with pipe-reactor melt granulation processes because they introduce too much water and thus give an unfavorable water balance. Dry collection in cyclones or in a baghouse is the logical solution to the water-balance problem, but this can introduce problems because of the high hygroscopicity of most urea-based products. In 1979, a baghouse dust collector was installed on the miscellaneous dust pickup system at the TVA granulation pilot plant. Before that time, a wet scrubber had been used, but pilot-plant data indicated that less than half of the dust solution produced could be returned to the process for many grades containing urea. A pulse jet-type baghouse collector was selected because higher air-to-cloth ratios could be used and the baghouse would be physically smaller than a "mechanical shaker" type. An air heating-recirculation unit was provided to allow introduction of heated ambient air into the baghouse inlet during operation and to allow heating and recirculation of air through the baghouse when it was not in operation.

After the first series of tests of grades containing both urea and sulfate, it was apparent that a special set of problems existed with the baghouse operation. Physical testing[24] had shown that a urea-based product that also contained sulfate, such as a 33-11-0-6S grade, was more prone to pick up moisture, and the moisture penetrated deeper into storage piles than was the case with 28-28-0 and 35-17-0 grade urea-ammonium phosphate products containing no sulfate. After installation of the baghouse, in the first series of tests producing 33-11-0 grade containing sulfate, the relative humidity of the air was greater than 60% and the product and dust tended to pick up moisture readily. The value of the air-recirculation system became obvious; the baghouse could not have operated if heated makeup air had not been added to the inlet airstream.

Initially, since heat requirments to keep the baghouse dry were not well defined, the temperature of the makeup air was controlled so that the inlet air to the baghouse was heated about 10°F to decrease the relative humidity of the air to 50% or less. To help determine the humidity conditions inside the baghouse, a dew-point hygrometer was installed for testing. A schematic diagram of the installation is shown in Figure 4. It was assumed that humidity of air within the baghouse would be the same as the humidity of the baghouse outlet air. A portion of this exhaust air (about 1.25 Ft^3/h) is filtered and passed across a sensor mirror in the instrument and is returned to the exhaust stream. The mirror surface temperature is very accurately controlled at the dew point of the gases passing across it. The dry bulb temperature of the airstream is measured with a thermocouple. The dew point and dry bulb temperature of the gases are displayed on a digital readout and can be continously monitored. Another similar instrument is available on which relative humidity is displayed directly. Based on the physical properties of the grade being produced, a maximum relative humidity should be maintained which is below the critical relative humidity of the fertilizer product. It must be remembered, however, that critical humidity of a fertilizer varies with temperature. At the elevated temperatures existing in a baghouse, the critical relative humidity can be much lower than published values, which are usually for measurements made at 86°F[25].

At TVA, measurements of the critical humidity of a number of the urea-based granular products have been made over a wide range of temperatures to give data useful for baghouse control. Curves can be plotted from these data as shown in Figure 5. Curves such as these can be used in conjunction with the dew-point measurements to determine minimum safe operating temperatures for the baghouse. In the example shown on the figure, the dew-point measurement was 110°F, and the minimum temperature to prevent wetting during production of 33-11-0-4S, 17-17-17-5S, or 20-10-10-12S urea-based products would be 150°F. Addition of heat might be required to maintain this temperature.

In Summary, it is concluded that with sufficient experience in operating techniques, it is possible to produce good quality NF and NPK granular fertilizers using urea as a supplemental nitrogen source. Melt-granulation processes utilizing the pipe or pipe-cross reactor in conjunction with a rotary drum granulator are suitable for these products. Dry dust-collection systems are preferable over wet ones to satisfy the water balance. A baghouse dust collector is suited for use on miscellaneous dust pickup points for melt granulation processes. However, for fertilizers where urea is present in the formulation, it is desirable to have the capability to add heated makeup air to control the inlet air temperature to the baghouse so that the relative humidity of this inlet air is less than the critical relative humidity of the product.

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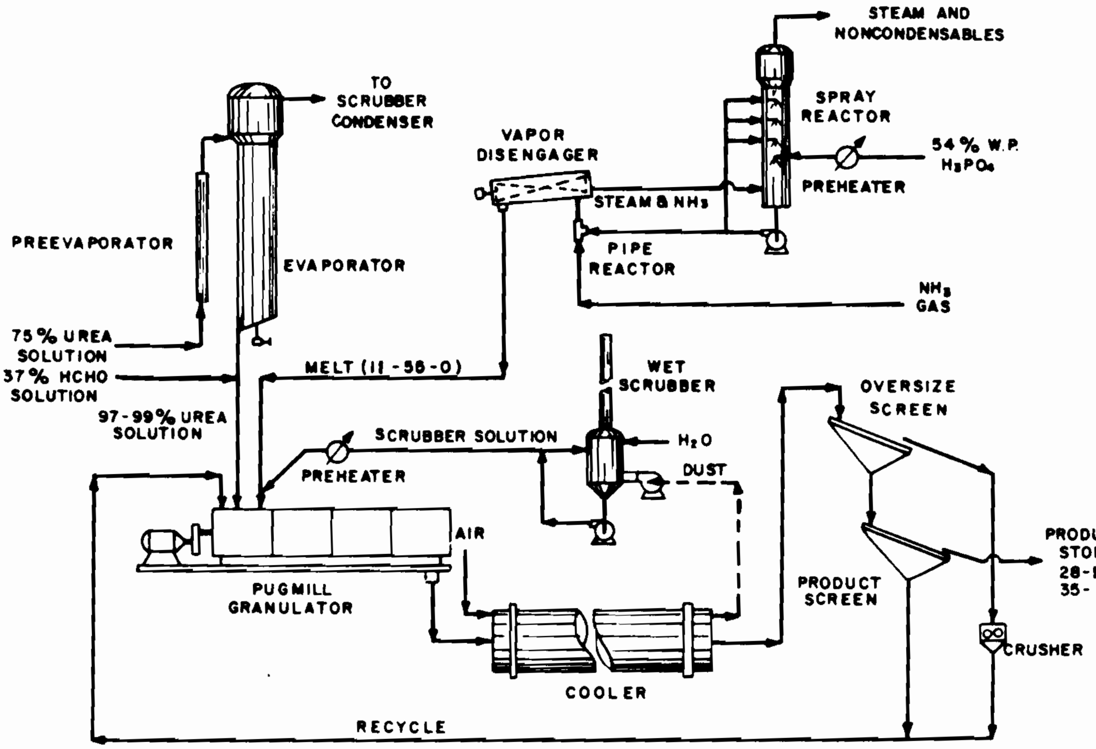

FIGURE 1

Pipe-Reactor/Pug Mill Process

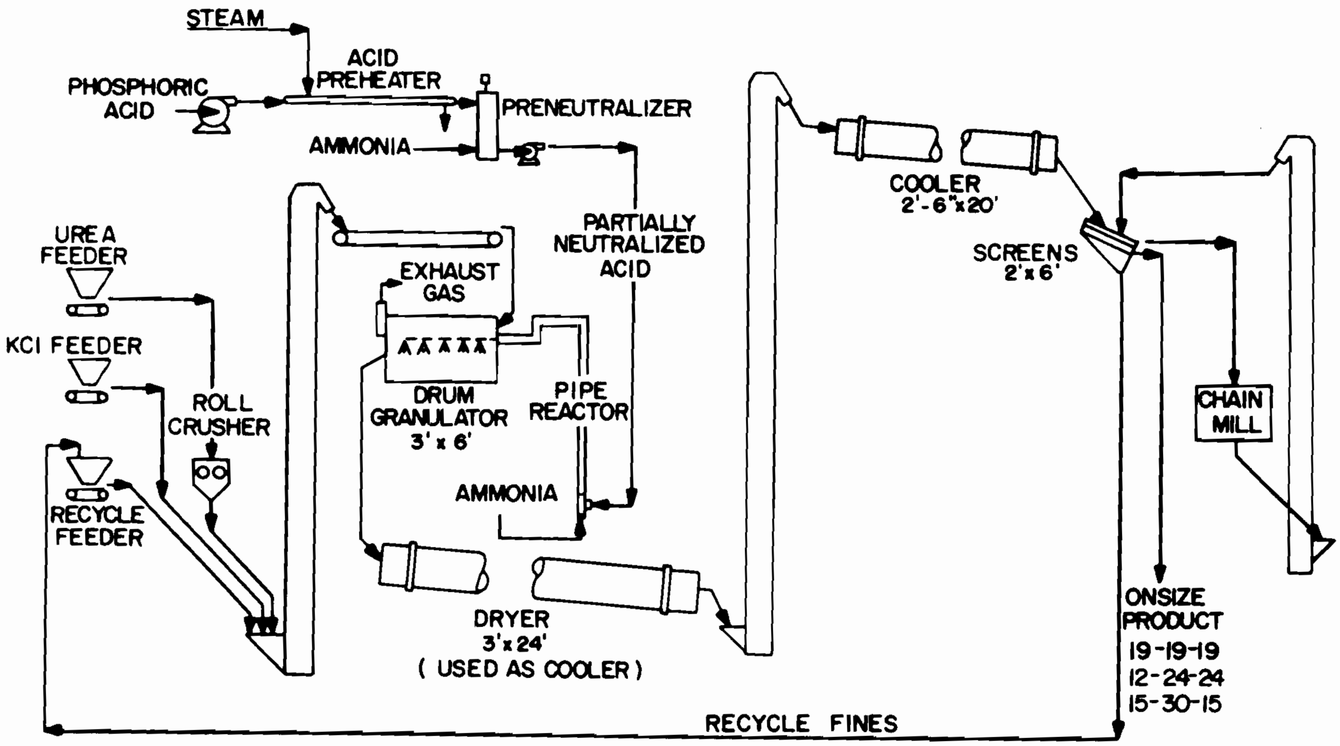

FIGURE 2

Pipe-Reactor/Drum-Granulator Process with a Preneutralizer

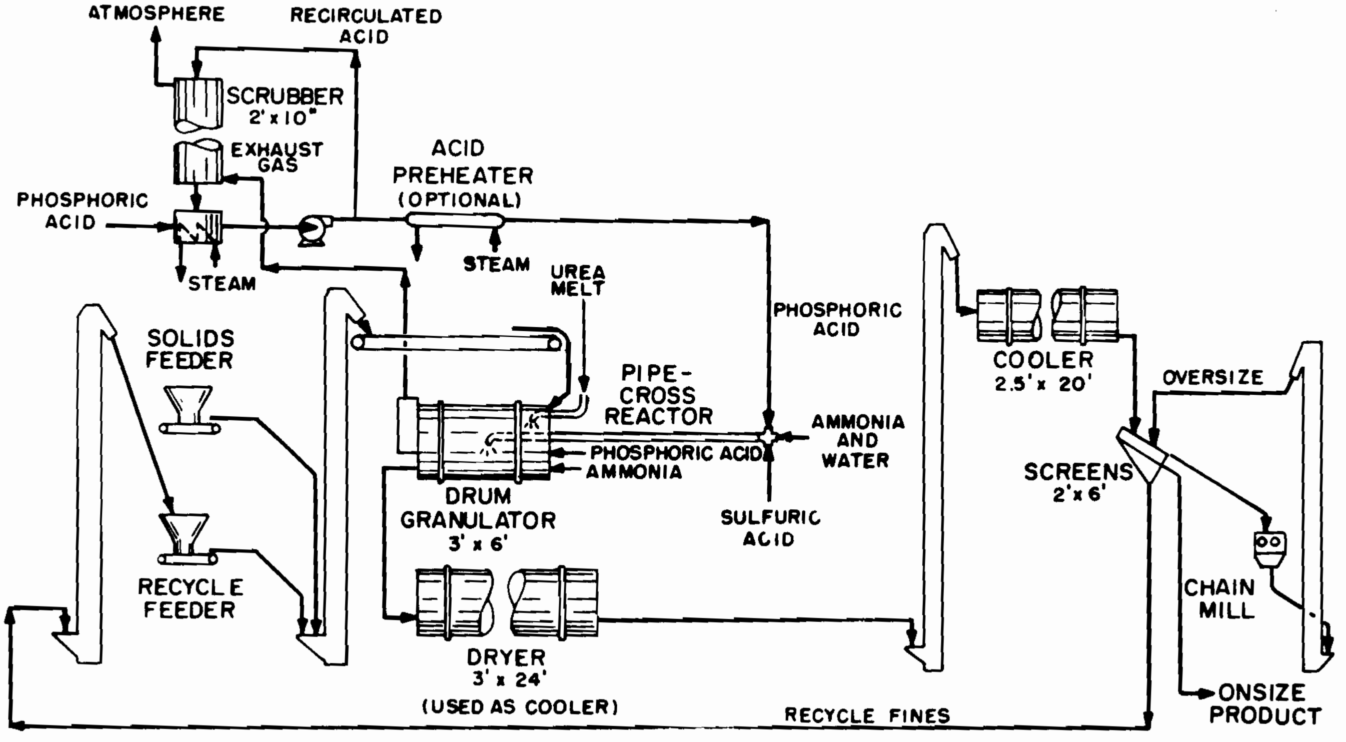

FIGURE 3

Pipe-Cross Reactor/Drum-Granulator Process

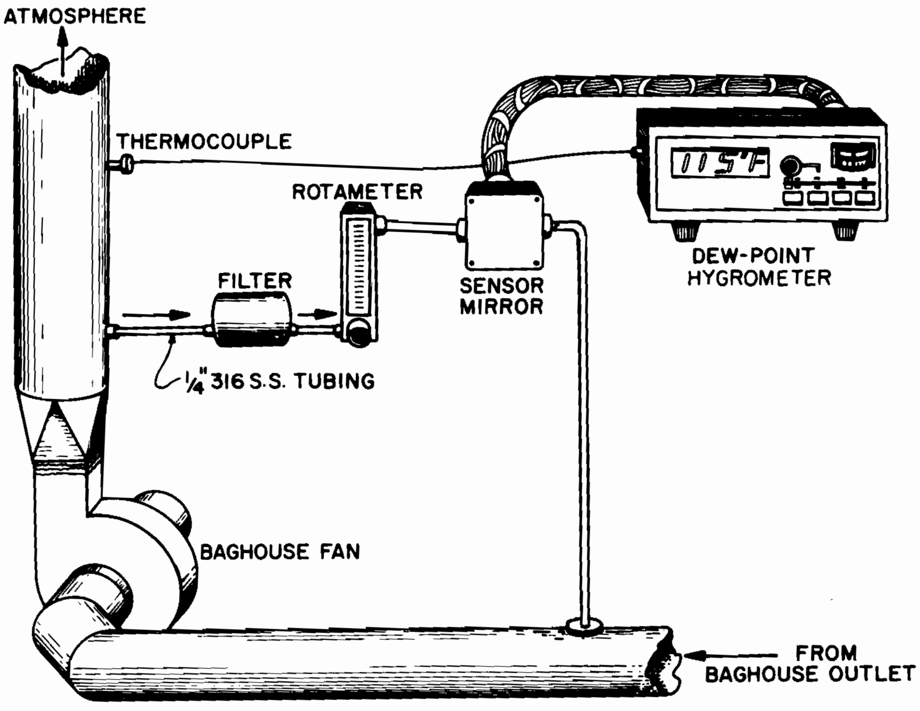

FIGURE 4

Dew-Point Hygrometer Installation on Pilot-Plant Baghouse

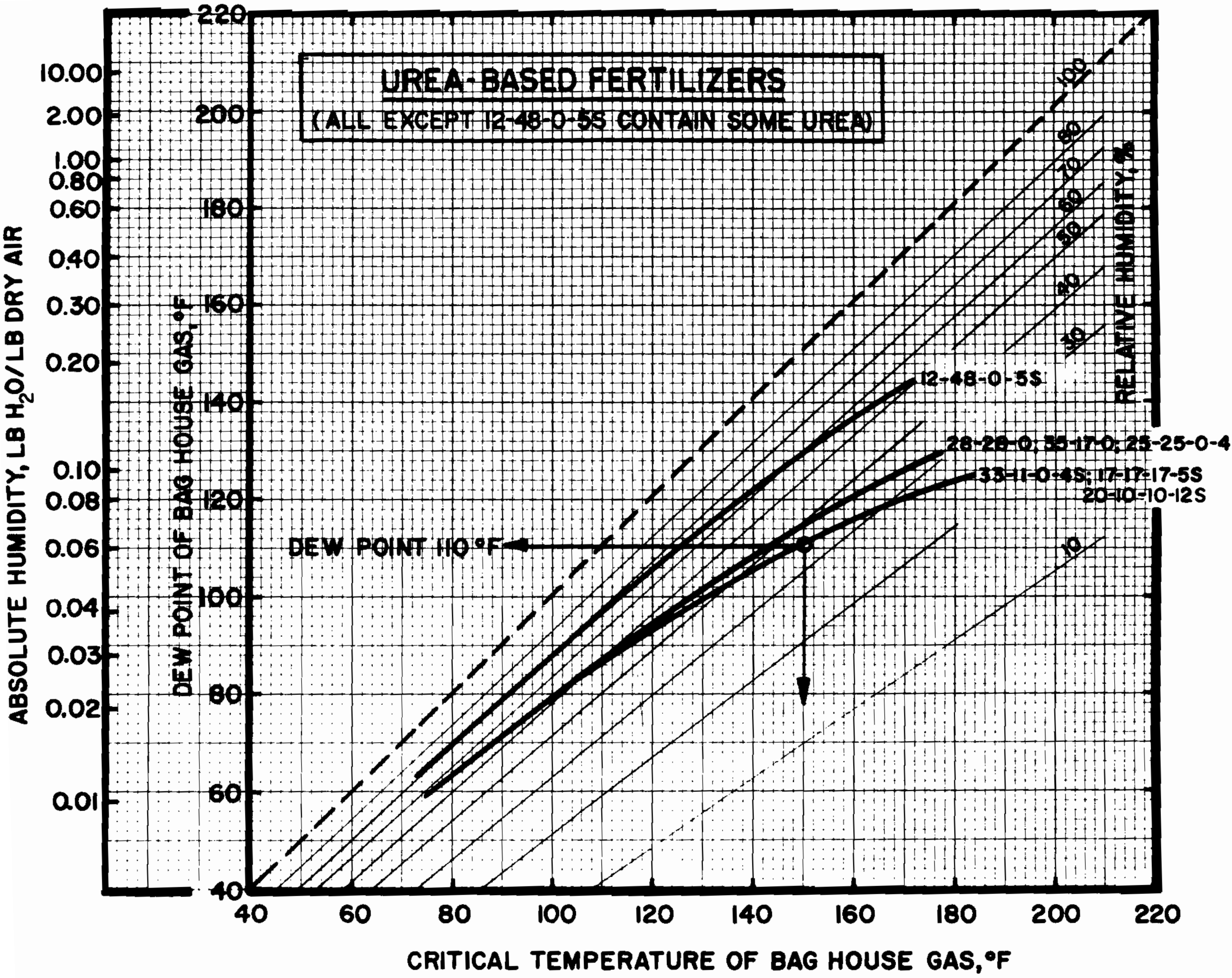

FIGURE 5

Effect of Dew Point of Baghouse Gas on Critical Gas Temperature Below Which Wetting of Fertilizer Will Occur

TABLE I

Typical Operating Data for Melt Production and Granulation, TVA Demonstration Plant

Nominal grade	28-28-0	35-17-0
Production rate, tons/h	18	13
Urea		
75% solution		
Temp, °F	200	202
Feed rate (100% basis), tons/h	8	8
Melt to pug mill		
Temp, °F	285	290
Concentration, %	99	99
Ammonium polyphosphate		
Melt to pug mill, tons/h	9	4
Temp, °F		
Phosphoric acid	130	-
Spray-reactor product	266	255
Pipe-reactor melt	422	412
pH		
Spray-reactor product	1.5	1.7
Pipe-reactor melt	3.4	4.1
Granulation		
Recycle		
Temp, °F	140	-
Ratio, lb/lb product	4.5	4.5
Granulator product		
Temp, °F	178	172
Screen analysis (Tyler), %		
+6 mesh	14	-
-6 +10 mesh	42	-
-10 +16 mesh	29	-
-16 mesh	15	-
Product		
Chemical analysis, %		
Total N	28.7	35.5
Total P_2O_5	28.6	17.0
Available P_2O_5	28.6	-
Orthophosphate P_2O_5	23.2	11.4
Polyphosphate, % of total P_2O_5	18.9	32.9
H_2O (Karl Fischer)	1.0	0.8
Biuret	0.5	-
pH	4.9	-
Screen analysis (Tyler), %		
+6 mesh	2	1
-6 +8 mesh	28	22
-8 +10 mesh	52	53
-10 +12 mesh	10	20
-12 +16 mesh	7	3
-16 mesh	1	1

TABLE II

Formulations and Operating Conditions for Production of NP and NPK Fertilizers by Pipe-Reactor/Drum-Granulator Process with a Preneutralizer

Nominal grade	19-19-19	12-24-24	15-30-15
Formulation, lb/ton of product			
Ammonia (gaseous)			
To preneutralizer	36	46	57
To pipe reactor	60	75	94
To drum	22	29	36
Total	118	150	187
Wet-process phosphoric acid (54% P_2O_5)	704	889	1111
Urea (46% N)	615	252	317
Potassium chloride (60% K_2O)	633	800	500
Preneutralizer			
Acid preheat temp, $^{\circ}F$	210	180	200
Slurry temp, $^{\circ}F$	293	290	282
$NH_3:H_3PO_4$ mole ratio	0.4	0.4	0.4
Pipe reactor			
Melt temp, $^{\circ}F$	432	440	435
Melt analysis, %			
Total N	11.8	11.6	12.2
Total P_2O_5	57.8	58.0	57.2
Polyphosphate, % of total P_2O_5	20	21	21
Drum granulator			
Recycle ratio, lb/lb product	1.7	2.3	3.3
Product temp, $^{\circ}F$	172	178	175
Moisture content, % AOAC (vacuum desiccation)	1.2	1.2	1.0
Screen analysis (Tyler), % retained			
6 mesh	4	33	22
8 mesh	14	62	40
10 mesh	35	84	58
12 mesh	52	91	68
16 mesh	83	97	83
Ammonia evolution, % of total feed	4	3	6
$NH_3:H_3PO_4$ mole ratio	1.3	1.3	1.4
Onsize (-6 +12 mesh) product analysis, %			
Total N	20.3	13.4	14.5
Total P_2O_5	20.1	25.1	29.6
K_2O[a]	19.8	24.3	18.6
Percent of total P_2O_5			
Polyphosphate	27	23	20
Water soluble P_2O_5	94	99	100
Available P_2O_5	99	100	100
Moisture (AOAC vacuum desiccation)	1.1	1.2	0.9

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[a] K_2O content high because sampling took place about 4 hours after changing from 12-24-24 grade.

TABLE III

Formulations and Typical Operating Conditions for Production of Granular Urea-Ammonium Phosphate Sulfate Fertilizers Using the Pipe-Cross Reactor and Drum-Granulation System

Nominal grade	33-11-0-5S[a]	33-11-0-3S[b]	33-11-0-3S[c]	33-11-0-3S[d]	32-16-0-3S	25-25-0-4S	25-25-0-4S	25-25-0-4S
Test no.	PCU-30	PCU-38	PCU-43	PCU-45	PCU-73	PCU-90	PCU-94	PCU-98
Length of test, h	5.1	5.8	5.5	5.0	4.5	4.2	4.8	5.8
Nominal production rate, tons/h	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5
Formulation, lb/ton of product								
Ammonia[e]								
To pipe-cross reactor	96	136	96	96	111	158	206	158
To granulator	21	29	27	27	31	48	0	48
Ammonium sulfate (20.7% N)	165	0	0	0	0	0	0	0
Wet-process phosphoric acid (54% P_2O_5)	411	411	411	411	621	971	971	971
Sulfuric acid to pipe-cross reactor (92% H_2SO_4)	200	200	200	200	200	266	266	266
Urea (46% N)	1217[f]	1183[f]	1259[f]	1259[f]	1150[g]	728[f]	728[f]	728[g]
Formulated melt $NH_3:H_3PO_4$ mole ratio	0.6	1.35	0.6	0.6	0.6	0.6	1.0	0.6
Pipe-cross reactor								
Phosphoric acid feed temp, °F	152	153	155	155	133	135	139	148
Equivalent acid concentration, % P_2O_5	40	41	47	39	48	53	54	49
Ammonia feed temp, °F	Amb	Amb	Amb	Amb	Amb	Amb	Amb	Amb
Melt temp, °F	269	278	276	264	387	359	403	306
Melt analysis, %								
Total N	11.3	16.8	37.0	13.0	12.7	11.4	13.8	9.8
Total P_2O_5	36.6	13.2	10.5	30.8	37.0	41.8	39.1	40.6
Drum granulator								
Recycle ratio, lb/lb product	3.8	3.9	3.6	3.5	2.8	5.5	7.0	4.3
Discharge temp, °F	170	179	175	186	179	192	181	175
Moisture (AOAC), %	1.2	1.3	1.0	1.3	1.3	1.2	1.3	2.2
Screen analysis (Tyler), %								
+6 mesh	23.5	12.1	10.7	7.1	5.7	12.6	34.4	18.1
-6 +10 mesh	31.9	49.8	34.5	45.0	47.3	65.6	57.7	63.7
-10 +16 mesh	29.6	27.4	31.7	37.4	28.8	17.8	7.5	13.5
-16 mesh	15.0	10.7	23.1	10.5	18.2	4.0	4.0	4.7
NH_3 evolution as % of total NH_3 fed	5.2	21.2	17.2	7.0	4.0	8.7	15.8	3.0
pH of granulator product	6.2	6.6	6.9	6.5	5.7	5.4	5.4	4.1
Onsize product								
Total N, %	33.9	34.6	36.4	35.6	31.5	25.2	25.4	25.1
Total P_2O_5, %	11.5	12.3	11.9	11.9	17.9	25.1	26.2	26.0
SO_3, %	14.0	10.3	8.5	8.6	10.0	13.4	13.3	12.3
As % of total P_2O_5								
Polyphosphate	10.9	5.7	10.9	11.8	5.9	13.9	20.6	6.9
Water soluble P_2O_5	91.3	93.5	92.4	94.1	92.7	92.4	88.9	93.1
Available P_2O_5	97.4	100.0	100.0	100.0	100.0	99.2	96.9	100.0
Moisture (AOAC), %	0.8	1.4	0.8	0.9	1.0	1.0	1.0	1.7

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[a] Five percent sulfur; ammonium sulfate added to bed; monoammonium phosphate mole ratio formulation.
[b] Three percent sulfur; diammonium phosphte mole ratio formulation.
[c] Three percent sulfur; urea added to the pipe cross; monoammonium phosphate melt ratio formulation.
[d] Three percent sulfur; monoammonium phosphate mole ratio formulation.
[e] Gaseous ammonia.
[f] Urea melt.
[g] Microprill urea.

TABLE IV

Formulations and Typical Operating Conditions for Production of Granular NPK Fertilizers Using the Pipe-Cross Reactor and Drum-Granulation System

Nominal grade	20-10-10-12S	15-15-15-9S	17-17-17-3S	17-17-17-4S	17-17-17-3S	17-17-17-3S	17-17-17-3S
Test No.	PCHA-6	PCX-93	PCX-150	PCHA-8	PCX-146	PCX-155	PCX-158
Length of test, h	6.0	5.7	5.6	5.4	5.6	5.0	4.5
Nominal production rate, tons/h	0.75	0.6	0.5	0.75	0.6	0.5	0.5
Formulation, lb/ton of product							
Ammonia							
To pipe-cross reactor	144[a]	146[b]	113[a]	161[a]	113[b]	146[b]	81[b]
To granulator[b]	0	29	33	0	33	0	33
Ammonium sulfate (20.7% N)	601	340	0	0	0	0	124
Wet-process phosphoric acid (54% P_2O_5)	370	561	647	630	647	647	647
Sulfuric acid (92% H_2SO_4)	300	320	200	250	200	200	100
Urea (46% N)[c]	340	207	484	448	484	484	484
Potassium chloride (60% K_2O)	333	500	557	567	557	557	557
Formulated melt $NH_3:H_3PO_4$ mole ratio	1.0	0.6	0.6	1.0	0.6	1.0	0.6
Pipe-cross reactor							
Phosphoric acid feed temp, °F	160	133	130	155	158	138	127
Equivalent acid concentration, % P_2O_5	44	43	51	50	48	49	52
Ammonia feed temp, °F	20	Amb	Amb	22	20	Amb	Amb
Melt temp, °F	240	327	372	290	421	352	312
Melt analysis, %							
Total N	16.4	11.2	11.2	15.0	11.4	13.8	10.5
Total P_2O_5	28.0	31.2	39.0	35.4	36.4	36.0	43.0
Drum granulator							
Recycle ratio, lb/lb product	3.4	3.3	5.1	3.8	5.4	6.3	3.6
Discharge temp, °F	158	183	172	166	179	174	165
Moisture (AOAC), %	0.9	1.6	1.6	1.1	1.5	1.2	1.5
Screen analysis (Tyler), %							
+6 mesh	10.0	10.0	30.7	12.3	8.7	32.9	11.0
-6 +10 mesh	32.2	57.6	52.9	36.6	59.1	48.3	60.2
-10 +16 mesh	32.2	26.1	13.8	33.8	26.4	15.8	26.7
-16 mesh	25.6	6.3	2.6	17.8	5.8	3.0	2.1
NH_3 evolution, as % of total fed	11.2	4.2	3.6	16.9	1.2	7.3	3.1
pH of granulator product	5.2	5.2	5.5	5.8	5.3	5.7	5.5
Onsize product							
Total N, %	19.8	15.5	16.7	17.4	17.1	17.7	17.0
Total P_2O_5, %	10.4	14.8	17.4	17.5	17.4	17.5	17.9
K_2O, %	10.8	15.6	18.3	17.1	17.3	17.3	19.0
SO_3, %	29.0	20.6	12.0	14.1	13.2	11.7	9.4
As % of total P_2O_5							
Polyphosphate	16.8	1.4	5.7	10.6	16.1	23.4	13.4
Water soluble P_2O_5	92.8	96.6	92.0	90.6	87.4	99.4	90.5
Available P_2O_5	100.0	100.0	100.0	100.0	96.6	100.0	97.8
Moisture (AOAC), %	0.9	1.2	0.8	1.1	1.2	0.7	1.1

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[a] Liquid ammonia.
[b] Gaseous ammonia.
[c] Microprill urea.

MODERATOR SHELDRICK: Thank you Melvin, for that very, very comprehensive and interesting review. We are running fairly late, however, this is an interesting subject, so I think we should spend at least ten minutes on questions. Mr. Singh and Mr. Norton please come to the platform to answer questions from our audience. (Applause)

QUESTION BY CHAIRMAN FRANK P. ACHORN: Mr. Singh, you are to be commended for making that excellent talk and coming such a long way. I am sure I would not be able to keep my eyes open if I were trying to do this. One thing that has concerned us about Urea-based fertilizers and in particular, the high analyses grades, is the storage of this product. If I understand correctly you do use a dehumidified building to store your "Triple 19". Are all of your fertilizers sold in bags and if so, what type of bags do you use? The other point is do you do any type of conditioning? Do you use any conditioning agent, whatsoever, on your Triple 19?

MR. T. SINGH—ZUARI AGRO CHEMICALS: Mr. Achorn, as I said earlier, we have dehumidification in the bulk storage area. The preportion of bulk storage to bagged storage for N.P.K. grades is 1:3. We can reach a maximum level of 3000 tons on bulk storage and about 10,000 tons on bagged storage. The bagged storage area is not dehumified. It is not necessary. The type of bags that we use are jute bags which have a polythylene liner. The sticking material is bitumen. We have found that the farmer likes this kind of bag. It is a 50 kg standard bag all over the country. He uses this to store his grain and for other miscellaneous purposes later on. All of our product is sold in bags and not a single gram goes out as bulk.

QUESTION—JOHN KRONSEDER - FLUOR CORPORATION: Do you have problems maintaining that dehumidification equipment with the hydrescopic material? Don't you have difficulity keeping your equipment clean?

ANSWER—T. SINGH: There is no recirculation on the dehumidification air. It all runs through, so we are not taking any air that is coming from the bulk storage which may contain some dust. The system basically consists of deabsorption media, which is lithium chloride in our case and the air sucked from the atmosphere passes through an absorption column where the air is taken in. The operation is about 40-42 degrees centigrade. This is not uncomfortable for people to work in the bulk storage. The dehumification, done by the absorption system, is one stream of air that comes in. We have a second stream, which you call dilution air, that comes in directly and joins there to reduce the temperature to 28 to 30 degrees centrigrade yet maintains the relative humidity lower than 45%. We have used this system to avoid the air conditioning unit. Otherwise, one could chill the dehumidified air by the air conditioning system which could be an energy consumer and also difficult to maintain.

MODERATOR SHELDRICK: Are there any other questions? If not, I would like to say again, to our two Speakers, we appreciate your most interesting discussions. I am sure your papers are going to be very interesting references. Thank you. (Applause)

MODERATOR SHELDRICK: Our next Speaker Dr. Rudy van Hardeveld, is also from overseas. He is no stranger to our Round Table. He is a Dutch National educated at the Free University of Amsterdam. He holds a Ph.D. Degree. He studied Physical Chemistry and Theoretical Physics. For a while he worked in the Catalist Research of D.S.M. and afterwards, in 1970, worked in D.S.M. Process Development. He says that he was re-educated as a Chemical Engineer, especially in fluidized bed technology. He worked with others on the scaling up of Fluid Bed Catalytic Preparations and Processes and a number of other Chemical Processes involved there. In 1974 he was put in charge of a large Demonstration Plant aimed at improving the design of "A Fluid Reactor" for DSM's Melamine Process. After successful conclusion of this project he was appointed Head of the Fertilizer Research Department. Rudy, we welcome you to present your Paper on the Production of High Quality Urea Prills. (Applause)

Production of High Quality Urea Prills

M. Willems - R. van Hardeveld
Presented by R. van Hardeveld

Summary

If in a prilling tower a urea melt is allowed to crystalize to prills without precautionary measures, the mechanical quality of the resulting prills may be very low. As is so often the case, it has been proved possible to make this quality too a matter of design, namely by seeding the urea drops with crystalline urea. Since UKF/DSM started applying this process, their urea has not pulverized during handling in bulk. UKF/STAMICARBON have applied for patents on this process in a large number of countries.

The use of suitable additives and coatings can improve other quality aspects to high standards.

Introduction

In the beginning of the industrial production of urea the product was available only in the shape of flakes or small crystals (100-250 um) which both were handled in bags. These products were both subject to severe caking. When in the mid fifties urea plant capacities increased to 100-300 tons/day the prilling technology was developed. In 1955 our first 150 ton/-day urea prilling plant was put on stream at our urea plant at Geleen (Holland). The prilled product was bagged at the plantsite, and no quality problems, especially no caking problems, occured. Urea became more popular as a fertilizer in the early sixties and at the end of this decade, plants were erected with capacities of

1000 ton/day. From this time on the bulk transportation of urea became more and more important too. The bulk transportion asked for higher standards of the mechanical properties of the product, especially of crushing strength and the shatterability, because in this case the product is subject to much higher mechanical forces in comparison with those during transport in bags.

Fertilizers of good quality should not pulverize during transshipment, not even at the high throughput rates of 500 t/h which are often applied, for this would cause segregation, which would result in high concentrations of fines in the heart of the bulk and in a great dust nuisance to the environment, besides increased caking of the products. This caking causes the well-known problems in unloading and strewing.

Also on the mechanical application of fertilizer, with the aid of, for instance a centrifugal spreader, the pellets should not pulverize, because if they did, deviations in the strewing pattern would occur on account of the different ballistic paths of coarse and fine products.

Initial experience with urea prills

The initial experience with prilled urea carried in bulk were not good. Much breakage during handling, dust formation, and caking occurred. This gave rise to the general opinion that prilled urea was not suitable for bulk transportation because of its low mechanical strength. Furthermore it became general practice to design the prilling plants for average prill diameters of about 1.7 mm. Due to both reasons, the low mechanical strength and the deviating particle size distribution, prilled urea was not popular in bulk blending. Especially in the US the more costly granulation plants were put on stream to produce urea meeting the bulk blend and bulk transportation standards.

When we were confronted with this problem, we started an investigation into the possibilities of improving the *mechanical strength* of urea prills, that is, making prills suitable for bulk transportation instead of having to adapt the handling and transhipment operations to the vulnerable urea prills. Also attention was given to the design of prilling towers for the production of prills with a mean diameter fit for bulk blending, i.e. a mean diameter of 2.0-2.2 mm.

The mechanical strength of urea prills

The mechanical strength of a prill comprises the following components:

a) crushing strength; this is the resistance to a static force

b) impact strength or shatterability; this is the resistance to a dynamic force

The crushing strength can be determined as described by, for instance, TVA in Physical Properties of Fertilizers (Bull. Y 147) and is expressed in kg/cm^2.

A method for determining the impact strength was developed in the course of the investigation. It involves the pneumatic shooting of prills against a steel plant, at a velocity of 21 m/s. The percentage by weight of prills not broken under this treatment was taken as a measure of the impact strength.

Laboratory investigations

Our investigation started when the crushing strength and the impact strength of the prills produced were determined daily over a longer period. A total of 63 samples was studied. The outcome of this investigation was:

1. The crushing strength never greatly deviates from the mean value of 25 kg/cm^2, for formaldehyde free product.
2. the impact strength can vary widely. The values found range between 10 and 75% unbroken prills after the shooting test (see Table 1).

Table 1

Frequency table of the impact strength of urea prills

number of observations	impact strength (% unbroken prills)
3	10
8	11-20
8	21-30
5	31-40
12	41-50
19	51-60
7	61-70
1	71-80
$n = 63$	μ - 45%
n	σ - 18%

Research with a light microscope using the oil imersion technique, with a scanning electron microscope and with X-ray diffraction on the urea prills revealed great differences between the texture of the prills in the samples with the low or the high impact strength. On the extreme ends are prills consisting of virtually one crystal (dendrites) and prills consisting of a great number of randomly orientated crystals. The former variety has the low, the latter the high impact strength. This is shown in Figures 1-11. The origine of this striking difference was discovered in studying the crystallization behavior of droplets of urea melt in a vertical windtunnel.

Through the matching of the upward air velocity and the falling rate a droplet was made to stand still in the wind tunnel and the crystallization process was recorded with the aid of a high speed camera (300 images/sec.). It appeared that the urea strongly supercools and that this supercooling can amount to 50°C. below the melting point. If, in the supercooled prill a crystallization nucleus if formed, a very rapid crystallization process takes place throughout the whole droplet which enevitably leads to the formulation of the dendritic (quasi-single) crystal structure of the weak prills. When fine urea dust was introduced into the wind tunnel no supercooling of the droplets occured and strong polycrystalline prills were formed. From these experiments it was concluded that:

1. Prills with a low impact strength are formed when urea is prilled in air containing very few or no seed particles. This is for instance the case when, as a result of high humidity of the air, the seed particles formed at the bottom of the prill tower dissolve.
2. By the introduction of seeds into the cooling air in a urea prilling tower the mechanical strength of urea prills can be considerably improved.

Plant scale investigation

The investigations were continued in our 1000 t/d plant. Urea was ground to seed particles which were blown into the prill tower. It was found that seeding particles in the range of 2-10 um offer the optimum combination of high collision probability and low weight requirement whereas they can be separated rather easily from the prilling air by scrubbing. A very beneficial effect of the seeding upon the impact strength was established. We were able to correlate the impact strength and the mean number of seeding spots from the results of a detailed scanning electron microscope study of the prills of a number of samples with different impact strengths, Fig. 12.

These data enable the determination of the quantity of seed material required for optimum seeding. This quantity depends on:

a) the diameter of the prilling tower, the diameter of the prill, the size of the seed crystals, the probability of a seed hitting a prill, the required number of hits and the effective seeding time.
b) the amount of prills passing through the tower per unit time does not play a role.

It was calculated that for our prilling tower approximately 5 kg/h of seed particles would be sufficient, assuming ideal dispersion in the prilling tower air.

In practice the feed rate of the seed crystals had to be raised to 10 kg/h because, probably as a result of non-ideal dispersion in the prilling tower, the maximum impact strength was not attained with a feed rate of 5 kg/h. A series of measurements carried out on our standard product between December 1980 and March 1981 yielded the results given in Table 2. UKF/STAMICARBON has applied for patents on this process in a large number of countries.

Table 2

Frequency table of the impact strengths of urea prills

number of observations	impact strength (% unbroken prills)
0	≤ 67
1	68-72
5	75-77
35	78-82
31	83-87
21	88-92
n = 93	μ = 83.5%
	σ - 4.5%

Mean particle size of prills

As mentioned already, prills with a particle size disctribution defined by average and standard deviation fit for bulk blending can be produced easily, now. This is possible on the one hand by an optimized design of the prilling tower and on the other hand by an improved design of our rotating prilling buckets, which led to a significant decrease of the standard deviation, σ. of the prills. In former designs of prilling buckets at an average prill size of 2.1 mm, $\sigma = 0.5$ was usual. This means that at a 95% of the particles fall in the sieve range $1,10 < d < 3.1$ mm. At present, prilling buckets can be cosnstructed with $\gamma = 0.3$ giving a 95% sieve range of $1.5 < d < 2.7$ mm. This optimized design and the smaller standard deviation led to a considerable decrease of the dimensions of the prill tower because these are determined entirely by the ballistic behaviour and the necessary cooling time of the largest prills produced. The compatibility of prills with a mean diameter of 2.1 mm with the average granulometry of U.S. bulk blend materials is shown in Fig. 13.

Additions and coatings

To lower the caking tendency of urea usually a small amount of additive is used. The best known additives at this moment are formaldehyde or formaldehyde derivatives. It is common knowledge that 0.2-0.5% of formaldehyde lowers the caking tendency to virtually zero, provided that the H_2O-content of the product is less than 0.3%w. A very favourable additional effect of the formaldehyde addition is the increase of the crushing strength of the prills from the usual value of 25 kg/cm^2 to 35 kg/cm^2.

If, at transhipment with very high throughput rates no dust nuisance is allowed sometimes a dust binding coating of the prills is desirable. Several suitable coatings are at hand amongst which are mineral oils and polyethyleneglycol. Usually additives in the order of 0.1% will suffice to meet the purpose.

Conclusions

In conclusion we may put that today's prilling technology allows the production of urea prills which can meet the highest quality standard as to:

- crushing strength
- impact strength
- mean particle size
- compatible particle size distribution for bulk blending
- free flowingness
- absence of dust and segregating fines

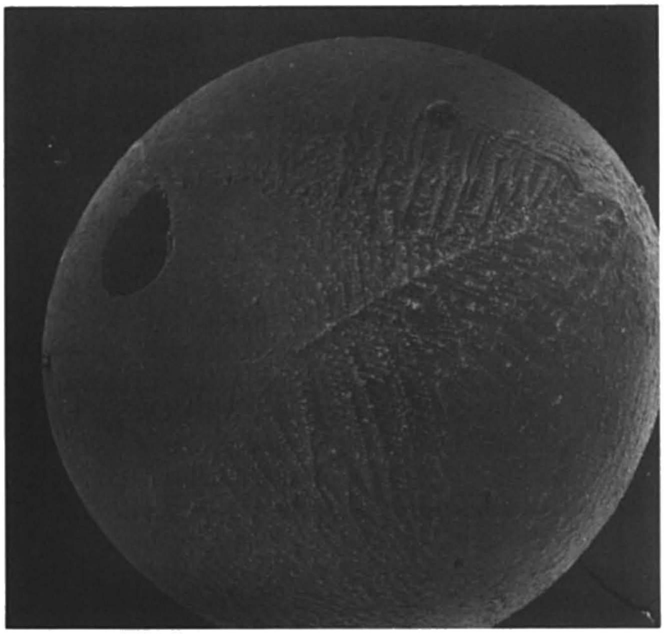

Figure 1
Appearance of Supercooled Prill
in Scanning Electron Microscopy
(SEM) (S 1970)

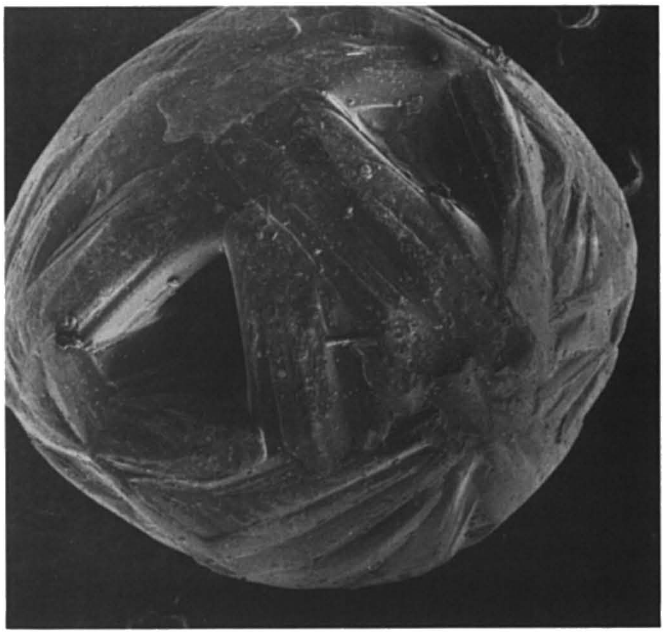

Figure 2
SEM-Recording of a Poorly
Seeded Prill (S 3994)

Figure 3
The Appearance of a Sufficiently
Seeded Prill in SEM (T 2314)

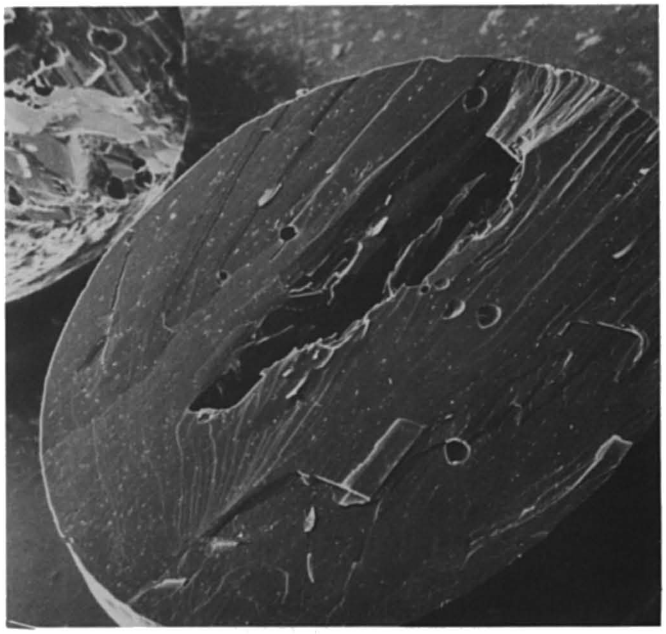

Figure 4
The Appearance of a Fractured
Supercooled Prill in SEM Showing
the Alignment of the Dendrites (S 4380)

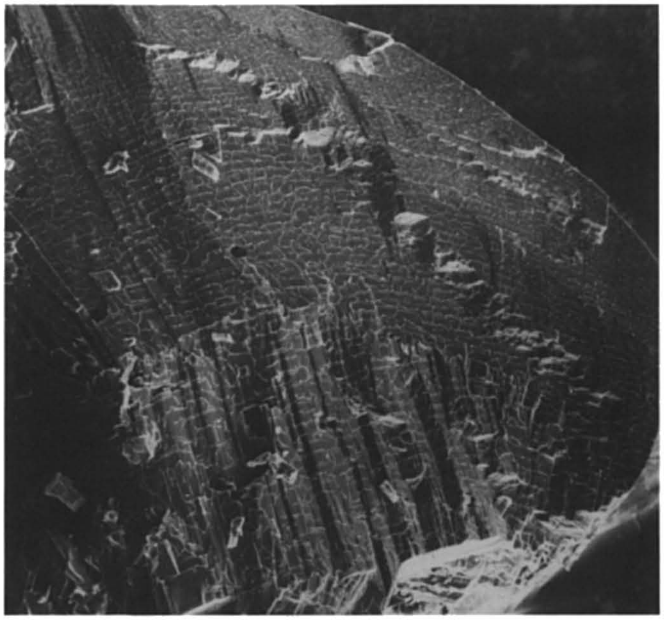

Figure 5
Fractured Supercooled Prill
Showing Very Clearly the Dendritic
Quasi Single Crystal Structure (S 6146)

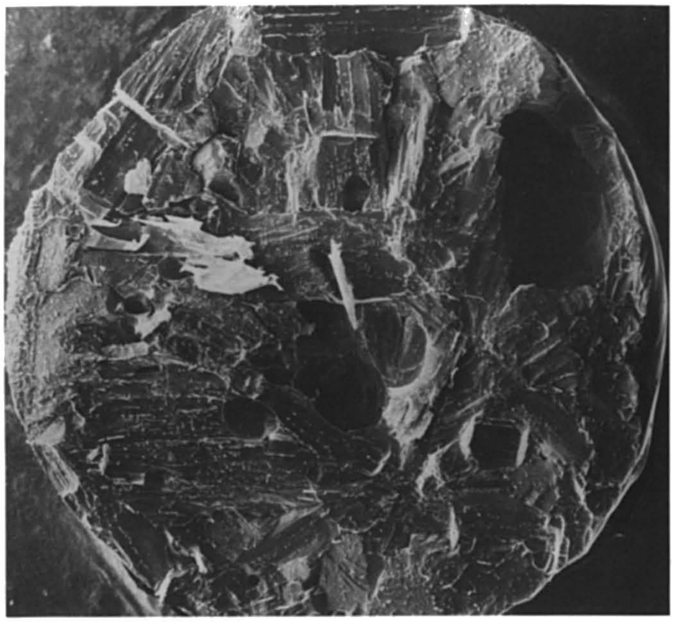

Figure 6
Fracture of a Prill with
Intermediate Seeding Level
Showing Random Orientation
of the Separate Single
Crystals (S 4498)

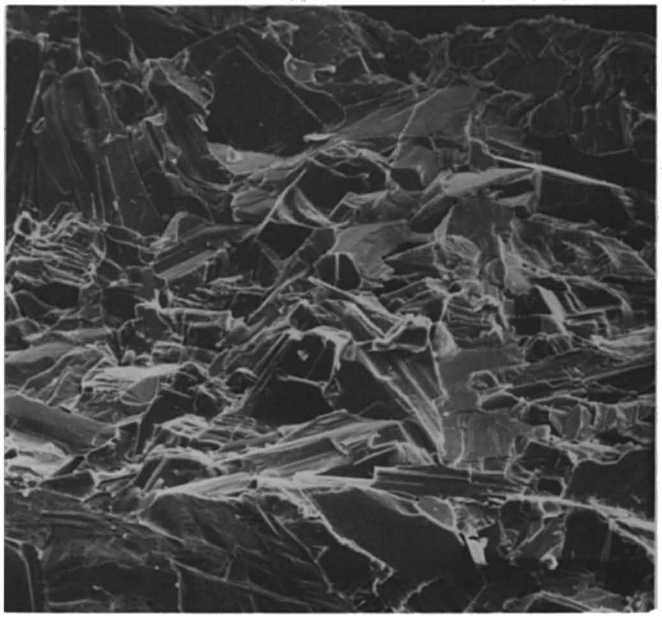

Figure 7
Fracture of a Highly Seeded Prill
Showing the Completely Random
Orientation of the Individual
Single Crystals (S 6125)

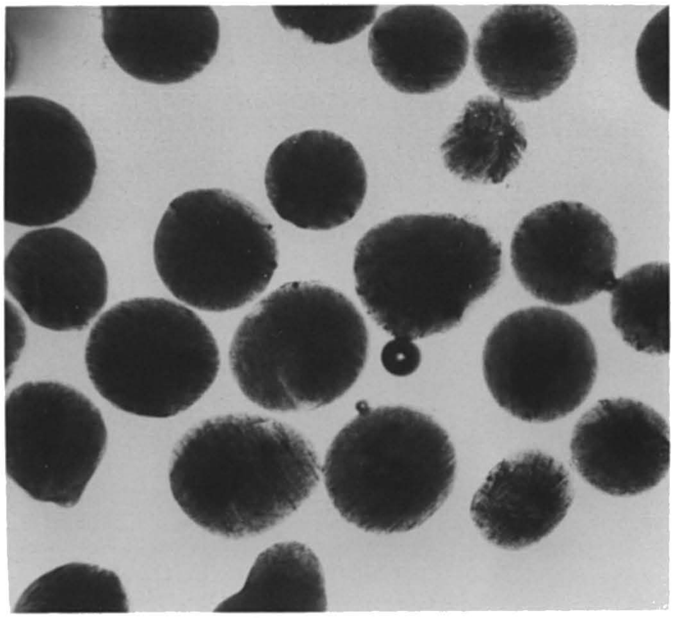

Figure 8
Appearance of Supercooled Prills
with an Impact Strength of 10% in
Oil Immersion Transmission Microscopy (40421)

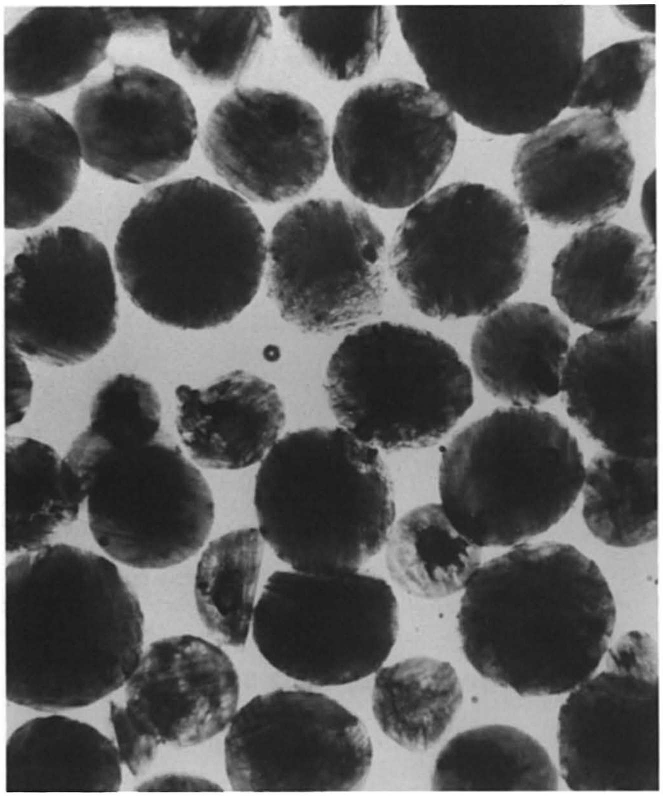

Figure 9
Supercooled Prills, Impact Strength
22% in Oil Immersion Transmission
Microscopy (40422)

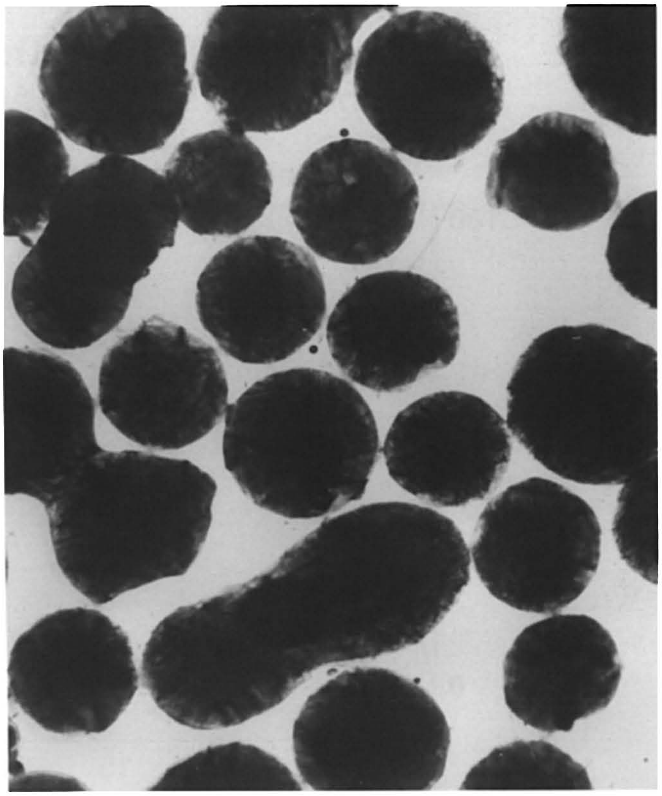

Figure 10
Prills, Seeded to an Intermediate
Level, Impact Strength 57% in Oil
Imersion Transmission Microscopy (40423)

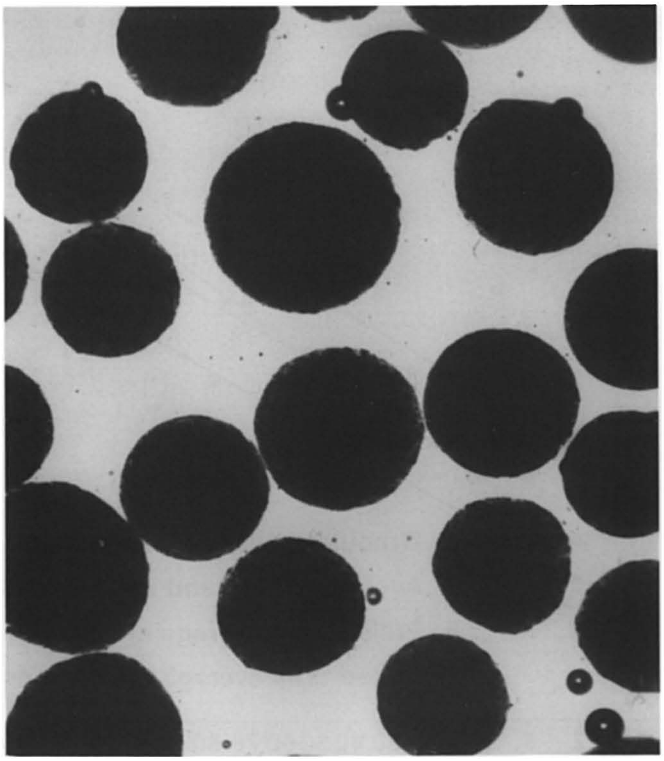

Figure 11
Well Seeded Prills, Impact Strength
81%, in Oil Immersion Transmission
Microscopy (40425)

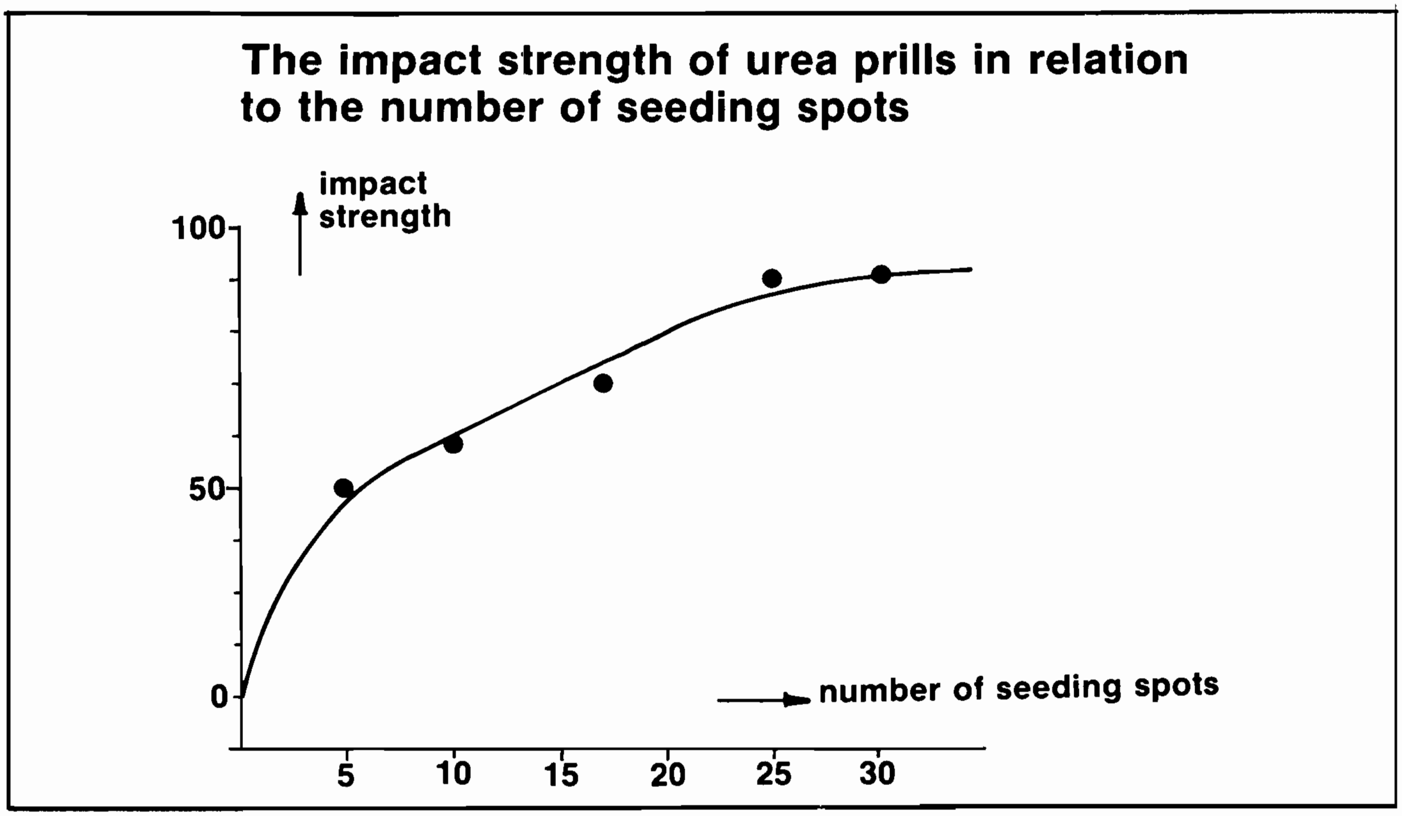

Figure 12

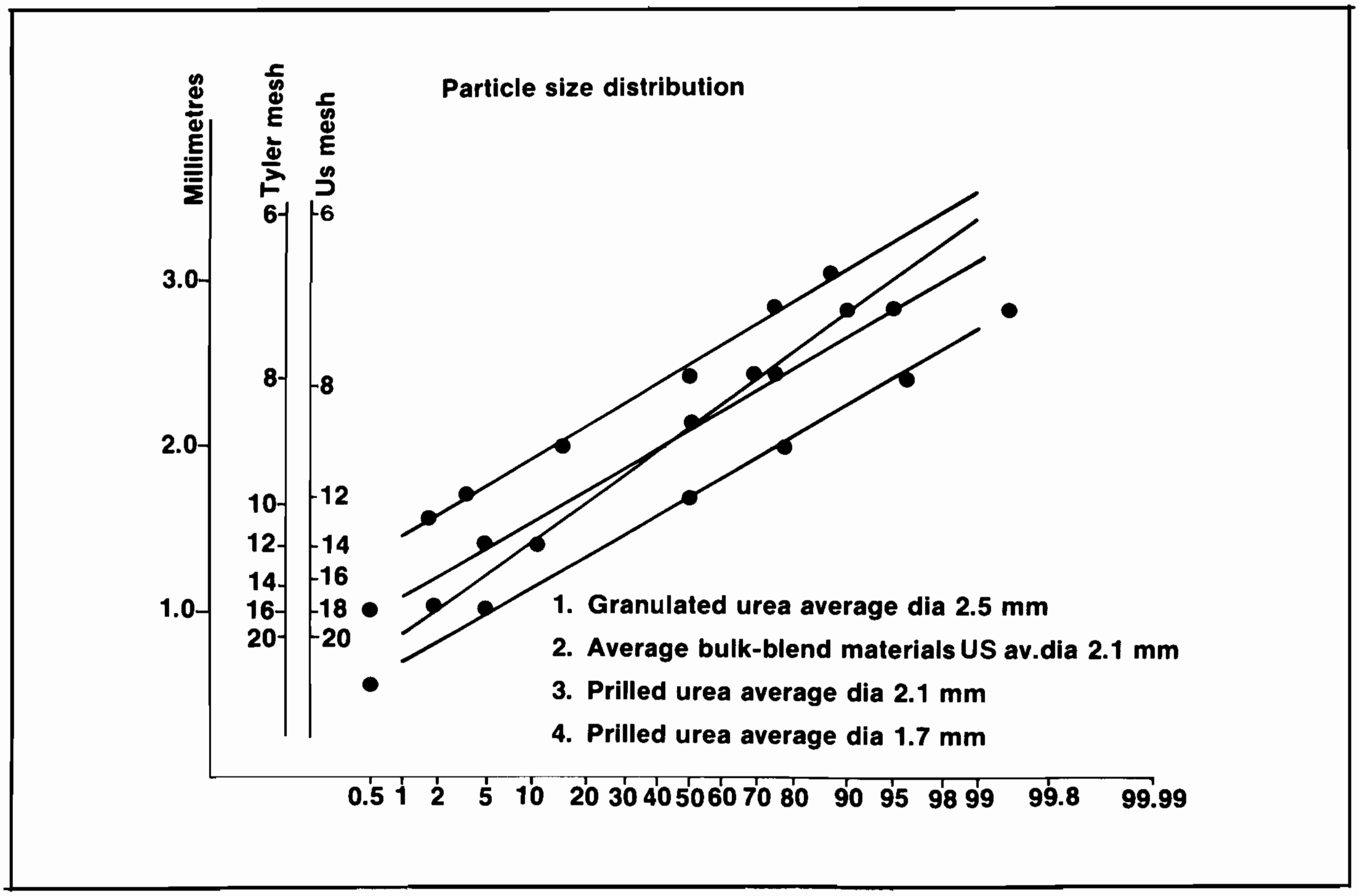

Figure 13

Frequency table of the impact strength of urea prills

number of observations	impact strength (% unbroken prills)
3	⩽ 10
8	11-20
8	21-30
5	31-40
12	41-50
19	51-60
7	61-70
1	71-80

N = 63

$\mu = 45\ \%$

$\sigma = 18\ \%$

Table 1

Frequency table of the impact strength of urea prills

number of observations	impact strength (% unbroken prills)
0	⩽ 67
1	68-72
5	75-77
35	78-82
31	83-87
21	88-92

N = 93

$\mu = 83{,}5\ \%$

$\sigma = 4{,}5\ \%$

Table 2

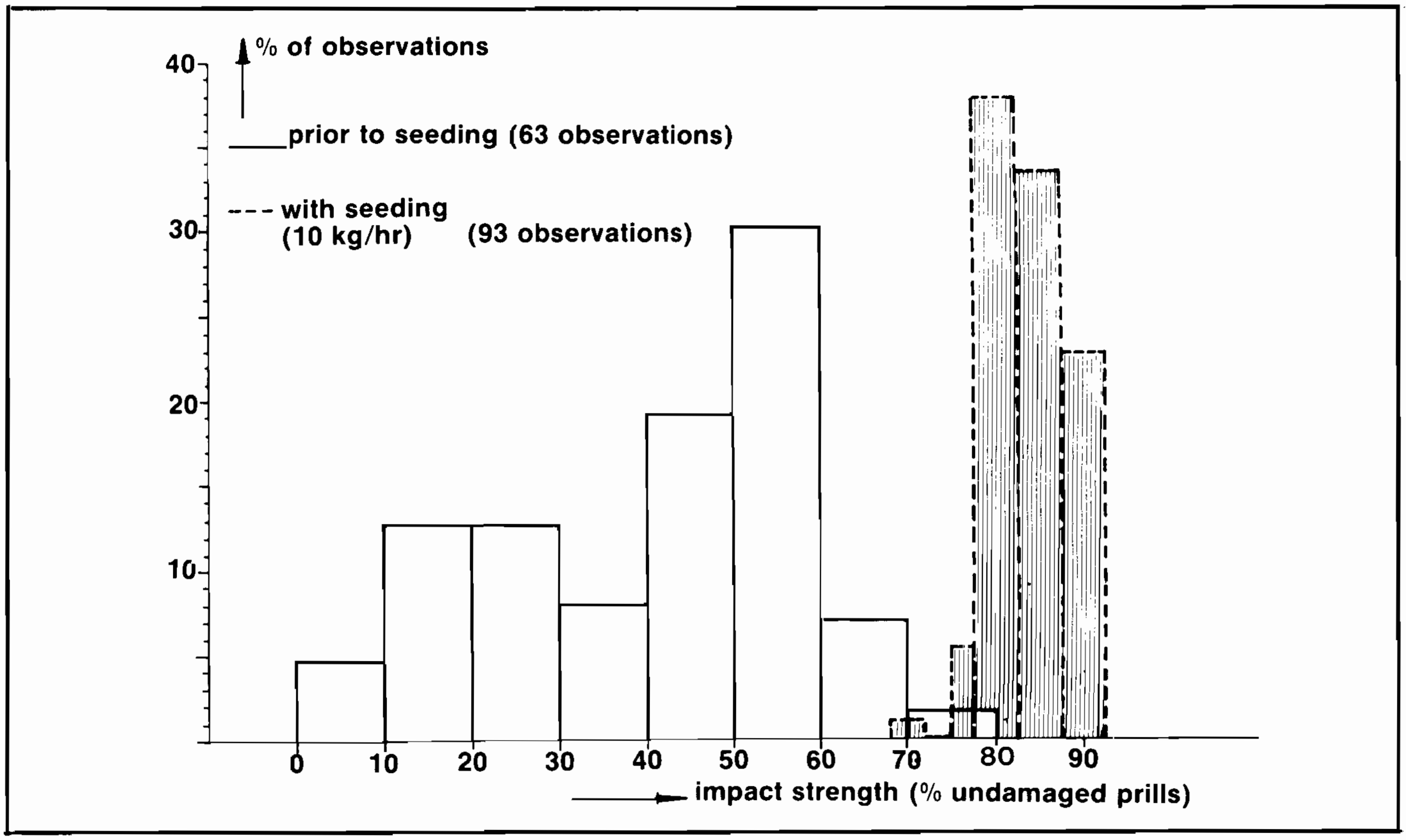

Table 3

MODERATOR SHELDRICK: Thank you Rudy. First of all, I would like to say we had a very good talk on how "basic research work" can lead to Process Development. The meeting is now open for questions on this particular "Technique". (Applause)

QUESTION FROM HAROLD BLENKHORN—NITROCHEM, INC: I wonder if you could say something about the technique for seeding your prills in the tower? How is the dust introduced?

ANSWER—DR. R. van HARDENVELD: We mill the necessary amount of urea prills which are blown by a pneumatic system into the prilling tower. All of this technology is under "Patent" which is being applied for.

Any further questions? If not, once again, Ruby, we thank you very much. (Applause)

MODERATOR SHELDRICK: The last paper this afternoon is on the commercial use of the Pipe Cross Reactor for DAP and MAP Production. This discussion will be given for David G. Salladay who is well known to most of you for his work on this topic. He is a Chemical Engineer with TVA and works in the Process and Product Improvement Section. He has worked on many areas of Process Design, Corrosion Control, Air Pollution Control, Plant Startups and Energy Conservation. He has a B.S. in Chemical Engineering from the University of Mississippi and an M.S. in Chemical Engineering from the University of Tennessee. He has industrial experience with Freeport Sulfur Company, in Louisiana, and with Amoco Chemical Company of Alabama. He has been with TVA for seven years, during which time he has authored or co-authoried 21 papers. That is quite an output. David, please. (Applause)

Recent Developments in Producing Monoammonium and Diammonium Phosphates Using the TVA Pipe Cross Reactor

D. G. Salladay - F. P. Achorn - J. L. Greenhill
Presented by D. G. Salladay

Granular ammonium phosphates continue to be the major source of phosphate fertilizer in the United States. A total of about 11 million tons of monoammonium phosphate (MAP) and diammonium phosphate (DAP) are produced annually. Although 9.4 million tons of DAP and only 1.5 million tons of MAP are produced, these tonnages are expected to equalize during the 1980's. Production of MAP by primary producers in large plants using pipe-cross reactors (PCR's) is increasing. By the end of 1981 at least four primary producers will be using PCR's to produce MAP. With the declining production of concentrated superphosphate (CSP) and the increasing levels of impurities in phosphate rock, MAP is becoming the product in which to use the more impure materials. Attempts to use high-impurity sludge acid in granular CSP is complicated by the very sticky mixture that results. Varying grades of MAP, such as 10-50-0 and 11-53-0, enable these impurities to be included without encountering the grade problems of 18-46-0 grade DAP.

Although interest in MAP is increasing, DAP continues to be the major phosphate fertilizer for both export and domestic use. Granulation plants in the Netherlands and Australia continue to use pipe-reactor melt-granulation technology to produce DAP. One basic producer in the United States continues to use the pipe-cross reactor in parallel with a preneutralizer tank to produce DAP.

Design and Operating Criteria for the Pipe-Cross Reactor

Recent field experience with PCR's in manufacture of MAP and DAP has shown the need for a second major design factor. Since the first PCR was operated seven years ago in Missouri, heat flux calculations have been used to determine the diameter of the PCR. The heat flux is a measure of the "intimacy" of contact between the acids and the ammonia and is expressed as Btu per hour per square inch of PCR cross sectional area. The second factor, the ammonia loading factor, is expressed as pounds of ammonia per hour per cubic inch of PCR volume. This second factor determines the time of contact of the acids and the ammonia. In early work, phosphoric acid, usually merchant grade containing 54 percent P_2O_5, was ammoniated to an NH_3:H_3PO_4 mole ratio of 1.0:1 with little difficulty. Ammonia loading factors of about 2.0 lb $NH_3/hr/in^3$ were sufficient. In producing DAP where phosphate is ammoniated to an NH_3:H_3PO_4 mole ratio of about 1.5:1, a PCR of larger volume is needed. The reaction is slower for the second ammonia molecule. In producing DAP, an ammonia loading factor of less than 1.2 lb. $NH_3/hr/in^3$ should be used. Concentration of the acid affects the length and resultant volume of the PCR required for complete reaction. As more PCR's have become operational at basic production facilities, lower concentration phosphoric acid has been used. If phosphoric acid used contains less than about 40 percent P_2O_5 or if large quantities of scrubber liquor are used with merchant acid, the ammonia loading factor even for MAP production must be lowered toward 1.0 lb. $NH_3/hr/in^3$.

All pertinent design and operating criteria for the PCR are listed below.

1. Optimum heat flux is 600 x 10^3 Btu/hr/in^2.
2. The ammonia sparger must protrude 19 inches into the reactor tube.
3. At least 0.3 pounds of water per pound of liquid ammonia must be mixed with the ammonia entering the PCR; this water can be supplied as scrubber liquor.
4. A minimum of 50 pounds of sulfuric acid per ton of product should be included in the formulation to prevent scale formation in the PCR.
5. A minimum of 100 pounds of phosphoric acid (wet-process) per ton of product should be included in the formulation to mimimize corrosion of the reaction tube. Impurities in the acid are not detrimental to reactor operation. Wet-process phosphoric acid containing as much as 20 percent solids has been used successfully.
6. Minimum length of the reaction tube is 9 feet. Maximum ammonia loading for MAP made from merchant grade phosphoric acid should be less than 2.0 lbs $NH_3/hr/in^3$ and for DAP manufacture the maximum ammonia loading should be less than 1.2 lbs. $NH_3/hr/in^3$. If MAP is produced from dilute phosphoric acid containing 30 to 40 percent P_2O_5, an ammonia loading of 1.2 lb. $NH_3/hr/in^3$ or less should be used.
7. Melt from the reaction tube should discharge at or before the center of and at least 2 feet above the bed of material in the granulator.
8. Best results have been obtained when phosphoric acid is added both to the granulator and to the PCR.
9. All sulfuric acid should be added to the PCR. This helps prevent formation of ammonium chloride particulate in the granulator.
10. Although a dryer is not needed when the PCR is used to produce MAP from phosphoric acid containing 46 percent or more of P_2O_5, it is advisable that the cooler be equipped with a burner for heating the equipment before startup.
11. Skin temperature of the PCR should be kept below 300°F. to avoid shortening the life of the pipe. This can be done by adding scrubber water to the pipe.
12. MAP must be produced in a PCR made of Hastelloy C-276, but a PCR made of 316L stainless steel can be used for DAP.

Design and Operating Criteria for the Ammoniator-Granulator-Dryer

Implementation of PCR melt granulation has also led to some changes in the design criteria for the ammoniator-granulator-dryer. Listed below are TVA's recommedations.

1. The length: diameter ratio should be 2.0 - 2.3:1 (2.3:1 optimal).
2. Retention time should be 3.0 to 4.0 minutes.
3. Volume of the bed should be 25 to 30 percent of the total volume.
4. Surface area of the cylindrical portion should be 1.0 to 2.0 ft^2 per ton of throughput per hr.
5. Mass flux should be 3.0 to 5.0 tons of throughput per hr per ft^2 of cross-sectional area.
6. Rotational speed should be 35 percent of critical or 27 rpm, where D is the diameter in feet.
7. Conventional ammonia sparger design should be used. Assure good coverage over the entire length

of the bed by using uniform spacing of holes. Preferred spacing is 1 inch; maximum spacing is 2 inches. Total area of holes for liquid NH_3 should be 0.0002 in^2/lb of NH_3/hr; total area of holes for gaseous NH_3 should be 0.001 in^2/lb of NH_3/hr.

8. In general, PCR melt granulation requires about twice as much sweep airflow as conventional slurry granulation. This airflow should be calculated at 145°F. saturated condition to remove all but 2 percent of the moisture in the fertilizer granules. The discharge end of the granulator must be closed so that this airflow will actually sweep across the granules.

Using the Pipe-Cross Reactor for Producing Monoammonium Phosphate

During the last year the major area of new activity was use of the PCR to make MAP. The steadily declining quality of phosphate rock has created increased quantities of sludge phosphoric acid. This acid, typical analyses of which are shown in Table 1, cannot be used in DAP without causing grade deficiences. In the past much of this acid was used to produce concentrated superphosphate. However, the market for superphosphate is not large enough to permit use of all the sludge acid in this process. Run-of-pile triple superphosphate inventories have grown during this past summer. Basic producers are looking at the production of MAP grades of about 10-50-0-2S for using these low-purity acids in the PCR. Previous work with a PCR in Missouri indicated that phosphoric acid containing 15 to 20 percent solids can be ammoniated without difficulty.

There are other advantages for producing and using MAP instead of DAP. MAP is easier to produce. Only about 2 or 3 percent of the ammonia fed to the process must be scrubbed, compared to about 15 percent in the DAP process. Also less ammonia must be shipped from its production site to areas where phosphoric acid is produced[1].

Several firms have used the PCR to produce MAP in "regional" NPKS plants. In one of these plants the preneutralizer tank has been replaced with a TVA PCR. Figure 1 is a flow diagram of a typical plant of this type. Although this plant has a dryer and two coolers, all of this equipment is not always required. Plant tests show that of merchant-grade phosphoric acid containing 52 to 54 percent P_2O_5 is used, there is enough chemical heat or reaction between the acids and ammonia to dry the product so that no fossil fuel is required. If the PCR is used, a suitable plant for producing MAP requires only one cooler; no dryer is needed. Plant tests indicated that a dryer would be required if the phosphoric acid concentration to the PCR was less than about 46 percent P_2O_5. This plant has a 9- x 20-foot rotary ammoniator-granulator discharging into a 9- x 60-foot rotary dryer. Material from the dryer is screened on oscillating screens, and oversize is crushed in cagemills. The mills have two rotating cages, one within the other, which rotate to opposite directions. Material from the crushers is returned to the screens for removal of product-size material. Fines from the screens are recycled to the ammoniator-granulator. Product-size material from the screens is cooled in a 9- x 60-foot rotary cooler (No. 1 cooler). Product from this cooler is rescreened on another oscillating screen. Fines from this screen are also recycled. Product-size material is further cooled in a second rotary cooler 6 feet in diameter and 60 feet long (No. 2 cooler). Material from this cooler is again screened with oscillating screens. In producing MAP, the recycle rate must be controlled. This is usually accomplished by using the "split boot" shown in Figure 2. This equipment is usually installed in the product discharge chute from the oscillating screens. Exhaust gases from the ammoniator-granulator and from the No. 2 cooler are scrubbed in a venturi scrubber with an exhausta blower having a capacity of 33,000 cfm.

A more detailed sketch of the ammoniator-granulator with the PCR installed in it is shown in Figure 3. The PCR is made of 6-inch Hastelloy C-276 pipe fittings and is similar to the design shown in Figure 4. Separate spargers for hot ammonia and scrubber liquor are installed. The sparger for hot aqua is arranged so that it discharges ammonia onto the center line of the reactor. The sparger for scrubber liquor is installed directly below the sparger for hot aqua. Four thermocouples are located along the bottom of the pipe at 2-foot intervals to measure the skin temperature. Ammonia used in the process is premixed with water to produce hot aqua in a small premixing chamber equipped with baffles. There is less vibration at the feed end of the PCR when this chamber is used.

The PCR is installed so that it discharges melt 1½ to 2 feet above the surface of the bed in the granulaor. The center of the melt spray is about 5 feet from the feed end of the granulator. Phosphoric acid is dribbled onto the bed through a separate perforated pipe sparger 15 feet long containing 20 quarter-inch holes. The amount of phosphoric acid is limited to that required to improve the shape of the granules (round). Ammonia is added to the bed through two plow-shaped spargers located about 6 and 13 feet from the feed end of the granulator. These spargers (Figure 3) have holes on both sides through which ammonia enters under the bed of material in the granulator. These spargers cause far fewer operating problems than the conventional long pipe sparger. It is possible to use the plow-shaped spargers without encountering high ammonia losses because in the PCR process for MAP, only a small amount of the total ammonia requirements is added to the bed in the granulator. Thus, the difficulty with pipe spargers bending and breaking in the granulator can be eliminated. The ammoniator-granulator has a retaining ring about 4 feet from the discharge end of the granulator, and there is no retaining dam at the discharge. This design gives the operator a better opportunity to observe granulation efficiency than when the dam is located on the end of the ammoniator-granulator.

This plant uses phosphoric acid (52.5% P_2O_5) produced from Florida phosphate rock and virgin 66° Be. sulfuric acid to supply the S of the grade. Other acids of different concentrations have been used to produce this product. A typical formulation used for the production of MAP of 11-53-0-2S grade is shown in Table 2 along with some of the operating data. The plant is operated at 25 tons per hour and the recycle rate is 3.8 tons of recycle per ton of product. Results are best when 75 percent of the total phosphoric acid requirement is added to the PCR and the rest of the acid is added above the bed of material in the ammoniator-granulator. All of the sulfuric acid is added to the PCR. About 60 percent of the total ammonia requirement is added to the PCR. The NH_3:H_3PO_4 mole ratio in the melt from the PCR is 0.6:1, and this ratio in the product is kept at 1.0:1 by maintaining a pH of 4.0 in the material from the granulator.

The product size distribution is excellent for bulk blending with granular urea, granular potash, and other granular fertilizers. It also provides some of the sulfur requirements in a most desirable form (sulfate S). The product has good hardness. Its average crushing strength is actually greater than for commercial diammonium phosphate (average of 9.9 lbs. for MAP and 8.9 lbs. for DAP)[a]. The product also resists abrasion and is generally free of dust[2].

One primary phosphate producer has just finished construction of a large granulation plant. This plant is equipped with a Hastelloy C-276 PCR designed as shown in Figure 5. This PCR, 10 inches in diameter and 18 feet long, is designed to produce 90 tons per hour of MAP of grade 11-53-0-2S. A slotted discharge has been recommended because of the large diameter of the PCR. (In general, open pipe discharges, with sleeves when necessary, are recommended for PCR's that are 6 inches in diameter or less to ensure good operation. One notable exception is the case when one of these smaller PCR's must be positioned closer than desired to the granulator bed.) PCR's with a diameter of more than 6 inches, such as this one, generally operate better and produce less oversize with slots. Initial operation of this PCR will be with 60 percent of the phosphoric acid fed to the pipe; the remaining 40 percent will be fed onto the bed of the granulator.

The MAP produced will be a dual use product that will probably be used in both dry bulk blends and fluid suspensions.

(A). Hardness test procedure given in TVA Bulletin Y-147

Using the Pipe-Cross Reactor for Producing Diammonium Phosphate

More than 9 million tons of DAP is produced annually in the United States. The PCR has been used to produce DAP in several pilot-plant tests. Data from two of these tests are shown in Table 3[3]. In Test 1, sulfuric acid was included in the formulation; in Test 2, it was not used. In both tests the equipment shown in the flow diagram (Figure 6) was used; however, fuel was not burned in the dryer and it was operated as a cooler. All of the phosphoric acid was first added to the scrubber and this partially neutralized acid was fed to the PCR. When sulfuric acid (92% H_2SO_4) was used, all of it was added to the PCR. The sulfuric acid was added because plant tests had shown that this helped prevent formation of scale in the reactor. This scale did not form in either test; however, the tests were only 6 hours in duration. In the plant tests longer operating times were used. When the sulfuric acid was not included in the formulation in the plant tests, a scale formed in the PCR which eventually caused it to plug. The pilot-plant test did show that when sulfuric acid was included (equivalent to 84 lbs 100% H_2SO_4 per ton of product) in the formulation, nearly all the P_2O_5 in the product was available. Also with this amount of sulfuric acid and using merchant phosphoric acid, it was still possible to produce the desired 18-46-0 grade. When sulfuric acid was not included in the formulation, the P_2O_5 availability was lower (97.7% of total P_2O_5). Chemical analyses of commercial DAP samples show that there is room to include 25 to 50 pounds of 100 percent H_2SO_4 per ton of product in the formulation. Pilot-plant data show that without using fuel in the dryer, it is possible to produce a product containing about 2 percent moisture and having good storage characteristics. The recycle rate was about 4 tons of recycle per ton of product. The PCR was operated so that the NH_3:H_3PO_4 mole ratio in the melt from the reactor was 1.32:1 in test 1 and 1.4:1 in test 2. The melt temperature was 240° in test 1 and 290°F in test 2. The NH_3:H_3PO_4 mole ratio in the product was calculated to be 1.78:1 in test 1 and 1.88:1 in test 2. Based on these results the capacity of a plant using the TVA conventional granular DAP process (4) could be increased from 1,800 tons per day to 2,200 tons per day by installing a PCR.

The flow diagram for the TVA conventional granular DAP process is shown in Figure 7. In this process filter grade phosphoric acid containing 28 to 32 percent P_2O_5 is usually fed to the scrubbers where it is partially ammoniated by ammonia loss from the granulator and dryer. This partially ammoniated acid is mixed in a preneutralization tank with commercial acid containing 40 to 54 percent P_2O_5. Two preneutralizers are shown in Figure 7, but usually only one of these tanks is used. Because it operates at a relatively high pH (6.5 to 7.0), it is made of stainless steel. When two preneutralizers are used, the first tank which operates at a low pH (2.0) has an acid-proof brick lining.

The partially neutralized mixed acids are further ammoniated to an NN_3:H_3PO_4 mole ratio of 1.4 to 1.5:1 in the preneutralizers. Addition of water is controlled to maintain a slurry temperature of 250°F. and a specific gravity of 1.5. This slurry is pumped to the ammoniator-granulator where it is mixed with recycle and further ammoniated to an NH_3:H_3PO_4 mole ratio of 2.0:1. Product from the granulator is dried in a rotary dryer, screened, and the product-size material is cooled. Oversize is crushed and returned with fines from the screens to the ammoniator-granulator.

In two commercial plants, one in Australia and the other in the Netherlands, the preneutralizer tanks have been replaced with a PCR. One company in the U.S. has installed a PCR in the granulator which is operated concurrently with a preneutralizer.

Figure 8 is a sketch of a PCR used for producing DAP. It has a different configuration from the PCR used for producing MAP or NPKS mixtures. Plant test results show that the PCR can be fabricated from stainless steel and the reactor can be used to increase the production rate of the plant. Operators report that it is much easier to produce DAP with the PCR than with the conventional preneutralizer. They report the following advantages for the PCR:

1. Since no slurry pumps are required with the PCR, problems associated with pumping slurry from the preneutralizer are eliminated.
2. Problems of occasional boil-over of preneutralizers are eliminated.
3. Time required for maintenance is less for the PCR than for the preneutralizer.
4. Problems with the exhaust system from the preneutralizer are eliminated.
5. The PCR permits easier correcting of adverse conditions because of the low retention time in the preneutralizer.
6. Generally DAP produced by the PCR process has less citrate-insoluble P_2O_5 than product from the preneutralizer process.
7. Usually higher production rates can be obtained with the PCR than with the preneutralizer.

Although there are advantages to using the PCR for producing DAP, there are some disadvantages. A scale forms in the reactor and after continuous operation of about one week, the reactor must be shut down and the scale must be removed with a chipping hammer. The type and amount of scale depends upon the source of rock used in manufacturing the wet-process phosphoric acid used in the process. Chemical analyses of scale from two rock sources are tabulated below.:

Phosphate Rock Source	Percent by weight							
	P_2O_5	N	P	Al_2O_3	Fe_2O_3	MgO	SO_4	SiO_2
Central Florida	17.7	9.8	23.5	10.1	0.57	0.67	2.0	15.5
Nauru	(predominantly $MgNH_4PO_4.H_2O$)							

Scale from the Florida rock source was found in a PCR in the U.S. and scale from the Nauru acid source was found in a PCR operating in Australia. Small-scale tests indicated that the scale of the U.S. source can be dissolved by filling the PCR with sulfuric acid. A soaking period of 24 hours is required to dissolve the scale. Therefore, by installing two reactors it is possible to alternate reactors so that one is operating while the other is being descaled. Tests of the Australian scale have not been conducted but probably this scale also can be removed by the same method.

Another problem has been removal of moisture from the ammoniator-granulator. Most ammoniator-granulators are designed so that there is very little passage of air through the granulator. The feed end is usually closed with a high retaining ring, ducts, chutes, and pipes. Most of the exhaust from the granulator is gas forced from the granulator, air from the operating area, and gas from the chute between the dryer and the ammoniator-granulator. In many instances there is not enough negative pressure on the ammoniator-granulator to avoid loss of ammonia and other gases at the feed end of the granulator. Adding a PCR increases the amount of gas which should be removed from the granulator because the steam that formerly discharged from the preneutralizer must be withdrawn from the ammoniator-granulator. However, there is a need in the conventional plants with no PCR to have an increased sweep of air through the ammoniator-granulator. The partial pressure at 167°F. of water and ammonia above the bed of material in the ammoniator-granulator is tabulated below (5):

Mole Ratio N:P	Partial Pressure, mm Hg	
	H_2O	NH_3
1.466:1	185.4	1.14
1.705:1	225.6	5.61
1.750:1	233.1	8.39
1.965:1	248.4	52.90

Partial pressure of water is much higher than the partial pressure of ammonia above the bed. Therefore, the volume of water which can be removed is substantially greater (4.7 to 162 times greater) than the volume of ammonia. Ammonia could easily be recovered in the scrubbing system and the water will be lost in the scrubber exit gas. Removal of this water from the ammoniator-granulator should lower the total moisture in the bed of material in the ammoniator-granulator which in turn will decrease the required recycle rate. The lower recycle rate will result in a higher production rate.

Since it is difficult to open up the feed end of the ammoniator-granulator for greater air flow, at least one company plans to install a forced air blower at this end of the ammoniator-granulator. A sketch of this granulator is shown in Figure 9. The sketch also shows the recommended design for a PCR for producing DAP. Pilot plant results show that with a straight pipe configuration there was less tendency to form scale in the PCR.

Summary

For several years regional NPKS granulation plants have been producing small quantities of MAP with the TVA pipe-cross reactor. Now primary phosphate producers are beginning to produce MAP at rates approaching 100 tons per hour by using large pipe-cross reactors. although much of the recent interest has been in MAP production, production of DAP with the PCR has continued at one location in the U.S. The DAP-PCR design has been refined and solutions to the scaling problems have been found. Several other primary phosphate producers are considering using a PCR to produce DAP.

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4. Achorn, F. P. et al., "Production of Granular Diammonium Phosphates," Patent Letters 3,153,574, December 8, 1960.
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Table 1
Typical Chemical Analyses of Sludge Phosphoric Acid

Constituent	Weight % Sample 1	Weight % Sample 2
P_2O_5	46.0	55.4
CaO	2.39	0.15
SiO_2	0.73	0.21
Fe_2O_3	2.09	2.30
Al_2O_3	1.39	1.50
F	2.39	0.64
SO_4, total	8.1	4.0
Na_2O	1.26	0.11
K_2O	0.30	0.14
Solids	11.2	21.0
MgO	——	0.65

Table 2
Production of Monoammonium Phosphate of Grade 11-53-0-2S Using 6-inch Pipe-Cross Reactor

Formulation (Lb/ton)		
PCR:		
Anhydrous ammonia		146
Phosphoric acid (52.5% P_2O_5)		1,515
Sulfuric acid (93%)		84
Granulator:		
Anhydrous ammonia		129
Phosphoric acid		505
Production Rate (tph)		25
Recycle Rate (tph)		95
$NH_3:H_3PO_4$ Mole Ratio		
PCR		0.6
Granulator		1.0
Heat Flux (Btu/hr/in^2)		330,000
Ammoniation Volume (lb/in^3/hr)		1.08
Product Chemical Analysis (percent)		
N		11.2
P_2O_5		53.4
Al_2O_3		1.6
Fe_2O_3		1.6
F		0.63
Screen Analysis (percent)		
+	0.3	0.3
—6 +14	96.4	96.7
—14 +16	2.0	98.7
—16	1.3	100.0
Average Crushing Strength (lb)		9.9

Table 3
Formulations and Typical Operating Conditions for Pilot-Plant Production of Diammonium Phosphate Using the Pipe-Cross Reactor and Drum-Granulation Process

Nominal Grade	18-46-0	18-46-0[a]
Test No.	1	2
Length of test, Hr.	5.4	5.8
Nominal production rate, ton/hr	0.35	0.61
Formulation, lb/ton of product		
Ammonia		
to pipe-cross reactor	330[c]	300[b]
to granulator	129	117
Wet-process phosphoric acid (54% P_2O_5)		
to pipe-cross reactor	1,721	1,721
Sulfuric acid (92% H_2SO_4)		
to pipe-cross reactor	91	——
Pipe-Cross Reactor		
Phosphoric acid feed temperature, °F.	155	155
Equivalent acid concentration, % P_2O_5	46	45
Ammonia feed temperature, °F.	25	ambient
Melt temperature, °F.	240	290
Melt analysis, %		
Total N	13.6	15.0
Total P_2O_5	44.0	35.4
$NH_3:H_3PO_4$ mole ratio	1.32	1.40

Nominal Grade	18-46-0	18-46-0[a]
Drum Granulator		
Recycle ratio, ton/ton product	4.1	4.0
Discharge temperature, °F.	190	202
Moisture (ADAC), %	2.5	2.1
Screen analysis (Tyler), %		
+mesh	1.9	7.9
—6 +10 mesh	81.6	77.1
—10 +16 mesh	16.1	12.8
—16 mesh	0.4	2.2
NH_3 evolution as % of total NH_3 feed	14.2	20.7
pH of granulation product	7.5	7.5
Onsize product		
Total N	18.2	18.1
Total P_2O_5	46.5	48.7
SO_3	5.3	——
As % of total P_2O_5		
Water soluble	87.2	86.4
Available	100	97.7
Moisture (ADAC)	2.3	1.9

[a] No sulfuric acid used in this formulation

[b] Gaseous ammonia

[c] Liquid ammonia

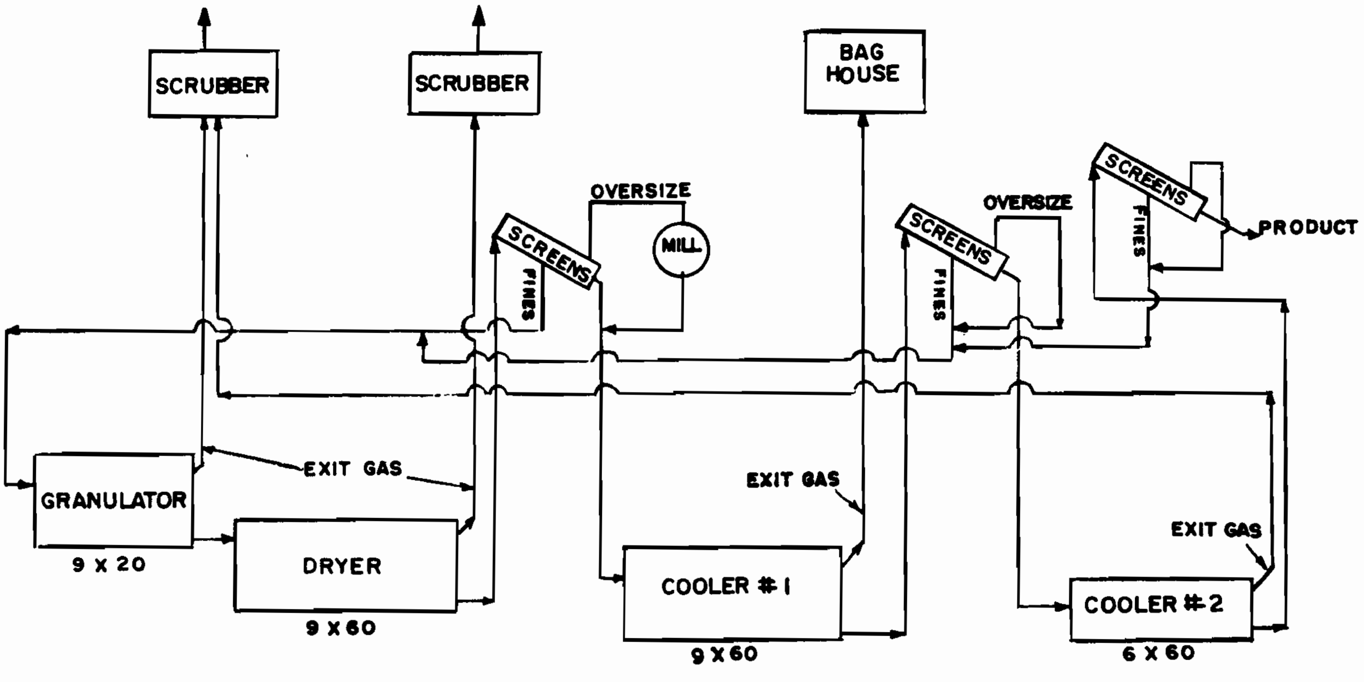

FIGURE I
FLOW DIAGRAM FOR MAP GRANULATION PLANT

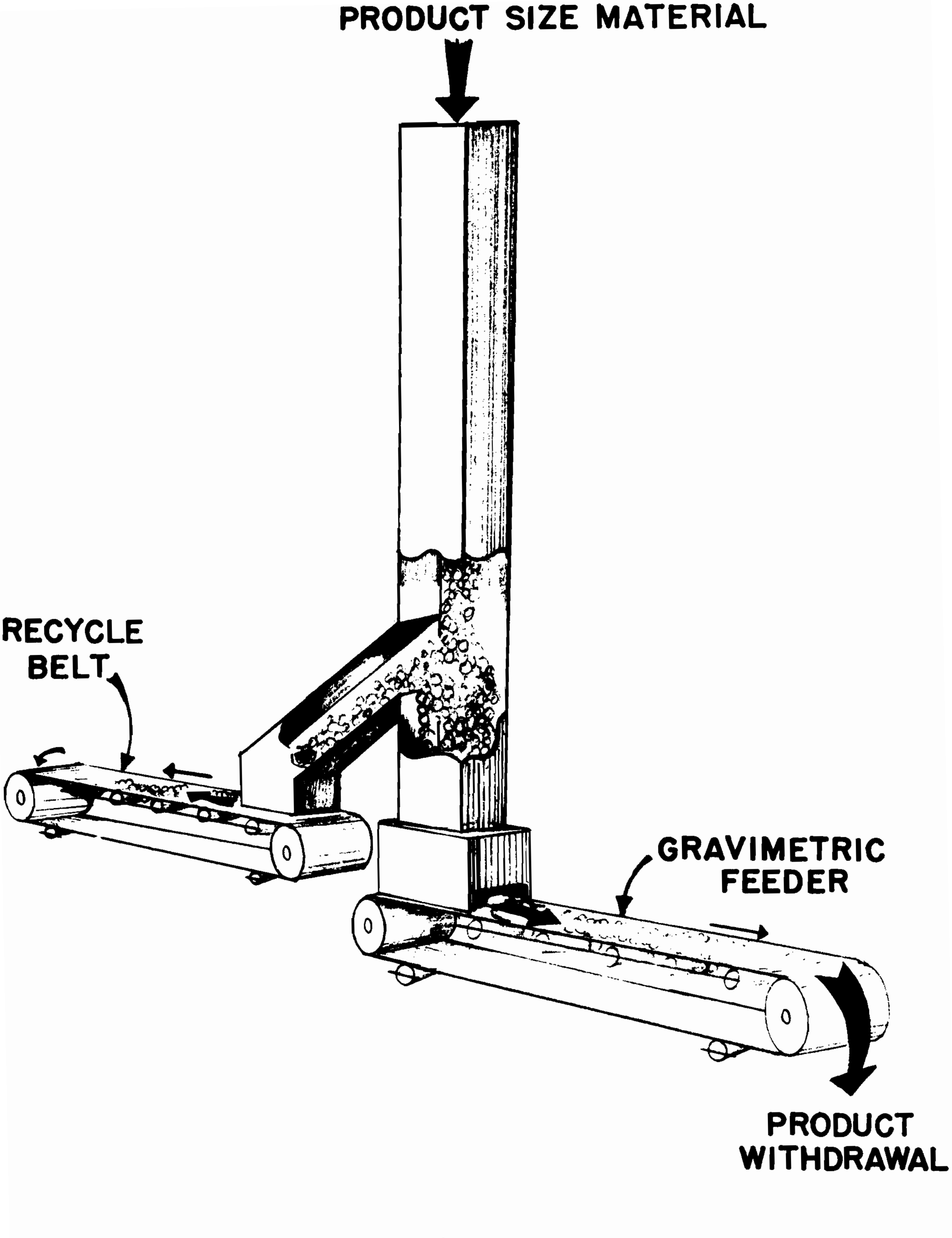

Fig. 2

SPLIT-BOOT RECYCLE CONTROL

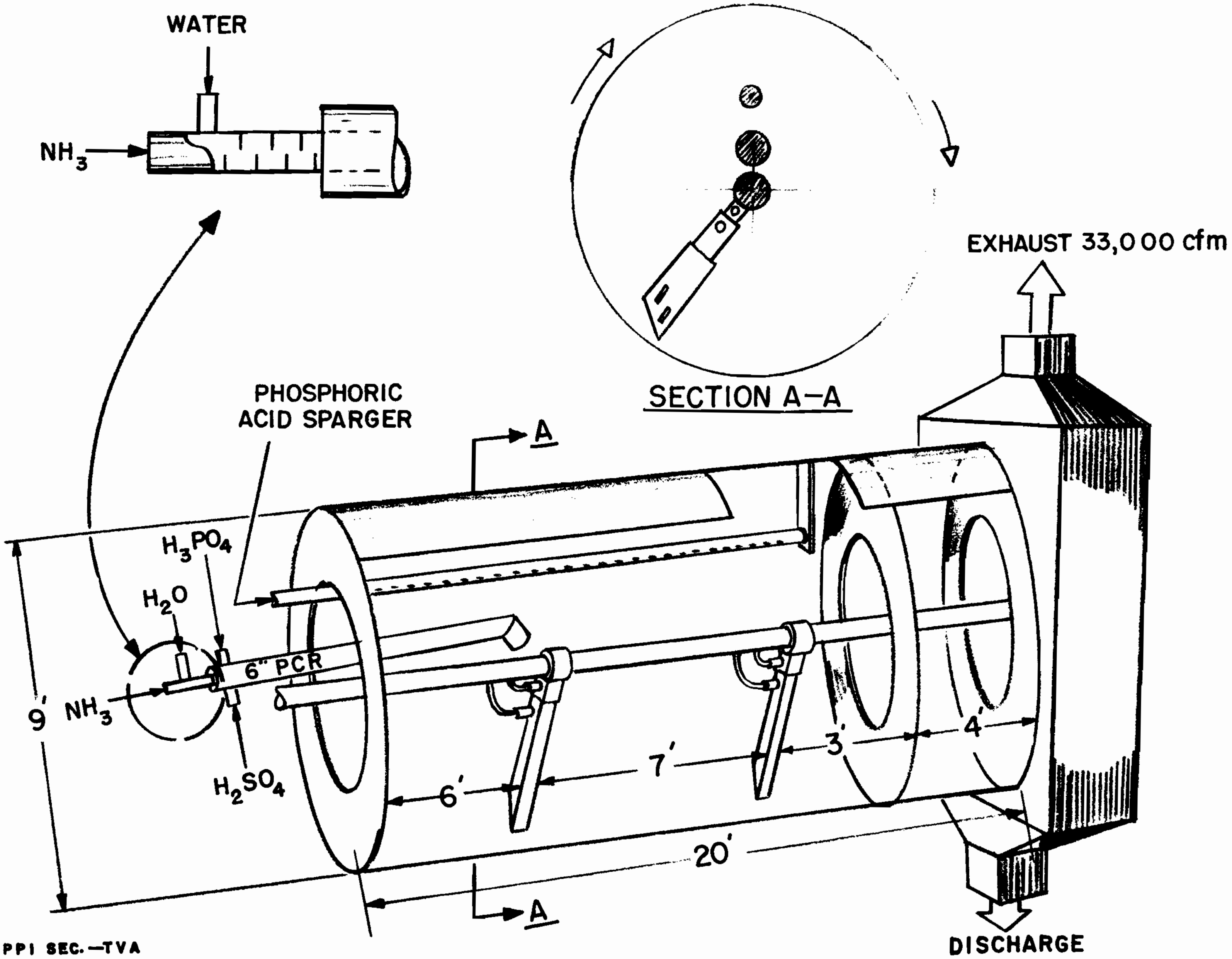

FIGURE 3
AMMONIATOR–GRANULATOR FOR PRODUCING MAP USING THE TVA PIPE-CROSS REACTOR

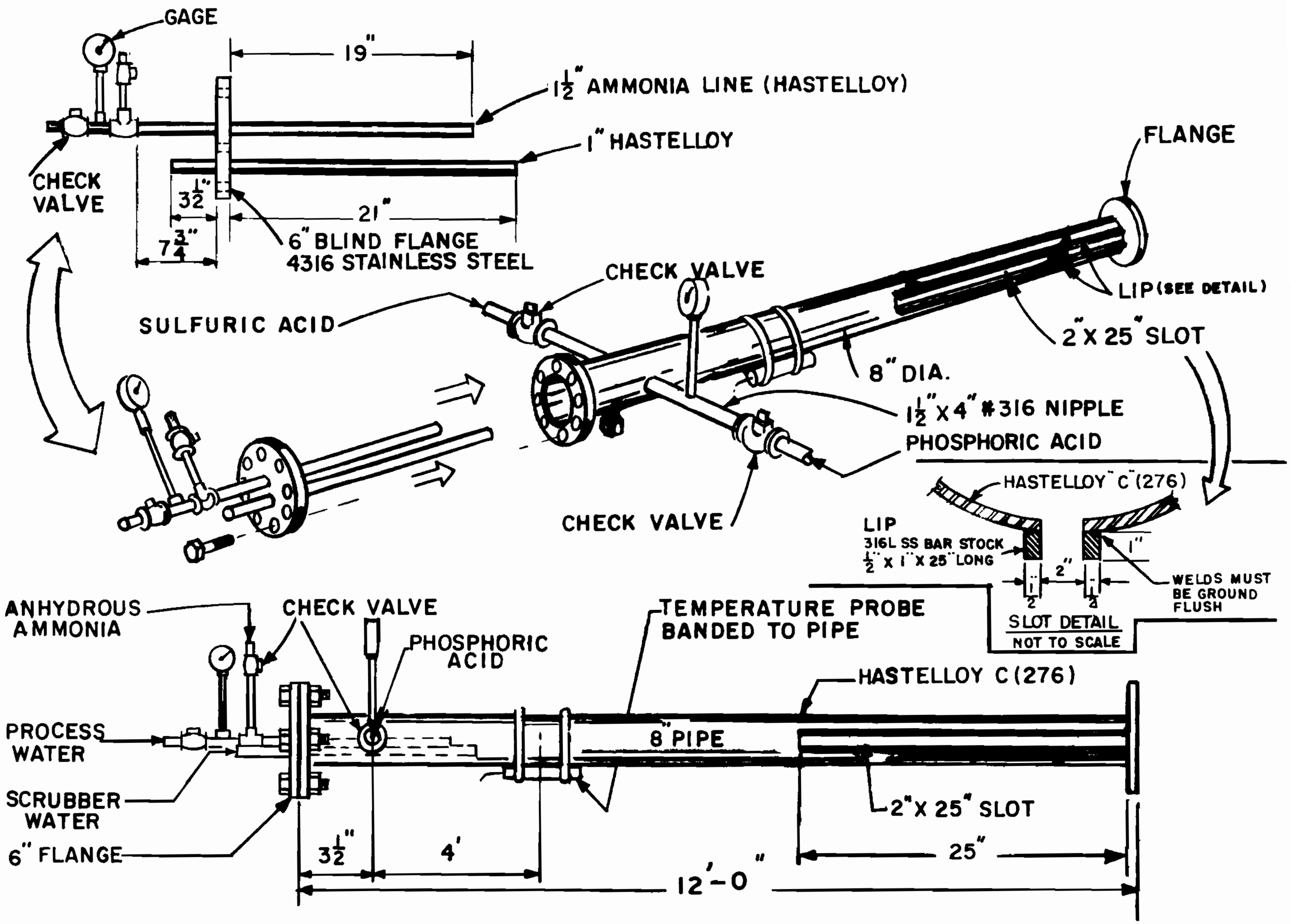

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FIGURE 4

PIPE-CROSS REACTOR
8 INCH DIAMETER HASTELLOY "C" REACTOR TUBE

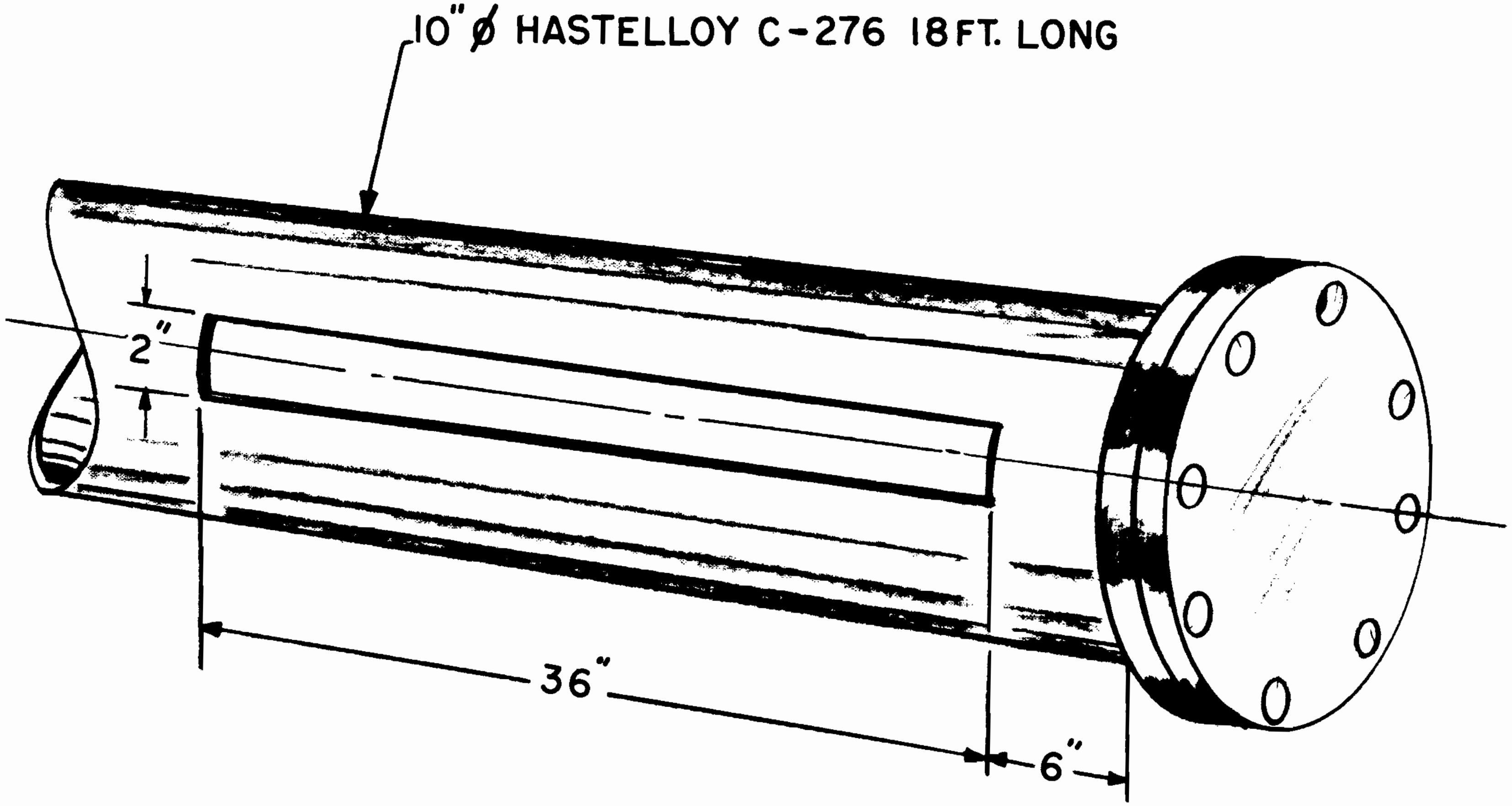


FIGURE 5

PRIMARY PHOSPHATE PRODUCER'S MAP PIPE-CROSS REACTOR

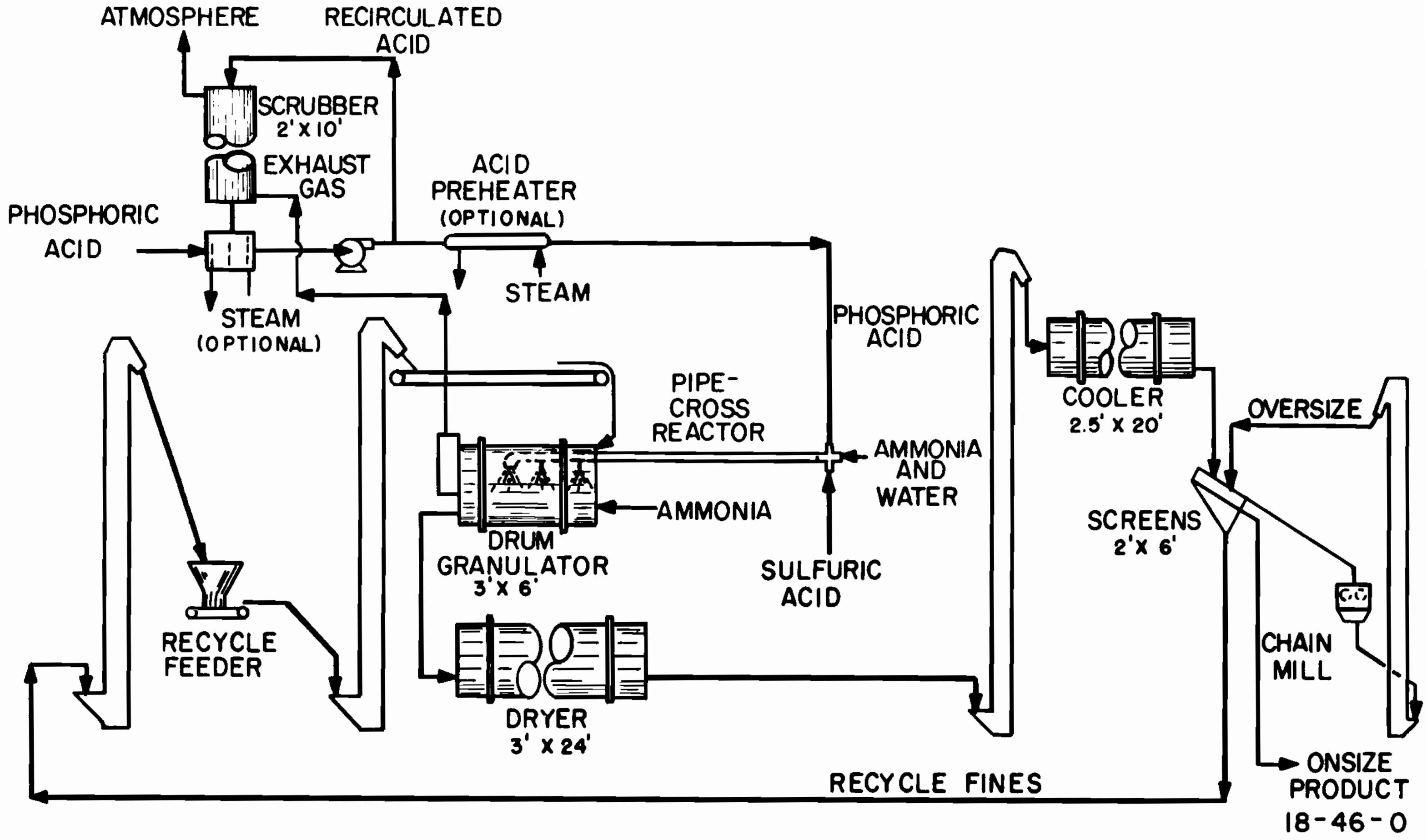


FIGURE 6

FLOW DIAGRAM OF THE GRANULATION PILOT PLANT FOR PRODUCING DIAMMONIUM PHOSPHATE USING THE TVA PIPE-CROSS REACTOR

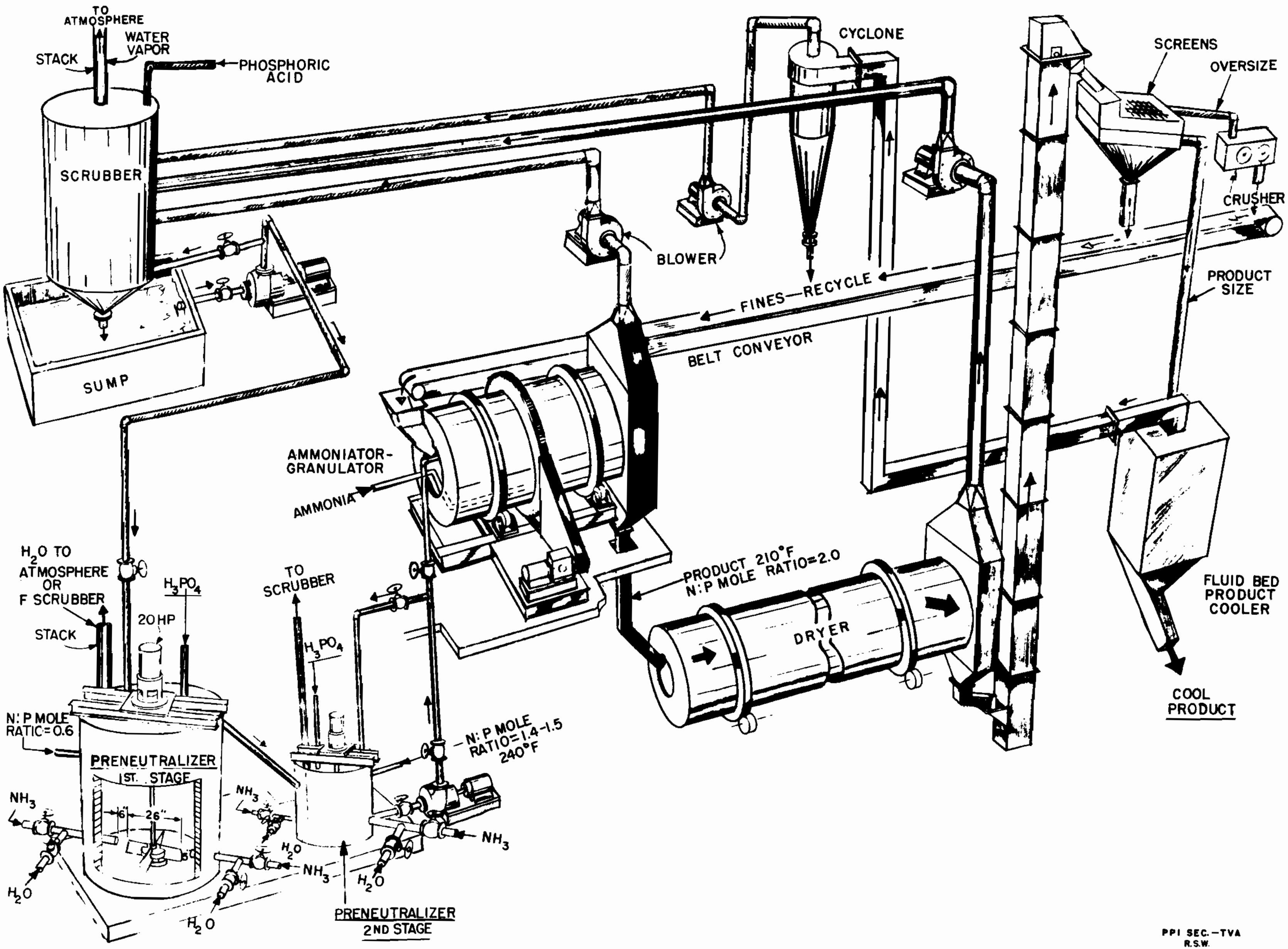
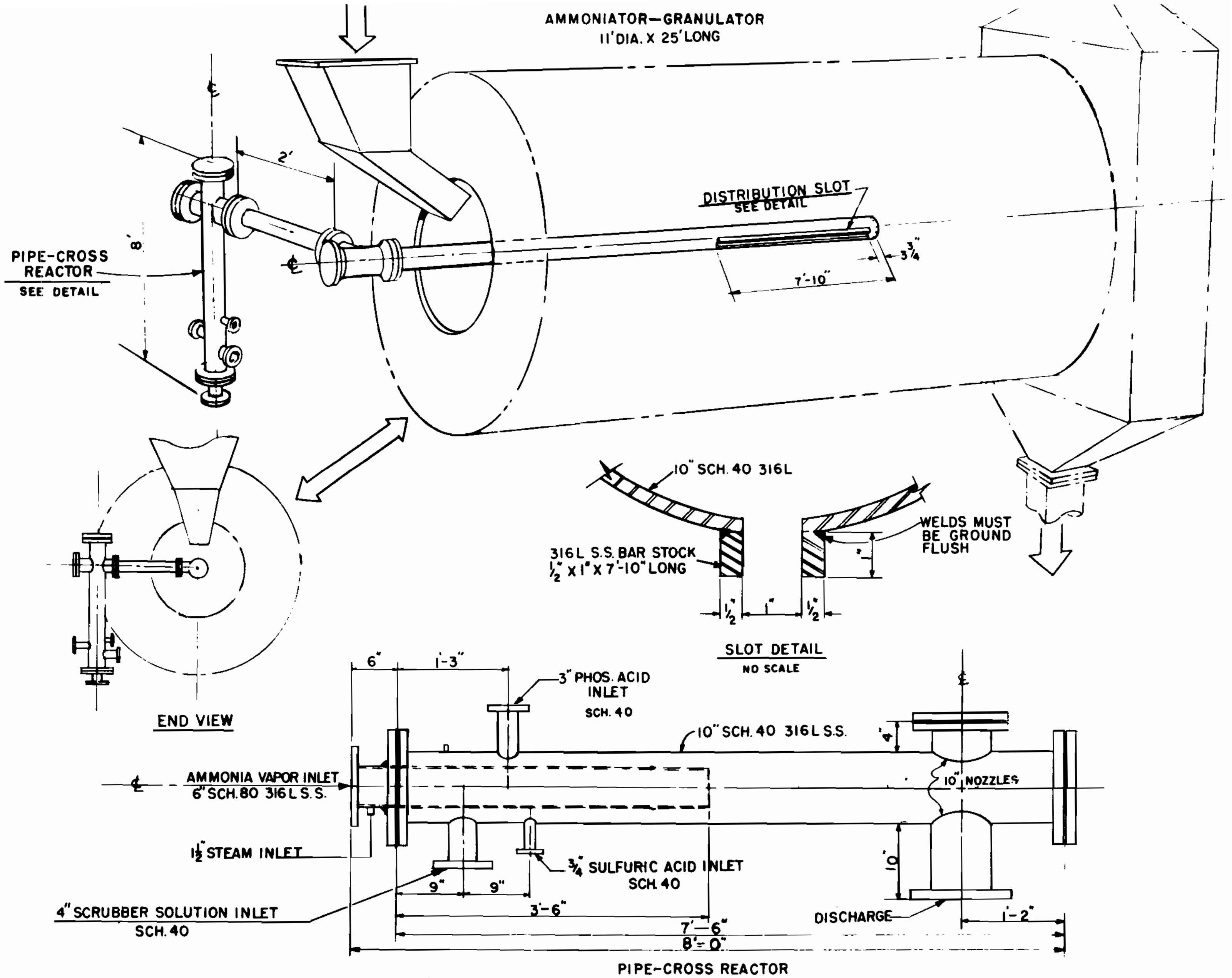


FIGURE 7

TVA PROCESS FOR PRODUCING GRANULAR DIAMMONIUM PHOSPHATE



PIPE-CROSS REACTOR
DAP PRODUCTION

FIGURE 8

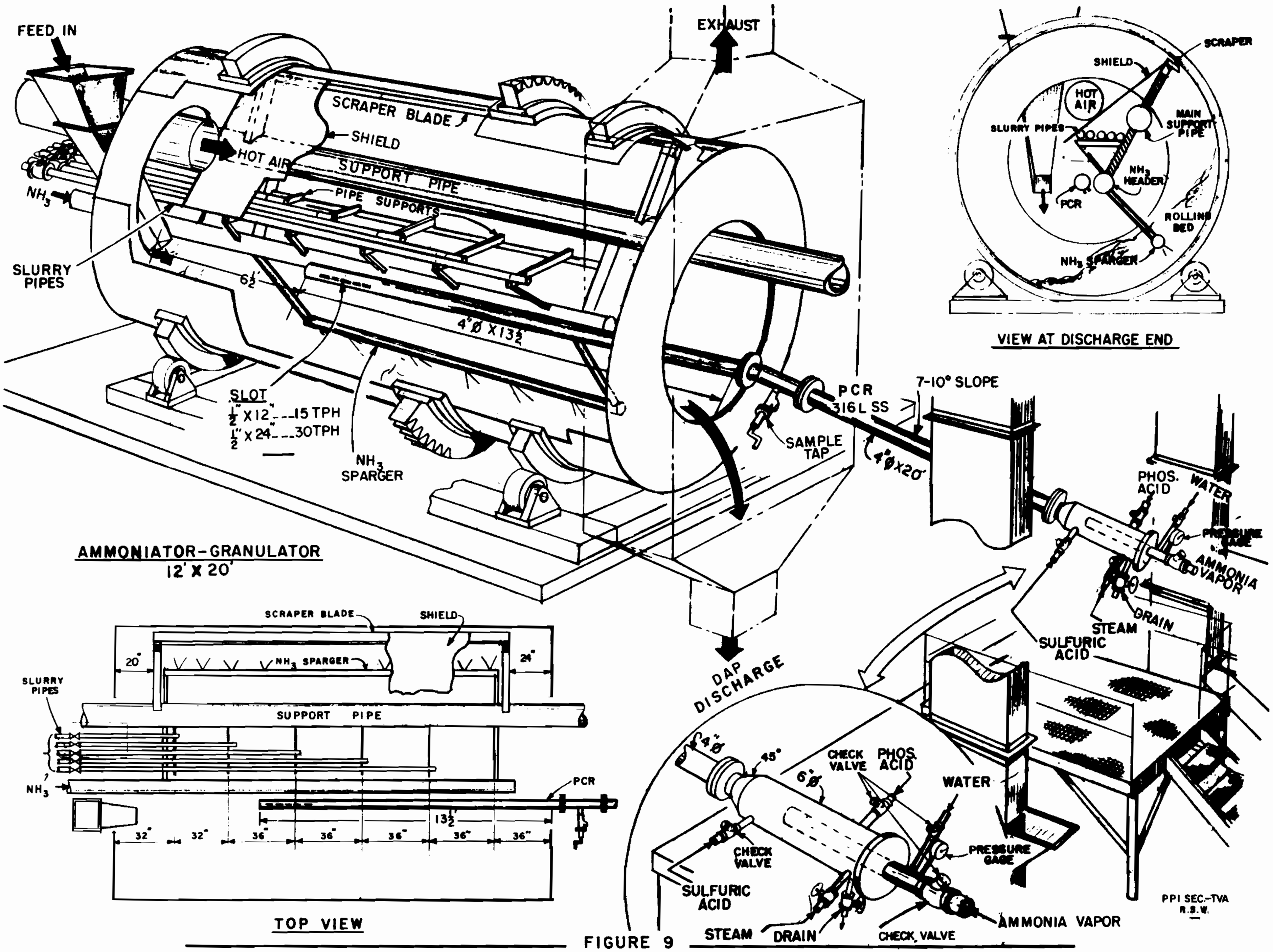


FIGURE 9

PROPOSED LOCATION OF DAP—PIPE-CROSS REACTOR
FLORIDA GRANULATION PLANT

MODERATOR SHELDRICK: Thank you, David, for an excellent presentation on what is becoming, obviously, a more and more important technique, not only in this country, but overseas as well. We get quite a lot of people that we have contact with, at the Bank, who want this technique. Fortunately, TVA and IFDC as well, are happy to provide this, not only in this country but in some of the developing countries as well. Gentlemen, have you any questions? (Applause)

QUESTION: HERB MacKINNON, AGRICO CHEMICAL CO.: David, when operating the reactor producing MAP, as you described, do you normally achieve any polyphosphate conversion and, if not, do you anticipate any problems.

ANSWER—DAVID SALLADAY: Okay, let's look at the temperature of the pipe a minute. This work which I describe today is essentially, 300°F. or less. We have had a process at the Center, I guess, has been operating six or seven years and 11-55-0 ammonium polyphosphate granular material is 15 to 20% poly obtained at about 420°F. We have been working with "one basic producer" on this ammonium polyphosphate granular process. It is not "commercial" yet with this company, however, we have been cooperating with a "basic producer" on the APP granulator. Over the last seven years, I can say about the "poly aspect", if you are "bulk blending" the only thing that "poly" can do for you is to give you a little better storability. You have a sponge for moisture. You could store it better but the reason people are interested in this "20% poly MAP" so to speak, is the use in suspensions. It is fabulous in the production of suspensions 11-55-0 — 20 poly will make 11-33-0 suspension that will store for years.

QUESTION—JULIO M. ENRIQUES - DAVY McKEE CORPORATION: When you are operating the pipe cross reactor, making DAP, do you use 54% acid? What type of "absorbant" can you use for absorbing "ammonia" out of the granulator and the "dryer?" If it is a higher percent than P_2O_5 acid does this give you problems with falling emissions or not?

ANSWER—DAVID SALLADAY: I probably did not mention, trying to get thru the slides, that the DAP work is being done with, roughly, 39% P_2O_5 acid. The particular plant we are in has a series of "venturi scrubbers" fed higher strength acid. We should talk a minute about the "mole ratio" of the "scrubber acid." This seems to be very critical in what we have seen working there and talking to people in Florida. You want to get this mole ratio up to a minimum of .55 to hold the flurine. You cannot go much higher than 70-75. The optimum operating condition for this "scrubber acid" in the DAP plants appears to be .55 to .75.

QUESTION—JACK C. FREDERICK - W.R. GRACE CO.: With the declining rate of rock today, in Florida, I see up there 80, 90, 100 lbs. of sulphuric to make DAP. I do not think there is room in that formula to make DAP, even today with that much sulphuric acid.

ANSWER—DAVID SALLADAY: I think this is true. The rock is going down and that is the reason that MAP is coming on. The 10-50-0 MAP can stand it. You are right.

MODERATOR SHELDRICK: Thank you David for the excellent presentation. I would also like to thank all of our speakers for their most interesting discussions and to our audience thank all of you for stiking it out even though we have used a little more time. We have had a full house all afternoon. This is very gratifying. This session is now closed. (Applause)

Wednesday, November 4, 1981

Morning Session

Moderator: Walter J. Sackett, Jr.

CHAIRMAN FRANK P. ACHORN: This morning Walter Sackett is going to be the Moderator. Walter is a member of our Round Table Board of Directors. He does an excellent job helping us plan the program. Walter is another leading Technologist in the Fertilizer Industry. He is President of the A. J. Sackett & Sons Company. They do a fantastic job with "equipment". (Applause)

MODERATOR SACKETT: Good morning, Gentlemen. We have a very interesting program this morning. It is a full program so, in order to keep on schedule, we will get right to it.

Our first Speaker is Herbert MacKinnon. Herb joined Agrico Chemical Co. in 1951, after receiving his B.S. Degree in Chemistry from Tuft's University, Medford, Massachusetts.

Herb served as Plant Superintendent at various chemical and fertilizer manufacturing plants during his first years with Agrico. During that period, he contributed to the developing continuous ammoniation and granulation technology for application to Agrico's fertilizer production. He later served as Manager of Fertilizer Manufacturing for Agrico.

During the 1960's, as manager of Planning, he planned Agrico's program for implementing computer applications to supply and distribution functions and operations control. Herb later managed Agrico's Supply and Distribution Department.

When The Williams Companies purchased Agrico in 1972, Herb assisted in development of Agrico's General Office Sales Program.

In 1974, Herb became Manager of Technical Sales, his present position with Agrico. In this new responsibility, Herb drew on his broad experience to direct the development of innovative programs for effective application of technology to Agrico Marketing. As Manager of Technical Sales, Herb has directed the development of Agrico's successful MAP and Fluid Blend Programs.

The most current development project of Agrico Technical Sales under Herb's direction is a microcomputer system to serve dealer marketing, agronomic, and operational control needs.

Herb is active in industry serving as a Director of The Fertilizer Industry Round Table, and Chairman-Elect of The Division of Fertilizer and Soil Chemistry of The American Chemical Society. He also serves on several Committees of The National Fertilizer Solutions Association. (Applause)

Use of MAP In Fluid Fertilizers

Herbert C. MacKinnon

Fluid Fertilizers continue to hold the position of fastest growing fertilizer form in the United States. In order to gain a perspective of the importance of fluids in the U.S., it will be helpful to look at some statistics. According to USDA reports, Fluid Fertilizers consisting of Nitrogen Solutions, mixed solutions and suspensions grew in nutrient volume at a compound annual rate of 7.2% during the decade ending in 1980. This growth rate compares to 4.9% for ammonia, 2.5% for dry fertilizers, and 3.6% for all fertilizers during the same period. U.S. Fertilizer Nutrient Consumption, as reported by USDA, is shown in Figure 1 for the period 1965 through 1980.

The fast growing fluid fertilizers accounted for nearly 17% of the U.S. fertilizer nutrient consumption in 1980. On a product volume basis, the fluid share of the 1980 U.S. market was 22.7%, somewhat higher than the nutrient volume share because of the lower analysis of fluids. Market shares for various fertilizer forms for the period 1965 through 1980 in the U.S. are shown in Figure 2.

Total mixed fluid fertilizer product volumes consumed in the U.S. in 1980, according to USDA reports, totalled 4.64 million tons. We estimate the MAP based Fluid Blends volume at 2.5 million product tons in 1980 consuming some 700,000 tons of MAP.

In 1975, when Agrico introduced its patented MAP Fluid Blend system to the market, most of the mixed liquid fertilizers were solutions or suspensions based upon polyphosphates. What little MAP that was produced in the U.S. was primarily for direct application. There has been significant growth in U.S. production of MAP since 1975. At least 10 U.S. producers in 1982 are expected to manufacture an estimated 1,500,000 tons of MAP. About half of this MAP product is expected to be consumed in Fluid Blend suspensions.

The graphic representation of U.S. fertilizer nutrient consumption growth shown in Figure 3 highlights the shift to Fluid Fertilizers which occurred in 1975. This increase resulted from expanded UAN manufacturing and distribution capacity, together with the rapid acceptance and growth of Fluid Blends.

The Fluid Blend fertilizer system has demonstrated success by meeting the needs of the U.S. market for the qualities of fluid fertilizers at costs competitive with basic dry blend products. Several fundamental concepts unique to Fluid Blends set this system apart from traditional dry and liquid systems.

MAP is a superior phosphate material for fluids for several reasons. It is manufactured easily in existing granulation plants from low cost process orthophosphoric acid. MAP has the high P_2O_5 content of phosphoric acid, yet is non-corrosive and easily transported and stored as a granular free-flowing material. There is no costly polyphosphate in MAP, nor is polyphosphate required in the Fluid Blend process. There were early concerns that orthophosphate Fluid Blends might not provide the same plant nutrition values as polyphosphate solutions. Agrico agronomists studied the plant nutrient properties and crop responses of orthophosphates and polyphosphates and found no replicative evidence to support the theory of superior plant nutritive value often attributed to the polyphosphates. There are handling advantages to the polyphosphate solutions, but these are obtained at a premium cost, as a result of additional processing and refinement, and force the polyphosphate user to a competitive disadvantage. A summary of Agronomic opinion on polyphosphates is included in Appendix "A".

Selection of MAP as the acid phosphorous source for suspensions avoids the handling and transportation penalities of phosphoric acid. These savings assure the Fluid Blend fertilizer dealer and his customers of quality fluid fertilizers at costs competitive with dry blend fertilizers. This is good news for the fertilizer dealers!

From the manufacturer's point of view, it first appeared that MAP would be more costly to manufacture than DAP. As a matter of fact, our early production imposed a cost penalty on MAP production. With experience we improved process control, and with efficiencies from increased volume, we soon found there was an effective productivity improvement in P_2O_5 granulation as MAP. Because of the solubility characteristics of MAP, recycle rates are low, allowing a productive improvement in granulation production of about 28.5%. In addition, product up-grading to 53 units of P_2O_5 compared to 46 units of P_2O_5 in DAP gains an additional 15.2% productivity increase. Total productivity improvement in MAP granulation is 48%. A basic manufacturer can potentially expand phosphoric acid up-grading capacity by about 50% without investing in additional granulation facilities. An additional benefit is that the exothermic ammoniation reaction provides all the heat required to dry the MAP product to less than 1% moisture. This is good news for the manufacturer!

For the fertilizer dealer, the low costs of MAP relative to polyphosphates as the fluid source does not come without some cost. The impurities included in MAP from use of the lower cost, unrefined process acid require the Fluid Blend product be in a suspension form. This creates a handling disadvantage but improves productivity by permitting nutrient concentrations in the range of 35 to 45 units, some 40 to 50% higher than typical clear solutions.

Processing and handling of Fluid Blend suspensions require more costly plant and process equipment. Development of the Fluid Blend system required design and manufacture of new process and handling systems. High shear mixing systems are required for productive dispersion of solids into liquid solutions and for efficient suspension gel formation. The density, viscosity and solids content of suspensions requires larger pump capacities, larger pipe diameters, heavier and more costly plant construction, greater power requirments and special process design to accommodate the reaction of anhydrous ammonia with MAP. The plant and process equipment investment can run 30% greater than that of a solution blending or dry blending plant. Operating requirements differ for Fluid Blends. The ammoniation and suspension gel forming process and suspension product handling requires a degree of sophistication in process and operational technique not required of simpler conventional processes.

The costs of additional plant investment and sophisticated operations are compensated by the competitive costs of the basic raw materials UAN, MAP, ammonia and muriate of potash; the capacity to effectively process the lower cost mineral forms of minor elements and micronutrients; and the value added to product form upgrading solid intermediate materials into complete fluid fertilizer products.

The process for converting MAP to 10-30-0 Fluid Blend base for further process to complete Fluid Blend products has been developed to a straight-forward and easily controlled system. The process objectives are:

1. Slurry MAP with H_20.
2. React slurried MAP with NH_3 and solubilize the ammonium phosphate.
3. Create a gel to suspend P_2O_5 impurities.
4. Control process to achieve desired crystal formation and maintain product nutrient and gel quality.
5. Recombine the ammonium phosphate base with potash, sulfur, micronutrients and chemicals as required for formulation.
6. Store, transport, and apply product in equipment designed to preserve product quality and effectively handle product viscosity, density, and suspended solids.

Typical design for an efficient and productive plant is described in Figure 4. This design features overhead tanks for efficient gravity feed of dry raw materials. These tanks can be easily modified to serve as fluid raw material tanks if desired. Flat-bottom storage tanks are used for UAN solution, but specially designed cone-bottom tanks equipped with recirculation nozzles are required for satisfactory storage and handling of suspension bases and products.

Several specially designed high shear, suspension mixers are now available and perform well as reactors, mixers, and suspension gelling systems. These units consist of a scale mounted batch tank, typically 1,500 gallon to 2,500 gallon capacity. A high shear turbine agitator in combination with a 5" or 6" pump, manifold, and piping system serves to slurry and mix the solid and liquid materials and form the suspension gel. Ammoniation is typically accomplished by injection of NH_3 into a recirculation stream of MAP slurry. A recently developed system to inject air into the recirculation stream improves ammoniation. The dispersed air cushions the vapor collapse hammer effect associated with the ammoniation reaction, speeds the reaction, and eliminates vibration and strain on equipment.

Sump systems to meet EPA requirements and prevent costly product loss from spills and loadout tanks, screens, piping and electrical power systems completes the Fluid Blend installation. Additional supporting facilities will include storage for dry and liquid materials, offices, truck scales, shops, and chemical storage. Typical battery limits, costs for product, process, storage, and shipping facilities for a plant with 25,000 tons production capacity, as described in Figure 4, will be $250,000. Figure 5 illustrates a Fluid Blend plant of this design under construction.

The competitive formulation costs of Fluid Blends derives from the use of MAP as the phosphate source. MAP can be produced in conventional DAP granulation systems using the same orthophosphoric acid and ammonia feed stocks as DAP. The N and P_2O_5 costs for MAP and DAP should therefore be equivalent. Since Fluid Blend formulation involves ammonia, UAN solution, and MAP, it is difficult to make a direct value comparison of material costs of dry and fluid products unless actual formulations are calculated.

A convenient alternate method of comparison is to develop Parity Values relative to DAP for MAP and other phosphate materials. Actual current market costs of DAP, ammonia, and UAN are used to derive a cost of MAP and other phosphates that develop values of N and P_2O_5 equivalent to current DAP values.

The Parity Value is developed by formulating an equivalent 18-46-0, as shown in Figure 6. By calculation, .8679 units of MAP will provide 46 units of P_2O_5, which is the P_2O_5 content of DAP. The NH_3 quantity, .0703 units is that volume of ammonia which is reacted with 11-53-0 MAP in the Fluid Blend process to form a 1.7 mol ratio (10-30-0) product. The factor for determining the NH_3 quantity for reaction with 11-53-0 MAP is 0.081. Thus, 0.081 multiplied by .8679 units 11-53-0 MAP develops .0703 units of required NH_3. UAN solution provides the balance of nitrogen needed to develop the total of 18 units for an equivalent 18-46-0.

Now that an equivalent 18-46-0 formulation has been developed, it is a simple matter to apply market values of DAP, UAN 28, and NH_3 to develop the value of MAP at parity with the N and P_2O_5 values of these commodities, as described in Figure 7. The symbols X, A, B, and C represent delivered values per ton of MAP 11-53-0, NH_3, UAN and DAP respectively. The parity value X for MAP is developed by substituting market values for A, B, and C. The equation may be restated as:

$$\text{11-53-0} = 1.1522\ \underline{\text{DAP}} - 0.0810\ \underline{NH_3} - 0.1099\ \underline{\text{UAN 28}}$$

In this restatement, the cost per ton of DAP, NH_3 and UAN 28 should be substituted for the underlined items and the arithmetic performed to develop the Value of MAP at parity with 18-46-0, NH_3 and UAN.

A series of equations are listed in Figure 7, which allows easy calculation of Parity Values of a number of phosphate materials. This concept recognizes the dominant market role of DAP in establishing phosphate commodity values. Purchase of fluid phosphate materials at Parity Prices will assure that the N-P costs of fluid products will be equivalent to N-P costs of dry blend product using DAP. The f (NH_3) data of Figure 8 represent ammoniation rates for the Fluid Blend reaction to form a 1.7 mol ratio (10-30-0) ammonium phosphate product.

An additional aconomic concept of importance to Fluid Blend growth is the improved transportation productivity provided by MAP. Figure 9 develops comparative transportation efficiencies for various phosphate materials compared to a base of 11-54-0 MAP. The data under "Transpt." indicates the unit volumes of materials that must be transported to provide the equivalent of one unit of MAP 11-54-0.

As an example, a dry blender formulating with GTSP 0-46-0 and Urea 46-0-0 would have to transport 1.413 units of product at a transportation penalty of 41.3% to provide the equivalent plant food values of one unit of 11-54-0 as shown below:

$$\begin{array}{l} 1.1739 \text{ units GTSP 0-46-0} = \text{0-54-0} \\ \underline{0.2391 \text{ units Urea 46-0-0} = \text{11-0-0}} \\ 1.4120 \text{ units equivalent} = \text{11-54-0} \end{array}$$

The value in Figure 9 for 0-52-0 Phosphoric Acid is adjusted for penalities of freight and tank car costs related to acid transportation. The value for DAP is adjusted to reflect transportation credit for the excess N provided when replacing MAP with DAP.

MAP based Fluid Blends offer a positive response to today's urgent need for improved productivity in the fertilizer industry. The depletion of low cost sources of U.S. energy and mineral resources for as far into the future as we can see will have costly impact on conventional systems of fertilizer manufacture and distribution. We can count on a future of increasing energy and raw material costs, high costs of capital, high costs of plant and equipment, high labor costs, and growing pressures in opposition to costs passthrough to consumers. Changes will be made in response to these economic pressures and MAP and Fluid Blends will likely be a major part of the change for the following reasons:

1. MAP provides a 50% improvement in P_2O_5 upgrading process and reduces process energy requirements.
2. MAP can be the universal phosphate, serving as an intermediate and end product for world agricultural P_2O_5 needs.
3. MAP offers productive improvement in transportation and handling.
4. Fluid Blends provides flexibility in formulation to productively use less refined, less costly materials.
5. Fluid Blends supports energy efficient custom application, as well as row application and starter programs.
6. Fluid Blend systems will serve agronomic and service needs of high crop yield programs, using greater plant density, more productive hybirds, and double-cropping systems.
7. Fluid Blend systems provide productive improvement through combined applications with chemicals, seed and micronutrients. Combined applications are effective because of the homogeneous Fluid Blend quality and uniform application.
8. Fluid Blend distribution favors larger, more productive distribution operations.
9. Flexibility of fluid formulations provides capacity for grower programs of highest productivity served by customized agronomic programs and services.
10. Finally, efficient, productive, flexible distribution systems can permit the fertilizer distributor to develop skills and become advisor to the grower on productive crop plans and programs, taking over functions no longer provided by industry and government.

We have discussed how MAP manufacturing productivity coupled with productive Fluid Blend distribution has effectively responded to industry needs. The reasons for the successful growth of these systems are economic, relating to costs, productivity, profits and energy utilization. The Industry has recognized the economic soundness of MAP manufacturing and distribution and some U.S. DAP production has already been replaced with MAP. The economic pressures which are developing from depleted, low cost mineral and energy sources in the U.S. demand productivity improvement to help offset increasing costs. Reinvestment with systems of greater productivity is necessary. As reinvestment decisions are made, I believe the industry will look favorably to the profitable productive opportunities of MAP, Fluid Blends and Fluid Fertilizers; and these productive systems may well become the benchmark of success for tomorrow's fertilizer manufacturing and distribution business.

APPENDIX A
Mono-Ammonium Phosphate (MAP) Versus Other Sources

In many cases, the selection of a fertilizer P source is not of major importance. There are many research reports that conclude that one P source is equal to another over a rather wide range of conditions. The important decision in these situations is to apply proper rates of P according to soil test results. Source preferences are sometimes made for non-agronomic differences /19, pages 95-97.

However, there are certain conditions where a particular type (source) of P can be agronomically better than others. This will depend upon specific crop-soil-placement factors. The following review is concerned with "special use" situations where MAP (mono-ammonium phosphate) can be equal to and often superior to other fertilizer P sources.

Young and Hicks[1] summarized the properties of MAP in 1967 as follows: "Mono-ammonium phosphate has agronomic advantages in some types of uses. Agronomic tests by TVA personnel show that mono-ammonium phosphate does not form apatite by reaction with calcium in soils as diammonium phosphate does, and that loss of nitrogen after surface application on calcareous soils is less with mono-ammonium phosphate than with diammonium phosphate. Also, use of mono-ammonium phosphate on nonacid soils results in increased response to phosphates because the soil is acidified. There has also been some interest in adaptation of the process because of the higher percentage of P_2O_5 in the granular mono-ammonium phosphate (55% *vs.* 46%) where storage and shipment of a good quality phosphate product are primary objectives."

The work referred to by Young and Hicks included comparison of AS, Urea, SU, UAP, AN, APN, APP, MAP, and DP[2]. This work showed that adding phosphate to surface applied urea on near neutral to alkaline soils reduced N losses. Severe N loss also was noted with similarly surface applied N when AS or DAP were the N sources. Maximum N recoveries were obtained with MAP, AN, APN, and APP under these test conditions. The reaction of NH_4-N sources with Ca in the soil was related to N losses. Terman and Hunt stated, "Thus, MAP was equally or more effective at all pH levels for supplying N to corn than other source." Work reported much later by Fenn of Texas[3] demonstrated that mixing as little as 30% MAP to a fertilizer blend could reduce NH_3 losses from ammonium N sources that are surface applied to calcareous soils. The soil reaction responsible for NH_3 losses with surface applied ammonium N sources was listed as being:

$$(1)\ NH^{+}{}_{4}\text{—}N + CaCo_3 \text{ Soil } {}^{H_2O}\ Ca\ So_4 \cdot 2H_2O + (NH_4)_2CO_3$$

The ammonium carbonate formed by this calcareous soil reaction is unstable and forms NH_3 +

CO_2 gases that can be lost through volitization if surface applied. The TVA work showed that DAP + DP added with the NH_4-N source urea could reduce the amount of $(NH_4)_2C)_3$ formed and thus reduce NH_3 losses. With MAP added (rather then DAP), different reaction products were formed that also prevented NH_3 losses. APP also formed different reaction products in soils, but it like MAP formed meta-stable reaction products that indicate an advantage of these fertilizers over DAP, Urea, and AS as sources of N on neutral to calcareous soils.

MAP versus DAP: Other studies[4] disclose that the pH of the soil solution with MAP is lower than that formed with DAP (about 4.0 with MAP compared with about 9.0 with DAP). The higher pH with DAP, reversion to water insoluble forms of soil P is greater when applied to calcareous soils.

MAP versus APP: Spratt[5] found APP to be slightly superior compared with MAP with wheat by continuing grain development period a longer period. Others found APP to be equal or slightly superior on MAP, possibly because of improved micronutrient uptake[6]. However, Dobson[7] found no differences between effectiveness of MAP and APP and found no difference in Zn uptake[7].

Mobility of P sources in soils has been studied by Hashimoto and Lehr[8]. The total distance of P movement in soils as well as distribution patterns of water-soluble P were similar for ortho and poly P forms studied. The theory that less "fixation" would occur with APP sources of P (as compared with ortho sources) was disproved by Lehr *et.al.* Yet in still another Iowa study reported by Subbarao and Ellis[9], plants given APP grew less than if given DAP. Here reaction products of polyphosphates formed an unavailable reaction product on high pH, calcareous soils.

Engelstad and Allen[10] of TVA found TPP to be less effective than MAP for corn when mixed through the soil on cool soils, but equal on warm soils or in bands. About half of the P in APP is TPP. These authors quote work by Gilliam where two sources were equally effective P sources.

Dr. Everett J. Dennis writes that "Polyphosphates are somewhat superior to orthophosphate, from my experience in the normal alkaline soil ranges. Polyphosphates are limited in the very acid and very alkaline soils". He describes "very alkaline" soils at pH above 7.9. He states poly and orthophosphates are equal at pH 5.8 to 7.0. By difference, at pH's 7.0-7.9, I conclude that Dennis feels the poly source has an advantage because of micronutrient complexing ability. He states that at the extremes in pH's, the biological reactions to hydrolize polyphosphate to plant available orthophosphates are limited, thus reducing effectiveness of the poly source. Dennis also points to the possible NH_3 release from DAP alkaline soils (that can reduce seed germination and increase N loss) that does not occur with MAP or APP.

Miller's work[12] indicates that lower pH's with MCP + $(NH_4)_2SO_4$ prevented the precipitation of Ca-PO_4 on root surfaces thereby causing the observed increase P uptake with $(NH_4)_2SO_4$ K_2SO_4 did not. The lower pH associated with MAP could also achieve the same situation in fertilizer bands. Studies by Bouldin *et. al.*[13] reveal that larger particles of water-soluble P sources such as MAP are most available to plants. This would be a "plus" for AGRICO's granular MAP.

Chemical compatibility of MAP is excellent. TFI's manual[16] shows it to be compatible with AN, Urea, AS, Triple, 0-20-0, CAP, KCI, and K_2SO_4. DAP is of "limited" chemical compatibility with single and triple superphosphates.

Toxicity hazard with DAP is greater than with MAP, especially on high lime, sandy soils[18] according to early work reported by Alfred and Ohlrogge. Root growth was also less with DAP than with MAP in sandy soil, but little difference was noted in finer textured soil.

Sample and Meredith of TVA summarized agronomic aspects of MAP at the 1975 TVA Fertilizer Conference held in Louisville[19]. They show why MAP is a better P source because: (1) it is an excellent blending material, (2) it is more flexible than DAP for blends, (3) MAP is better than DAP for blending with Urea for pH reaction reasons, and this reduces the final blend's toxicity and N-loss potentials, and (4) MAP is clearly better than DAP on calcareous soils for several reasons (as discussed elsewhere in this summary report).

Others have compared P sources with respect to their properties concerning the uptake of certain micronutrients. MAP (and Urea) were found to be effective carriers of $ZnSO_4$, but not ZnO[15]. Reason is that they fail to solubilize the ZnO. APP did. MAP with $ZnSO_4$ produced more growth of corn with higher Zn content than APP in quoted work by Terman (1966). However, MAP and Urea are about 50% as effective as APP with ZnO.

Kansas data by Adriano and Murphy[17] show MAP (banded) was better than APP if no zinc is added, but the MAP and APP were equal if adequate Zn was added. Yield and element levels were used as criteria. The authors quote several references where APP would be better than MAP as a P source, vice versa, and "no difference" situations. MAP and APP were equal in P uptake in the Kansas study and both were better than TSP. In this study MAP and APP had equal effects on increasing Mn uptake. Similar effects were quoted on carrier influence on plant Mn uptake (in Michigan with soybeans).

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FIGURE 1

FERTILIZERS

SHARE OF U.S. MARKET
NPK TONS (Millions)

	NH_3	FLUIDS	DRY	TOTAL
1965	1.3	1.1	8.6	11.0
1970	2.8	1.9	11.4	16.1
1975	3.3	2.3	12.0	17.6
1980	4.5	3.8	14.7	23.0

FROM USDA

FIGURE 2

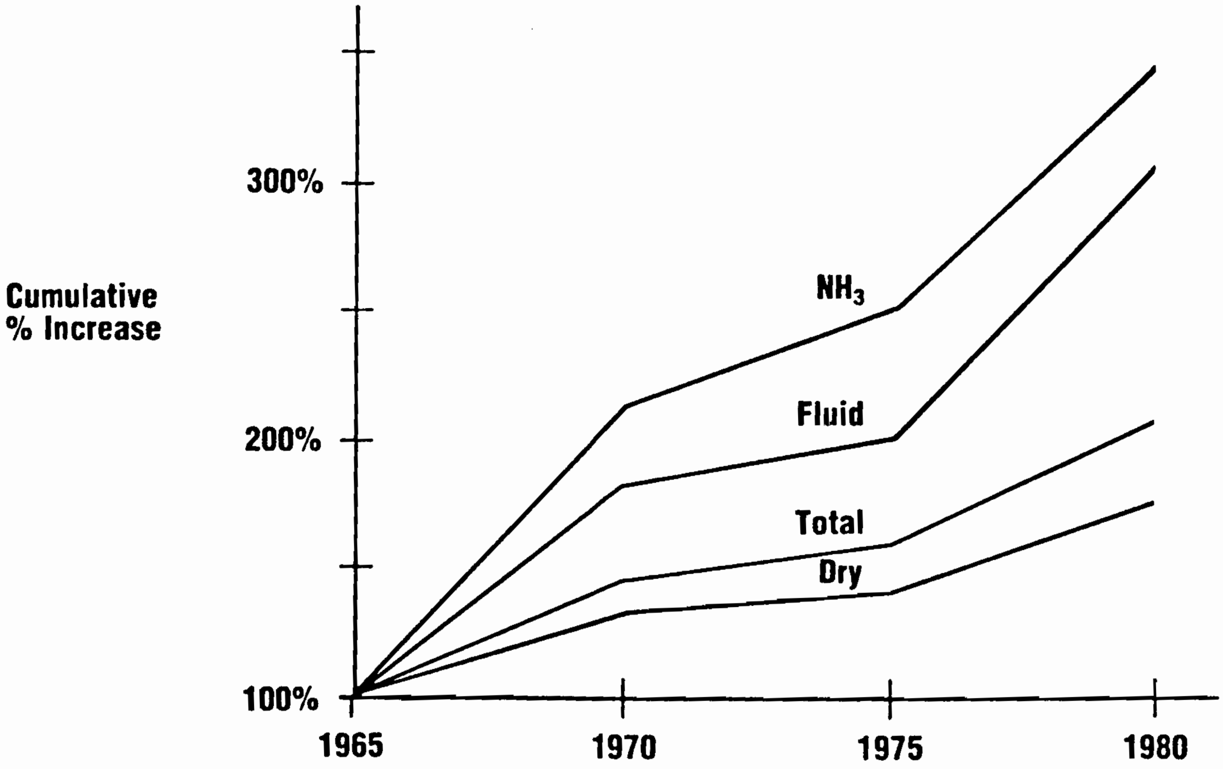
FERTILIZERS

SHARE OF U.S. MARKET
NPK TONS %

	NH_3	FLUIDS	DRY	TOTAL
1965	11.8	10.0	78.2	100
1970	17.4	11.8	70.8	100
1975	18.8	13.0	68.2	100
1980	19.6	16.5	63.9	100

FROM USDA

FIGURE 3



U.S. Fertilizer Consumption by Type
From USDA

FIGURE 4

Agrico Fluid Blend Plant Design For High Productivity (5,000 to 25,000 Tons Per Year)

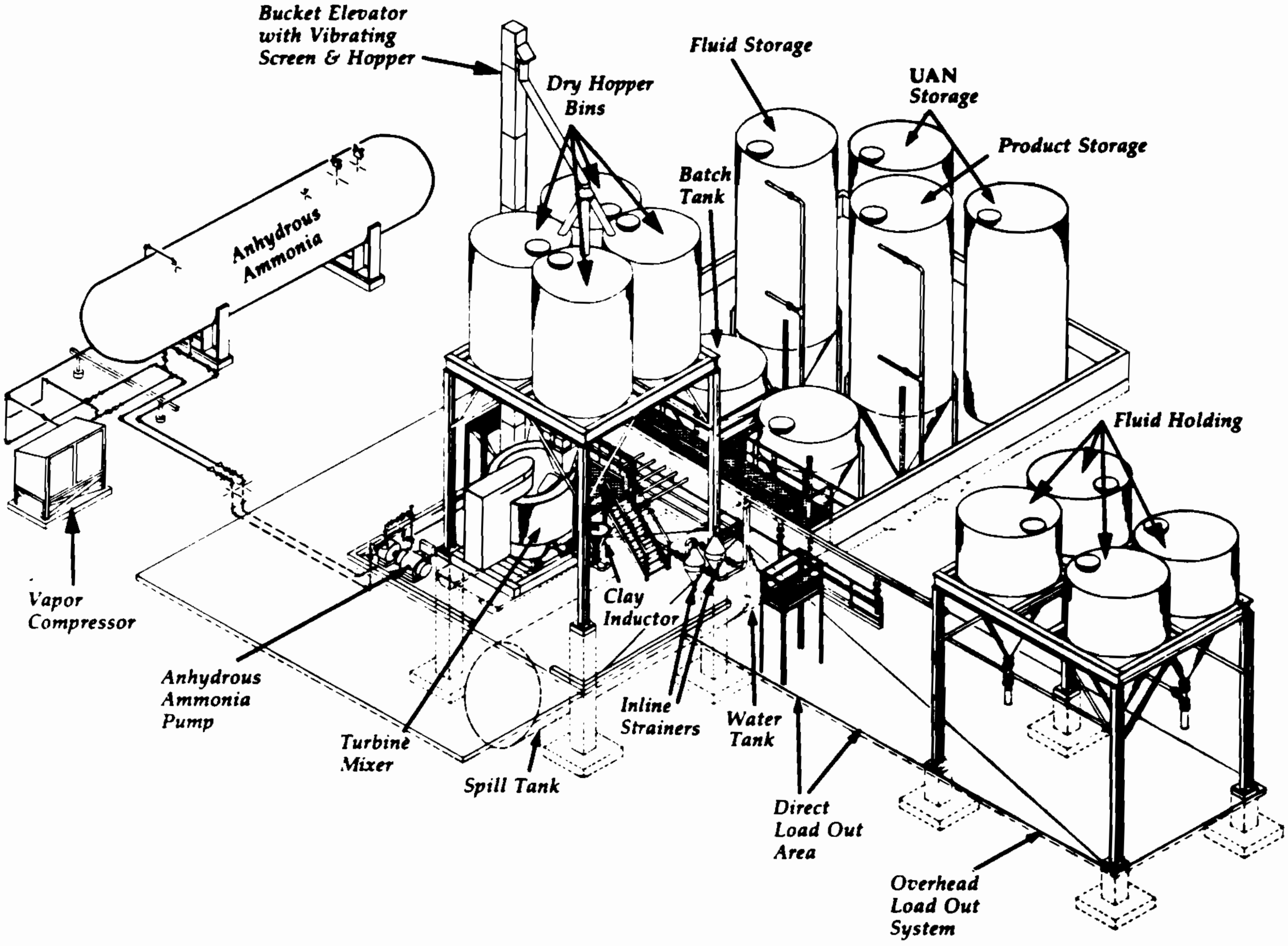
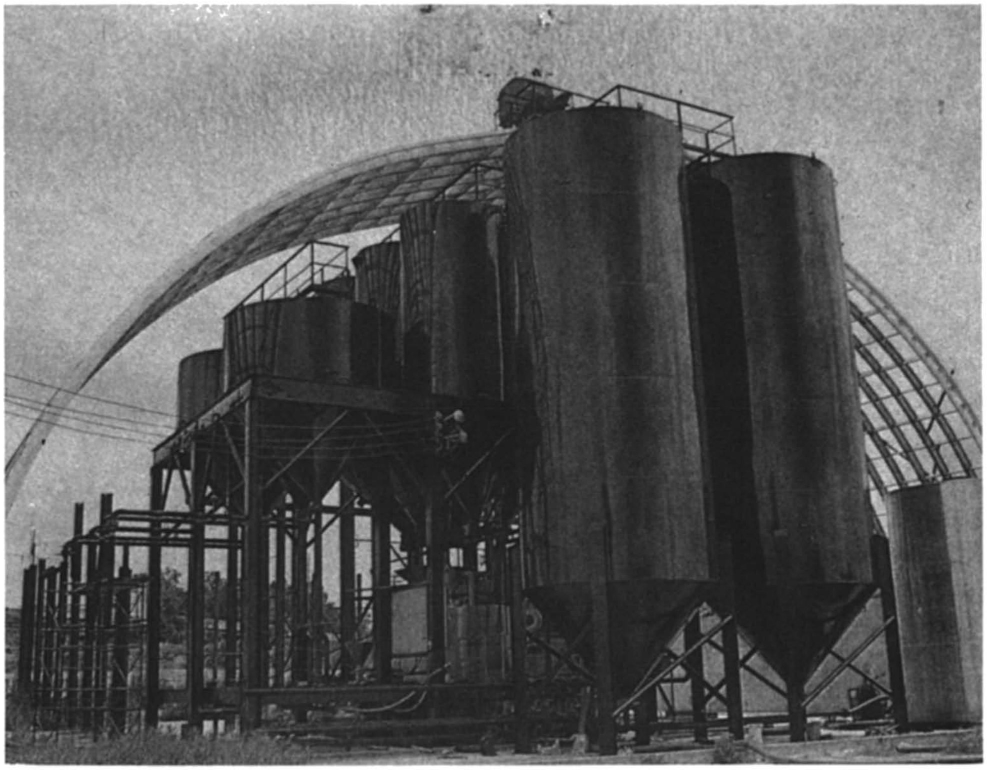


FIGURE 5



FLUID BLEND PLANT
DURING CONSTRUCTION

FIGURE 6

EQUIVALENT DAP

.8679 Units MAP 11-53-0 = 9.55-46.0-0

.0703 Units NH_3 82.25-0-0 = 5.78-0-0

.0954 Units UAN 28-0-0 = 2.67-0-0

1.0366 Units Equivalent = 18-46-0

FIGURE 7

PARITY VALUES

.8679 MAP 11-53-0 @ X

.0703 NH_3 82.25-0-0 @ A

.0954 UAN 28-0-0 @ B

Equivalent DAP 18-46-0 @ C

$$X = \frac{(C - .0703A - .0954\ B)}{.8679}$$

11-53-0 = 1.1522 DAP - 0.0810 NH_3 - 0.1099 UAN 28

FIGURE 8

AMMONIUM PHOSPHATES

AT PARITY WITH

DAP, NH_3 & UAN 28

	f (NH_3)
0-54-0 = 1.1739 DAP - 0.2187 NH_3 - 0.1122 UAN 28	0.1287
10-30-0 = 0.6522 DAP - 0.0621 UAN 28	0
10-34-0 = 0.7392 DAP - 0.0160 NH_3 - 0.0711 UAN 28	0.016
11-33-0 = 0.7174 DAP - 0.0683 UAN 28	0
11-37-0 = 0.8044 DAP - 0.0160 NH_3 - 0.0772 UAN 28	0.016
13-38-0 = 0.8260 DAP - 0.0667 UAN 28	-0.004
10-50-0 = 1.0870 DAP - 0.0810 NH_3 - 0.1037 UAN 28	0.081
11-52-0 = 1.1305 DAP - 0.0770 NH_3 - 0.1077 UAN 28	0.077
11-53-0 = 1.1522 DAP - 0.0810 NH_3 - 0.1099 UAN 28	0.081
11-54-0 = 1.1738 DAP - 0.0850 NH_3 - 0.1121 UAN 28	0.085
11-55-0 = 1.1956 DAP - 0.0890 NH_3 - 0.1145 UAN 28	0.089
13-52-0 = 1.1305 DAP - 0.0530 NH_3 - 0.0107 UAN 28	0.053

FIGURE 9

P_2O_5 PRODUCT HANDLING
AND
TRANSPORTATION COST FACTORS

		f		COST	PENALTY
MAP	11-54-0	1.0	x $35 =	$35.00	0
DAP	18-46-0	1.051		36.79	5.1%
MAP	10-50-0	1.082		37.87	8.2
ACID	0-52-0	1.172	x $52 =	60.94	17.2
GTSP	0-46-0	1.413		49.46	41.3

MODERATOR SACKETT: Thank you, Herb for an excelelent paper. The effort was apparent and the quality of slides was terrific. If you want to get your point across have slides like that! Really great! We will, in the interest of time, hold the questions from the floor until our final Speaker has given his discussion. (Applause)

MODERATOR SACKETT: Our next Speaker is Bruce Remick, Director - Aglime Marketing - National Crushed Stone Association. Bruce has a B.S. in General Agriculture 1955, Cornell University, and a M.S. in Agronomy, 1961, Louisiana State University.

EXPERIENCE: Director of Aglime Marketing, National Crushed Stone Association (NCSA), 1979 to present; Director of Marketing Services, Agrico Chemical Company, 1976-1979; Staff Agronomist, Missouri Farmers Association, 1970-1976. Earlier agri-business experience included technical and sales positions with ARCO Chemical Company and International Minerals and Chemical Corporation.

AREA OF SPECIALIZATION: Directly responsible for the development and implementation of the NCSA National Aglime Marketing Program, including design and publication of marketing aids, development of visual materials, organization and conduct of training seminars for the aglime industry and other program-related activities.

ADDITIONAL INFORMATION: Active member and official representative of NCSA to the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America.

Bruce will speak on "Why and How To Use Aglime. (Applause)

Why and How To Use Aglime

Bruce W. Remick

I want to begin by saying I feel I am among old friends, having spent over fifteen years in the fertilizer industry myself before moving to Washington.

This morning I want to address two essential questions which, I believe, the fertilizer industry needs to have satisfactorily answered if it is to start placing the proper emphasis on aglime and the practice of liming in its product and promotion programs to farmers.

One, why should farmers apply aglime and you, whose main concern is the production, marketing, and sale of fertilizers, promote its use? Two, how should it be applied for maximum effectiveness?

My purpose in doing so is to both underline the importance of aglime in crop production generally, and more particularly, to demonstrate to you who work in the fertilizer industry, especially to those of you in marketing and sales, the positive effect the proper use of aglime can have on the performance of the fertilizer products you sell to farmers.

If you were to ask the leading agriculturalists in the United States today what they regard as the practices most essential to crop production, most would place the correction and maintenance of soil pH high on their list of priorities. Most of them would also agree that agricultural limestone, or aglime, is probably the most effective material available for that purpose.

That lime enhances farm productivity has been known for thousands of years. In terms of twentieth century agriculture, excessive soil acidity is now widely recognized as a leading cause of reduced productivity where many of our prime agricultural soils are concerned, and where aglime has been properly applied to correct soil acidity — it represents over 90 percent of all liming materials used in the U.S. — it has produced significant benefits to the agricultural producer, in terms of increased productivity and income.

Yet, in spite of the recognized importance of liming to production agriculture, annual aglime usage in the United States has historically fallen critically short of the total tonnage required nationally to maintain the pH of our agricultural soils at agronomically acceptable levels — or about 30 million tons applied as compared with an annual need of 90 million tons or more based on State Land Grant College and Soil Conservation Department estimates.

The disparity between need and actual usage of aglime in view of the recognized benefits associated with it suggests factors are at work in the marketplace which are discouraging its sale and use. Farmer attitude is certainly one of them. While the application of fertilizer and agricultural chemicals has become an annual event on most U.S. farms, the practice of liming is frequently ignored. Even when the need is strongly indicated by soil test, aglime is usually applied on an "if weather, time, and money permit" basis to crop land only after other crop operations have been completed.

However, farmers operating on acid soils are going to have to reset their priorities. Soil acidity, left untreated, only gets worse. The natural tendency of many soils in areas of moderate to heavy rainfall is to become acid with time. Many factors, both natural and man-made, contribute to the process which, if not controlled with the regular application of agricultural limestone, can result in acid soil conditions severe enough to seriously reduce crop yields and cause severe economic loss to the farmer.

Soil acidity is one of the most widespread and frequently overlooked agricultural problems in the U.S., particularly in the eastern one-half and in certain high-rainfall areas along the west coast of the country. If you market fertilizers in these areas, strong emphasis on liming should be made an integral part of your own, or your dealer's, program selling approach to farmers. You will be doing them a valuable service.

What benefits is the farmer getting for his aglime dollar? Let's look briefly at the agronomic ones first, and then go to the "bottom line", the increased income possibilities from liming. Aglime, properly used, contributes to higher crop production in several ways. By neutralizing soil acidity it minimizes the adverse effects of high concentrations of soluble aluminum, iron, and manganese, normally associated with acid soil conditions, on phosphate availability and plant growth.

Liming to the proper pH increases soil microbial activity. Because beneficial soil organisms tend to be most active in a neutral or near neutral soil, the process of organic matter decomposition, a factor in soil aggregate formation, with its associated improvement in soil aeration and drainage, is accelerated, creating more favorable conditions for crop growth. Root nodule bacteria responsible for nitrogen fixation in legumes also function best under these conditions.

Calcium and magnesium depleted by leaching, crop removal and erosion are returned to the soil when aglime is applied, an important factor both in pH correction and total soil nutrient balance and availability.

But the effects of a good liming program extend beyond its influence on soil fertility. The effectiveness of certain herbicides, especially the triazines, i.e. Atrazine, Metribuzine (Sencor, Lexone), and Cyanazine (Bladex) is known to increase when the soil pH is maintained at 6.0 - 6.2 or higher.

The "bottom line" where the use of aglime is concerned rests on the fact that these beneficial effects readily translate into increased yield and dollar returns to the farmer. For example:

1980 results from a series of continuous corn plots established by the Agrico Chemical Company at Washington Court House, Ohio (Table 1) showed that the application of aglime significantly increased the incidence of grain yields in excess of 140 bushels per acre under conditions of both high and low fertility.

Table 1

Corn Response To Lime At High and Low Soil Fertility Levels

Plot No.	Soil test Situation	Avg. Corn Yield BU/A	No. Out of 16 Plots Exceeding 140 BU/A
1	Acid, Low P-K	101	1 (6%)
2	Limed, Low P-K	127	5 (31%)
3	Acid, High P-K	145	11 (69%)
4	Limed, High P-K	152	16 (100%)

Soil pH of acid plots — 5.0-5.5

Limed plots receive annual applications of aglime at rates necessary to adjust and maintain soil pH at 6.5

Each plot divided into 16 equal-size sub-plots for statistical data collection. Washington Court House, Ohio, 1980

In a 1975 University of Maryland trial designed to measure the effect of aglime and fertilizer on corn yield, (Table 2), results clearly showed that they both increased grain production where applied individually, but that yields increased dramatically when aglime and fertilizer were applied together.

Table 2

Aglime-Fertilizer Interaction and Corn Yield Response

Plot	*Yield Bus/Acre*	*Value of Corn (@) 2.75 Bu*	*Fertilizer (1) Cost*	*Aglime Cost (2) @$15/Ton (3 Year Period)*	*Value Over Untreated Plot*	*Net Return on Each Invested*
1	22.7	62.43	None Used	None Used	0	0
2	98.7	271.43	$52.20	None Used	$209.00	$3.00
3	47.5	130.63	None Used	$10.00	68.20	5.82
4	114.1	313.78	$52.20	10.00	151.35	3.04

(1) Fertilizer cost for one year

(2) Aglime cost @ 2 tons/acre pro-rated over 3 years

Source: V. Allan Bandel, University of Maryland

In a survey conducted by the Potash and Phosphate Institute, of 549 corn producers in 33 states who achieved 200 bushels or more per acre during the 1975 and 1976 growing seasons, soil test results showed that all but two, or over 99 percent of the fields reported in the survey *had pH levels of 6.0 or higher.*

And in a four-year Ohio trail concluded in 1979, (Table 3), the total cumulative alfalfa yield produced in the three aglime-treated plots during the period of the project averaged approximately twice the total yield from the unlimed plot for the same period. In an actual situation, this added production would have represented an increased return of from $2.97 to $10.20 per dollar spent on aglime.

Similar yield responses from liming have also been obtained with cotton, soybeans, and other crops.

Table 3

Total Yield and Return on Investment Effect of Aglime on Alfalfa Yield and Income

Soil pH after cropping	**Lime applied 1974 (T/A)**	**Yield 12% H20 hay (T/A)**	**Yield increase over check (T/A)**	**Value of increase yield/a ($/A)**	**Cost of lime/b ($/A)**	**ROI Added Return per $1.00 Spent of aglime**
5.	0	8.1				
5.6	2.5	14.1	6.	$420.00	$ 37.50	$10.20
5.8	5.	17.1	9.	630.00	75.00	7.40
6.	10.	16.6	8.5	595.00	150.00	2.97

R.O.I. — Return on Investment

/a Alfalfa at $70/t
/b Lime at $15/T
Source: John F. Trieweiler, Ohio State University

However, certain application guidelines must be followed to achieve maximum crop response and income from a liming program. Use of a quality product is a prerequisite. For aglime, this means one with the highest possible calcium carbonate content or neutralizing value (80-90 percent or higher is ideal) and a fineness of grind which will permit 50-60 percent of the aglime in a given lot to pass 60-100 mesh. Application rates should be based on recommendations provided by an accredited soil testing laboratory. Spreading should be done uniformly. Finally, wherever conditions permit, aglime should be incorporated.

Incorporation is not a problem where conventional on deep tillage is concerned. Under certain cropping conditions, however, this may be impossible, making it necessary to consider alternative methods for obtaining a good aglime-soil mix.

Where permanant pasture, and established stands of alfalfa and other forages are concerned, aglime and fertilizer application in conjunction with seed bed preparation and establishment will provide desired soil incorporation. Application at the time of disking prior to reseeding and renovation of permanent pastures will produce the same result. Although top dressing assures the application of needed quantities of aglime and fertilizer during interim years it does not permit mixing of these ingredients in the root zone.

Where acid soil conditions prevail in connection with no-tillage operations, special care should be taken to plow the treated area on a regular basis if soil drainage and field topography permit. A three to four-year interval is usually adaquate. No-tillage and certain reduced tillage systems can cause the accumulation of aglime at the soil surface. Although this may achieve the desired pH adjustment at the soil surface, subsurface soil acidity is not appreciably affected where these tillage systems are followed unless plowing or some other form of incorporation is practiced at regular intervals.

No-tillage and reduced tillage systems can also lead to other problems. Acid-forming fertilizers applied to no-till corn at high rates and all owed to accumulate at the soil surface, where no aglime is applied, can cause precipitous declines in the pH in the top few inches of soil, a fact which can have serious implications for the effectiveness of certain surface-applied herbicides, especially the triazines, and all that this entails in terms of potential yield loss and problems at harvest time. A case in point: reductions of up to 1.5 pH points within just a few weeks following the application of 160 lns per acre of nitrogen to no-till corn have been documented on some soils in Maryland. Situations like this can be prevented by liming according to recommendation and periodic incorporation by plowing or disking.

Returning to my original question, why should you promote the application of agricultural limestone? The evidence speaks for itself. It is economically unsound to apply plant food and not apply aglime to the soil where it is shown to be needed by soil test. Fertilizer nutrients, especially phosphates, and the triazine herbicides require a near neutral to neutral soil pH to perform effectively. By not giving due emphasis to the application of aglime in your total fertility recommendations to farmers, you are allowing a serious omission to occur in your marketing programs.

Corn producers spend an almost unbelievable number of dollars on each crop. On a national basis these figures average approximately:

$12 to 15 per acre for seed corn
$18 to 20 per acre for weed control
$ 8 to 18 per acre for soil insect control
$12 to 15 per acre for corn borer control
and $65 to 102 per acre for fertilizer

for a total of from $118 to $168 per acre. These are costs beyond land, machinery, machinery operation, taxes, interest and labor, and represent annual expenditures on soils where acid conditions are reducing the return on this huge investment by as much as 25 percent or more — in some cases by as much as 50 percent. Speaking in these terms, a good liming program represents one of the farmer's most cost-effictive means of increasing his return on this large investment.

Farmers rely heavily on their fertilizer suppliers for advice on fertilizer products to use and practices to follow in producing their crops. You, and the dealers who handle your products greatly influence farmers decision to use fertilizer and aglime, and need to promote both with equal emphasis.

A fertilizer program on acid soil cannot produce the desired result if it does not include the application of aglime at recommended rates. By renewing the emphasis on liming in your fertility recommendations to customers, and underlining the importance of following through with application, you will open up increased income possibilities for them and assure increased prosperity for your fertilizer business.

MODERATOR SACKETT: Thank you, Bruce, for a very interesting paper and again I compliment you on the quality of the slides. (Applause)

Our next peper is co-authored by Harold D. Blenkhorn and Jesse Ku. Harold will present the paper. Harold is a native of Nova Scotia and grew up on a farm. He obtained his Bachelor of Science Degree from McGill University in 1950, majored in Chemistry and Soil Science. He has been variously employed in soil fertility research and industrial chemistry. He joined Nitrochem, Inc. in 1961 and his present position is Manager of Technical Services. Harold is also our Round Table Vice-Chairman and heir apparent to Frank Achorn. I would like to present Harold Blenkhorn. (Applause)

Production of Clear UAN Solutions Form Solid Sources of Ammonium Nitrate and Urea

Jesse C. Z. Ku
Harold D. Blenkhorn
Presented by Harold D. Blenkhorn

The nitrogen complex operated by Nitrochem Inc., in Maitland, Ontario was originally designed with bagging facilities for its ammonium nitrate and urea production. As a result of increasing demand for bulk product, it was decided a few years ago to discontinue the practice of bagging and convert the warehouse and shipping operations to a bulk handling system.

Following the conversion, it became evident that the additional mechanical handling of the nitrogen materials in a bulk system resulted in a certain degree of prill breakup, making it necessary to screen the products prior to shipping. The screen reject material consists of prill fragments and loose coating agent. In addition, there are prills crushed under the wheels of the front-end loaders, spills, etc., which when combined with the screenings amount to a significant quantity of scrap material.

The contaminated and off-specification material which is generated in the storage and shipping operation presents a disposal problem and also represents considerable value in terms of nitrogen content. These impure products cannot be returned to the process. In considering various ways of reclaiming this scrap material, it was decided that the most practical route was to dissolve it and recover the nitrogen in the form of clear urea-ammonium nitrate (UAN) solutions.

The concept of the recovery process is to dissolve the solid ammonium nitrate and urea in water, allow the foreign matter to settle to the bottom of the vessel, and draw off the supernatant liquid as UAN solution. This concept, however, is complicated by the fact that the scrap material contains about 2.0% of clay coating agent. The particle size of the clay is in the order of .5 microns. Their rate of settling in a relatively viscous solution such as UAN 32 is extremely slow. Efforts have been made to separate clay particles from UAN solutions by the use of a centrifuge, cartridge filters, and filter presses, but these methods are either ineffective or prohibitively expensive.

Removal of Clay Particles

The main problem with the clay contaminant is that the particles carry electrical charges which cause them to repel each other and remain more or less in a dispersed state in the liquid. This physical property of the particles suggests that the problem might be solved by neutralizing the charges with a suitable additive. As part of the effort to develop an efficient and practical process, a series of bench-scale tests were carried out to determine the effect of flocculating agents on the settling rate of the clay particles.

UAN solution was prepared by dissolving scrap ammonium nitrate and urea in the required volume of water. Sedimentation tests were carried out in 500 ml cylinders. The first additive tried was an inorganic coagulent (aluminum sulphate) which had very little positive effect on the settling rate. An organic flocculant, however, produced striking results. A high molecular weight cationic polymer added at the rate of 4 ppm caused rapid settling of the clay particles, resulting in a supernatent layer of clarified UAN solution.

When the polymer was added to the solution, the flocs formed immediately and the settling took place rapidly. After 30 minutes the sludge level dropped to 40% of the volume. After four hours the supernatant layer began to clear, and sludge volume was reduced to 24%. In the cylinder containing the untreated solution, the sludge level after four hours was still at 85% with a turbid liquid layer. (Figure 1)

The settling rate of the clay in the solution treated with 4 ppm polymer was measured at 1.25 cm per minute in the 500 ml cylinder. Additional tests were carried out to determine the optimum polymer dosage. Doubling the rate of flocculant to 8 ppm had the effect of doubling the settling rate to 2.5 cm per minute. Further additions of the flocculant did not increase the settling rate. (Figure 2)

The polymer is in white powder form and is prepared as a .05% aqueous solution. It is added to the makeup water to provide the desired level of flocculant.

There are two distinct stage in the sedimentation process. The first stage is "zone settling" in which the flocculated particles fall quickly and gather loosely in the lower part of the vessel. This is followed by the "compression" stage in which the sludge layer gradually compresses to a constant level. Sedimentation tests with UAN 28, 30, and 32 showed that their final sludge volumes were respectively 13%, 16%, and 20% of the original volume. (Figure 3) Reclaiming the scrap material as 28% or 30% nitrogen solutions would be a simpler proposition than 32% because of reduced sludge loads. Because of market demand, it was necessary to design the process to recover the nitrogen as UAN 32.

The sludge portion which settles out from UAN 32 solution contains 20% of the input nitrogen, representing a recovery rate of 80% of clear solution. As a means of recovering more nitrogen, the clear solution was drawn off and a volume of water equal to the sludge was added. This was agitated and again allowed to settle. Figure #4 compares the settling rate of the washed sludge with that of the original crude UAN 32 solution. The compression stage begins earlier at the point where the sludge is about half of the initial volume. the final sludge level is about the same as in the first settling stage. By this approach, half of the nitrogen contained in the sludge layer of the first stage of settling is recovered as a clear dilute (16% N) solution. The clear solution was added to the makeup water as part of the solute for a succeeding batch of crude UAN 32. A complete cycle of the process demonstrated that the two-stage sedimentation system was a workable process for the recovery of nitrogen from the scrap material.

Design and Operation

The physical facilities of the process (Figure 7) consist of one 25 ton dissolving tank, two 100 ton sedimentation tanks, and one 70 ton holding tank for 16% UAN solution. The input materials to the system are 40 tons of ammonium nitrate, 31 tons of urea and 27 tons of water. The output consists of 80 tons of clear UAN solution, and 20 tons of sludge containing about 4 tons of ammonium nitrate, 3 tons of urea, 2 tons clay, and 11 tons of water. Material balance and process flow diagrams are shown in Figure #5 and #6.

The initial step is the preparation of crude UAN solution in the remelt tank. This vessel is submerged in the ground with two feet exposed above ground level. This is to facilitate the charging of dry materials through the top with a front-end loader. A 25 ton batch contains the following:

	Charged to Remelt Tank (lb.)	**Recycle UAN 16 (lb.)**	**Total**
Ammonium Nitrate. .	20,000	2,500	22,500
Urea.	15,000	2,000	17,500
Clay.	1,000	——	1,000
Water.	3,000	7,000	10,000
Corrosion Inhibitor	75	——	75
Flocculant (.05% solution).	800	——	800

Dry materials are charged into the tank with a front-end loader. The quantities are approximated according to the number of bucket loads added. Dissolving is accomplished by heating with a steam coil mechanical agitation. When the batch is dissolved, corrosion inhibitor is added and the analysis is checked by specific gravity measurements (see Figure 8) and if necessary, adjusted to the correct composition and nitrogen content. The crude solution is then transferred to the sedimentation tank by a 200 USGPM slurry pump. Transfer time is about 30 minutes.

The flocculating agent is added through the transfer line to the sedimentation tank. The .05% polymer solution is prepared in a 4,000 lb. batching tank sufficient to treat 125 tons of solution. The polymer is injected into the transfer line by a positive displacement metering pump which is adjusted to match the delivery time of the batch transfer from the remelt tank. The polymer dosage in the UAN 32 solution is maintained at 8 ppm.

Three to four batches of crude product are successively charged into the sedimentation tank and the sludge is allowed to settle over night. Based on the settling velocity of the flocculated clay as established by laboratory tests, the tank was designed to a height of 16 feet to provide for complete settling during a twelve hour period.

At the end of the sedimentation stage, the clarified UAN 32 (80% by volume) is withdrawn through a 3 inch outlet located four feet above ground level by a 240 USGPM transfer pump. The solution passes through a 70 micron filter and is transferred to the main solution storage tank. The sedimentation tank is provided with a second clear solution outlet located two feet above ground level. This is to accommodate variations in batch sizes and sludge loads. There is a sample line on each of the two outlets to check the sludge level.

The sludge layer is washed with an equal volume of water, agitated by a steam sparger located in the bottom of the tank, and again allowed to settle. The diluted clear liquor (55% by volume of 16% N solution) is transferred to a holding tank to be recycled for the preparation of succeeding batches of crude UAN solution.

The sludge which remains after the second settling stage is withdrawn through a 3 inch bottom outlet through a flexible hose into a "sludge wagon" (1000 USG liquid manure tank) by means of a pump which is mounted on the unit. The sludge is discharged into nearby pond which has a capacity for 750 tons of sludge. The pond is lined with plastic sheeting to prevent seepage of nitrates into the ground water.

The sludge consists of 10% clay, 20% ammonium nitrate, 15% urea, and 55% water. Further settling takes place slowly in the sludge pond, leaving a supernatant clear 16% UAN solution which may be recycled to the recovery system. It is expected to recover 50% of the nitrogen in the pond sludge for an overall efficiency of 95% nitrogen recovery in the operation.

The system operates with two sedimentation tanks used alternately for clarification of 32% and 16% UAN solutions. The sequence of operations is as follows:

Day One	**Tank #1**	**Tank #2**
Day Operation —	1) Pump out clear 16% solution. 2) Remove sludge. 3) Charge with crude 32% solution (3 to 4 25 ton batches.	1) Pump out clear 32% solution. 2) Dilute and wash sludge.
Overnight Operation —	First stage settling: clarification of 32% solution.	Second stage settling: clarification of 16% solution.
Day Two		
Day Operation —	Same as tank #2, day one.	Same as tank #1, day one.
Overnight Operation —	Same as above.	Same as above.

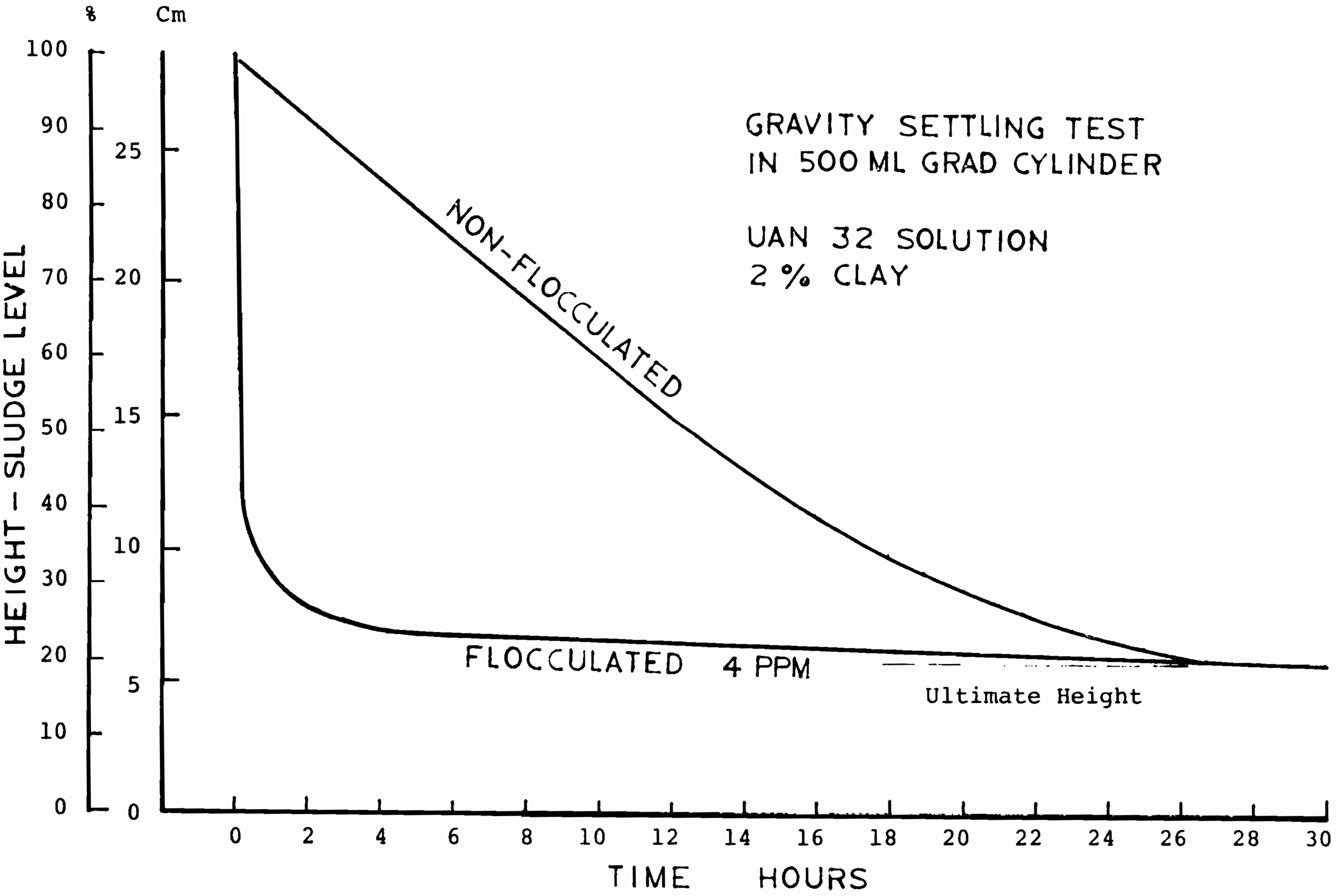
Operating Personnel

1 Operator — Solution preparation and transfer.
1 Operator — Operation of front-end loader and sludge wagon.

The installation cost of the recovery system is approximately $200,000 including the dissolving tank, two sedimentation tanks, dilute UAN storage, pumps, filters, polymer supply system, sludge wagon and sludge pond construction. The cost of the polymer is $2.50 per pound, or about 4¢ per ton batch of clarificatied UAN 32 solution.

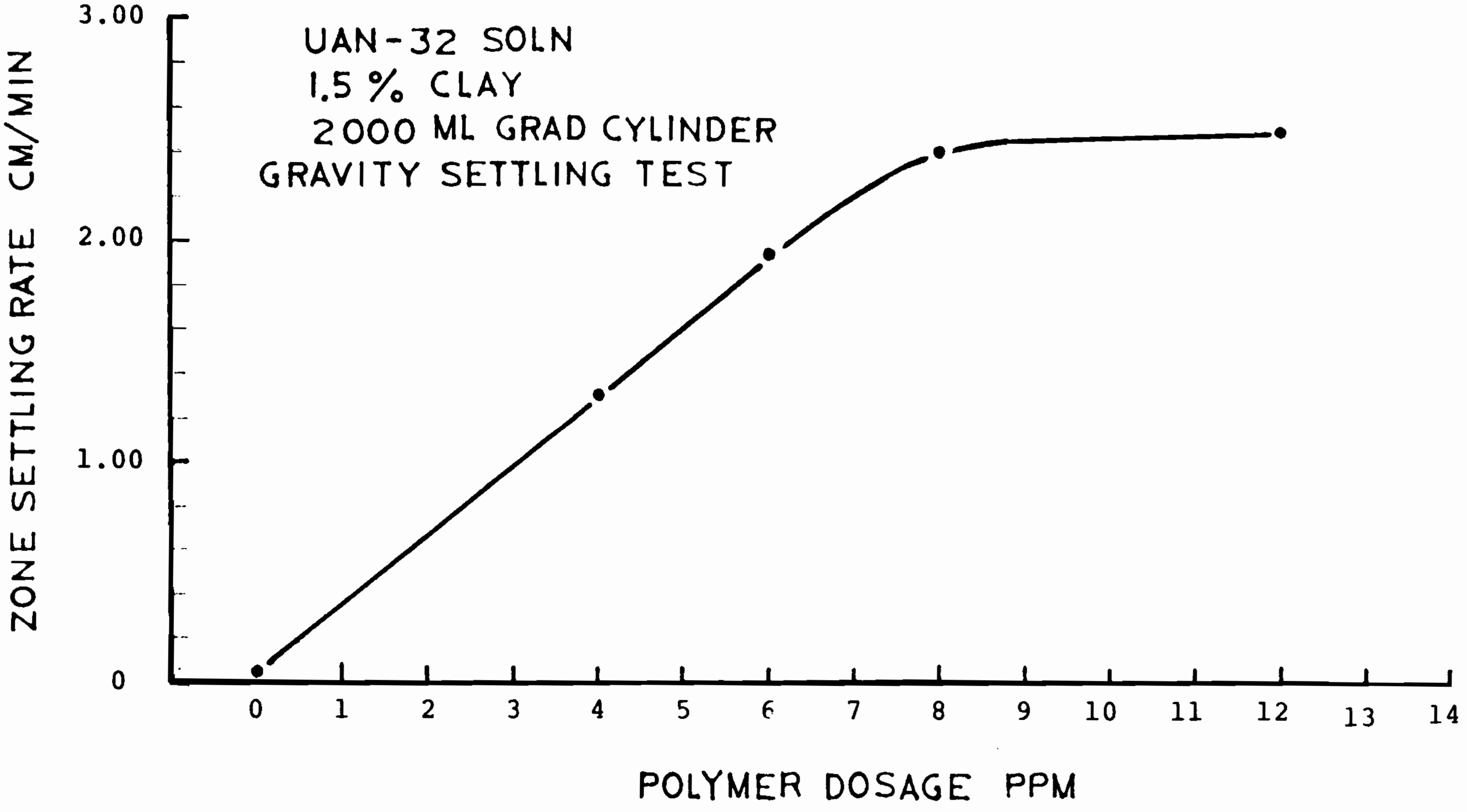
The system began operating in the spring of 1981 and to-date has recovered more than 3,000 tons of clear UAN 32 solution from otherwise unmarketable ammonium nitrate and urea. The production rate is about 60 tons of solution per day.

One difficulty with the process arises from coarse foreign matter which passes through the coarse grating provided under the opening for charging the scrap product through the top of the makeup tank. This material — bits of paper, plastic, wood, etc., occassionally plugs the slurry pump and transfer line, and to some extent, passes into the sedimentation tank. It is intended to install a filter on the intake side of the slurry pump which is designed to be easily removed and cleaned. elimination of the problem should reduce the time required to charge the sedimentation tanks and increase the production rate.



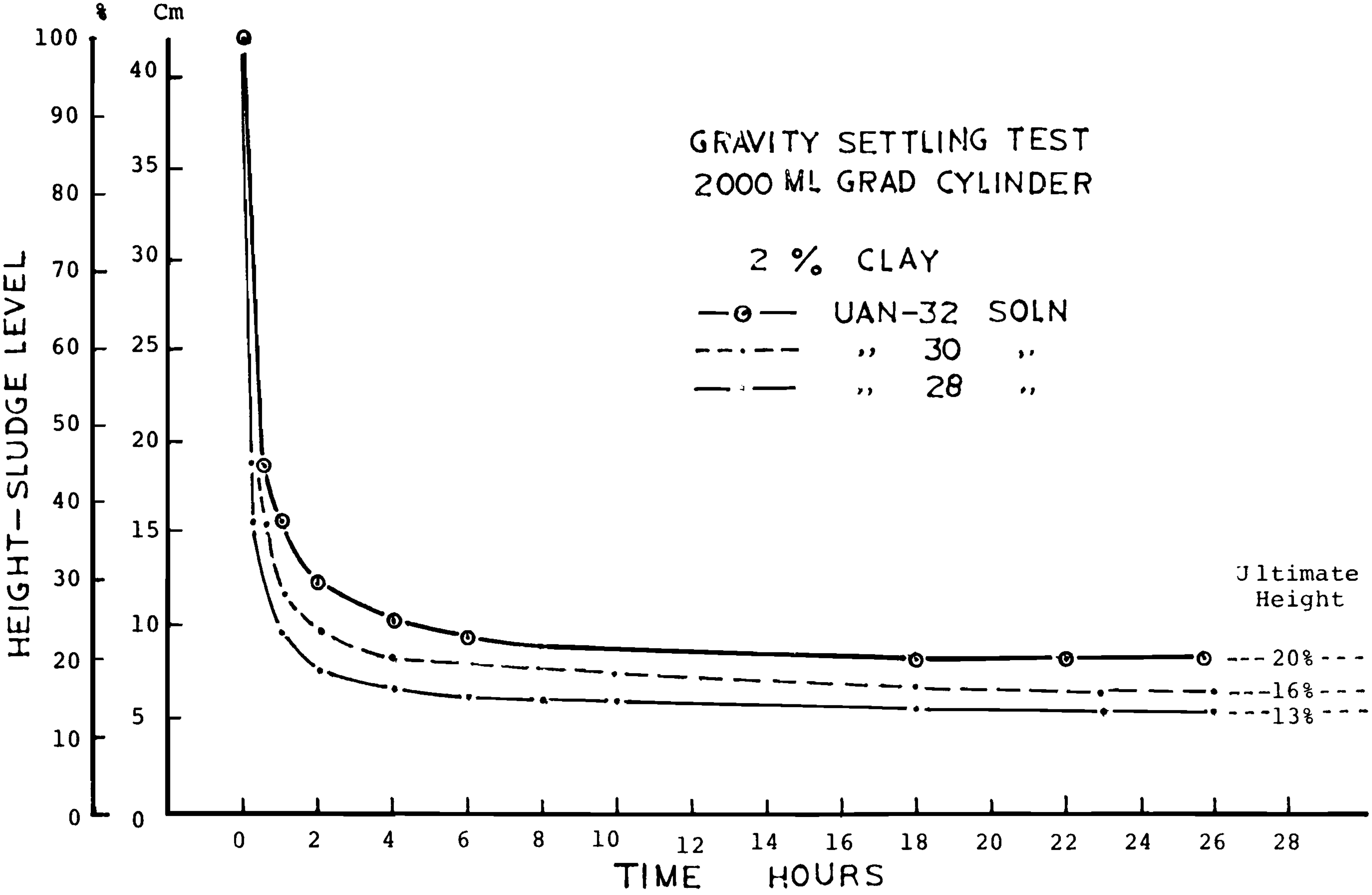
SETTLING TEST - UAN SOLN CONT. CLAY

FIG.-1



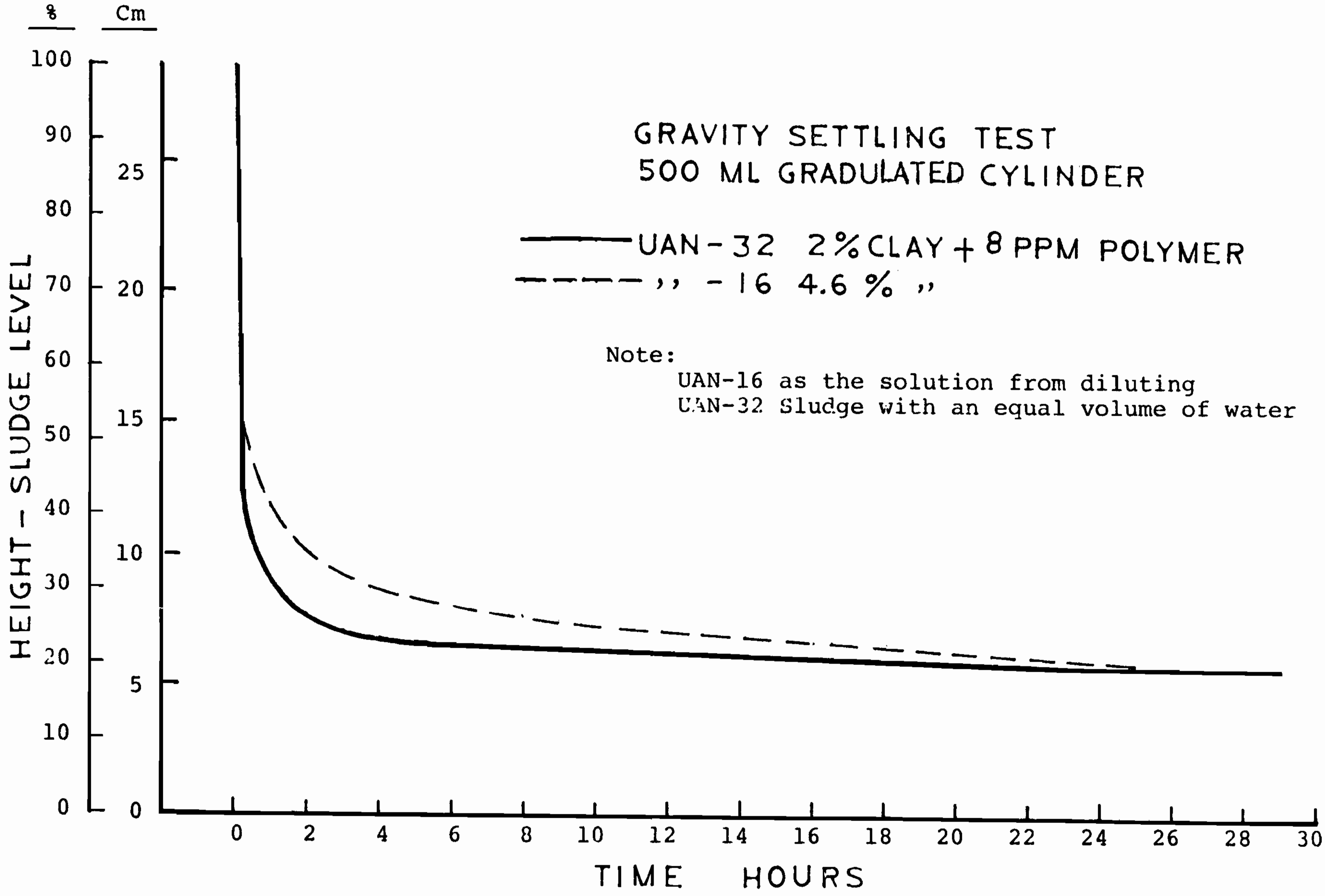
FLOCCULANT DOSAGE TEST

FIG.-2



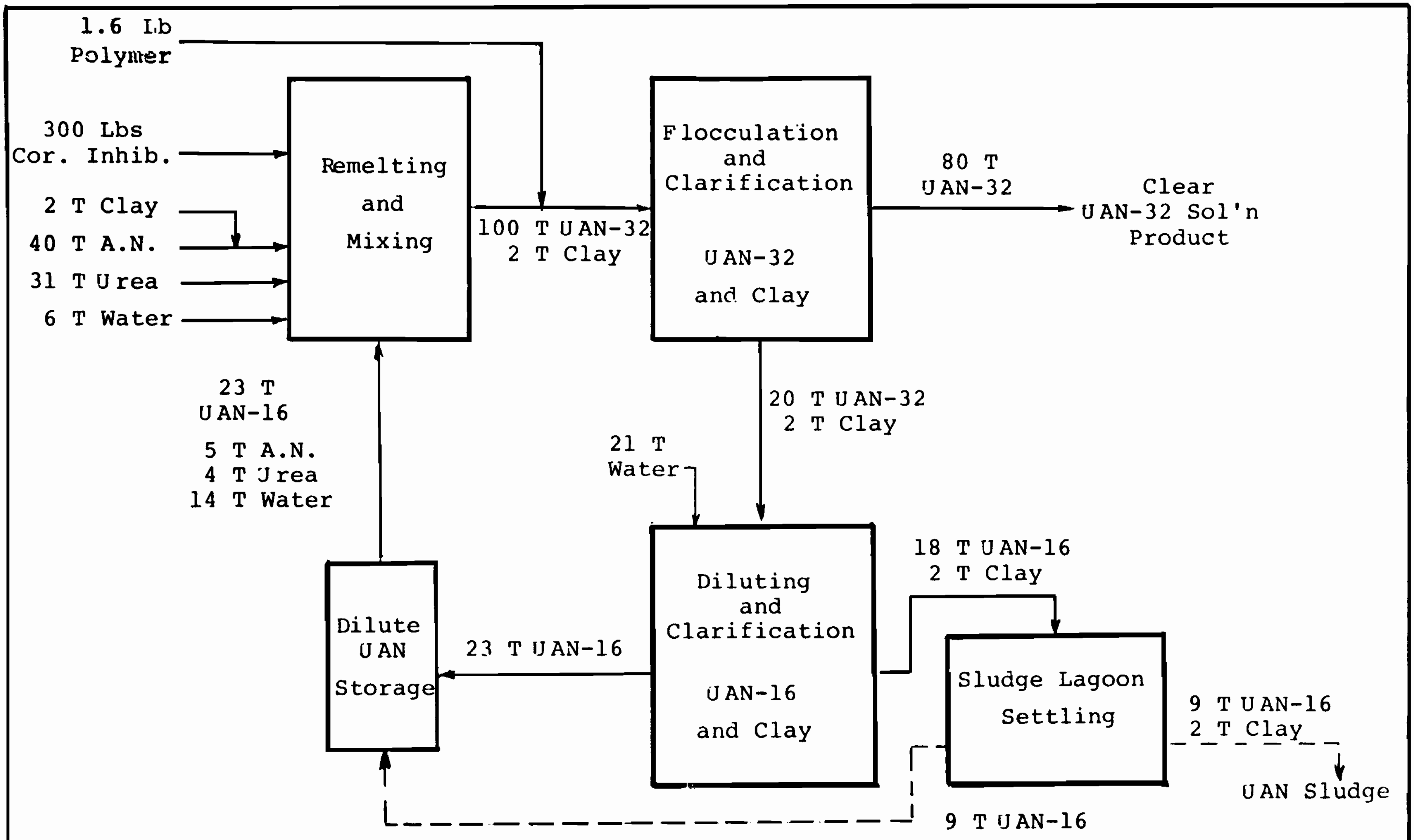
SEDIMENTATION TEST–DIFF. UAN SOLN. CONC.

FIG.-3



SEDIMENTATION TEST - DILUTED UAN SLUDGE

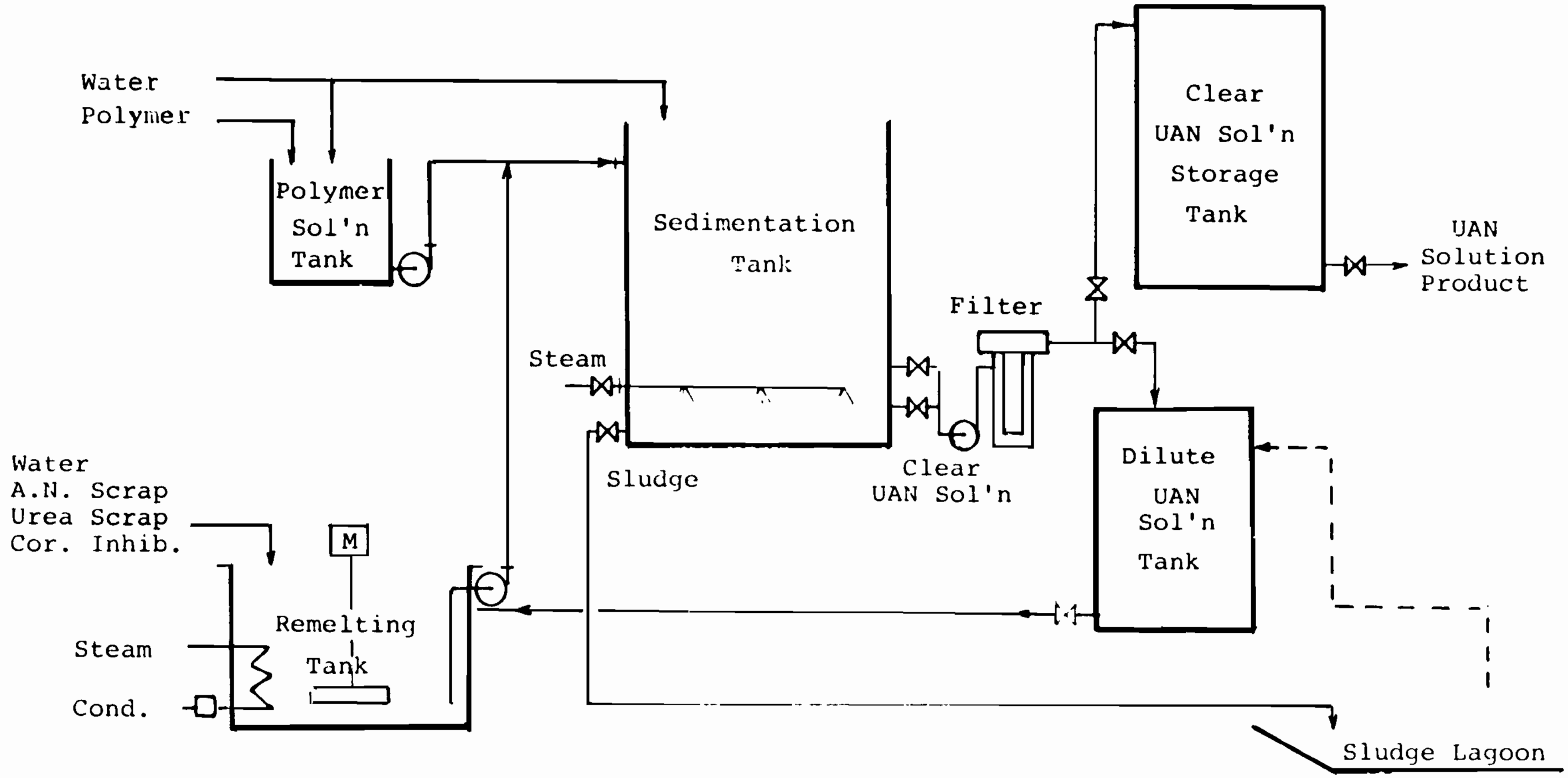
FIG.-4



UAN SOLN PROD. SYSTEM:

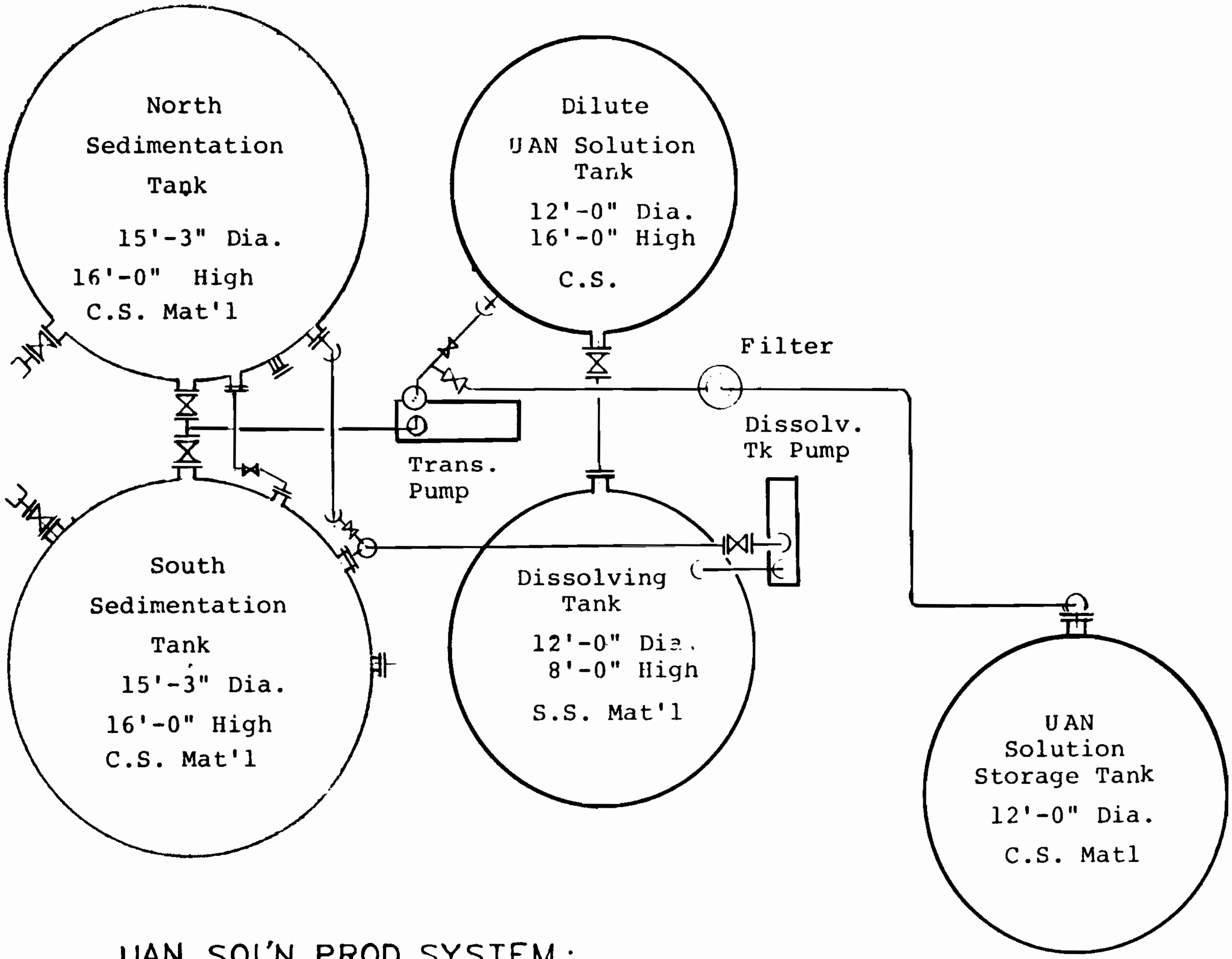
MATERIAL BALANCE

FIG.-5



UAN SOLN PROD. SYSTEM : PROCESS FLOW DIAGRAM

FIG-6



UAN SOL'N PROD. SYSTEM: PLANT LAYOUT FIG.-7

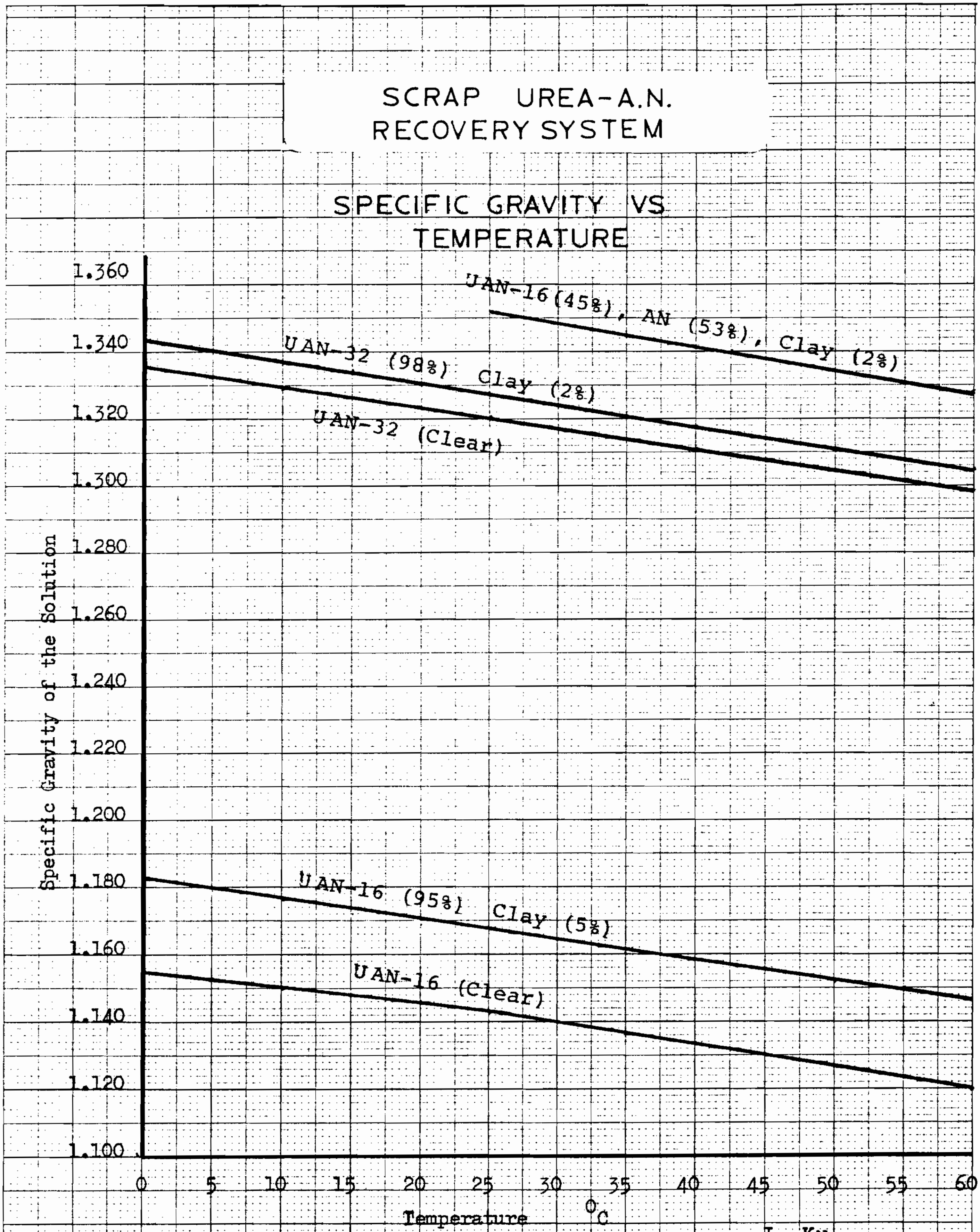


FIGURE - 8

J. Ku
W. McKnight
12,9,80

MODERATOR SACKETT: Thank you Harold. You had a very interesting paper. I would also like to thank Harold for his invaluable assistance to me personally in getting this morning's program organized. (Applause)

QUESTIONS: At this time we will take whatever time is needed for our first three Speakers: Herbert C. MacKinnon, Bruce W. Remick and Harold D. Blenkhorn.

QUESTION—RICHARD A. DENNIS -AMERICAN CYANAMID CO.: Harold Blenkhorn you talked about the use of polymer as a settling aid. You neglected to say what polymer. Could you enlighten us on that?

ANSWER—HAROLD D. BLENKHORN: I am sorry. I can't tell you. Mr. Ku had intended to be here and he could have answered this question. It is, I understand, a very commonly used polymer, used in water purification. From the original notes that Jesse gave me for preparing this paper, he simply said it was a high molecular weight. I can't tell you exactly what the chemical composition is. There's one thing I should have mentioned. I mentioned a 90% recovery rate. The contents of the pond, of course, will very slowly settle. They have been drawing off some of the clear liquid from the top of the pond and poking that back through and achieving, actually, about a 95% recovery.

RICHARD DENNIS: Just when I sat down, a gentlemen behind me asked what happens when the sludge builds up in the pond. Is your pond big enough to accommodate all or it?

ANSWER—HAROLD BLENKHORN: We have a much larger pollution control system under construction which will accommodate some of the sludge in the event that it catches up on us. We have, also, to some extent, actually applied that to corn locally in the area. One of our operators has a custom application operation, mainly in herbicides and UAN solutions. In fact, I worked with him on the typical nitrogen content of this sludge a particular dilution that would work through the sprayer. From the gallons delivered and from the nitrogen content, we did work out a satisfactory way of applying this directly to the soil.

QUESTION—FRANK ACHORN: I have a question for Herb MacKinnon. In making MAP's, there's MAP's and then there's MAP's, and then there's MAP's. There's MAP's within MAP's. Do you have some additional information you can give us concerning specifications for impurities and the effect of impurities in MAP on the storage characteristics (two or three days storage) of suspensions made from MAP?

HERB MacKINNON: That's certainly a very pertinent question, Frank. The program that we have worked on within our company is a rather high quality MAP. Initially, it was an 11-54-0. I guess I should say, in the very beginning, it was 11-52-0. In our opinion, the 11-52-0 was sort of a borderline product. We could live with it but, for general use in introducing a new product, we felt we should have a little better purity, so we went to 11-54-0. Later, we backed off to 11-53-0 which let us have one grade of MAP for our international and domestic requirements. As you go to lower analysis MAP's, impurities build up and these will give you some problems. They are difficult to suspend for any length of time. They tend to settle out. If they do, they tend to compact rather badly. It's not that you can't handle them, it's that you need to take aims to keep your product agitated in storage or you need to add polyphosphate to help improve the storing qualities. Polyphosphate will enhance the soluability and it tends to prevent the sediment from packing.

QUESTION—HAROLD JONES - THE J. E. BAKER COMPANY: We are in the limestone business, too. I would like to address this to Bruce Remick. I know the requirements for limestone in the western areas are not quite as fine as they are in the east. I was wondering if this might be a detriment to the limestone results in some of those areas?

BRUCE REMICK—NATIONAL CRUSHED STONE ASSOCIATION: The soils in Iowa, for example, are very rich. It actually takes higher rates of application to effect the same change in acidity that you might require on a coaser or lower cation exchange soil. To answer your question, there are many soils in the midwest that have a low pH reading and do require as much, if not more, limestone than some of the soils here in the east. The degree of acidity and the extent of it is tied very closely to rainfall. There are soils out in the midwest that do have a severe pH problem much the same as there are here in the east. I don't think there's a significant difference in that respect between soils in the east and those in the west. Naturally, the higher the pH, the less ag lime is required. At the same time, on soils where heavy applications of nitrogen are applied annually, you are still going to require the limestone to correct and counteract that effect.

QUESTION—HAROLD JONES - THE J. E. BAKER COMPANY: I think you may have misunderstood my question. I was thinking of the fineness of grain here in the east. We require much more through the 100 mesh than some of the midwest requirements for fineness in limestone. I am just wondering if the fineness of the limestone was greater. I know some of the requirements are very coarse in limestone requirements in the west, where here we require 70-80 percent through the 100 mesh, their requirements are even less. I was just wondering if they used a finer lime, would some of their pH requirements be brought up quicker with less material?

ANSWER—BRUCE REMICK - NATIONAL CRUSHED STONE ASSOCIATION: Yes. The rate of reactivity is inversely proportional to the coarseness of the material. The coaser the material, the slower it will react. The finer it is, of course, the more effective the liming material will be at getting the job done.

QUESTION—HAROLD JONES - The J. E. BAKER COMPANY: Do you expect their requirements to go in that direction?

ANSWER—BRUCE REMICK - NATIONAL CRUSHED STONE ASSOCIATION: The lime loss situation in the United States is really a mixed bag. If you survey the existing lime laws in this country, and they are all over the map, in terms of the breakdown in fineness categories, calcium carbonate equivalents and so on, required for ag lime for commercial sale, it is very difficult to find a standard. Some states do not even have a lime law at all. Illinois is one example. Until the laws can be tightened up, so to speak, and a criteria for quality can be standarized, it is difficult to say which way they will go. There's no uniformity in the law. The law basically governs the type of material that will get into commercial channels. In Iowa, there is increased interest in the finer product, but in Illinois, for example, the industry has presently decided to police itself. They don't want to pass a lime law in Illinois because they feel it just means more regulations, so they want to govern themselves. So, how fast they will move to finer, high quality ag lime will depend on the desire of the industry to do it. It's difficult to predict.

MODERATOR SACKETT: No more questions? Okay, we will get on with our program. (Applause)

MODERATOR SACKETT: Our next Speaker is Patrick E. Peterson, Manager Special Services CF Industries, Inc.

Pat will discuss "Quality Control of N and P Materials in Bulk Blending—Producers Point Of View".

Pat received his B.S. Degree in Chemistry from Marquette University in 1960. From 1960 to 1970 Pat worked as an Analytical Chemist at Argonne National Laboratory.

In 1970 Pat joined CF Industries as Analytical Chemist in the Technical Services Department. In 1971 he was transferred to CF's Bartow Florida Plant where he held positions as R & D Chemist, Supervisor Environmental Monitoring and Control and Enviromental Engineer. In 1980 Pat transferred to CF Industries Corporate Offices as Manager Special Services. Pat we welcome you to start your discussion. (Applause)

Quality Control Of N and P Materials In Bulk Blending Producers Point Of View

P. E. Peterson

CF Industries is a Co-operative based manufacturer and distributor of N & P fertilizer materials. During the calendar year 1980 CF shipped approximately 2.7 million tons of phosphate products DAP and GTSP and 1.5 million tons of granular urea to Member Co-Ops.

With this commitment to providing good quality fertilizer materials CF Industries is well aware of the problems caused by segregation due to unequal size distribution of blending materials. And with this in mind CF early in 1976 instituted a study of our production screening analysis which showed that we were furnishing our Members with urea that averaged about 70% +8 mesh on a Tyler screen and DAP and GTSP averaging about 17% +8 Tyler mesh. Efforts were immediately started to decrease the size of the urea and to increase the DAP and GTSP size. These efforts resulted in product which has the following typical sizing distribution:

Tyler Mesh	Cumulative Percent Urea	TSP & DAP
+6	0	1
+8	32	27
+10	95	78
+14	98	98
+20	99	99.5

Currently our average runs very close to these typical specifications. This is shown by the statistical analysis of shipping samples.

This effort to achieve this balance and to continue it is not without its problems. I would like during the course of this talk to point out some of these difficulties with each individual granular product (I will not consider *prilled* materials in this discourse).

The first product to be considered is grannular urea. CF Industries currently employes the spray coating type drum granulator process. This process can produce an unusually large size granule, as noted by our pre-study size results. To reduce the size distribution a production sizing development program was undertaken at the manufacturing plants.

Contrary to information from the granulation plant designers and various other segments of the fertilizer industry, a simple screen change to affect product size distribution is not enough. The original material size was between a +6 Tyler and +8 Tyler mesh screen. This material did not dry blend well with phosphate and potash fertilizer materials.

To begin the sizing development program one of the urea trains was fitted with screens of #7 Tyler and #9 Tyler to try and reduce the amount of material in the +8 Tyler mesh size in the final product. To shift the overall product size downward. It became quite apparent immediately that this change was not as simple as it first seemed.

Crusher speed and grate size also had to be changed. More oversize to the crushers resulted in an increase in horsepower on the crushers of 15-20- H.P. Wire size of the screens also had to be considered, and thru experimentation a size was established.

This sizing held until 1978 when it was thought that further reduction of the overall product sizing could be accomplished by fitting a #10 Tyler screen in place of the #9. This effort to now screen the product between +7 and +10 caused such an overload on the crushers that the thru-put production rate of the train was reduced by more than 25%. This product was abandoned in favor of total production capability and the original +7 to +9 range reinstalled.

In 1980 further reduction in overall sizing was achieved when the spray boom was redesigned to prevent overlapping of the sprays inside the drum granulator.

Comparison of Typical Urea Size Analysis
Cumulative Percent

Tyler Mesh	Pre 1976	Pre 1980	Present
+6	1	0	0
+8	75	37	30
+10	92	96	92
+14	100	99	99
+20		Trace	Trace

The problem, as noted with urea has been reduce the size distribution to make it more compatible with the smaller phosphate and potash fertilizers. This has been accomplished to a great degree by the above mentioned changes and recent results out of TVA on pan granulated urea and the new falling-curtain process have shown even better results.

Now, we will consider the problems encountered with granular phosphate fertilizer size distributions.

Simplified DAP Flow Sheet That Is
Representative of DAP Plants
(See page 117)

Variations in the DAP size distributions arise at two points in the production unit, at granulation and at screening. To better understand these problems I would like to review a simplified DAP flowsheet that is representative of our DAP plants.

Starting at the top, ammonia is added to phosphoric acid in the reactor tank. Roughly two-thirds to three-fourths of the ammonia is added here. The slurry from the reactor is pumped to the ammoniator-granulator and sprayed into a rolling bed of recycled dry DAP material. The remainder of the ammonia is added by sparging under the rolling bed. The discharge from the granulator is then dryed and screened. The screens split the material into three streams, oversize, undersize and product size. The (crushed) oversize and undersize are recycled to the granulator. Some product is recycled to the granulator for granulation control with the remainder being cooled and sent to storage.

The size distribution of DAP product depends on two factors:

1. Size distribution of the screen feed.
2. Efficiency of the screening operation.

The size of the screen feed is controlled by the granulator-ammoniator operation. The screening efficiency is determined by:

1. Screen loading.
2. Mechanical operation of the screens.
3. Operator attention.

Granulation of DAP is affected by non-controllable factors that are esssentially mechanical such as:

1. Type of granulator.
2. Size and speed of the granulator.
3. Point of addition of the granulator feed materials.

And by controllable factors which are essentially chemical in nature such as:

1. Amount of water in feed.
2. Amount of recycle.
3. Amount of ammonia added.
4. Temperature in the granulator.

Basically, the size of the material exiting the granulator is dependent on the amount of liquid phase in the granulator. Inability to control the amount of water fed and the amount of recycle is the most frequent cause of granulation problems. The water input will change with a change in feed acid water content. Recycle rate will change with any change in size distribution from the granulator or with any problem in screening. The only recycle control is the amount of product size being recycled.

This leads to an important fact of DAP production; that the operation of both the granulator screens are equally important since each affects the operation of the other.

The only stable DAP production operation is the production of fines. The reason for this is that fines are produced when the liquid phase in the granulator is low. This condition is caused by an increase in the recycle rate and this increase is caused by high fines or oversize production, since both return as recycle with no surge to control the returned rate.

Both of the conditions mentioned above will also cause a smaller than desired size distribution from the screens. For example, overloading of the oversize screen will carry some of the larger product size material with the oversize. And overloading of the product screens with fines will cause fines to report to the product.

Maintaining a uniform distribution of the feed to each screen is difficult. The feed is first split into two parts with each part feeding a pair of screens. This is the most difficult split to balance. Each of the two splits is then divided to the screen pairs.

In addition to dividing the feed evenly to each screen the feed must be distributed evenly across the screen. The screening operation itself can affect not only the size distribution of the product but granulation by changing the amount of recycle. Even with adequate screen capacity the screening operation must be closely monitored to insure:

1. That the total feed is evenly divided to each screen.
2. The feed to a given screen is uniformly distributed across each screen.
3. The screen surfaces are kept clean and not allowed to blind.

4. The vibrating mechanism is operating properly.

The first two items have the effect of overloading the screen or screens. Item 3 has the effect of installing screens with smaller openings. All the first three items will cause the larger product size to recycle with the oversize. Item 4 will allow much of the fines to go to storage with the product. The type of screens at CF's plants will allow a fairly good separation on the oversize screens without good vibration when the size distribution of the feed is good. Item 4 will also reduce recycle (send fines with product) and will decrease granulation production. Maintaining good screen vibration can be a problem. There are some 20 vibrators in each DAP plant that need frequent checking for proper operation. This adjustment requires an electrician and a mechanic because there is a single power supply for all vibrators on one screen. The mechanic adjusts the vibrator with guidance from the electrician to balance the power used by each vibrator and keep it within the load rating of the power supply.

Nitrogen grade problems due to lower rock quality may lead to poor granulation. For example a different amount of moisture for good granulation may be needed than for good ammonia reaction. Also, extra ammonia may be added in the granulation to improve the percent nitrogen. This will cool the granulation bed and in effect dry it out causing the production of fines. Trying to keep the moisture content high will lead to screen build-up and blending.

The production of GTSP has essentially the same problem as that of DAP with the exception of nitrogen grade problems.

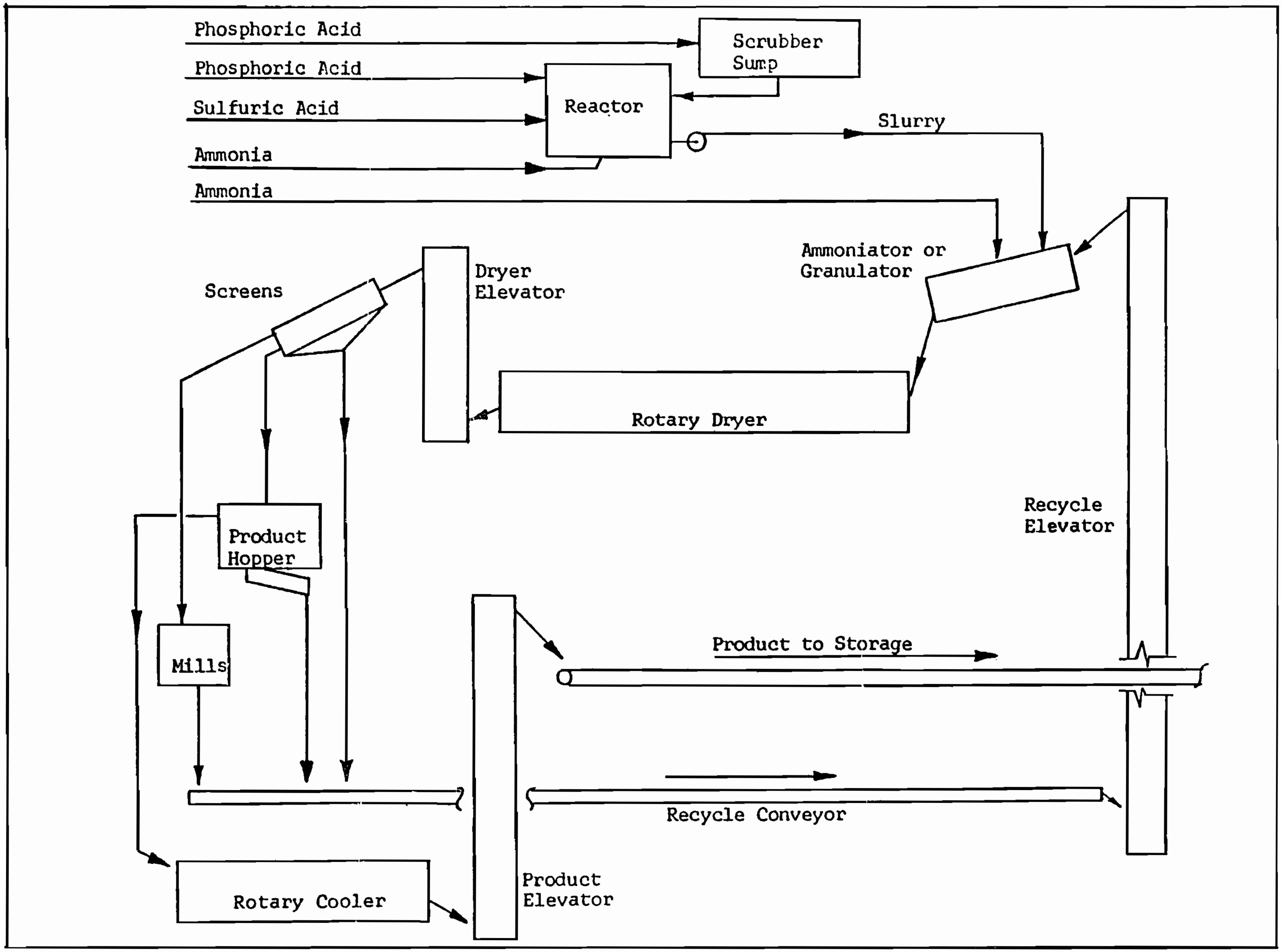
This first portion of my talk has covered the production problems faced in granulating fertilizer materials. The second problem area, one which sometimes is not given as much consideration as the first, is shipping. This is caused by the natural segregation which occurs in storage piles and other factors.

You may recall that in the beginning of this paper I stated that CF Industries shipped approximately 4.2 million tons of granular fertilizer. Considering that the bulk of this material is shipped by 100 ton hopper car, this would equate to tens of thousands separate units.

To insure that each of these units contains a representative size distribution requires careful material handling. Two of the problems during storage is the formation of lumps, possibly due to moisture, humidity, pressure, temperature, etc., and fines resulting from product breakdown or carryover from production. To combat this problem CF at its plants and warehouses has installed Rotex double deck screens which remove oversize (lumps) and fines. With proper maintenance and operation of the screens these problems can usually be completely eliminated.

The greatest problem is the segregation in the storage pile. CF has installed automatic reclaimers at its Florida phosphate plants which in theory reclaim the product uniformly. However, the basic loading tool in the fertilizer industry is the payloader. The material size distribution in each individual loading will depend on the way the operator "works" the storage pile. To be honest this is a problem area which CF has worked to minimize problems but some still exist. These may be due to high inventories. Storage configuration, or operation performance.

In summary, CF has succeeded in increasing the DAP and GTSP size distribution while decreasing that of urea to give more compatibility for bulk blending. Some further size reduction for urea may be possible, but DAP sizing has reached an optimum level based on current production methods and levels. Thank you all. (Applause)


Phosphoric Acid
Scrubber Sump
Phosphoric Acid
Reactor
Sulfuric Acid
Slurry
Ammonia
Ammonia
Ammoniator or Granulator
Screens
Dryer Elevator
Rotary Dryer
Recycle Elevator
Product Hopper
Mills
Product to Storage
Recycle Conveyor
Rotary Cooler
Product Elevator

MODERATOR SACKETT: Thank you Pat. Your discussion was very interesting and informative. (Applause)

We will have questions for our audience when we conclude our two remaining discussions.

Our next Speaker is Leo Bewer, Technical Services Manager for the Potash Corporation of Saskatchewan Sales Limited. Leo serves as liason between the Five PCS Mines and has the responsibility of Quality Control Surveillance for PCS Sales. He has "hands on" experience with every facet of the potash refining process, including Direct Digital Control Computer Control Processing. From 1972, until he joined PCS Sales in 1980, he was employed by Cominco Potash. He attended the University of Saskatchewan, graduating with a Bachelor of Science Degree in 1978. Leo will discuss Quality Control - Particle Size - Bulk Blending - Producers Point of View. Leo please. (Applause)

Quality Control - Particle Size of Potash Materials In Bulk Blending Producers Point of View

Leo J. Bewer

The major difficulty in the bulk blending of fertilizers is segregation after mixing. The physical properties that cause segregation are well known and have been publicized and discussed at length. We are all aware that particles which are variable in size will be affected by vibrations, rolling action, and ballistic action which results in particle segregation causing non-uniform fertilizer blends.

All right, we agree that if all particles in all the raw materials for blending were of equal size, we would probably eliminate the problem of particle segregation. Well, PCS has five mines and I know how difficult it is for these operations to produce a uniform particle size, let alone an entire fertilizer industry.

So what is the solution? Well, before you can work on the solution you have to identify the problem. We must ask ourselves:

1. How far apart are we?
2. What do we have to do to get together?

First, how far apart *are* we? It was reported in the minutes of the TFI's Resource Management Committee meeting held on August 5, 1981 in Scottsdale, Arizona, that the TFI Particle Size Task Group attempted to determine the particle size range of fertilizer distributed in the industry by asking for copies of product data sheets covering, urea, DAP, Granular potash, ammonium nitrate and Coarse potash from members of the Product Quality Subcommittee. About all that could be determined was that all products were essentially —6 +14 Tyler Mesh, except Coarse potash, which was —6 +20 Tyler Mesh. Only the potash manufacturers use standard Tyler sieves exclusively to describe the particle size distribution of their products. Data sheets for N and P products used both U.S. and Tyler Screens and there was no consistent series of sieves used.

Well, what do we have to do to get together? The Canadian Fertilizer Institute's (CFI) Engineering and Technical Committee's working group on quality control examined several concepts for use as a voluntary particle size guideline for blending products. They settled on a concept they call the "Size Guide Number". The Size Guide Number is obtained by plotting a screen analysis for each product on a cumulative logarithmic Tyler standard screen scale. A line is drawn from the 50 percent cumulative weight point on the vertical axis to a point where this line intersects the screen curve. At the point of intersection, a vertical line is dropped to the screen opening scale. This point of intersection is read in millimetres. The millimetre reading is taken to the second decimal place, rounded to the nearest unit of five and multiplied by 100. (Slide One)

Using the CFI's proposed method for determining the Guide Number, one can calculate the Size Guide Number for ammonium nitrate, urea, ammonium phosphate, triple superphosphate, and potassium chloride. The following is a Size Guide Number comparison of these products. (Slide Two)

Ammonium Nitrate	— commercial Prills	- 180
	TVA Granular	- 210
Urea	— Commercial Prills	- 180
	TVA Granular	- 210
Ammonium Phosphate	— Commercial Prills	- 270
	TVA	- 240
	Commercial	- 190
Triple Superphosphate	— Commercial Granular	- 200
	TVA Granular	- 200
Potassium Chloride (PCS Mining)	— Granular	- 250
	Coarse	- 170

Given these products, what would be the proper selection of products that would be compatible for blending purposes. May I suggest a Size Guide Number between 180 and 200.

PCS Mining has already started to work toward the production of a common screen size among its five divisions. Recently, one of the five PCS mines has modified and purchased new equipment in order to produce a new Coarse screen size that can, in time, be employed by the other four mines.

The new screen size was selected for better size compatibility with other fertilizers and will assist in obtaining better blends. Once the singular Size Guide Number can be achieved for the one product, a similar course of action will be taken until a uniform Size Guide Number can be produced at each of the mines for all products.

Many factors were considered during the proposal of the Size Guide Number system.

1. Unit trains are loaded continuously to maintain an adequate inventory in the five K Centers located in Iowa and Illinois. The particles must therefore be of sufficient screen size to compensate for the degradation that accompanies additional handling in the warehouses.

2. Environmental agencies in both Canada and the United States maintain a close watch to ensure pollution standards are not violated by dust emissions.

3. Fertilizer Regulatory bodies in Canada and the United States sample and analyze regularly to ensure plant nutrients comply with government regulations. There are severe penalties for those who fail to comply, ranging from two to ten times the retail value of the measured deficiencies.

My suggestion for a Size Guide Number of 180 and 200 is not the ultimate solution. There are products that do not fall in the 180 to 200 range. Commercial ammonium phosphate and granular potassium chloride at 270 and 250 for example, are quite compatible.

However, blenders are experiencing difficulties in obtaining a uniform blend. With a Size Guide Number system and a good educational program, the Fertilizer Industry will have taken a positive step to improve the quality of blends.

There is another subject that deserves brief comment. The outside storage of potash.

Potash is both hygroscopic and soluble and is therefore susceptible to weathering.

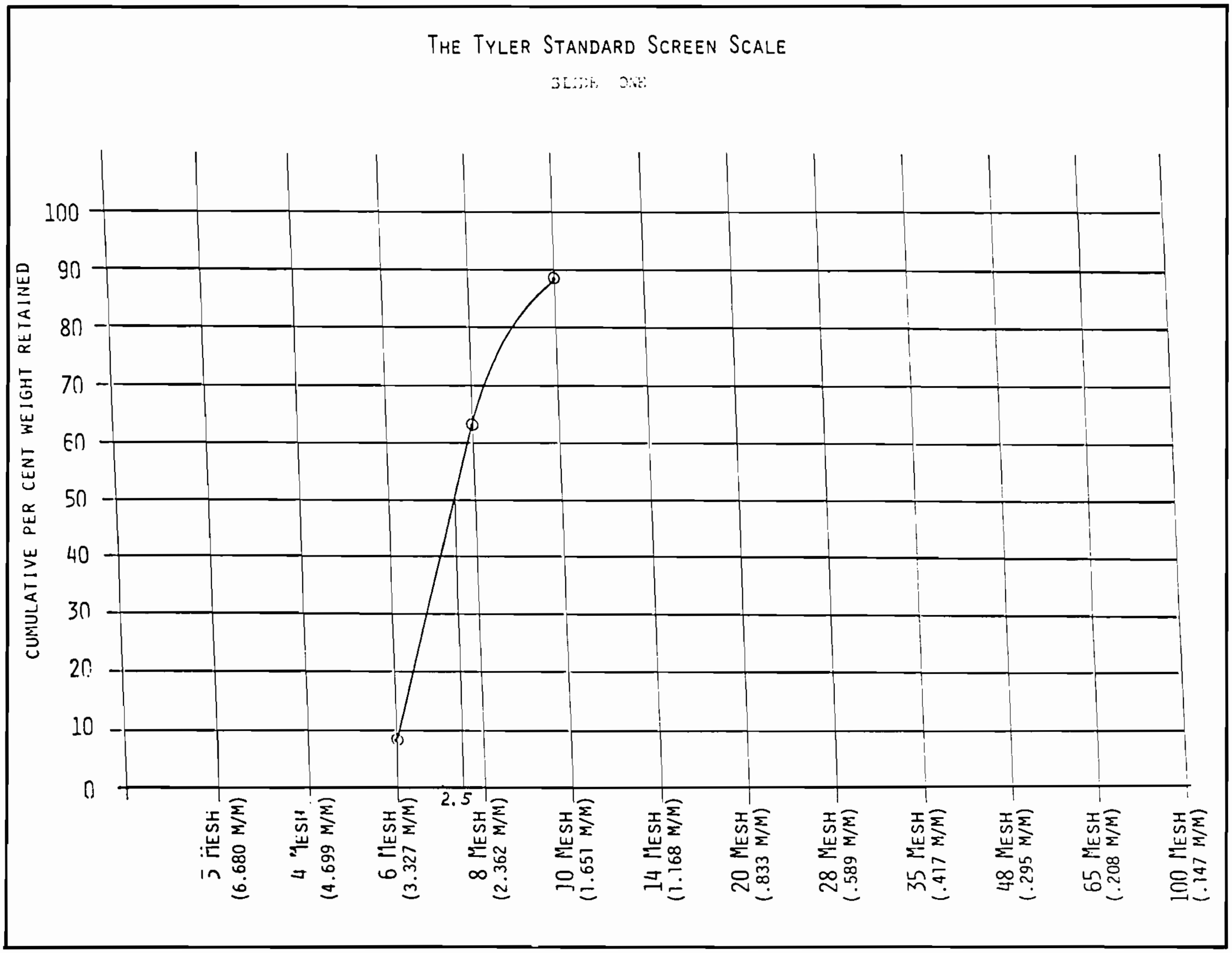
I know of cases where potash has been successfully stored outside without covering. But the weather was ideal, i.e. no exposure to moisture or high humidity.

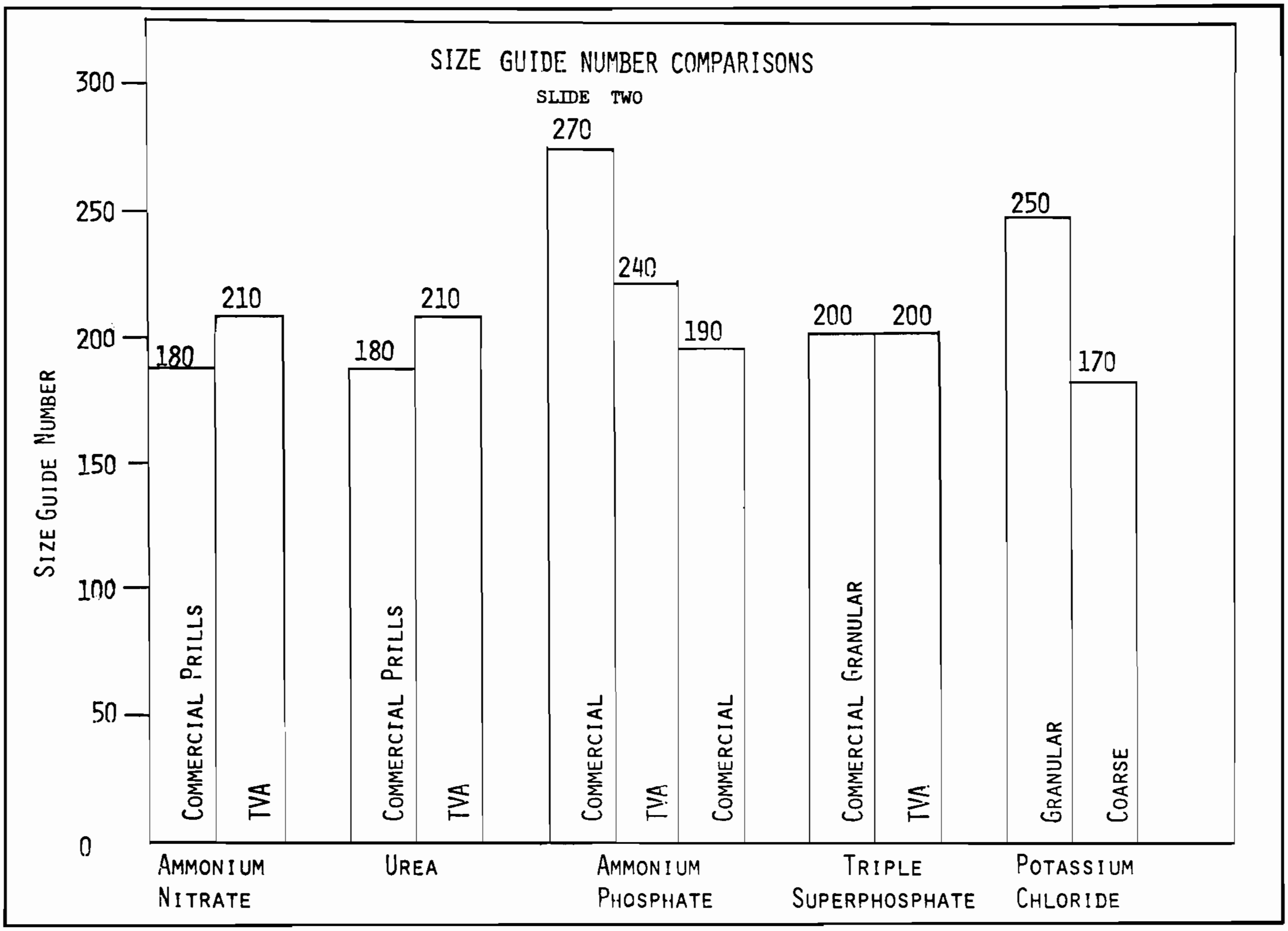
How often do we have these ideal weather conditions? Certainly not 100 percent of the time.

There are times when it may rain heavily during unloading or after unloading such that the product pile may not properly dry out prior to deep moisture penetration. If this occurs, the pile may ultimately dry out but the product could be severely caked and degradated.

It need not rain for the product to absorb moisture. Potash will absorb moisture if the relative humidity exceeds 85 percent.

Therefore, the covering of potash when stored outside is strongly recommended.





MODERATOR SACKETT: Thank you Leo, for your very interesting and concise report. (Applause)

MODERATOR SACKETT: Our next Speaker, will be Jean L. Cheval, United Cooperative of Ontario, Canada. He was born and raised on a farm in Northern France and receives his University Education in Lille, France. He is a member of the Institute of Management Sciences and has been associated with the Fertilizer Industry, in Canada and the United States, for the last 25 years. He has been Fertilizer Operations Manager of United Cooperatives of Ontario since 1975. Jean Cheval will speak on Quality Control in Bulk Blending from the Blenders Point of View. Jean Cheval please. (Applause)

Quality Control In Bulk Blending Blender's Point Of View

J. L. Cheval

I welcome the opportunity to present to you the blender's point of view on the problem of quality control.

To put things in persepective, let me tell you something about UCO and the Ontario blending industry.

UCO has paid great attention to quality control ever since bulk blending operations started on a large scale in the late 60's. This attention has resulted in a consistantly better than average performance. The seventy or so bulk blenders and bagging plants of the Co-op system are closely monitored by the inspectors of the Plant Products Branch of Agriculture Canada, and we process in our own central lab hundreds of fertilizer samples every year. Inbound materials are tested not only for our chemical analysis but also for particle size. Over the years, UCO has developed knowledge of products and product handling which is communicated to blender operators of the Co-op System at blender schools. For instance, weighing materials in the most favourable order and mixing for the optimum amount of time are two of the topics covered in blender schools. These schools are extremely popular with our Cooperatives and are held every year.

The Fertilizer Institute of Ontario has, for the last several years, organized blender workshops, which have been very successful. Success not only in attendance but also in improvement of quality control. The TFIO quality check list for bulk blenders was originally designed by Mr. R. M. King, Chairman of the Quality Control Committee of TFIO.

In Canada, fertilizers are monitored at the Federal level. As I indicated before, samples are taken, at the blenders, by inspectors of the Plant Products Branch of Agriculture Canada. Results are sent several times a year to each company. Area and national averages are also released to Industry organizations.

Tolerance levels for Nitrogen, P_2O_5 and K_2O in mixes are extremely tight. For instance 17.9% Nitrogen in a 19-19-19 would be reported deficient even if P_2O_5 and K_2O were above 19%. The combined nutrient level (CNL) must also be equal to or higher than 98%, or it will be reported deficient. Tolerance levels for fertilizer mixtures in Canada are shown in Table 1. However, I will point out that fertilizer manufacturers, on the average, overformulate. The national average for CNL has always been over 100 in at least the last twelve years and always over 102 in the last six years. As one would expect, formulation overage, or plant food give-away, affects the rate of deficiencies. This relationship is illustrated in Figure 3, plotted on semi-log paper, the dotted line at the top represents the average of twelve years of data for mixes in Canada. The dotted line at the bottom redpresents the average of six experiments at two UCO bagging plants. At these plants, employees were unaware of the tests. There was no equipment change, no procedure change. The only change was in material supply. The Potash was selected to match the other materials used. There is no doubt in my mind that these results can be duplicated in many locations. In fact, I would not be surprised to hear that some of you have been doing even better for years. No question about it, particle size has been recognized as the major problem for a long time. Two decades ago Mr. George Hoffmeister of TVA explained the importance of particle size matching. His message has been repeated many times. Only two years ago Mr. Hubert Balay of TVA addressed the Round Table on this topic.

Many blenders take the position that the particle size distribution of Diammonium Phosphate should be the norm for other materials. After all DAP has the largest volume in blends. This position has been reinforced by the introduction of granular Urea and progress made in compaction of granular Potash.

Granular Urea is less hygroscopic than prilled Urea. It seems to be harder than prilled Urea and therefore generates less dust than prilled Urea in certain handling situations. Urea, of course, whether granular or prilled, has the advantage over Ammonium Nitrate of safety and it does not crack when going through some temperature changes, as Ammonium Nitrate does.

The compacted Potash we use resists breakdown better than some crystalline Potash. It also mixes very well with our other materials.

To compare particle size characteristics we, in UCO, plot the information on a poor man's version of the Tyler standard screen scale. The reason for this type of graph is simple: Given the same data, two different people will, on Tyler paper, plot curves of different shapes. We simply use a straight edge and join the points. The position of the +8, +10 and +14 vertical lines depends on the characteristics of the so-called average material. The idea is to have a straight line from 2% on +6 to 97% on +14 for the average material, and the dotted lines define the acceptable deviations.

When the materials are well matched as shown on Figure 6, the probability of deficiency drops significantly, and formulation overage can be reduced.

But consider the case of my poor cousin Fred. Fred is a blender operator in Ontario. A well-trained expert in his field, although not currently employed in the Coop system. Fred has tried everything he could do in his plant to improve reliability. He even has recently installed a digital read-out to replace the dial on his batching scale. Fred takes great care to handle materials properly to avoid contamination and to minimize segregation in storage. Fred formulates precisely, including a 2% overage (2% is all that hsi boss, a former accountant, will let him get away with). Fred weighs the materials accurately. He has set the timer for the mixer to the optimum for his system: exactly 20 revolutions, and yet the inspector reported deficiency after deficiency. What can Fred do? Fortunately, he had sampled the materials several times last spring. Nothing wrong with chemical analysis he told me. But for the screen tests, he did not know what to make of them.

The way I see it, his materials are what I call a "divorce" case. They will separate promptly the instant the perfectly mixed blend drops into the farmer's bulk spreader, so, in due time Fred went to his boss, with a copy of figures in one hand, and a symbolic hat in the other. his request was simple. Could he please get some, say a car or two, of that new blender-grade Potash, or even some granular to try and reduce the rate of deficiencies? The answer was short and to the point— "How much?" "Well, said Fred, I think I will reduce cost by about one half percent while at the same time improving quality control". and he did. The morale, gentlemen, is "Quality Costs Less."

Some will ask "How bad is bad?" or, can you, with one single number, tell us essentially as much as you do with this graph?"

The Canadian Fertilizer Institute has recently approved such a number. We call it "size guide number", and was initially proposed by Mr. J. Sinclair. It simply is the median of all particle sizes. For practical purposes it is expressed in millimeters times one hundred, with the last digit rounded to either five or zero. As you can see in Figure 8, our 35% on +8 and 85% on +10 will correspond to a size guide number of 220.

The size guide number is a step in the right direction. I think it will help blenders to select more compatible materials. It certainly will help to adjust formulation overages: the larger the gap between size guide numbers of the various materials, the higher the overage required for a desired level of quality control.

At the same time I suspect that experience will soon indicate that standard deviation of the size guide number is also an important factor. I certainly hope that more work will be done, by TVA, by the producers and the blenders on the relationship between variability in size guide numbers and rate of deficiencies.

By now it has become clear to most of you that I strongly believe in the power of the blender operator to improve quality. Faced with an excessive number of deficiencies the operator will try the "quick" fix first. That is — increase overages. And I have shown the limits of that approach. He may try next change in procedures, change in equipment, change in people. It is far more effective (and generally more economical) to do something about particle size matching. With the continued help from producers, I am convinced that quality control can be improved significantly over a relatively short time.

TABLE 1
TOLERANCE LEVELS IN CANADA

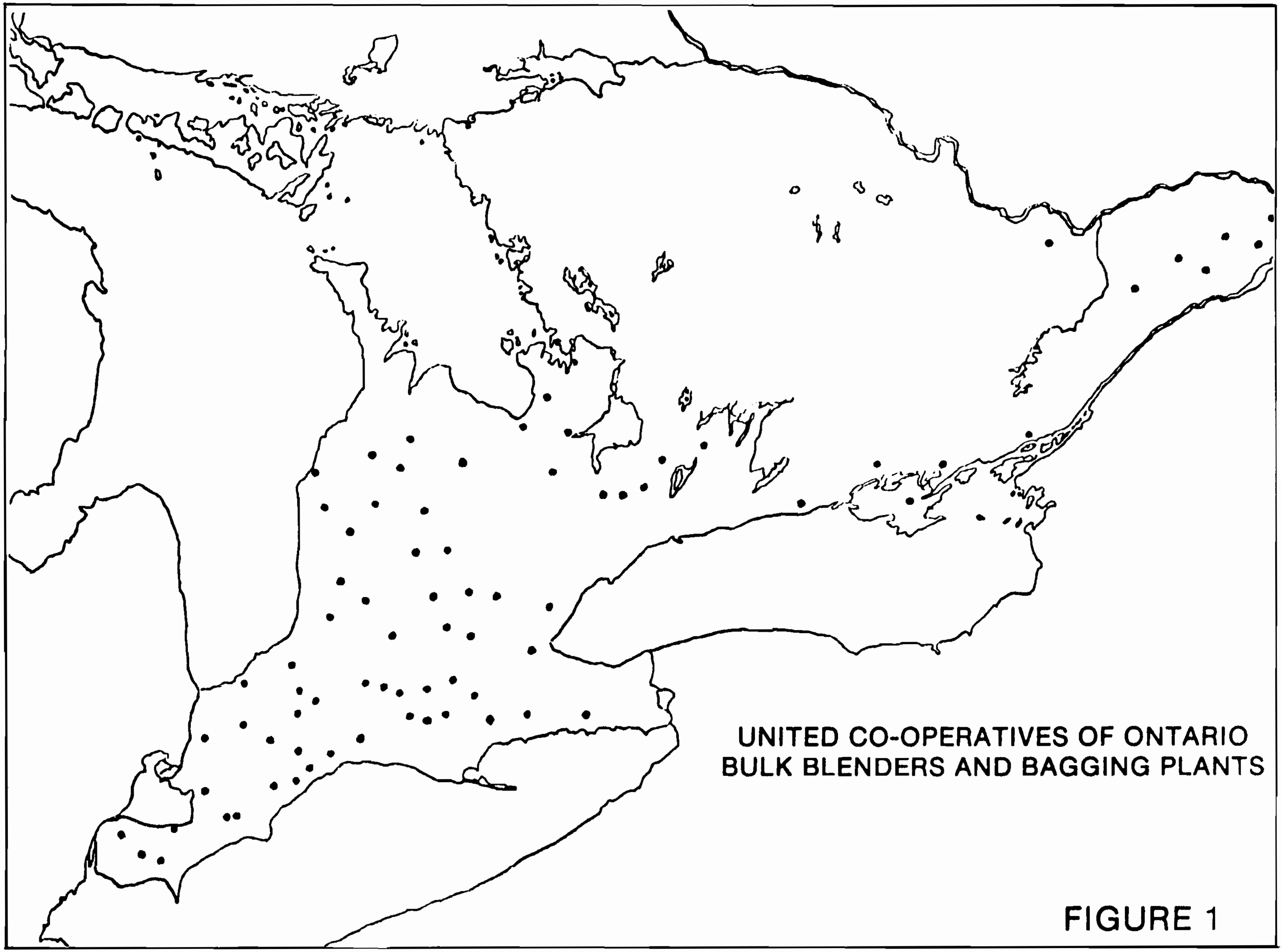
NUTRIENT GUARANTEE	FOUND VALUE MUST BE AT LEAST	
	N	P_2O_5 or K_2O
3 or less	Guarantee—0.3	Guarantee—0.3
4	3.3	3.3
5	4.2	4.2
6	5.1	5.1
7	6.0	6.0
8	7.0	6.9
9	8.0	7.8
10	9.0	8.7
11	10.0	9.6
12	11.0	10.5
13	12.0	11.4
14	13.0	12.3
15	14.0	13.2
16	15.0	14.1
17	16.0	15.0
18	17.0	16.0
19	18.0	17.0
20 or more	Guarantee—1.0	Guarantee—2.0

COMBINED NUTRIENT LEVEL

$$\frac{2.5\ N_A + 2\ P_2O_{5A} + K_2O_A}{2.5\ N_G + 2\ P_2O_{5G} + K_2O_G} \geqslant .98$$

WHERE THE SUBSCRIPT A STANDS FOR "ACTUAL"

AND THE SUBSCRIPT B STANDS FOR "GUARANTEED"



UNITED CO-OPERATIVES OF ONTARIO
BULK BLENDERS AND BAGGING PLANTS

FIGURE 1

TFIO QUALITY CHECK LIST FOR BULK BLENDERS

BEFORE THE BATCH:

1. ARE THE PILES LEVEL AND FREE FROM CONTAMINATION?
2. ARE THE MATERIALS COMPATIBLE?
3. IS THE EQUIPMENT CLEAN AND EMPTY?
4. HAVE YOU CHECKED THE SCALE?
5. DOES THE SCALE READ 0?

BATCHING:

1. DID YOU ADD THE MATERIALS IN CORRECT ORDER?
2. DID YOU WEIGH THE MATERIALS ACCURATELY?
3. DID YOU MIX FOR THE CORRECT LENGTH OF TIME?
4. DID YOU KEEP A WRITTEN RECORD OF BATCH WEIGHTS?

AFTER THE BATCH:

1. IS THE EQUIPMENT CLEAN AND EMPTY?
2. DOES THE SHIPPING FORM SHOW THE REQUIRED INFORMATION:
    - NAME AND ADDRESS OF MANUFACTURER?
    - NAME AND ADDRESS OF CUSTOMER?
    - GUARANTEED ANALYSIS?
    - TOTAL BATCH WEIGHT?
    - SIGNATURE OF CUSTOMER?
3. DID YOU CLEAN UP AND PLACE ALL WASTE IN WASTE BARREL?

**The
Fertilizer
Institute
of
Ontario
Inc.**

FIGURE 2

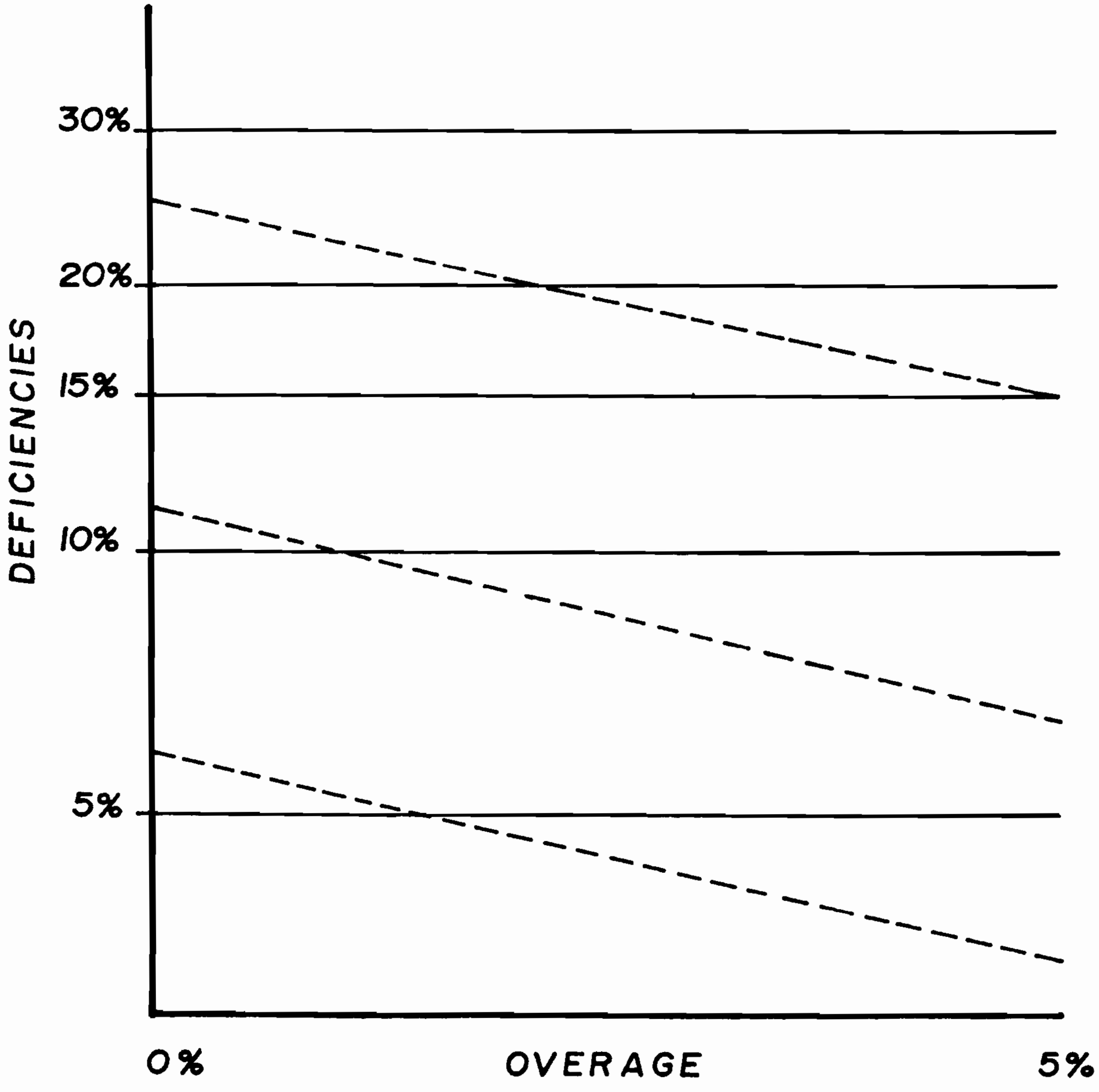
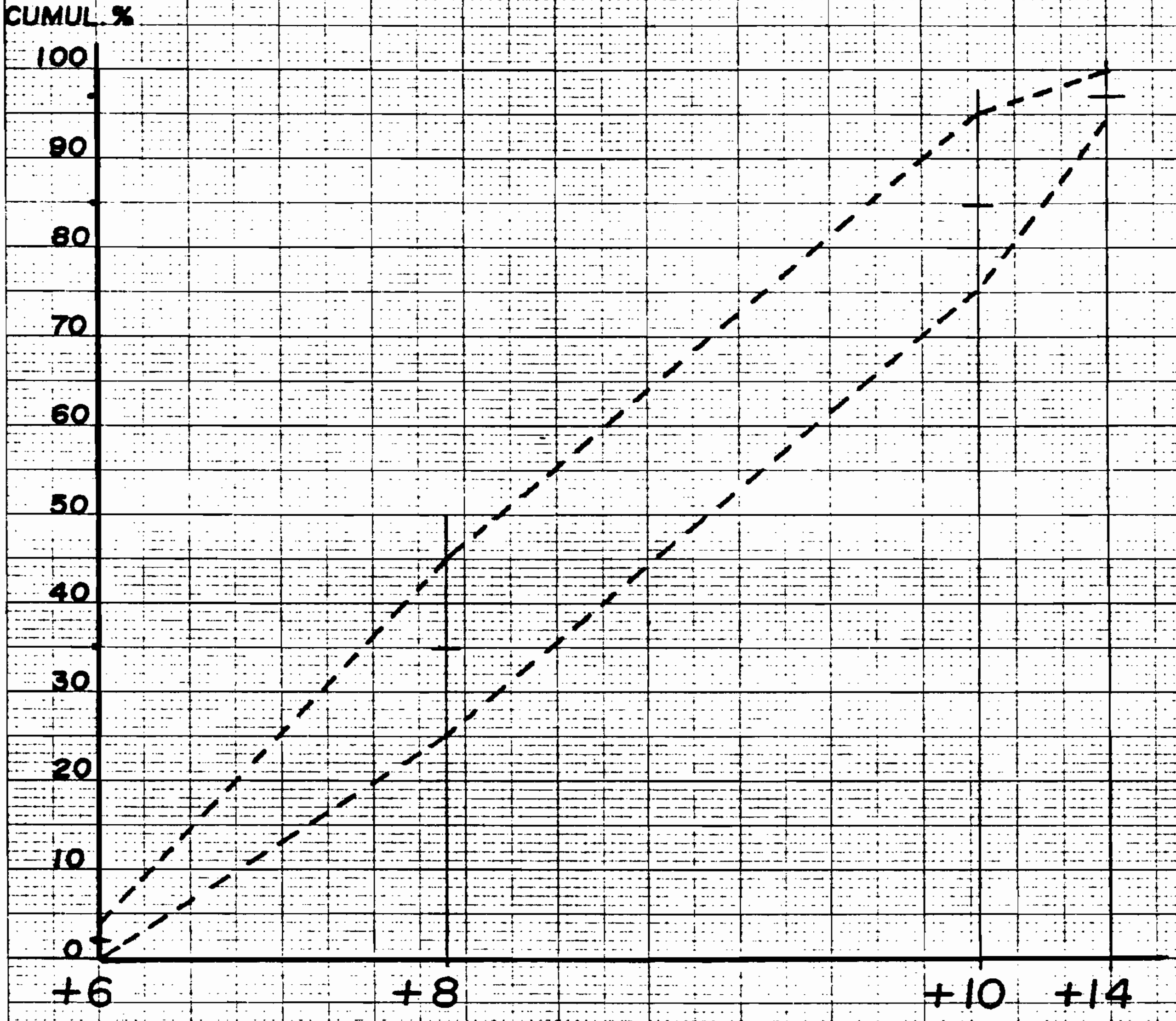


FIGURE 3



PARTICLE SIZE EVALUATION

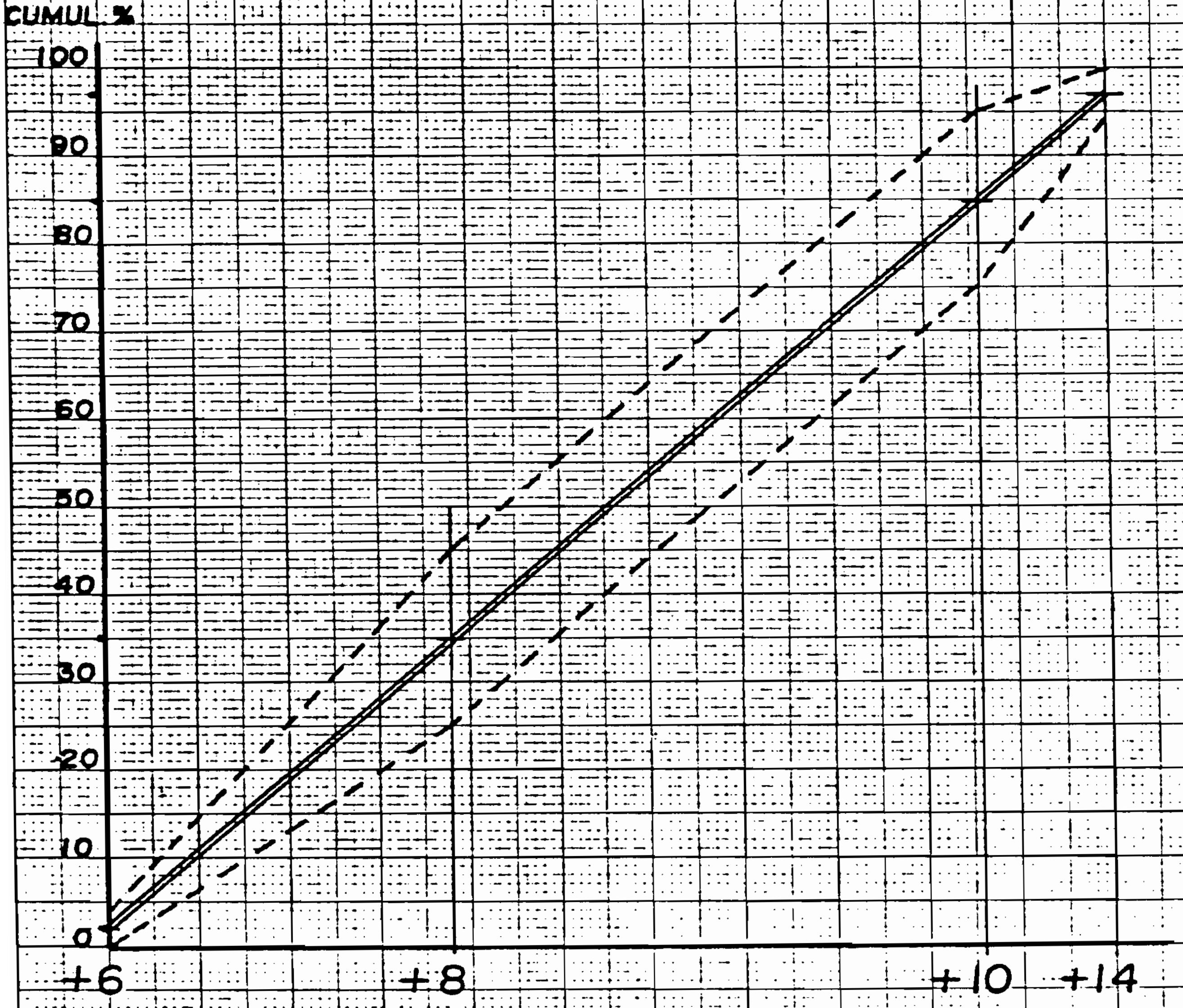
TYLER MESH

LOCATION: ______________________

PRODUCT: ______________________

DATE: ________________

FIGURE 4



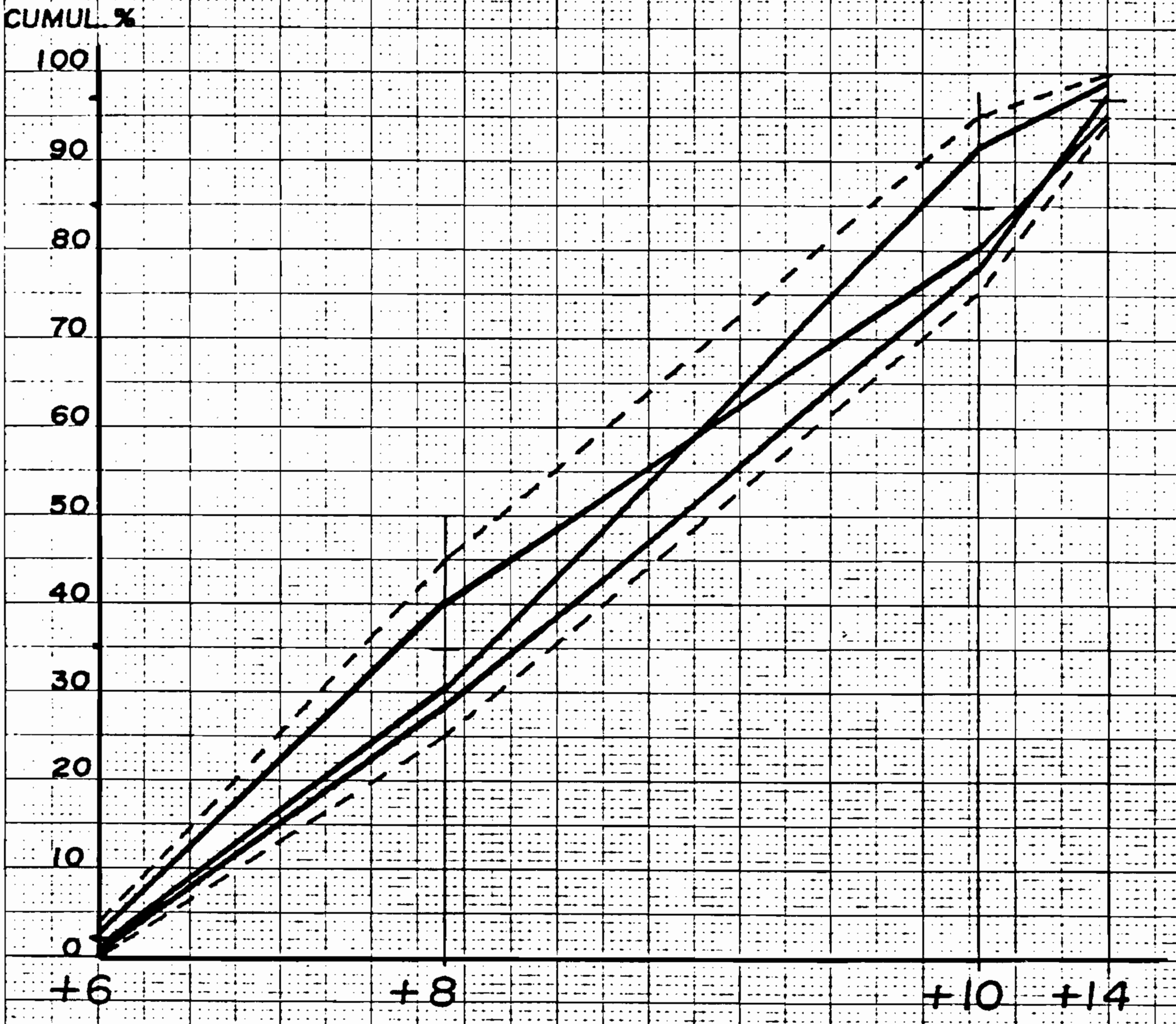
PARTICLE SIZE EVALUATION
TYLER MESH

LOCATION: ______

PRODUCT PERFECTLY MATCHED MATERIALS

DATE ______

FIGURE 5



PARTICLE SIZE EVALUATION

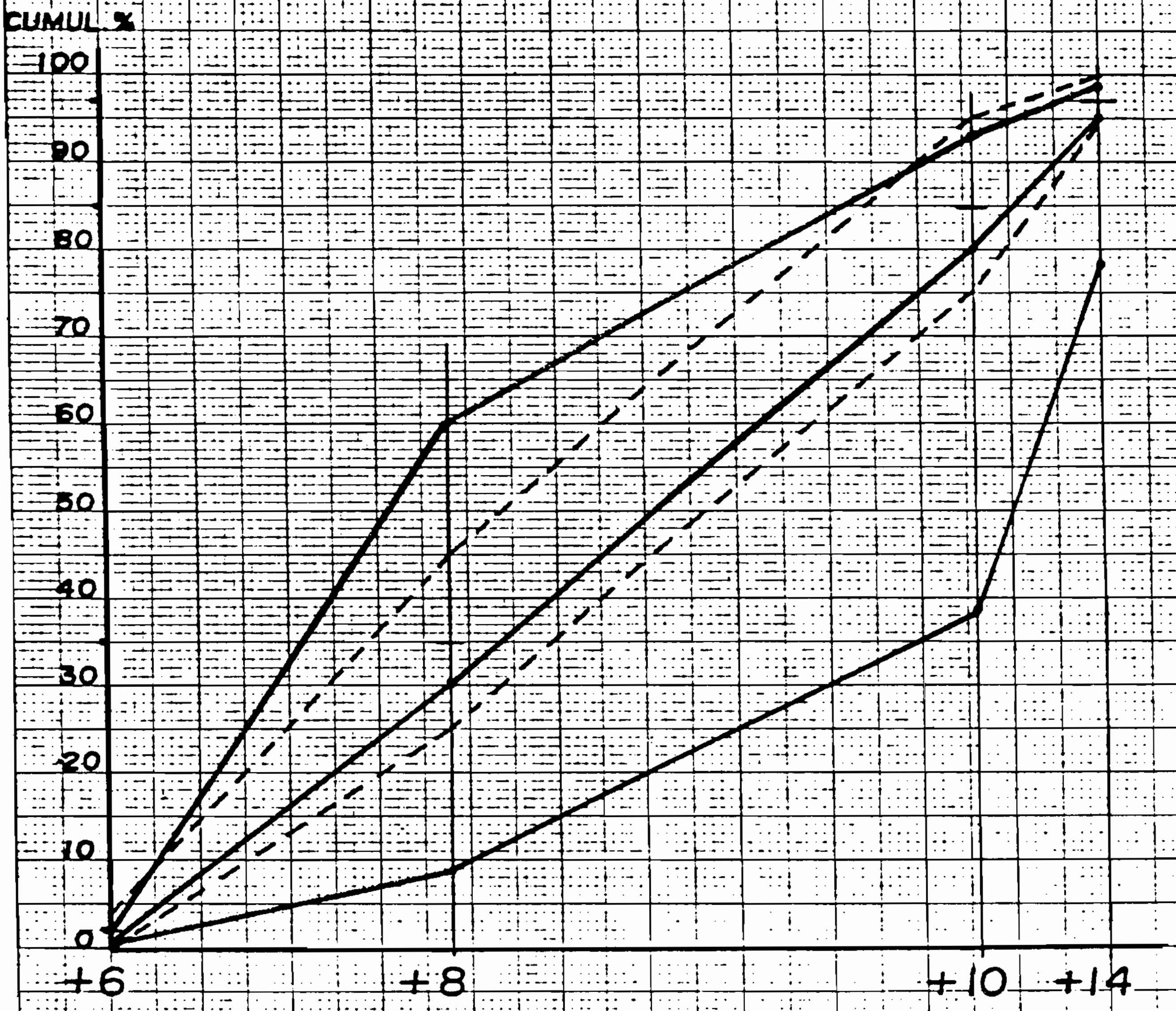
TYLER MESH

LOCATION: ____________________

PRODUCT: MATCHED MATERIALS

DATE: ____________________

FIGURE 6



PARTICLE SIZE EVALUATION

TYLER MESH

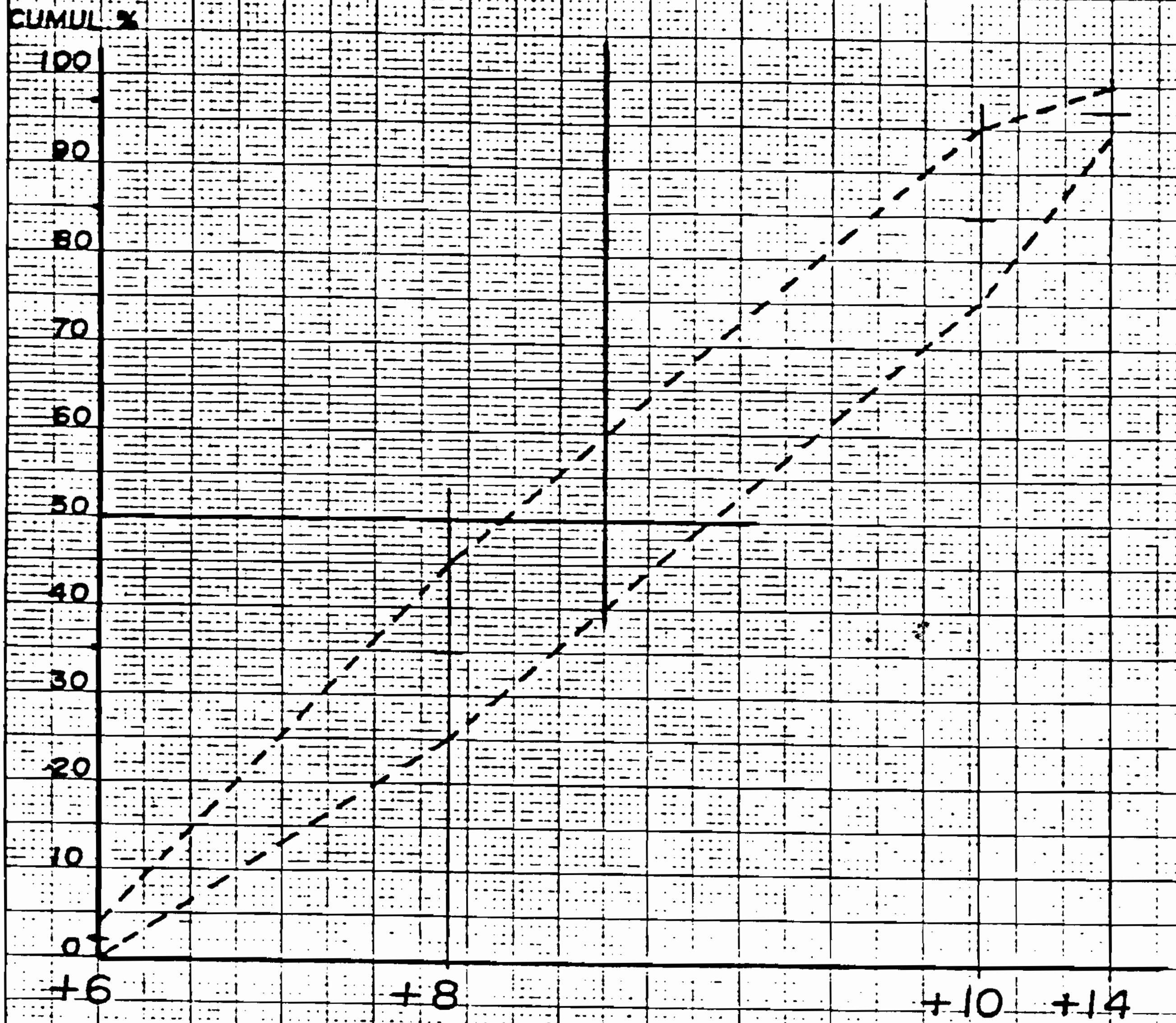
LOCATION: ____________________

PRODUCT: IMPROPERLY MATCHED MATERIALS

DATE: ____________________

FIGURE 7

SIZE GUIDE NUMBER
220



PARTICLE SIZE EVALUATION

TYLER MESH

LOCATION: ______________________________

PRODUCT: ______________________________

DATE: ______________________

FIGURE 8

MODERATOR SACKETT: Thank you Jean for a very informative discussion. (Applause)

Our last three Speakers, for this Morning Session, have moved right along and we are right on schedule. We have time for questions from the floor. I will appreciate Messrs: Peterson, Bewer and Cheval come to our platform. Many thanks for each of your most interesting and valuable discussions. (Applause)

QUESTION—TRAVIS HIGNETT - IFDC: I have three questions: (One) How did DAP get to be the size standard? (Two) How did the size of DAP get to be the size that it is? (Three) Is it the best size?

The reason for these questions: I have been in Europe several times and noted bulk blending and the market for bulk blending in Europe is growing. This Spring I was in Ireland and noted they have gone over entirely to bulk blending. Their standard is 2 to 4 millimeters, and all of their materials conform to that standard. Visually they look quite a bit larger than our materials. they get DAP and TSP from Tunisia and granular Urea from Holland. Granular Calcium Ammonium Nitrate is blended and packaged in Ireland. They get their Potash from Germany. That size standard is pretty much uniform throughout the European Common Market.. It occurred to me that there might be some advantage to this larger size and there might be less problems with moisture absorbtion and possibly caking. Eventually, I suppose, there may be a growing market in Europe for materials for bulk blending and possibly there will be some imports from Europe into the United States. Wouldn't it be worthwhile to consider some kind of compromise size?

MODERATOR SACKETT: That was a long question!

ANSWER—PATRICK E. PETERSON - CFI: I am going to give a short answer! The first question: How DAP got to be the standard size? I will put "standard" in quotation marks. It has to be the standard because that is as big as we can make it right now to ship that many tons. So, as Howard Cosell says, "I am telling it like it is". I am not going to saddle our company with some "pie in the sky" number. That is the reason. The second question is: How did DAP get to be the size standard? I will say it is thru the hard work of our Engineering and Production Departments when we realize and looked at the first study and found out that we were down around 17%. I am a Plant man and a Home Office man and have been in both places. I realize that I am not an expert on granulation, but I am smart enough to realize that it is part "art and part science". Well, we have combined the Art and Science and we came up with a product based on our method of production. I am not saying that down the road there will not be improvements, at least for DAP. Our amount of shipping material, a million and a half tons, out of one plant, is what we can supply our members on an equal size distribution. We feel that it is compatible now, of course, with our Urea which we have brought down in size. I am not familiar with the European Market, therefore, I cannot really comment on the rest of your question.

QUESTION—PATRICK E. PETERSON - CFS: Travis, what type of tonnage are you talking about? You were saying something about Ireland. What is the amount of tonnage that they move?

ANSWER—TRAVIS P. HIGNETT - IFDC: I am quite not sure. It is a small country.

PATRICK E. PETERSON - CFI: A million and one half tons of DAP would probably cover it up.

TRAVIS P. HIGNETT - IFDC: They do not use very much DAP because most of their blends are high nitrogen.

PATRICK E. PETERSON - CFI: If our production needs were less, of course the size could be increased through selective screening.

TRAVIS P. HIGNETT - IFDC: That means that the bulk of their material is nitrogen material and DAP has to confirm with it.

PATRICK E. PETERSON—CFS: They are moving the DAP towards the nitrogen material.

TRAVIS P. HIGNETT—IFDC: I should say, the whole of Ireland, less than one million tons of material, however, the whole of Western Europe is locked in on that two to four millimeter particle size.

PATRICK E. PETERSON—CFS: I am afraid I cannot address that subject.

QUESTION: S. J. COUSINS - ADELAIDE & WALLAROO FERTILIZER, AUSTRALIA: Travis Hignett's comments were fairly relevent to our situation. We are unable to import a satisfactory potash material for blending with our size of N and P. We developed a fairly simple granulation process for N and P or Potash, and we took the route of granulation rather than compaction. I would like to address my question to Leo Bewer and ask him to comment on the effects of particle shape, as well as sizing, on segregation with bulk blending.

ANSWER: LEO BEWER - PCS: Particle shape, to my knowledge, has never been a major factor for blending. In the mines that compact, they put on a certain number of millimeters of water through a buf mixer, and then put it through a separate dryer in order to glaze the particle. The reason they do this is to give it a high polish so that, while being handled and in transit, it will not abrade as easily as if it had not been glazed. Particle shape, as such, for storing is not that crucial for the products that we have. I have seen a lot of bins and there has never been a problem of storing because of particle shape. The only thing that they want to find out is if it is dusty. The dustiness, of course, is caused from handling and handling is abrasion. So, the products are polished to prevent readily abrasion and, as far as storing is concerned for our products, there should be no difference in storage.

COMMENTS FROM TERRY FREDERICK—IFDC: I think George Hoffmeister and his group at TVA, once did some work to comment on the last question, the results of their work indicated that particle shape and density were not as important as the particle size range in a bulk blend when you consider segregation. The particle size is the governing factor. The shape is not as important.

COMMENT FROM S. J. COUSINS—ADELAIDE & WALLAROO FERTILIZER DOMPANY, AUSTRALIA: We also found problems in shipping where particle size was important. To avoid compaction in our rail and trucks, we found that the angular shapes tended to compact down with the vibration of long distance traveling. That is why we went to a rounded particle like Urea Prill rather that the fragmented type particle. We did achieve good abrasion resistance as well.

MODERATOR SACKETT: I would like to thank all of our Morning Speakers for their most valuable discussions. (Applause)

Our program for this afternoon will start at 1:30 P.M.

Wednesday, November 4, 1981

Afternoon Session
Rodger C. Smith, Moderator

CHAIRMAN FRANK P. ACHORN: Our Moderator this afternoon is known Internationally and Nationally. He has been a strong supporter of Our Round Table. Without his help, and the help of a few others like him, Our Round Table would not run as smoothly, as it does. Rodger please. (Applause)

MODERATOR SMITH: Thank you Frank. We will get started. I want to welcome you to this Session of The 1981 Round Table. We will remind you again, as many of you know, The Fertilizer Industry Round Table was formed quite spontaneously as the result of a natural need, among fertilizer producers, to have information useful to fertilizer operations.

This afternoon we are privelged to share six highly professional and practical reports on "The Speakers' Respective Experiences" with widely different aspects of fertilizer production, dust control, environmental management, phosphate rock evaluation and a report on anti-caking agents. Three of our speakers are employed in the European Fertilizer Industry. During the past few years it has been my pleasure to visit many European Fertilizer Manufacturers and I have gained great respect for their technical skills. We welcome these Gentlemen and all of the Overseas Participants to this 1981 Round Table. (Applause)

To kick off our Afternoon Program we have two fellows, who have contributed very much to Our Round Table: John L. Medbery and Glen A. Feagin of IMC. Their subject is "Fertilizer Plant Dust Control Through The Use Of Scrubbers". This discussion is a critical one in "Granulation Plants" and often is the factor that precipitates a decision to close a plant or to go to bulk blend. Glen will give this discussion. Glen is a Chemical Engineer graduate of Georgia Tech. He has managed several mixed fertilizer plants for IMC and for the past several years he has been Manager of Fertilizer Technology. Glen please. (Applause)

Fertilizer Plant Dust Control Thru The Use of Scrubbers

Glen A. Feagin — John L. Medbery

Presented By Glen A. Feagin

The Department of Labor, Occupational Safety and Health Administration; as authorized by Congress under the Occupational Safety and Health Act (OSHA) has set Permissible Exposure Limits (PEL's) for worker exposure to most chemicals.

Tests run at IMC plants by OSHA inspectors and our own people indicate that most of the dust in a mixed fertilizer plant falls into the nuisance category.

However, if a plant handles minor elements and/or phosphate rock, it may have to deal with PEL's for zinc oxide, manganese, lead, phosphate rock and fluorine.

The PEL's now are:

● Nuisance Dust	15	Mg/M^3
● Zinc Oxide	15	Mg/M^3
● Manganese	5	Mg/M^3
● Lead	.05	Mg/M^3
● Phosphate Rock	5	Mg/M^3
● Particulate Fluoride	3	Mg/M^3
● Gaseous Fluoride	2.5	ppm

This is an 8-hour time weighted average.

Since the PEL for nuisance dust applies to all plants regardless of size or type, let's use it as the basis for some calculations and try to determine how much dust can be discharged into a plant before the limit is exceeded.

Let's consider a simple case. A closed building and a dust that stays in suspension for an hour. Then, the amount that can be discharged depends on the size of the building.

A typical bulk blending plant is about 75 feet wide by 125 feet long and 20 feet high. That is a volume of 5300 cubic meters. With a PEL of 15 Mg/M^3 there can be as much as 79,635 Mg of dust in the air. Converting to English units, that is 2.8 ounces or 16 teaspoons.

Even in a large storage building, say 175 feet wide by 400 feet long and 45 feet high, we can only discharge 1.5 pounds.

It is easy to tell if the PEL is being exceeded in your plant. If, at the end of their shift, your employees have to brush dust off of their clothes, they are probably being over-exposed.

Believe me when I say these PEL's are tight. Just for fun, run your own calculations for lead.

We were not too concerned when these PEL's were first published. Our plants appeared to be fairly clean. However, when we actually put sampling pumps on employees and ran tests, we found exposure levels ranging from 8 to 140 Mg/M^3 with most of the exposures in the 20 to 40 Mg/M^3 range.

Since the obvious corrections had already been made, such as closing up transfer points and fixing holes in chutes, we had no other choice except to install dust collecting equipment, especially at our larger plants.

(Figure 1) Basically, there are two types of dust collecting systems — wet and dry.

Wet collectors were selected because:

1) Our granulation units have wet scrubbers and we are more familiar with wet scrubbers than with dry scrubbers.
2) Wet collectors are much smaller in size than dry collectors and would fit into our existing buildings.
3) Our plants could handle the water-dust slurry easier than they could handle the dry "face powder" discharge from a bag collector.

The first scrubbers were installed in 1978 at four plants on what is called the "base mill". That is where the dry materials are assembled and weighed for the granulation unit.

They were 4000 cfm units designed by Mr. James B. Madsen and Mr. Daniel R. Brown of IMC. (Figure 2) they worked, but they were on the small side. It seems that once you clean up the dust from one discharge point, you always find another.

Our standard is now a 7000 cfm unit. (Figure 3) by varying the fan speed, they can be operated from 4000 cfm up to capacity.

We have 12 of these wet collectors in operation and 2 more in the planning stage.

Jim and Dan designed these scrubbers to be as simple as possible and planned for them to be installed by plant mechanics.

The scrubber itself is constructed of fiberglass reinforced polyester resin with 5% antimony trioxide as a fire retardant. It is 42-inches in diameter and 8-feet, 4-inches high. It operates with a pressure drop of 7-inches of water. The venturi section consists of 8 — 1" Schedule 40, 316 stainless steel pipes placed across the inlet to the scrubber. Two — 1-inch pipes spray a minimum of 10 gpm of water per 1000 cfm of air into this section. Water pressure at the scrubber is about 35 psi.

Since dirty water is used as a scrubbing media, spray nozzles connot be used. They plug too easily.

Water from two additional 10 gpm spray pipes continuously wash the bottom cone to prevent material build up.

One unique feature of these systems is that the cleaned air is discharged back into the building instead of to the atmosphere. This means that there is no point source discharge and no periodic stack sampling required. It does mean that a mist removal section is required and that the discharge air must be very clean and water free.

An 8-inch thick layer of 2-inch diameter polypropylene balls sandwiched between two layers of FRP floor grating makes an efficient mist removal section.

A 6-inch PVC drain line returns the water to the pump. A minimum fall of 3 feet per 100 feet of run is required to prevent build up.

On the first system, the fan was installed before the scrubber since fans are more efficient with the total system static split between the inlet and outlet side of the fan. However, it was difficult to keep the fan clean and in balance especially when superphosphate dust was handled.

The fans are now located after the scrubber and handle clean air. The total system static is 14 inches of water.

For any dust collection system to work, the air ducts must stay clean as long as possible and be easily cleaned when they do clog. Our duct system was designed and installed with this fact in mind.

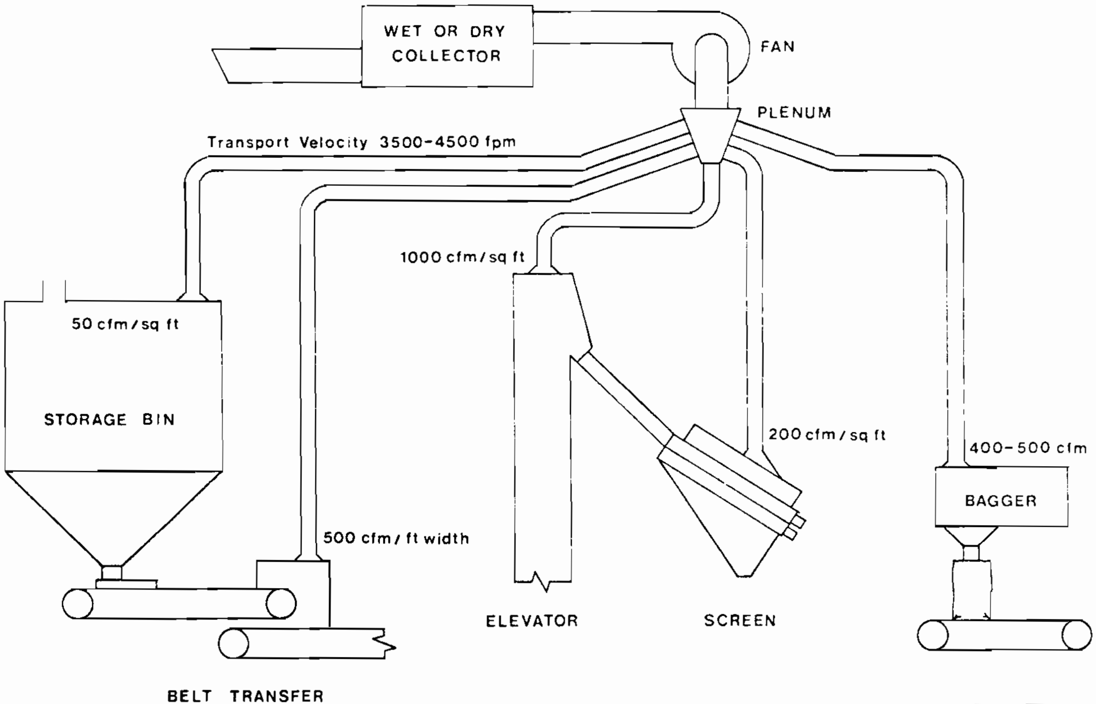
Some design features are:

- Each pick up duct actually is a separate collection system. If it stops up, dust pick up is lost only at one point — not all points.
- By making the friction loss in each run essentially the same, no dampers are required and the system is self-balancing.
- Each pick up duct runs to a common plenum. This is connected to the scrubber by an 18-inch diameter FRP duct. Air velocity in this connecting duct is about 4000 feet per minute.
- Only two size ducts are used. Either a 6-inch duct with a capacity of 800 to 1000 cfm (Figure 4) or a 4-inch duct handling 400 to 450 cfm. If additional capacity is required, two ducts can be connected to the same pick up point.
- All ducts are constructed of PVC pipe. Flexible PVC hoses, with an outside diameter equal to the PVC pipe, is used to connect the duct to the plenum. They provide the flexibility needed for easy alignment and connection.
- Hoses are kept as short as possible because they plug easier and wear faster than PVC pipe.
- Commercial available PVC drainage waste and vent pipe fittings are used as connectors. 45 Degree WYE fittings are used in most placed instead of 90° or 45° ells. The extra opening is used as a clean out and inspection port.
- None of the pipes are cemented in place. All joints are slip fit and held in place by metal pins.
- Each WYE clean out opening is closed with a plywood disk. They are also held in place by pins and secured to the WYE with a length of PVC cord.
- Pick up points are constructed of 1/4" PVC plate.

A PVC welding machine is essential for construction and maintenance. They are inexpensive and any welder can easily learn to use them.

They were used to construct special slip joints which are placed in each horizontal run.

A section of pipe is split and rewelded so that it will slip inside a normal coupling. To remove a horizontal



COLLECTION OF AIRBORNE FERTILIZER DUST

FIG. 1

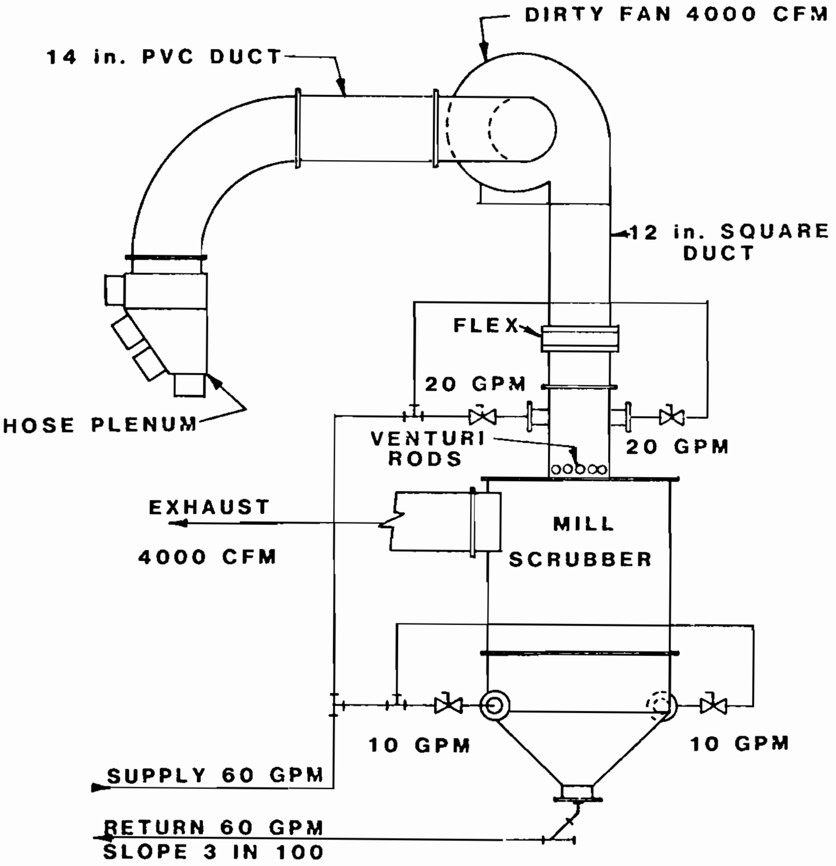
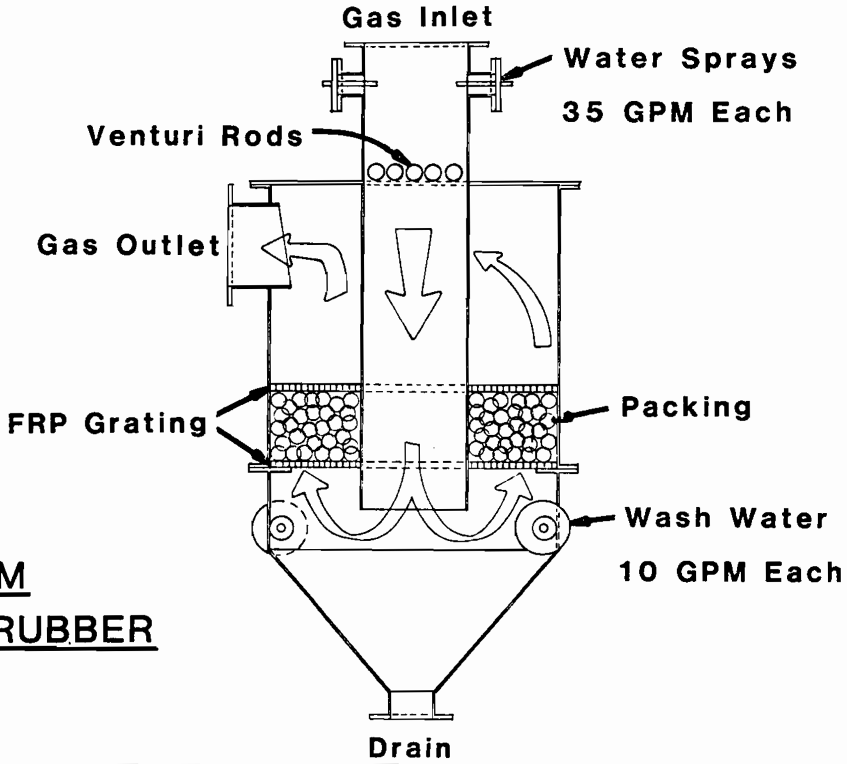


FIG. 2

4000 CFM MILL SCRUBBER



IMC
7000 CFM
MILL SCRUBBER

FIG. 3

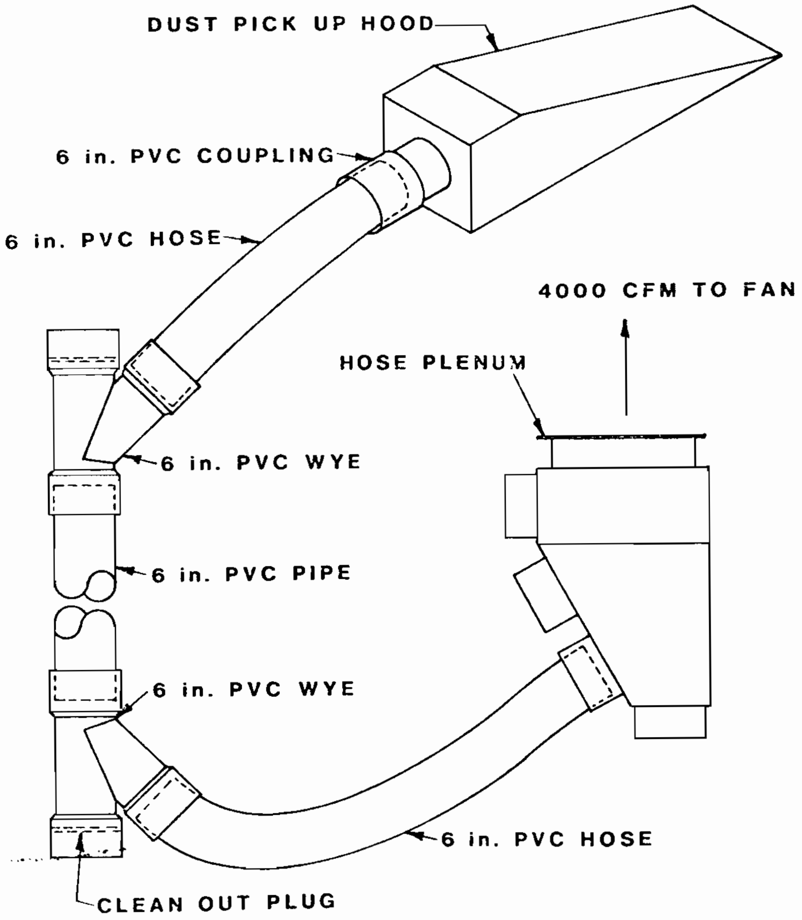


FIG. 4

1000 CFM HOOK-UP

section, just push this slip pipe into the coupling and drop the pipe.

The basic construction rules followed were:

1) All duct runs should be as vertical as possible.
2) All ducts must be accessible for cleaning from a maintenance platform.
3) All ducts and pick up points must have clean out openings.
4) A pressure switch must be installed on the water line. No water — no air. Without water the scrubber will clog in minutes.
5) Use stainless steel bolts on scrubber connections.
6) Use twice as many support brackets on ducts as you think are necessary.

The cleaner the water the better. How the dust water slurry can be disposed of will depend on the location. At most of our plants, we have been able to discharge it into our granulation scrubber system.

However, at our Florence, AL plant, we installed a system consisting of two — 4000 cfm and one 7000 cfm collectors to clean up a shipping complex containing two bagging mills and one bulk shipping mill. In season, these mills will ship over 1000 tons per day.

A common pumping system supplies water to all three scrubbers. It was impossible to return the slurry to the granulation unit so a 20 cubic foot capacity plate and frame filter press was installed.

the filter requires cleaning each time 200 tons are shipped. Twenty cubic feet of solids weigh about 1300 pounds so this is a dust pick up of 6.5 pounds per ton of fertilizer shipped.

The filter cake comes from the press just dry enough to handle and is returned to the granulation unit as a raw material.

I do not have time to really discuss pick up point design and location, but I will say "close them up". 1000 cfm isn't very much air. Flexible strips around hoppers and closed hoods on elevator feed points makes a big difference. You really have to work at it if you are going to meet the 15 Mg/M^3 PEL.

These units are not cheap to install, maintain or operate. Typical unit costs are:

● 7,000 CFM Scrubber	$5,000.
● 100 GPM Pump w/15 HP Motor	3,000.
● 7,000 CFM Fan w/25 HP Motor	2,500.
● Pipe and Ductwork	4,000.
● Installation & electric	4,500.
	$19,000.

If a filter press is required, this will cost an additional $25,000.

The system requires some daily cleaning and a general cleaning every 3 or 4 weeks. This depends on water quality and the amount of dust being picked up. The ducts clog faster in humid weather than when the air is dry.

Tests made after these units were installed showed dust exposure of 8 to 40 Mg/M^3 with most tests running 12 to 17 MG/M^3.

The 40 Mg exposure was found on an open mouth bagger operator standing over a spillage screw near where it discharges into an elevator.

Dust control is not easy or cheap. In the last 5 years, Rainbow has spent well over a million dollars on dust control and we still have a long way to go.

If you get the general dust level in a plant down below 25 Mg/M^3 most of your people will not believe that they are exceeding the standard. As I said, you really have to work at it to get to the PEL.

MODERATOR SMITH: Thank you Glenn. I think you will agree with me that IMC has considerable experience in the whole field of "Dust Control And Containment". That was certainly a well prepared and very illustrated presentation. Since the subjects for discussion this afternoon are somewhat diverse, I think, it would be easiest if we took questions after each Speaker. Are there any questions for Glenn Feagin? (Applause)

QUESTION—FRANK ACHORN: I have always been a proponent of using plastic pipe in plants. One of the complaints, that our operating people have had, has been the expansion of plastic pipe when it is heated. You obviously have not had any problem with that.

ANSWER—GLEN FEAGIN: You do have problems with that because the holes flex.

FRANK ACHORN: You connect it with holes in between it?

GLEN FEAGIN: Yes. In the long run, if you are using PVC electrical ducts, you have to put in expansion joints. All of these joints were put together with a short piece of flexible hose. Use twice as many supports as you think you will need.

FRANK ACHORN: Do you prefer welding the connections rather than glueing them?

GLEN FEAGIN: None of the connections are put together permanently. They all slip-fit.

MODERATOR SMITH: Another question? If not, thank you again Glen. You gave us a very thorough, practical, excellent discussion on "Fertilizer Plant Dust Control." (Applause)

MODERATOR SMITH: Moving on to another subject. Although, the handling of fertilizer continues to trend towards bulk, the packaging of fertilizer is still an "Important Operation" in many fertilizer plants, especially those plants, manufacturing starter lawn and other specialty fertilizers. The packaging and handling systems used influence the productivity of those plants and "customer satisfaction."

Our next Speaker will present and discuss a Motion Picture" illustrating "Modern Packaging and Palletizing Systems" at work. Robert J. Vrabel is a Mechanical Engineering Graduate of Ohio State University. He has been in materials handling for ten years, the last three years, Manager of Sales and Engineering for Haver Filling systems. Bob Vrabel please. (Applause)

Modern Packaging Systems

Authored By:
Anton Spiekermann, Haver & Boecker
Gernot Schaefer, Beumer Maschinenfabrik
Presented By
Robert J. Vrabel, Haver Filling Systems, Inc.

First Half of Discussion: Haver Bag Filling Equipment

Seond Half of Discussion: Beumer Automatic Palletizers and Shrink Wrapping Equipment

First Half of Discussion
Haver Bag Filling Equipment

Introduction

Haver Filling Systems, Inc. and Beumer Corporation, respectively are the USA subsidiaries of their West German parent companies, *Haver & Boecker* and *Beumer Maschinenfabrik K. G.* Haver is the manufacturer of bag filling systems, and Beumer manufactures palletizers, and shrink-wrap equipment.

In a joint effort, they compiled a film presentation which displays modern packaging technology, that is operating in the granulated fertilizer industry today.

Split into two film segments, the *first* ten minutes will depict several systems for filling free-flowing products into valve bags and open-mouth bags. We define free-flowing products as those which are granular, gritty, or grain-stuffed such as fertilizer granulates, sugar, sand etc.

The *second half* of the film will show a range of automatic palletizers and shrink wrap equipment for covering palletless stacks as well as stacks with pallets.

(Photo 1) *Filling Fertilizer Granulates into Open PE-Bags*

The film begins with the filling of fertilizer granulates into open PE-bags on a net weigh station. As the bag is attached, the operator discharges the 50 kg pre-weighed amount from the net weigher which is located above the funnel. Simultaneously, the upper inner bag is stretched by means of the clamping jaws, which stretch the whole bag circumference, so that the neck of the inner bag fits tightly and thus prevents the settling of dust, which is a condition that cannot exist for the proper welding of PE-bags in the next step. The filled bag falls on a batten (wooden slat) conveyor and is either transported to a plastic sealing machine, or to a sewing machine. In this case, the open bags are directed into the sealing machine by hand.

The guaranteed output of this type of bagging station which has 2 HAVER net weighers is 1200 bags/h, each 50 Kg PE flat bag filled with fertilizer granulates, grain size 2-4 mm, at a bulk density of 1.0 Kg/1, (62.4 lb/ft^3). Furthermore, under these conditions, a capacity of up to 1400 bags/h of 50 Kg is also possible.

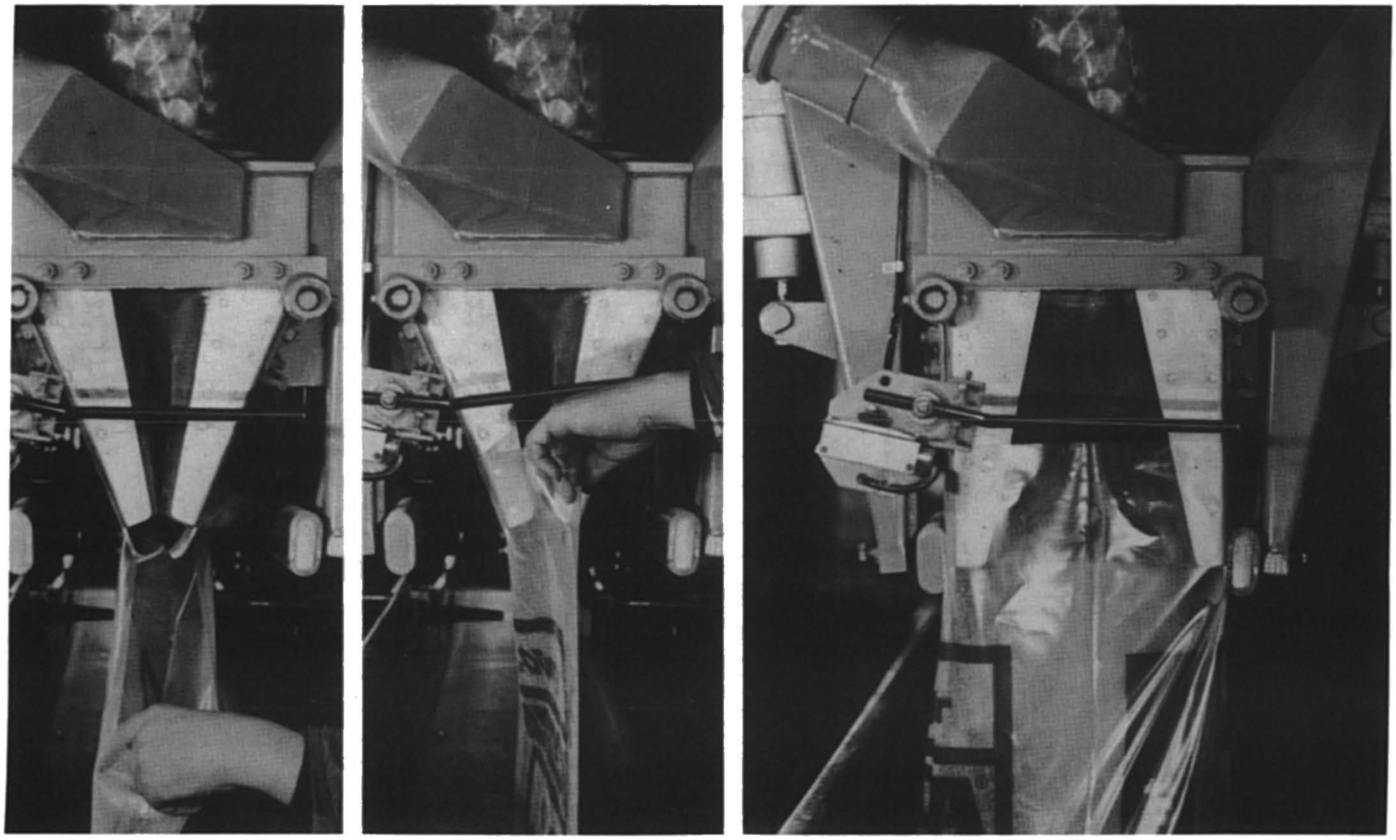


Photo 1
Filling Fertilizer Granulates Into Open PE Bags

(Photo 2) *Filling Fertilizer Granulates into Value Bags*

(Photo 2A) *Net Weigh Scale above the Filling Device*

The next part shows a (2-spout valve and 1-spout open top) bagging station type 2N - 2FO, filling fertilizer granulates. The operator, sitting between the filling tubes, easily attaches the empty valve bag to the spout. As he attaches the valve bag, a micro switch is activated and the bag is fastened and filled with a burst of air, simultaneously, the scale discharges the preweighed load. After completion of the filling process — which is controlled by a time relay — the filled bag falls onto a bag conveyor belt, on which it will then be transported, properly aligned, to the loading plant. This bagging station has an output of 1200 bags/h (50 Kg size).

Utilizing the same net weigh scales, the moveable (combination — valve bag/open top bag) filling device as shown, can be maneuvered into position by hand, so that open-mouth bags can be filled. This unique HAVER high-capacity bagging spout is adjustable in height, so that it accomodates bags of various lengths. This type of machine can also be supplied in the one- or three-spout valve filling spout models, which can be designed in accordance with plant layout requirements and output. Furthermore, stationary or portable free-fall stations for filling only valve bags are also available.

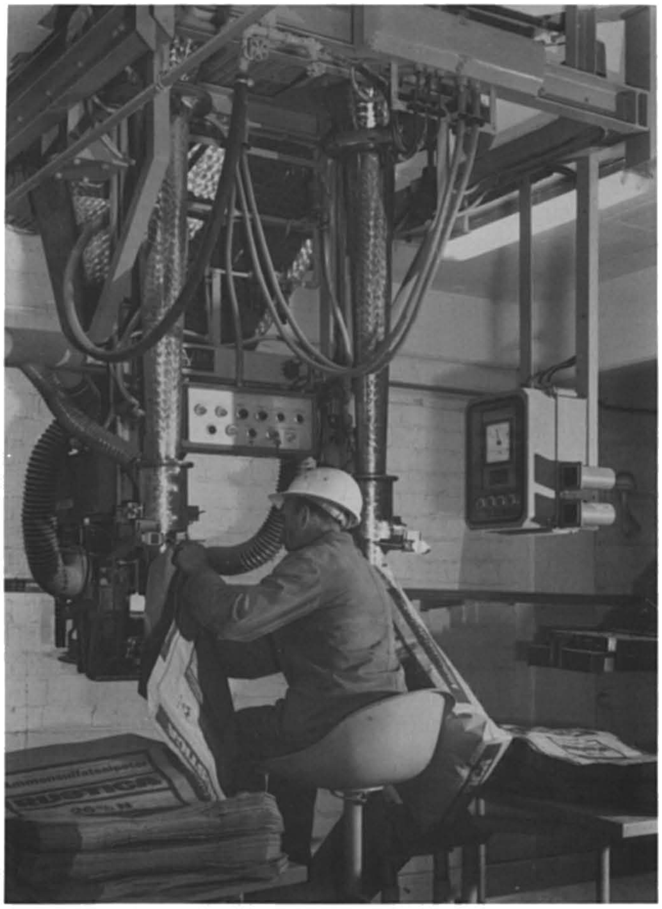


Photo 2
Filling Fertilizer Granulates Into Valve Bags

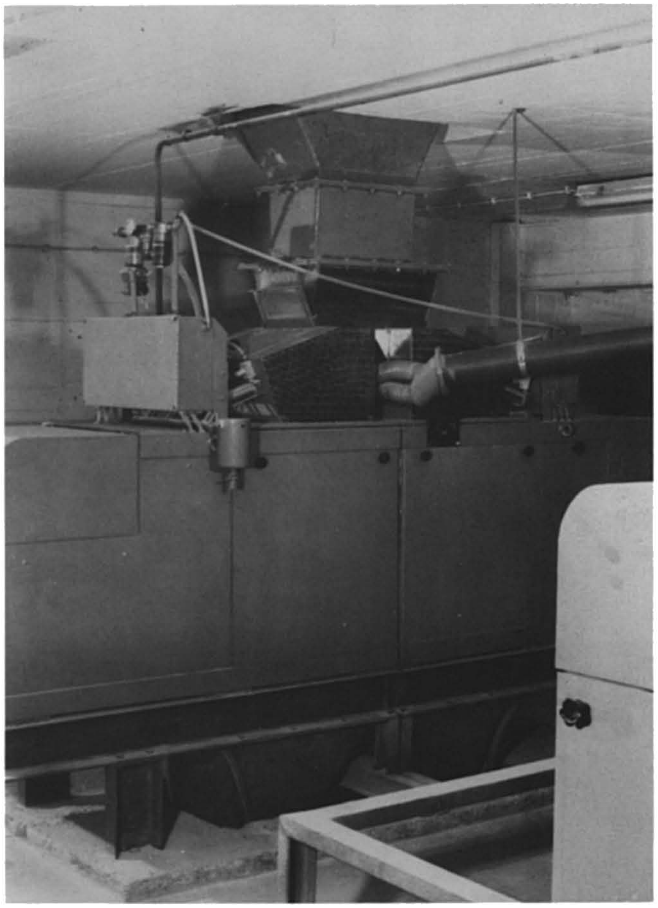


Photo 2A
Net Weight Scale Above The Filling Device

(Photo 3) *Filling Valve bags, using the Free-Fall Roto-Packer*

The next section shows the HAVER Free-Fall Roto Packer, which has much to offer if high capacity is required. Moreover, these high capacity Roto packers are commonly used for filling of only one product type or products of similar qualities, such as a bagging plant that has direct ship loading. The advantage of the Roto Packer is the evenly-spaced distance between the filled bags on the conveyor belt. This 6-spout packer as shown has a capacity of 1750 bags/h of 50 Kg size, and it can fill either paper bags or PE bags.

A 10-spout Roto Packer, as used for filling of urea, has a capacity of 2000 bags/h of 50 Kg size.

Note that our free-fall stations can be equipped with automatic valve bag applicators as well. The purpose of such equipment is to improve the local working/operating conditions.

(Photo 4) *Filling PE Granulates into PE Gusseted Bags, using the Rollopack*

The next film segment shows the HAVER ROLLOPACK, beginning with a general view of our electronic weigher. For this type of weigher we guarantee a weight tolerance of better than ± 20 grams (.7 oz). The weighing system is equipped with a scale beam, that has a weight transmission of 1:10, and the weigher operates with a differential transformer.

Eventual vibrations in the weighing system can be partially absorbed by oil dampers.

Here we show the filling of black polyethylene granulates, whereby the pre-weighed quantity is dropped into the bag directly from the discharge funnel above the spout. The output is about 650 - 700 bags/h each 50 Kg; the maximum output of a Rollopack for gusseted bags is actually 800 - 850 bags/h of 50 Kg.

The film shows in detail, the operating sequence, which begins at the opening and attaching of the Rollopack fabricated bag, then to the bag stretching with simultaneous air release, to the bag filling, and then to the placing of the bags onto the acceleration belt.

The filling process begins after the empty bag is attached onto the HAVER high-capacity bagging spout and the empty PE gusseted bag is "shot" into filling position as it travels over the air-eliminating rollers by means of a tappet. In viewing this sequence, it seems that the bag is inflated with air, but this is not the case. due to the filling process itself, particularly the high speed of material drop, there is a brief air bubble which appears above the product, but which then disappears with the dust collection process.

When attaching the empty bags, the "screen welding" can be clearly seen at the upper edges of the PE bags. By means of this "welding", the gussets remain folded during the filling process. This system has the advantage that the gussets of the bags cannot unfold themselves, however the resulting disadvantage is that there results a small filling opening of the gusseted bags. The width of this filling opening is an essential factor in reaching the maximum capacity of the machine.

At the present time, we are working out a system which is able to fully open the guesseted bag (as with flat bags), and keep it fully open during the filling process, so that faster filling and better de-aeration can be obtained. Then, after completion of filling, the gussets will be refolded and the toy seam welded.

By means of the acceleration belt, the filled bags *-with the top side guided by tubes* - are transferred to the welding equipment. First, when arriving at the plastic sealing machine, the bags are trimmed at the top, and this includes the screen welded part. Following this, they arrive at the welding zone, then the bag goes to the pressing and cooling station for final formation of the top seam. Finally, this foormed, filled, and sealed bag goes to the palletizing station.

In all cases, only PE foil (film) with random print is being used. Random print means that the printing can be found somewhere along the flat side of the bag. Using this type of printing, results in the advantage of needing only one type of film. Furthermore, such a printing is especially used in the lastic industry, where sometimes

Photo 3
Filling Valve Bags Using The Free-Fall Roto Packer

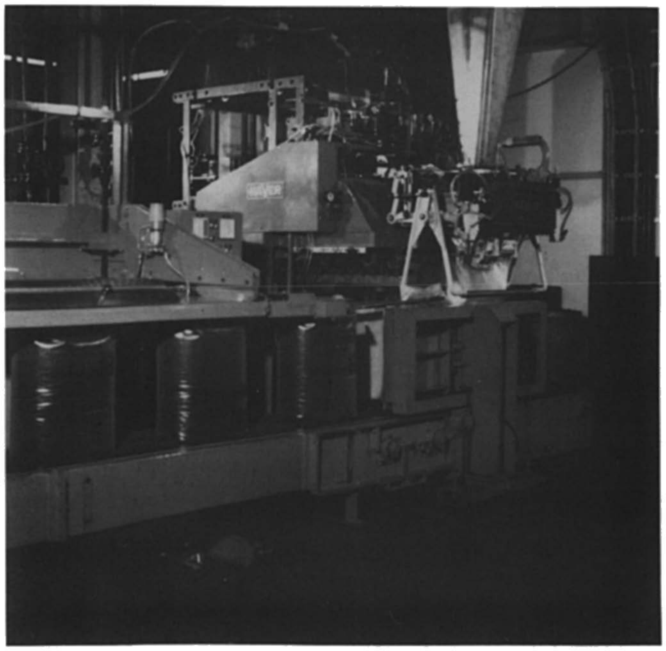


Photo 4
Filling PE Granulates Into
PE Gusseted Bags Using Pollopak

up to 30 products are to be filled with only one machine, using one type of film.

During the production of gusseted bags, the code number is imprinted on each bag by a hot embossing press. By changing the print tray — which is equipped with another preheated code number — within one minute, one can change from one type of product to another. The length of the bag can also be quickly adjusted by means of a lever arm.

(Photo 5) *Filling Fertilizer Granulates into PE Flat Bags, using the Rollopack*

Next, the movie shows the filling of fertilizer granulates into PE flat bags. Wherever fertilizers are filled, we do not work with random printing, but rather with fixed - positioned printing. The bag length is determined via photocells which respond to print marks, and signal the proper cutting of the bag.

When filling different types of fertilizers, each product type is filled into bags that have its own special printing. If there are differences in bag lengths, the print codes can be positioned accordingly. Therefore, different foil/film rolls are usually kept in stock.

Furthermore, it is customary in the European fertilizer industry, that two, maximum of three, qualities of products are handled with the same machine, so it does not compare to the wide variety of bags and film that are required in the plastic filling industry.

The output of a Rollopack for PE flat bags, as seen in the movie at ICI Works at Severnside, U.K., is 1200 bags/h of 50 Kg. In principle, the filling process is the same as the filling of gusseted bags, however, when filling flat bags, the quantity to be filled is prestored in the bagging spout *and not* - as is with gusseted bags -discharged from the net weigher when attaching the bags.

(Photo 6) *Filling Fertilizer Granulates into PE Flat bags, using the Rollopack*

Next, the movie shows the Rollosack which is being utilized for the filling of prefabricated PE flat bags that are shingled onto a reel. The operation of this automatic machine is considerably easier, because there is *no need* for either a bottom seam welder, or a counterbalanced roll-off system, as is required with the HAVER ROLLOPACK. This advantage has an influence on the maintenance of this machine.

The individual bags — exactly positioned by a photocell - are guided to the transfer point. When the first bag is lifted by gripper arms, the next one is firmly held in place by a clamping bar, so that, if an electrostatic charge condition exists between the bags, no two bags are lifted at the same time. After opening the flat bags at the vacuum station, the bag is placed by means of lever arms on the high-capacity bagging spout, which also holds the automatic bag stretching and infeed device. From this moment, the filling and closing operation proceeds in the same way as with the ROLLOPACK, as previously described.

For filling fertilizer granulates, the capacity of this HAVER ROLLOSACK is 1200 - 1300 bags/h of 50 Kg.

It is noteworthy that, through a recent development, we are now in a position to offer a fully-automatic ROLLOSACK for filling polypropylene bags which have a PE inner liner. Output at the present time is 1000 - 1200 bags/h of 50 Kg. The ROLLOSACK can also be used for filling into paper bags, either flat or gusseted type. One of these machines is already in operation where it is filling products into paper gusseted bags that are referred to as "aerodense".

Future HAVER developments include an automatic machine (SACKOMATIC) which feeds paper flat bags from a bundle (instead of from reels) to the high capacity bagging spout. This machine will have a capacity of 1000 - 1200 bags/h of 50 Kg and will be available in early 1982.

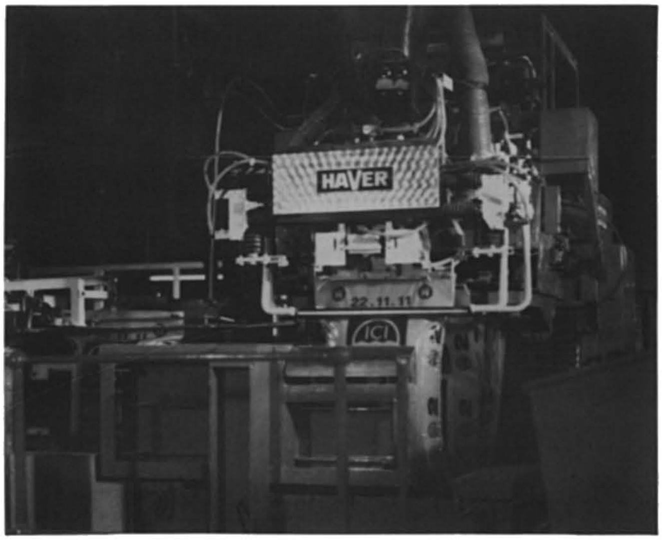


Photo 5
Filling Fertilizer Granulates
Into PE Flat Bags Using The Rollopack

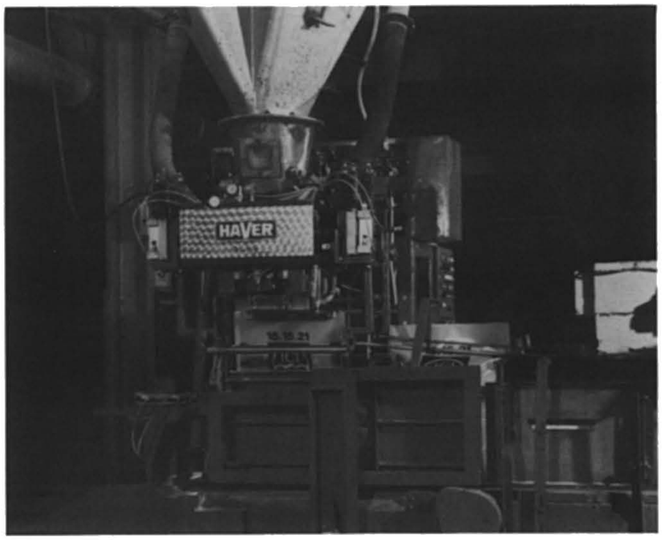


Photo 6
Filling Fertilizer Granulates
Into PE Flat Bags Using Rollopack

Second Half of Discussion Beumer Automatic Palletizers And Shrink Wrapping Equipment

Index of Illustrations

Index of Tables

1. Introduction

The shipment of bagged chemical products is accomplished by means of either individuall loaded bags using conventional bag loading machinery[1] or in the form of pre-palletized bag stacks using wooden or plastic pallets to support the load. In addition to the use of pallets, the bag stacks are sometimes protected by film hoods or strips to secure the load.

The shipment of bagged goods in the form of individually loaded bags is labor intensive, both on the sending and receiving end. Particularly in those cases where the material coming from the bagging installation is directly loaded without being put into intermediate storage and where no automatic loading systems are present[2], this type of shipment will remain widespread in the future.

Large bundles, however, offer many advantages for both sender and receiver in every stage of the shipping, transport and storage operations. However, the shipment of large bundles using pallets for load support has its disadvantages which can be attributed to the nature of the pallet itself: the handling and storage of empty pallets, the exchange and repair of pallets — all are expensive; due to the danger of damage to the load, the use of pallets for ship transport has very limited possibilities; the bag stack, even when protected by a film hood, is still not protected on all sides from the elements, so that outdoor storage is usually not acceptable, requiring the use of warehouses.

Taking the labor intensity of individually loaded bags and the disadvantages of the use of pallets into account, there is still a demand for a system which processes large bundles as one unit independent of pallets or pallet-like load supports (Illustration 1).

With the Beumer-Paketpak (R) installation for palletless shrink wrapping of bag stacks, B. Beumer Maschinenfabrik, after long years of research and development, put a packing and shipping process which

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(1) Beumer, B., *The Latest Technology in Bag Transport and Loading Machines, Die Muehle und Mischfuttertechnik,* 110 (1973), Issue 10, pp. 327-329.

(2) Remmert, J., *Automated Bag Loading with the Autopac II,* Zement-Kalk-Gips, 29 (1976), Issue 3, pp. 146-150.

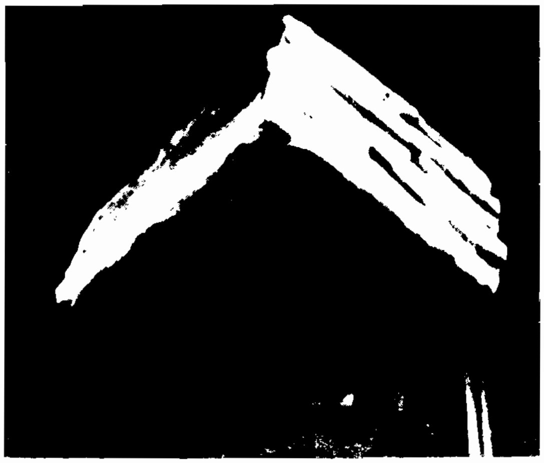


Illustration 1

eliminates all the above disadvantages into operation in the West German chemical industry for the first time in mid-1981 (Illustration 2).

The following report deals with the technology of palletless shrink film wrapping for bag stacks, installations and alternative packing methods, data on wrapping film and cost investigation. Compared with the building materials industry, the products of the chemical industry present many additional difficulties for loading. The experiences gained in the chemicals area, therefore, can be easily applied to the cement, lime and gypsum industries where the packing demands are of a simpler nature, as, for example, paper and valve bags are used instead of the PE-bags, pillow-type and side-gusseted bags usual in the chemical industry.

Illustration 2

2. *Wrapping Film Data*

For the palletless wrapping of stacks, both thermal shrink film and stretch film are available. Stretch films are used in packing systems which work according to the strip or band wrapping methods. Due to the difficulties inherent in these systems in achieving a watertight packing unit, these methods have not been successful for the palletless wrapping of bag stacks. The stretch film systems' energy efficiency advantage over the shrink film system is outweighed by the disadvantages as far as packing technology is concerned.

The film to be used for palletless wrapping of bag stacks is therefore thermal shrink film, i.e., special plastic film which shrinks when exposed to heat and subsequent cooling, securely surrounding the package and holding it together.

2.1 Specifications for Standard Shrink Film for the Palletless Wrapping of Bag Stacks

Thermal plastics are used in the production of shrink films. Low density polythylene, with the international designation LDPE, is especially well suited. Polythylene has significant advantages over other thermal plastics in its great strength and tear resistance, very low water absorption, high resistance to chemicals, ease of handling and, because it is a mass-produced plastic, its reasonable price. As pure low density polyethylene is composed only of carbon and hydrogen, it burns down to only carbon dioxide and steam without leaving any residue. The gases given off by burning are non-toxic and completely harmless. In addition, polyethylene does not emit any harmful substances into the ground water or the atmosphere. It can be processed in waste disposal installations without problems.

For the above reasons, PE-film is considered the standard shrink film to use. Sometimes stabilizers are added against short wave radiation, heat and other climatic factors. For special applications, flame retardants can also be added to the PE-film. Before it can be printed, the ink-repellant film surface must be specially treated.

As shrink film for wrapping bag stacks, it is necessary to have a film with approximately the same shrinking properties in both lengthwide and crosswise directions. As a rule, the shrinking value is from 35-45% crosswise and from 45-55% in a lengthwise direction. This type of film is designated bi-axial shrink film. Such film should be approx. 150 - 200 my (6-8 mil) thick, that is, the same thickness as would be used for heavy-duty packing. In practice, one should start with a thicker film, gradually reducing the film thickness through testing and experience.

The film comes in the form of tube film, as it is produced by an extruding process. The tube with side folds required for forming the film hood is formed by a side folding device. The tube film can be made into flat film by making a cut in one or both sides.

The following survey shows the main chemo-physical values and DIN-designations (German Industrial Standard designations) for standard PE-shrink film. (Table 1) At this point, the GKV (German organization for plastic research) testing and evaluation clauses for high pressure polyethylene products should be mentioned[3], which contain terminology and maximum tolerance levels which are important in those cases where a compliance with these clauses has been agreed to between buyer and seller.

TABLE i: SPECIFICATIONS FOR A STANDARD PE-FILM FOR THE PALLETLESS SHRINK WRAPPING OF BAG STACKS

Characteristic	Dimension	Testing Method	Normal value
Thickness	mm	DIN 53370	0.15 - 0.20
Density	g/cm^3	DIN 53479	0.92 ± 0.002
Melting Index	g/10 min.	DIN 53735	0.1 - 0.3
Melting point	°C	accd'g to Kofler	110° C
Tear resistance	N/mm^2	DIN 53455	lengthwise: 15 crosswise: 14
Stretch allowance	%	DIN 53455	lengthwise: 250 crosswise: 400
Permeability - water vapor	g/24 h	DIN 53122	less than 1 at 200 my
Surface strength puncture resistance	Ohm	DIN 53482	10^{17}
Temperature tolerance	°C	+)	—30 to +60
Light tolerance	h	+)	unstablized: 500 - 1000 stabilized: over 2000

+) approximate values, partially determined under laboratory conditions

To complete the picture, multi-layer or separable layer films as well as "powdered" films should be mentioned here. These special films were developed in order to eliminate or reduce the film's sticking tegether in those cases where the packing film for the bag stack and the film used to produce the individual bags are identical, having the same melting point. So, when using a multi-layer film, for example, with bags of polyethylene, a two-layer packing film can be used with an outer layer of polyethylene and an inner layer, that is, the layer which will be next to the bags, made of, for example, polypropylene. The "powdered" films are used according to the same principle as the multi-layer films, whereby the "layer" touching the bags consists of talcum powder or the like.

Multi-layer films are very expensive compared to single-layer films. A technically flawless machine design, however, can eliminate sticking of packing film and bag, or at least keep it to an acceptable minimum, without requiring the use of special films. As a rule, then, multi-layer films do not have to be used. When paper bags have to be wrapped, as in the building materials industry, this presents, of course, no problems of this kind at all.

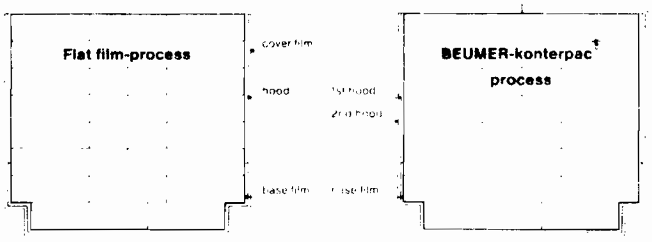
2.2 *Required Film, Film Costs, Film Supply*

The film required for each bag stack is determined by the packing method chosen as well as, of course, by the stack dimensions. The stability requirements of the stack also have an influence on the amount of film required, the stability requirement being determined by the forces exerted on the stack, which in turn depend on the frequency of stack transferral and the method of transport.

Two Beumer packing techniques can be chosen. These are:

1. the Beumer flat film process and
2. the Beumer konterpac (R) method.

The technology of both these methods will be described later. Here we will deal with only the basic differences between the two techniques (Illustration 3).



BEUMER-paketpac® in flat film design or as BEUMER-konterpac® process

Illustration 3

The required film (G_{ttl}) is calculated as follows:

$$G_{ttl} = G_{1st\ hood} + G_{2nd\ hood} + G_{flat\ film} + G_{base\ film}\ (kg),$$

and

$$G_{hood} = F_{hood} \times d \times 8\ (kg)$$

$$G_{flat\ film} = F_{flat\ film}\ d \times 8\ (kg)$$

$$G_{base\ film} = F_{base\ film} \times d \times 8\ (kg),$$

In addition, the film surface of the hood is calculated from the hood length L as well as from the tube circumference U resulting from the dimensions of stack width B, stack depth T and stack height H, taking the required excess dimension a into account.

$F_{hood} = U \times L\ (cm^2)$,

and

$U = 2\,(B + T) + 4 \times a\ (cm)$

and

$L = \frac{B}{2} + a + H\ (cm)$.

therefore, hood weight G_{hood} results in

$G_{hood} = [2\,(B + T) + 4a] \times \frac{B}{2} + a + H] \times d \times 8\ (kg)$.

The weight of flat film $G_{flat\ film}$ is calculated from the stack width B and the stack depth T, taking the overhang on all sides b into account:

$G_{flat\ film} = (B + 2b) \times (T + 2b) \times d \times 8\ (kg)$.

An extra base film, which may be needed for additional reinforcement of the package base, is calculated in the same manner. The overhang c may in this case be smaller than in the case of the flat film, because basically only the recesses in the package base need reinforcement, so that the side overlapping of the base film with the hood, which is drawn over it later, can be eliminated.

Example for calculating:

Bag dimensions (full bag)	60 x 40 x 15 cm
Bag weight	50 kg
Number of layers	7 + 1
Number of bags	39
Packing pattern	7 alternating layers in 5-fold bonded pattern + 1 layer in 4-bag chimney pattern
Stack weight	1.95 t
Stack width B	100 cm
Stack depth T	120 cm
Stack height H	120 cm
Excess a	5 cm
Overhang b	30 cm
Overhang c	20 cm
Film thickness d	0.02 cm
Density of PE-film 8	0.00092 kg/cm³

Example 1:

Flat film process (packing unit consists of a base film, a film hood and cover piece of flat film):

$G_{hood} = [2\,(B + T) + 4a] \times \frac{B}{2} + a + H] \times d \times 8\ (kg)$

$G_{hood} = 1.4812\ kg$

$G_{base\ film} = (B + 2c) \times (T + 2c) \times d \times 8\ (kg)$

$G_{base\ film} = 0.41216\ kg$

$G_{flat\ film} = (B + 2b)\,(T + 2b) \times d \times 8\ (kg)$

$G_{flat\ film} = 0.52992\ kg$

$G_{1\ total} = 1.4812\ kg + 0.41216\ kg + 0.52992\ kg$

$G_{1\ total} = 2.42328\ kg$

Taking a film price of DM 2.80/kg of PE-film into account, the packing material costs using the flat film process amount to approx. DM 6.80/1.95 tons or approx. DM 3.50/ton. When eliminating the additional base film, the material costs are reduced to approx. DM 5.60/1.95 tons or approx. DM 2.90/ton.

Example 2:

Beumer konterpac (R) process (packing unit consists of a base film and 2 folly overlapping film bonds):

$G_{2\ total} = 1.4812\ kg + 1.4812\ kg + 0.41216\ kg$

$G_{2\ total} = 3.37456\ kg$

This results in packing material costs of approx. DM 9.45/1.95 tons or approx. DM 4.85/ton, or, when eliminating the additional reinforcing base film, approx. DM 8.30/1.95 tons or DM 4.25/ton.

Quite clearly, the packing material costs are higher when using the konterpac (R) process than with the flat film method. With a difference in cost of about 40 - 50 % per stack or per ton of packing material, it should be very carefully considered whether the konterpac (R) process, which uses more material, or the film-saving flat film method should be used. The decision is dictated by the accompanying conditions — storage, transfer and transport conditions of the package. In many cases, the decision will be made in favor of the flat film process, which has the additional advantage of having no welded on the package surface. In addition, as will be pointed out later, an installation working by the flat film process requires less space, which is reflected in building investment. This process is also simpler from a technical point of view, requiring less investment in machinery.

For a quick, rough survey of the packing material costs resulting from the use of film hoods, the graph, Illustration 4, is useful.

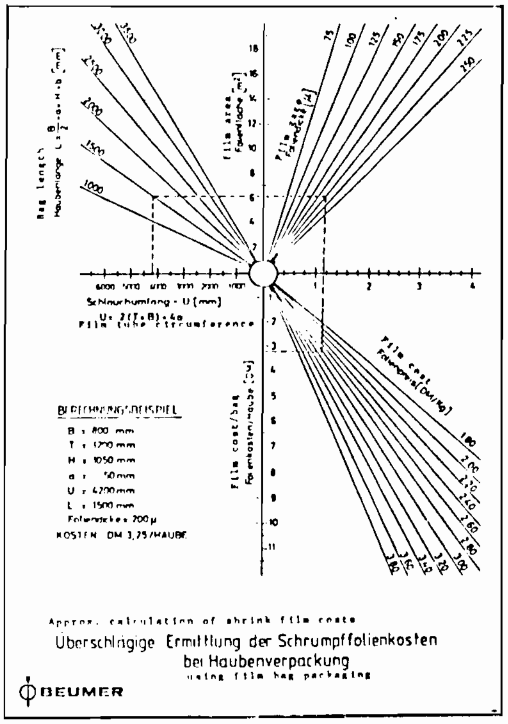


Illustration 4

In addition to the film actually used in the packing process, the amount of film supply kept in the packing line, which determines the intervals between changes of film rolls, is of interest to the operators of the line. These values can also be roughly outlined in a graph. (Illustration 5).

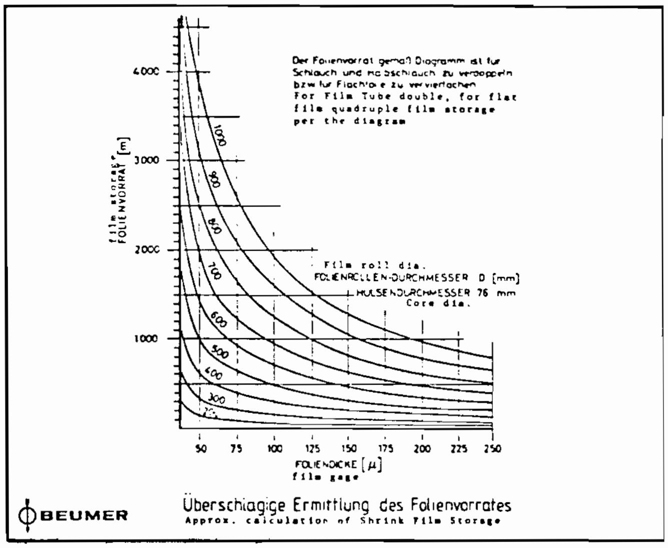


Illustration 5

3. *Fully automatic Palletizing and Packing Lines*

The Beumer Paketpac (R) lines consist of the high capacity palletizer and the subsequent equipment for completely surrounding the bag stack with wrapping film, including the elements for heating the foil. Here, there are especially great demands made on the palletizer because the accurate formation of the bag stack is of utmost importance and basic to the following film wrapping process and for the final quality of the wrapped bundle. This is true for all types of packed goods, and especially for the bagged products of the chemical industry and for some materials of the building materials industry. As a rule, due to the use of plastic bags and frequent use of pillow-type bags and to the characteristics of the material itself, the bagged products of the chemical industry present more difficulties for palletizing than do those of, for example, the cement industry. The palletizers of the Beumer Paletpac (R) series are equipped with the most modern components, making these machines particularly effective for palletizing difficult materials[4].

3.1 *High Capacity Palletizers*

In the Paletpac (R) line, which includes types 800/1200, 1200/1600, 2000/2400 and 4000, a new series was developed about three years ago which is now found in operation in numerous branches of industry. While the Paletpac (R) types 800/1200 (Illustration 6) and 1200/1600 (Illustration 7) are primarily used for special products of the building materials, chemical and feedstuff industries, the machines in the 2000/2400 capacity class are found over-whelmingly in the cement industry (Illustration 8). While developing the new palletizer series, particular emphasis was placed on extremely careful bag handling, avoiding any bag deformation or strain, as well as on a very compact machine design, good accessibility of all machine parts and high operating reliability, both of mechanical and electro/electronic parts. New components, such as an entirely new bag turner (Illustration 9), a bag distributor and a full pallet turning system allow for reliable palletizing with well-formed stacks, even when working with difficult material.

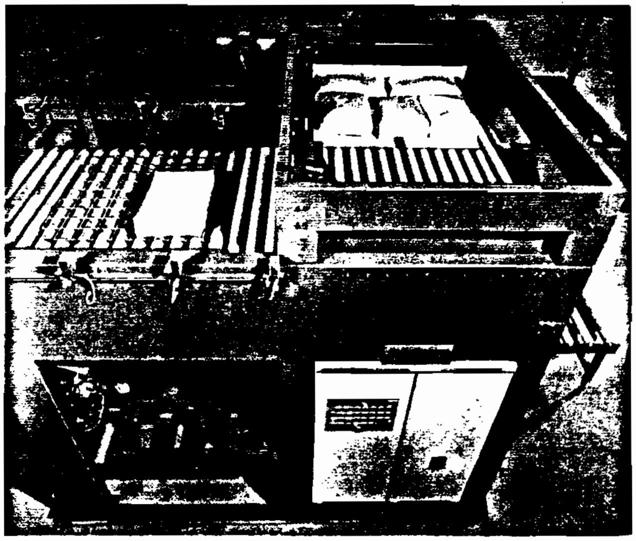


Illustration 6

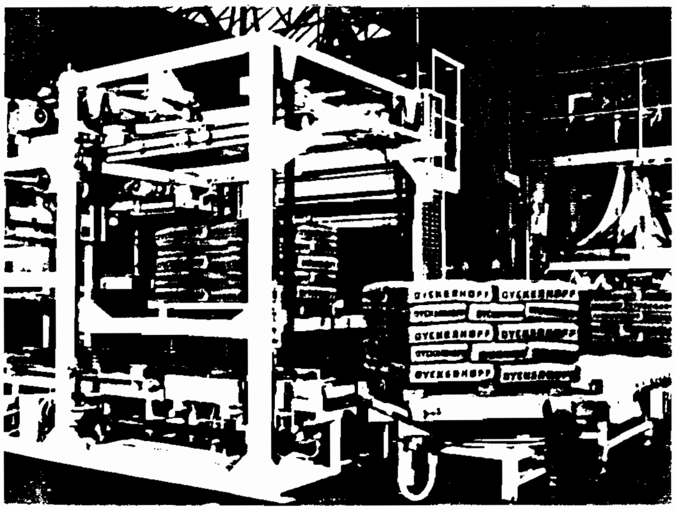


Illustration 7

A new capacity dimension was reached in the building materials area parallel to the development of new high capacity rotating packers with the development of the Paletpac (R) 4000, now ready for production.

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(4) Schaefer, G., *Installations for the fully automatic Palletizing and Loading of Bags onto Trucks*, Zement-Kalk-Gips, 34 (1981), Issue 6, pp. 306 - 308.

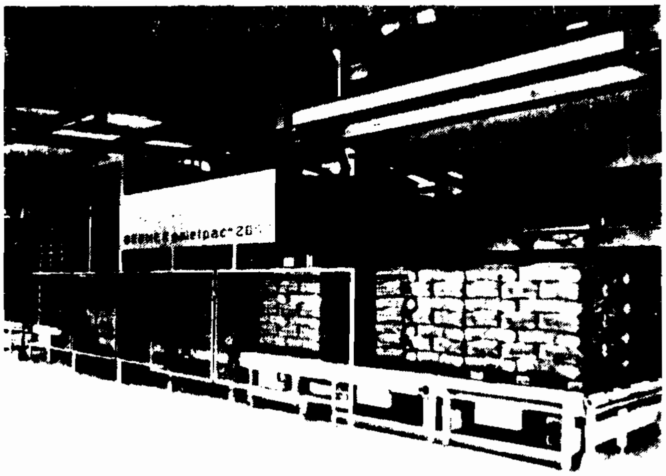


Illustration 8

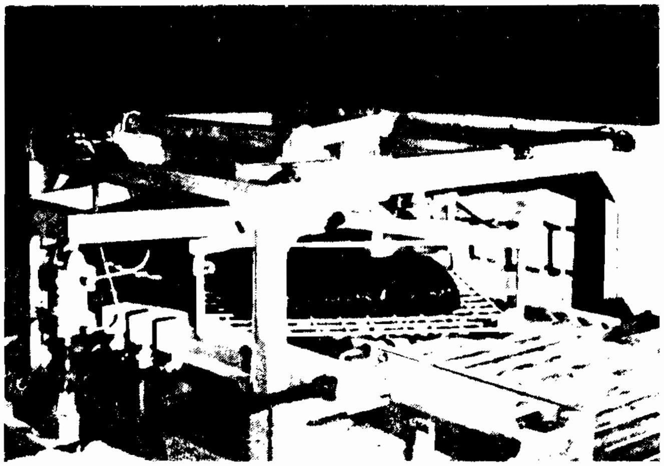


Illustration 9

A programmable electronic memory unit is used for controlling the Paletpac (R) machines. Many reputable hardware suppliers may be chosen from. Beumer itself supplies the software. Command signals are given by means of proximity switches and gallium-arsenide emitters. Mechanical switches were omitted for reasons of operational reliability.

A palletizer which handles the product with extreme care is a must for the production of stable shrink wrapped bag stacks without pallets. Often the better palletizer is the deciding factor when choosing the subsequent packing method.

3.2 The Beumer Paketpac (R) Line for Palletless Shrink Film Wrapping of Bag Stacks

A description and comparison of the two alternative packing methods mentioned, that is, the Beumer flat film process and the Beumer konterpac (R) process, follows.

A comparison of the systems will show that there is much to be said for the flat film process and that the konterpac (R(method is designed mainly with special applications in mind. Space requirements for the installation as well as film requirements and operating costs are all taken into consideration in this system comparison. Of course, both processes offer high quality packing and an extremely stable packing unit.

3.2.1. The Beumer Flat Film Process

The flat film line consists of the palletizing system and the Paketpac (R) installation, which together make up a fully automatic stacking and packaging unit (Illustration 10). The bag stack is formed by one of the above mentioned Paletpac (R) palletizers, with the last layer of the stack smaller than the remaining layers. The normal layers are formed, as a rule, in alternating 5-fold bonded patterns and the final, smaller, layer formed in a chimney pattern consisting of 4 bags. It is also possible to form the normal layers in the 5-fold pattern and the base layer in a 3-fold pattern, or, with a normal layer consisting of 3 bags, the base layer can be formed from 2 bags. This depends upon the bag dimensions, the size of the pallet and the palletizing pattern which may be determined by external factors. The small final layer allows for formation of recesses on the left and right sides of the normal layers, into which the lifting apparatus (such as fork lift) can reach later in order to lift the stack and transport it after it has been turned 180° in the stack turner of the packing line (Illustration 11).

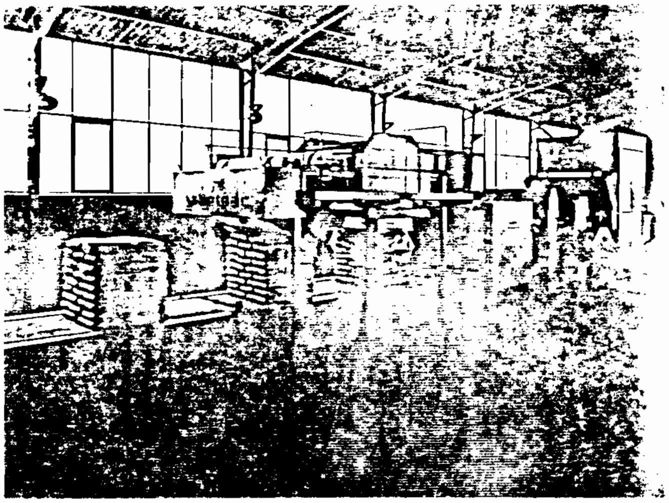


Illustration 10

The bag stacks leaving the palletizer go through the packing process as shown in Illustration 11. The process begins with the placing of a piece of flat film onto the bag stack in order to reinforce the film wrapping in those areas which will later form the base of the package and to protect it from damage by the conveying equipment. This cover sheet is put into place by two pneumatic clasps. Then the stack is brought into the automatic hood forming machine. This machine forms a hood from tube film with deep side folds, the correct length being measured by an automatic stack height sensor and then pulled from the supply roll.

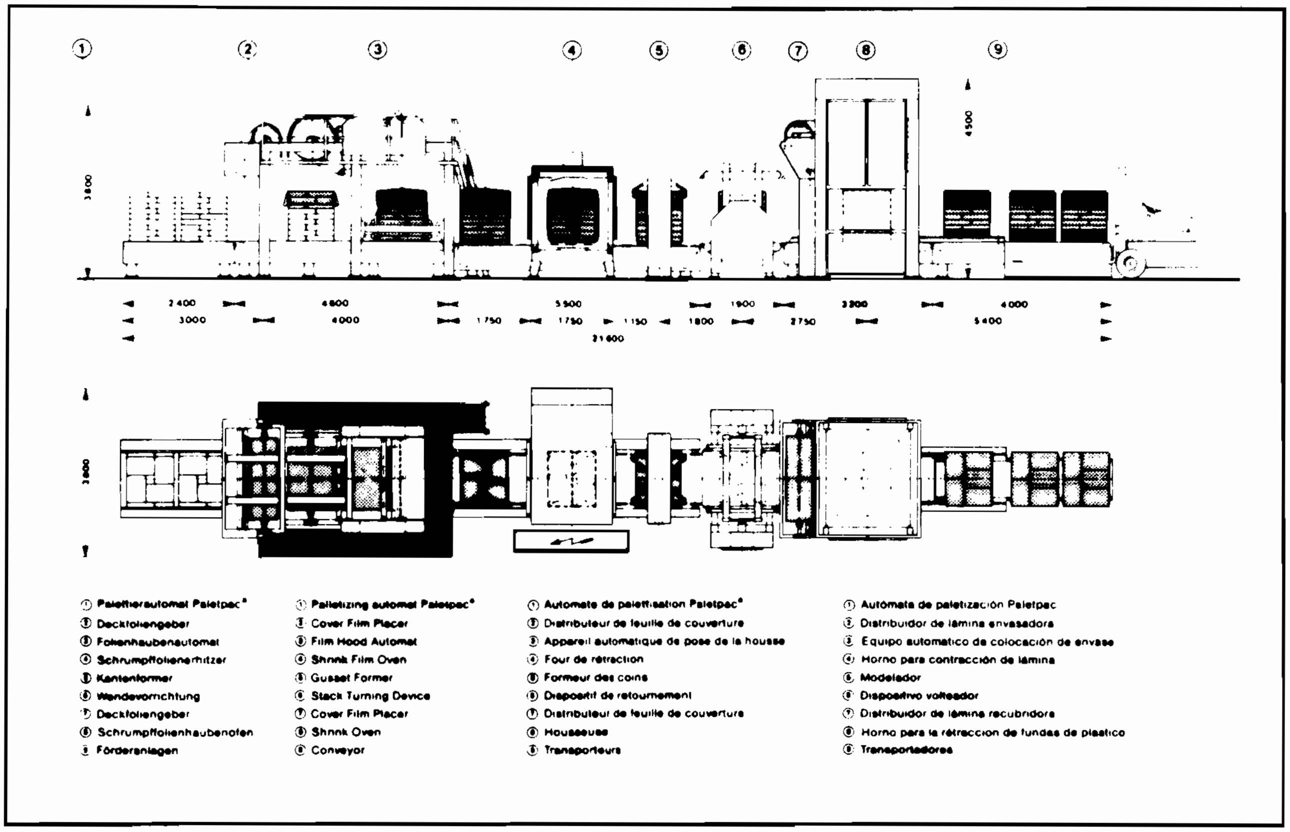


Illustration 11

Then a seam is welded in the film, forming a hood. A cutter separates the hood from the film tube. The hood is then grasped on its four lower edges by pneumatic clasps, opened, and pulled over the bag stack. In the next step, the bag stack, now partially surrounded by a flat film and a film hood, is brought into a tunnel oven and heated at a shrinking temperature of approx. 200° C. Among other things, the shrinking temperature is determined by the thickness of the film. This heating and subsequent cooling off causes the film to shrink and securely surround the bag stack.

After passing through the shrinking oven, a shaping device forms the recesses which result from the difference between the smaller 4-fold layer and the remaining 5-fold layers. Later, the fork lift will reach into these recesses. It is very important that these recesses are formed as rectangularly and neatly as possible in order to avoid damage to the film wrapping later during transport.

During the next step, the bag stack is turned 180° and the recesses for the fork lift reshaped. During the same process, the upper and lower surface of the bag stack are pressed completely flat. This guarantees for stable stacking of the packages during intermediate storage. The turning device consists of 2 short belt conveyors which are moved toward each other by means of a hydraulic drive, clamping the bag stack between them. The entire component is hydraulically turned 180° after the bag stack has been brought in between the belt conveyors. After leaving the turning device, the stack surface which has not yet been convered with film becomes the upper surface. The upper surface of the stack is now covered with another piece of flat film and the stack brought under a lowerable hood oven.

After the hood oven has been lowered, it only heats that part of the bag stack which has just been covered by the piece of flat film which overhangs the stack on all sides. This process avoids a reheating of the other parts of the bag stack after they have already been heated once in the tunnel oven. To heat these parts of the stack again would deform the recesses for the lifting apparatus and require an additional shaping followed by an expensive cooling of the stack base. The use of the hood oven is very simple technically and avoids the considerable expense involved to an additional shaping and cooling of the stack base.

Bar chain conveyors are used in the area of the tunnel oven. In the remaining parts of the line, belt roller conveyors are used, as this type of conveyor provides for a particularly smooth run for the packages.

The entire system is controlled by a free programmable electronic unit, the hardware for which can be chosen from many reputable firms.

The large bundles produced in the flat film process are waterproof and can be reliably transported. They can be stacked one on top of the other during intermediate storage or transport.

3.2.2 The Beumer konterpac (R) Process

The packing line of the Beumer konterpac (R) process differs from the flat film line only in that, instead of the film cover placer in the area of the hood oven in the flat film method, there is a second automatic hood forming machine located between the stack turning station and the hood oven. As, with the Beumer konterpac (R) process, the second hood almost completely overlaps the first hood already drawn over the stack, the hood oven must be lowered further than is required by the flat film which hangs over the stack on all sides in the flat film process. Illustration 12 shows the Beumer Paketpac line in the design required for the Beumer konterpac (R) process. Because of the use of the hood oven instead of a tunnel oven, stations for reshaping the recesses and cooling of the package base are not required here either.

A comparison of both systems shows that the konterpac (R) line is somewhat longer than a line working by the flat film method. However, through the use of the hood oven, it is still shorter than a line which requires stations for subsequent treatment of the package base, which in turn require not only additional building space but also greater investment in machinery and increased machine maintenance.

Reference has already been made to the various film requirements of the two processes. It is possible, in order to reduce the film used in the konterpac (R) process, to shorten the second hood so that it only overlaps the first hood as far as the piece of flat film does with the flat film method. However, this does not have any significant advantages in practice, but even has the disadvantage that the upper surface of the package has a seam and, in addition, a somewhat expensive second automatic hood forming machine is required as compared to the flat film placer.

3.2.3 Shortened Lines for Reduced Capacity

The capacity of the Beumer Paketpac (R) line working by the above flat film and konterpac (R) processes is 60 to 70 packages per hour. Such a high capacity installation can be too large for operations with average or low bagging output. While in the cement industry, as a rule, reduced capacity lines are not acceptable, lower hourly output is not unusual in the chemical and related industries.

There are two possibilities of reducing machinery investment, operating expenses and space requirements. On the one hand, parts of the line can be run in reserve, on the other hand the circulation principle can be used, whereby the material passes through certain components twice. It is possible to use the reversing operation and the circulation principle with both the Beumer konterpac (R) and flat film processes.

A line working in reverse operation is sketched in Illustration 13. Eliminating the last flat film placer (flat film process) or the second automatic hood forming machine (Beumer-konterpac (R) method) and of the se-

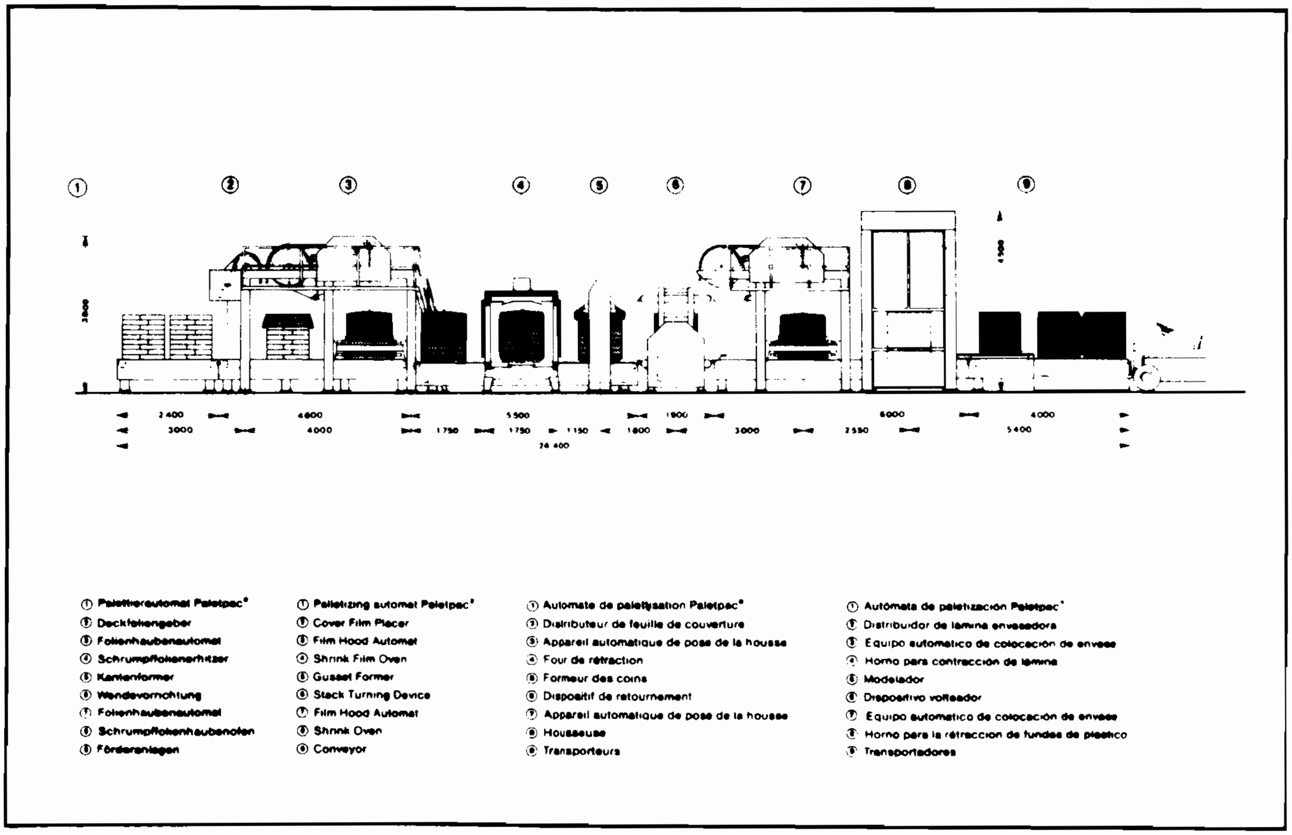
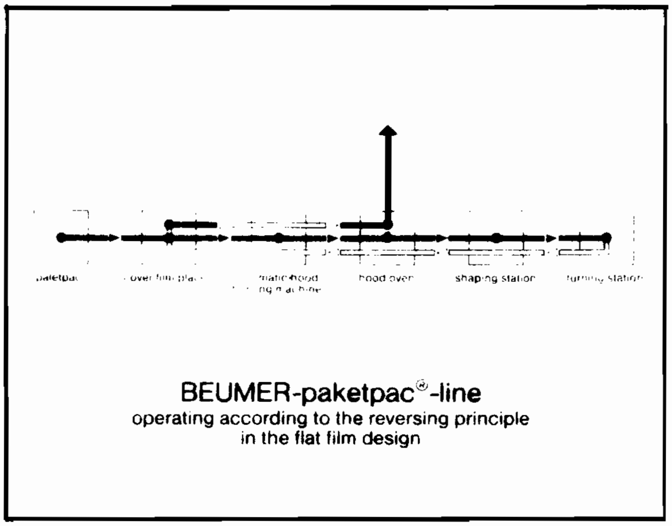


Illustration 12

cond film heater, the package is reversed after passing through the turning device and brought again to the front of the first flat film placer (flat film process) or to the first automatic hood forming machine (Beumer konterpac (R) method.) It is then covered again with a piece of flat film or a hood and heated. The package is then brought through the shaping and turning stations, which are now not in operation. For heating the film, a hood oven which is lowerable in two stages should be used exclusively, in order to avoid in this case as well the necessity of subsequent treatment of the package base. As an alternative to the two-stage lowerable hood oven, a shrinking column should also be used with burners which only heat the upper part of the stack when it passes through the second time. A line working in reverse operation can have a reduced capacity of 15 to 20 packages per hour. Savings in machinery investment are approx. 15% compared with the full-length Beumer-konterpac (R) line and approx. 10% compared with the full-length flat film line. The building length can be reduced by about 6 m with the konterpac (R) process and 4 m with the flat film method.

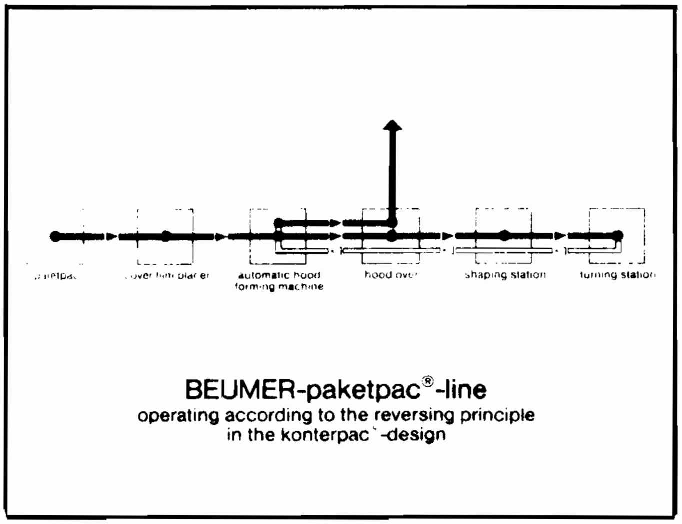
With a line working on the circulation principle (Illustration 14), the same machine components are eliminated as in the case of the reversing method, however, some additional conveying equipment is necessary. This results in a considerable increase in capacity over the installation working in reverse operation. For the heating elements, the same applies as in the case of the reversing principle. Capacity of the circulating line is approx. 30 packages per hour. Savings in machinery amount to approx. 10% with the konterpac (R) process and approx. 5% with the flat film method. Compared to the full-length konterpac (R) line, approx. 10 m less building length is required and, with the flat film method, approx. 8 m are saved. However, the width of the installation is increased by approx. 3.5 m.

The altered version of the Beumer Paketpac (R) line are mainly interesting from the point of view of the reduction in building length in the case of the flat film process and the reduction in machinery investment with the konterpac (R) method.



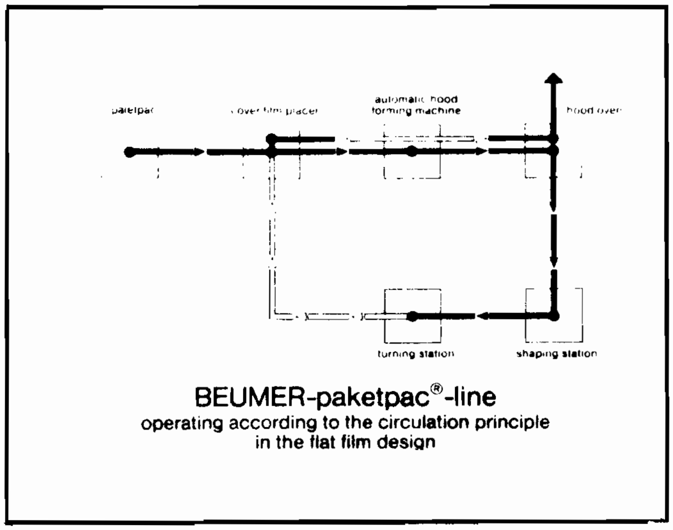
BEUMER-paketpac®-line
operating according to the reversing principle
in the flat film design

Illustration 13A



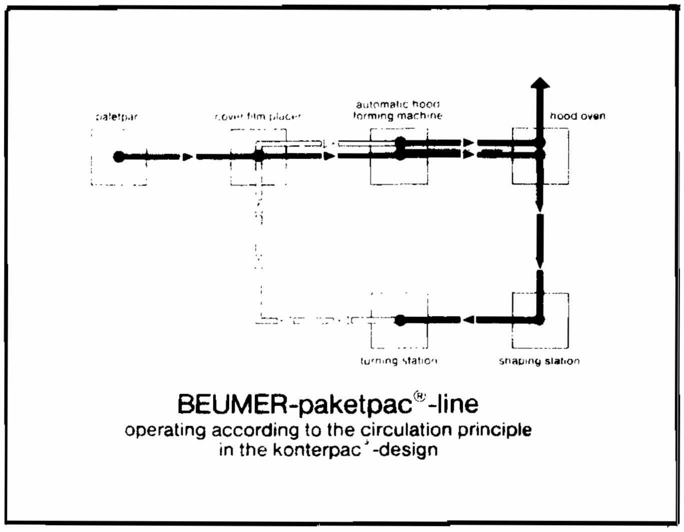
BEUMER-paketpac®-line
operating according to the reversing principle
in the konterpac®-design

Illustration 13B



BEUMER-paketpac®-line
operating according to the circulation principle
in the flat film design

Illustration 14A



BEUMER-paketpac®-line
operating according to the circulation principle
in the konterpac®-design

Illustration 14B

4. The First Installation in the West German Chemical Industry — Project Data for a Fully Automatic Palletizing and Packing Line for PE-Bags operating according to the Beumer-konterpac (R) Process

After thorough market research, the Chemische Werke Saar-Lothringen GmbH, D-6643 Perl, a subsidiary of CdF Chimie S.A., Paris, decided to install a fully automatic installation for bag palletizing and palletless shrink film wrapping in order to improve the efficiency of their bag processing. The decision was made in favor of a Beumer paketpac (R) line working according to the Beumer konterpac (R) process (Illustration 2).

The packing installation begins with a Beumer paletpak (R) palletizer type 1200/1600 D (Illustration 15), chosen for its careful bag handling qualities and for its modern bag turner (Illustration 9). The bag stacks then pass through the Paketpac (R) line, which has already been shown in principle in Illustration 12. This line differs from the full-length line in the illustration in that the hood oven is located at a right angle to the second automatic hood forming machine, as the existing palletizing and storage hall do not allow for a full-length installation. Adjacent to the hood oven are 3 waiting positions for 2 finished packages each (Illustration 16). The packages, which are standing in pairs, can be picked up by a fork lift with corresponding long forks (Illustration 16). The packages are then stored either in the Paketpac hall or in the open near the spot where they will be loaded onto railcars (Illustration 17).

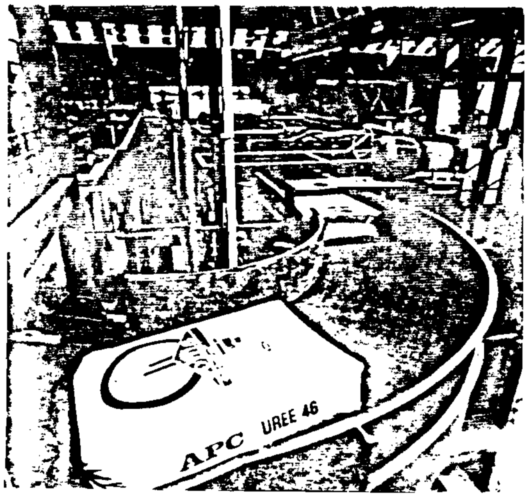


Illustration 15

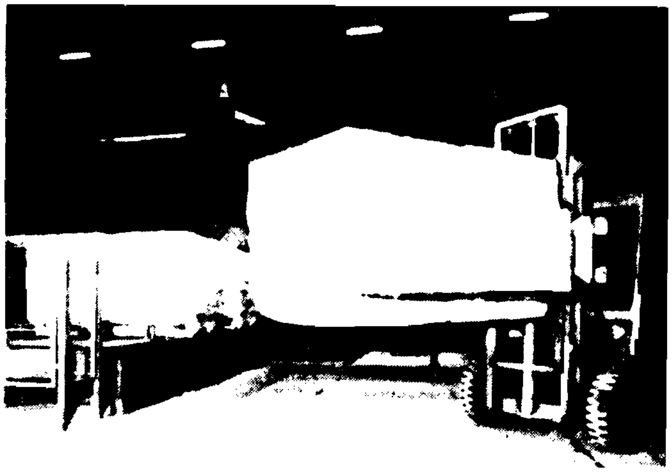


Illustration 16

Table 2
Project Data for a Paketpac (R)
Line Operating at a German Chemical Firm

Product	urea prills
Bag type	valve bag
Bag material	PE
Bag weight	50 kg and 40 kg
Bag dimensions (full)	50 kg bags, 5-fold bonded pattern: 72 x 48 x 20 - 21 cm
	50 kg bags, 3-fold bonded pattern: 84 x 42 x 20 - 21 cm
	40 kg bags, 5-fold bonded pattern: 69 x 46 x 17 - 18 cm
Packing pattern	3-fold bonded pattern and 5-fold bonded pattern
Number of layers	max. 9 + 1,
	in practice:
	50 kg bags, 5-fold bonded pattern 6 + 1
	50 kg bags, 3-fold bonded pattern 7 + 1
	40 kg bags, 5-fold bonded pattern 8 + 1
Stack dimensions	50 kg bags, 5-fold bonded pattern: 144 x 120 x approx. 140 cm
	50 kg bags, 3-fold bonded pattern: 126 x 84 x approx. 160 cm
	40 kg bags, 5-fold bonded pattern: 138 x 115 x approx. 180 cm
Stack base dimensions	50 kg bags, 5-fold bonded pattern: 120 x 120 cm
	50 dkg bags, 3-fold bonded pattern: 84 x 84 cm
	40 kg bags, 5-fold bonded pattern: 115 x 115 cm
Palletizing capacity	1200 bags/hour
Packaging capacity	40 packages/hour
Film material	high pressure polyethylene shrink film

Table 2 (continued) **Project Data for a Paketpac (R) Line Operating at a German Chemical Firm**

Film thickness	200 my
Electrical rating of installed machine incl. heating	approx. 200 kW
Required air pressure	6 bar
Air consumption	approx. 25 Nm^3/hour
Electrical insulation	IP 54
Surface treatment	zinc plated and several coats of paint
Surface area requirement	incl. 3 x 2 removal points, platforms and safety clearances: approx. 200 m^2

The 40 kg bags will most likely be preferred in the future.

The line can be run using pallets as an alternative to be palletless process.

The Paketpac (R) line was delivered in the Fall of 1981 and put into operation in November/December of that year.

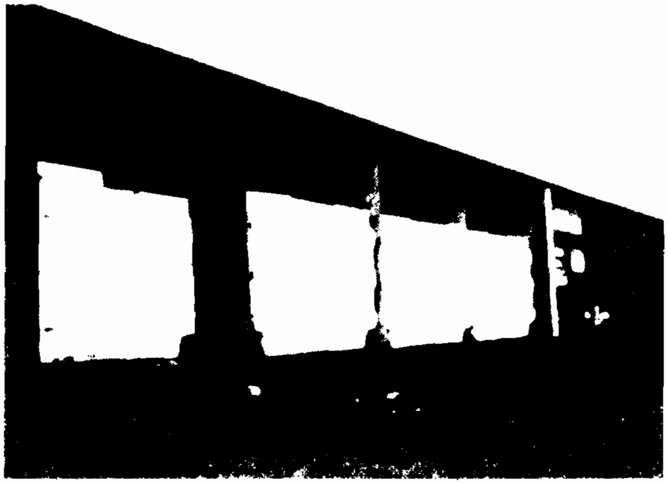


Illustration 17

Illustration 18

5. The First Packing Line in the West German Cement Industry operating according to the Beumer Flat Film Process — Project Data

The Paketpac (R) line working according to the Beumer flat film process is in operation at a cement plant near Beckum, after it had been previously completely assembled in the manufacturer's plant for experimental purposes and for careful synchronization of all components (Illustration 17).

Illustration 18 shows the placement of the final flat film by the film placer integrated with the hood oven. During the lowering of the hood oven, the flat film, which has been precisely measured and positioned beforehand, is separated from the film supply.

Illustration 19 shows the intermediate storage of packages, which were produced in this line, at a construction site.

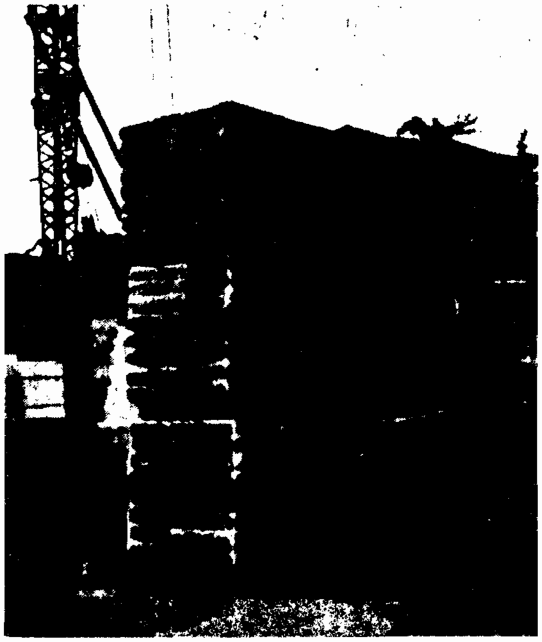


Illustration 19

Table 3:
Project Data for a Paketpac (R)
Line in a German Cement Plant

Product	portland cement
Bag type	valve bag
Bag material	paper, 2 - 5 layers
Bag weight	50 kg
Bag dimensions (full bag)	600 x 400 x 130 mm
Packing pattern	5-fold bonded pattern
Max. number of layers	9
Max. stack dimensions	1000 x 1200 x 1200 mm
Stack base dimensions	1000 x 1000 mm, chimney pattern
Packaging capacity	60 - 70 packages/hr.
Film material	high pressure polyethylene shrink film
Film thickness	200 my
Installed electrical rating	210 kW
Required air pressure	6 bar
Air consumption	20 m^3/hr.
Electrical insulation	IP 44
Required surface area	incl. 2 removal points, platforms and safety clearance approx. 82 m^2

6. Summary

The palletless shrink film wrapping process for bag stacks offers a new shipping method for bagged material in large bundless. The disadvantages of the labor intensive individual bag loading process and the frequent problems involved with the use of pallets can be avoided. The large bundles are waterproof so that it presents no problem to store them outdoors. The stability of the packages allows for frequent transfer of the packed material as well as for stacking of the packages during storage and transport.

This process is already in use in the chemical and cement industries in West Germany.

The Paketpac (R) lines working according to the Beumer flat film and Beumer Konterpac (R) processes differ in the way in which the package surface is covered with film. The flat film process makes use of a piece of flat film which overlaps the stack on all sides, which is then welded to a hood which was drawn over the stack previously. With the Beumer Konterpac (R) method, a second hood is drawn over the package after it has passed through the bag turning station. Both lines make use of a lowerable hood oven instead of a tunnel oven in order to avoid deformation of the stack base after it has been shaped. Therefore, a reshaping and subsequent cooling of the base area is not necessary.

The most relevant project data for the Beumer Paketpac (R) lines operating in a plant in both the West German chemical and cement industries are given as examples.

MODERATOR SMITH: Thank you Bob. I think, we will all agree, "Bagging and Bag Handling" has come a long way in the last number of years, eliminating or reducing a very heavy and arduous part of the fertilizer operation, as well as for other industries.

We also have with us Gernot Schaefer, Managing Director, Beumer Maschinenfabrik K. G. and Anton Spiekermann, Manager of Engineering, Haver and Boecker; both headquartered in West Germany. Will you please stand up. (Applause) Questions please.

QUESTION—BILL COATES - DEKKER REUCHLIN - HOLLAND: Have you been successful in developing a value sack for hygroscopic fertilizer? I noted that I.C.I. was still using a heat sealed bag. Does this mean that I.C.I. has not been satisfied with the value bag?

ANSWER—ANTON SPIEKERMANN: I.C.I. are using open mouth flat bags. In U.K. costs are 15 to 20 percent less than other bags and that is the reason why.

QUESTION—T. SINGH - ZUARI AGROCHEMICAL - INDIA: In the presentation it was stated that the accuracy of the machine is about 20 grams. How often is the machine to be calibrated?

ANSWER—ANTON SPIEKERMANN: The machine calibrates itself. It has an automatic correction device. This means for each weighing it corrects itself. It is not necessary, to correct for each weighing. You can correct every ten times or every ten minutes. It is up to you or up to negotiations how we deal with it. The electric weigher, which we have shown in the film has an output of about 800 weighings per hour, therefore, if you correct everytime — the output drops.

MODERATOR SMITH: We had better move on with the program. We certainly thank you Anton Spiekermann, Gernot Schaefer and Robert Vrable. Your two part discussion covering "Modern Packaging Systems" was very interesting. Thank you. (Applause)

MODERATOR SMITH: Many of you, who have operated plants having bagging equipment, know that the paper used, and its construction, are also critical to productivity, cost control and customer complaints.

St. Regis Paper Company has long served the fertilizer industry. Our next speaker is S. G. Stephens, Director of Licenses Relations and Manager of Technical Services, for St. Regis. He is a graduate of Yale University and has also served St. Regis as Marketing Manager. He will inform us about Stress Kraft a new production medium. (Applause)

Stress Kraft Technical Results

S. G. Stephens

Good Morning. I'm going to cover today some of the specifics regarding our new Stress Kraft.

You've heard a great deal about this paper and the machine called P5, which you will take a tour of later today. The width of the machine is about 9 meters — speeds are up to about 915 meters per minute and it has a production capacity of approximately 215,000 metric tons per year. The basic weight capability of this machine will be from 81 GSM to 163 GSM of shipping sack paper. It will manufacture this paper exclusively.

As you know, St. Regis has discontinued the manufacture of extensible paper and instead will be supplying Stress Kraft.

There are many important aspects of the machine which impart to the paper its impressive physical properties.

This slide shows the ten basic steps involved in the production of Stress Kraft. I'll take each step and describe it briefly and relate to you its importance in providing these properties.

(Step #1) During preparation wood chips are moved by conveyor belt rather than blowers. Belt conveyor guards against chip damage, such as the formation of "fines", or damage to fiber segments that lack strength and harm the tearing strength of paper. Wood chips are then screened to remove "fines" and the over-sized chips to provide uniform wood chip size for pulping. This results in uniform fiber characteristics after the pulping process.

(Step #2) In the manufacturing process two vessels are used for digesting, or cooking, the wood chips. These are Kaymr Digesters the first vessel impregnates the chips with cooking chemicals and the second vessel dissolves the undesirable binding substance in the wood, call lignin. After cooling the residual liquor is removed from the pulp in a third vessel without exposure to air by a process called diffusion washing. This procedure maintains the fiber strength.

(Step #3) In the refining process the primary fiber wall is removed through high consistency refining. Conventional refining systems abrade the primary and secondary walls of the fiber, but with Stress Kraft a portapulper is used to knead the fiber against itself while increasing pressure with an ever-diminishing sized screw. This process removes the primary wall with a minimum of fines, thereby improving tearing resistance while minimizing the increase in the paper's air resistance. The squeezing process makes the fiber tougher, resilient and able to absorb tearing energy by imparting dislocations in the fiber, which causes greater shrinkage of the wet web during drying. Then the fiber is developed and hydrated in low consistency refining to obtain the properties desired.

(Step #4) The next step in the process is forming — this produces a uniform mat of dispersed fibers. (Wet web uniformity is essential for uniform drying and point-to-point uniformity in the final product.)

(Step #5) The fiberous mat is then pressed to remove water and initiate the forming of fiber-to-fiber bonds. At this state uniformity is the desired element. We use the latest state-of-the-art press with a variable crown press roll to assure uniformity of moisture across the complete web.

(Step #6) A minimum of open draws ensures that the tender wet web is not robbed of its potential strength by stretching. The wet web is carried on felts into the dryer section from the press section.

(Step #7) Three gauges continuously monitor web moisture to allow its control across the web, and to ensure correct moisture levels into and out of the Flakt Paper Dryer where shrinkage is very much moisture related. Uniform Shrinkage depends on even cross-web moisture which insures uniformly high stretch in sack paper.

(Step #8) A breaker stack press is located immediately ahead of the Flakt Paper Dryer to control final web density. A superior strength sack paper must be controlled to a specific density. Too low a density will result in strength loss, while too high a density will cause high air resistance in the paper. High air resistance may impede the filling of valve type sacks, such as those used for cement. Also, the embossing roll for manufacturing ribbed stress Kraft is located in this section.

(Step #9) Tension-free drying in the Flakt Paper Dryer allows the majority of the web shrinkage to occur in a free state, greatly enhancing tensile energy absorption. The paper runs through the dryer on a cushion of air about 1/10th of an inch above the blowers.

(Step #10) In coventional papermaking when the web is pulled through the dryers from section to section, it stretches and weakens, losing some of its potential strength. However, with Stress Kraft, shrinkage occurring in the Flakt Paper Dryer continues until it is finally dried and on the reel. Web contraction is allowed to continue for best quality. The digital drive on the P-5 machine allows for precise sectional speed controls, resulting in a sheet with a higher degree of stretchability.

This stress-free drying process takes place at the precise moment when the web is most prone to shrink. This results in high stretch and tensile energy absorption, especially in the cross machine direction.

The 10-step process results in a superior shipping sack paper where the cross-directional tensile energy absorption properties have been substantially increased. This slide shows the cross-directional strength for 50 lb. natural extensible and 50 lb. natural shipping sack on P-4 and P-3 by specific reel position, as you will note on the bottom. The green curve is for extensible; the red for natural shipping sack. In the cross-direction the edges of the web are free to shrink and this results in an average stretch of about 5½% on flat draft and about 6 to 7% on extensible. In the center of the web drying is restrained and cross-direction strength is reduced 40 to 45% for both grades.

You will note that the Stress Kraft in the 50 lb. grade will have a minimum of 10.5 ft. lbs. per ft.^{2} T.E.A. in the cross-direction. The minimum P-5 shipping sack specification will require 90% improvement in the cross-direction T.E.A. from conventional Kraft.

Before going further, perhaps a little background of the various elements that went into the concept of Stress Kraft is in order.

As you know, we have been monitoring the concept of Flakt dried paper for years, especially that produced by Korsnas. In the spring of 1979 our Pensacola pulp was shipped to Norway for a trial at the Randhelm Mill, which has a Flakt Dryer. It was disappointing as only about 70% of the desired T.E.A. properties were obtained. The primary cause was attributed to improper refining.

The Kraft Division then considered sending chips from Pensacola to Lapaz, Canada, where they also have a Flakt Dryer. However, after consideration of their facilities we decided that they, too, did not have the refining capabilities desired and this idea was dropped.

The Kraft divison then decided they could produce a "Tension-Free" dried paper at their own Ferguson Mill. This decision was based largely on their efforts of ten years ago when they developed high-performance paper. The major difference this time was to split the web at the wet end with a conventional squirter and with slack draws by controlling the speeds of the rollers in the drying section they were able to produce in effect a "pilot plant" Stress Kraft, although in this case a highly expensive pilot plant. This then is the paper that the bag division has been conducting all the bag tests and trials on since January, 1980.

As mentioned previously, by utilization of these processes allowing more shrinkage, the 10.5 ft. lbs. per sq. ft. of cross direction T.E.A. was accomplished with this simulated Stress Kraft. The Kraft Division actually exceeded their goal, which was 90% of the T.E.A. set as a tentative specification.

Laboratory Testing Program

Next I would like to discuss our laboratory testing program. Having achieved the essential strength and performance properties we felt desirable, the first order of business was to determine just how well the simulated Stress Kraft made at Ferguson would perform when converted into various types of shipping sacks.

The 3-ply 50 lb. (81 GSM) Stress Kraft was compared against the 3-ply 50 lb. (81 GSM) extensible, a 3-ply 60 lb. (97 GSM) flat Kraft, and a 4-ply 50 lb. flat Kraft in pasted valve bags.

Slide 6: As you see here, this slide shows drop test results for the sewn open mouth bags which were filled with 57 lb. (25.9 KG) of calf feed.

The drop tests were encouraging enough to lead into the second phase of the lab testing program. This phase was to determine specific basis weight constructions for target markets. For this 81, 97 and 114 GSM paper was made at Ferguson, shipped to Pensacola and then converted into bags and tested. The following slides show some of these results:

Slide 9: This is a clay mineral slide — 2/50 Stress Kraft versus 2/60 natural Kraft pasted valve bags for lime. As you can see, the Stress Kraft out-performed the present construction.

Slide 10: This is a feed slide which shows 2/60 Stress Kraft pinch bottom versus 2/60, 1/50 natural Kraft for 57 lbs. of feed. Please note how the Stress Kraft bag out-performed Ralston's current feed bag.

slide 11: this is a flour slide which shows a 1/60, 1/70 Stress Kraft pinch bottom versus 1/60, 1/50, 1/60 natural Kraft for 100 lbs. of flour. The Stress Kraft bag performance is quite comparable to the present construction used for flour.

Slide 12: The sugar slide — this slide shows 160 lb. Stress Kraft bag versus a 210 lb. natural Kraft bag for sugar. This 210 lb. is the minimum natural Kraft requirement for 100 lb. of sugar for shipment by rail. The results are impressive in demonstrative Stress Kraft performance.

In addition to the above, we tested many constructions in a number of different basic weight combinations in all style bags, tests that we hoped would answer specific questions that were raised relative to performance as our testing program proceeded.

Improvement of Sewn End Strength

During our testing we found there was some concern regarding performance of the end strength in 2-ply SOM Stress Kraft bags. Consequently a study was undertaken to see if there was cause for such concern. Such items as tape, thread, stitches per inch, etc. were all investigated as a result of this study we are recommending the following:

A. A 90 lb. minimum basis weight tape, which can be either flat or crepe.
B. 12/5 cotton or 50/50 cotton-polyester thread.
C. 3.0 stitches per inch with the smallest size needle that will give adequate sewing.
D. The length ratio of the needle to looper should be 2½ to 1. The looper should be about 4 to 5 inches longer than the length of the tape. This is the same as current recommendations.
E. Filter cord can be crushed paper, cotton or folded filter band.
F. Single thread is also acceptable, which allows for grip-n-rip.

Low Temperature Testing

Another concern was to determine if there was a problem with Stress Kraft in low temperatures as far as performance was concerned. Drop test studies were conducted at a local meat packer. 2/60 Stress Kraft bags were drop tested against 3/50 natural Kraft bags. The bags contained approximately 50 lbs. of SR-9 hot melt pellets. Bags were first placed in the freezer and then were drop tested at a temperature of approximately 0°F. The results showed that the Stress Kraft bags were equal to the natural Kraft bags.

To confirm these laboratory results a pallet load (20 each) of the above bags were sent to our Omaha, Quincy and Salt Lake City bag plants for further drop testing and evaluation. The test consisted of storing the bags out on the shipping dock exposed to cold, and being handled by being re-palletized several times and finally drop testing. The tests were conducted in January and February of this year, and the weather conditions at the time of the test were: Omaha - sub-zero, Quincy - 6° and Salt Lake City about 25°F. The results confirmed that the Stress Kraft bags gave equivalent performance to the natural Kraft bags. The results of the tests in Omaha are probably more significant as the tests made there were under more severe conditions.

Compatibility with Extensible

Because there are no plans of producing bleached Stress Kraft in the foreseeable future, for our customers currently using a bleached outer ply we have investigated the compatibility of using bleached extensible as the outer ply in combination with inner Stress Kraft plies. Our tests show that extensible is compatible and it can be used as the outer ply. Therefore, all bleached outer ply sheets will be converted to bleached extensible when used with Stress Kraft inner plies. This can be either regular or embossed. However, we are not advocating that Stress Kraft and extensible be mixed indiscriminately in bags. The total properties in machine and cross-machine direction, along with T.E.A. would not permit this. This solution is intended only for the bleached outer ply.

Two-Ply Film Kraft Bags

As we got into the Stress Kraft program we became acutely aware that to convert the many 3-ply plus film bags to Stress Kraft constructions it became essential to us to have a two-ply film Kraft bag. Consequently a number of trials were conducted with the film as the inner ply and as the intermediate ply in both PBOM and PVE bags. For SOM bags this would not pose as a problem.

For PBOM bags our greatest concern was with the film as the inner ply, since we would have to flush cut the first film ply with the Kraft ply. As a result, the outer ply would be the only one holding the end closed.

Our drop test showed that there is adequate end strength in this regard and that the performance of a 2-ply PBOM bag should not be a problem with film as the inner ply. We are in the process now of field testing this particular construction with both Anheuser Busch and Reichhold. With respect to the film as the intermediate ply in a 2-ply PBOM bag, the film is flush cut and laminated to the back side of the inner Kraft ply, so there are two plies providing end strength here. Steve Keppel will be discussing in greater detail the stepping patterns on this.

For PVE bags, all our efforts have been directed toward solving the perforations of the film in the intermediate position, which is necessary for the HP cement bag. We have conducted a limited amount of trials in the field with successful results and Steve will be talking more about the specifics regarding this development. We believe it gives us a great plus in this regard, and the end result provides a package with a number of advantages:

A. Faster filling times because of better porosity.
B. More accurate weights because of less back pressure.
C. Improved strength due to the new stepping pattern.

We anticipate the porosity of the Stress Kraft produced on P-5 to be in the range of 35 seconds per 300 CC, so this should also provide us with a sheet which is porous enough for bags for cement, lime, etc.

Field Testing Program

Having completed the basic laboratory studies, the next phase of the Stress Kraft program involved confirming our laboratory results by conducting customer field trials. For this, target accounts were selected in the following major markets: Clay/minerals, cement, chemicals, feed, fertilizer, flour, grain, plastic, salt, seed and sugar. Trial orders of from 1-2MM bags were solicited. The bags were manufactured and they were field tested.

Leaving very little to chance, procedures were established to give strict control over all of these trials. Technical service monitored each factory order for proper specifications before releasing the order to the manufacturing plant. Sample bags were then sent to technical, where the quality of the bag was either accepted and the order released for shipment to the customer, or rejected to be made over again. The initial target account trials were evaluated by technical services, experienced plant and/or sales personnel.

Because of the strict control over this program, to date we have not had any failures, i.e., problems related to improper bag construction recommendations. We have encountered minor bag breakage due to skip longitudinal glue seams and inadequate spot and bottom pasting that were not evident in the sample bags checked by technical. Other damage due to snags, severe humping in the cars, punctures on conveyors, etc. were encountered, but had nothing to do with the Stress Kraft paper.

Now, to summarize on a general basis, the following are some basic do's and don't's, and other bits of information that have been generated through the many studies we have conducted:

1. Stress Kraft can be capcoted.
2. Stress Kraft can be foil laminated.
3. Wet strength Stress Kraft will be available.
4. We expect the slide angle of Stress Kraft to be comparable to presently manufactured Kraft.
5. The porosity of Stress Kraft is expected to be comparable to Kraft presently being manufactured about 35 second per 300 CC.
6. Bags currently having a bleached outer ply will be converted to bleached extensible outer ply-regular or embossed.
7. We can and have all styles of bags, including bags with PE film, foil and valeron as a reinforcing ply.
8. We are currently staying away from pet food and lawn and garden bags. Stress Kraft is not compatible with Flexo, Greeseproof, or clay coated sheets, and further studies are needed

before any final determination can be made.

9. We are also currently staying away from D.O.T. hazardous material bags requiring special permits. These are the bags that have the basic weights, barriers, etc. specified. For example, caustic soda, 44-D bags for poisons, etc. These specialized items will be studied at a later date.
10. Also, we have purposely shied away from government bags calling for specific basic weights and bag constructions. Current projects are underway to determine Stress Kraft bag constructions for the CSM type bag, flour and bulgur, and we have had excellent initial success in this regard to date.
11. While this may not be a big problem in your respective countries, the shipment of commodities is highly regulated in the United States. In this regard we have reviewed essentially all the commodities that are presently put in bags. With most commodities we see no problems converting to Stress Kraft. However, there are items that will require test permits, and we have been dealing with the rail and truck classification boards to help our customers obtain these special test permits in order to get the packages approved for their specific commodities after an initial test.
12. Since there will be approximately a 20% reduction in basic weights, comparing Stress Kraft to the regular shipping sack, the number of bags per pallet can be increased by this amount. This can result in a decrease in the pallet cost to the customer by approximately 20%. Also, where bag storage is a problem Stress Kraft requires less space.
13. Depending upon how the customer currently ships his products, it is possible that some savings in shipping costs could be obtained due to less tare weight. This, however, will have to be determined on a customer basis since such things as the number of bags per shipment, present freight rate, etc. All have to be considered.
14. It is not anticipated that siftage will be a problem when converting from a 3-ply to a 2-ply bag. Our new stepping patterns for both pasted and pinch bottom bags provide adequate protection against sifting. Also, our tests have shown that the end strength is not diminished. In fact, with regard to converting information we do not anticipate any serious differences between natural shipping sack grades we have been converting and Stress Kraft. Specifics on ink consumption, plate wear, adhesive penetration, machine speeds, efficiencies, standards, etc., will be enumerated on by production.
15. To date there should be no problem on adjustments on customers packing and/or closing equipment by converting from natural to Stress Kraft. Stress Kraft bags work as well on the packers, conveyors and palletizers as well as natural constructions.

In essence with Stress Kraft we are promoting two things — equal performance at a lower cost or improved performance at the same cost. We are providing more packages per tree. In effect, providing an image of conservation of raw materials and energy.

We have found Stress Kraft to be an exciting new technical development that will significantly have an impact on the multiwall industry in the United States and, hopefully, world-wide.

Thank you. (Applause)

MODERATOR SMITH: Thank you, Sandy. That certainly sounds like a rather important development in packaging which is still very important to the fertilizer industry. Are there any questions?

QUESTION—TRAVIS BARHAM - ST. REGIS PAPER CO.: Will this paper be available to our competitors.

ANSWER: It will be available in the marketplace.

MODERATOR SMITH: Thank you very much, Sandy. (Applause)

Sorry, Slides were not available.

MODERATOR SMITH: In 1976 I had the pleasure of visiting the Kemira Oy Plant at Siilinjarven, Finland. One statistic that impressed me was that about 30% of the original capital cost of the plant was for environmental control equipment. In 1981, that percentage figure for environmental equipment is commonly experienced. I am particularly pleased that our next speaker, Timo Karjalainen is with us today to explain some of the conditions requiring their control program and especially the reasons for its success. Mr. Karjalainen achieved an M.S. Degree at the Technical University in Helsinki, Finland. He was employed in research and development in the electro-chemical field. In 1969 he went to Kemira Oy Siilinjarven Plant as a Chief of Laboratories. He is now responsible for pollution and quality control. Mr. Karjalainen, we welcome you to Our Round Table. (Applause)

Minimizing Effluent Discharge At Kemira Oy's Siilinjarven Works and Mine

Timo Karjalainen

Siilinjarven works and mine —
Kemira Oy's newest fertilizer plant

Kemira oy was established in 1920 to guarantee the fertilizer supply in Finland. In 1980 Kemira Oy's turnover was 2 400 million finnish marks and the company was employing over 7 000 persons.

The manufacture of fertilizers remains always the main line of production of Kemira Oy, although the product range covers today pest control chemicals for agriculture, titanium dioxide pigments, industrial chemicals, chemicals for water purification, viscose fibres and explosives.

The technical and economic expertise accumulated during the years has also made it possible to export know-how. In this respect the main fields are apatite beneficiation and fertilizer production processes. Kemira Oy's experts have accomplished such assignments for several countries, both through direct contacts and through the world bank. An NPK process has been sold to Denmark and a number of other projects are being prepared. Kemira Oy is ready to sell its pollution control technology as well.

Siilinjarven works and mine are Kemira Oy's newest fertilizer plant. The complex was commissioned in 1969. The local apatite deposit contributed largely to the choice of Siilinjarven as plant site. Siilinjarven works employ 650 persons and the production capacities are as follows:

Compound fertilizer	400 000 t/a
Sulphuric acid	290 000 t/a
Phosphoric acid (P_2O_5)	120 000 t/a
Nitric acid	110 000 t/a
Apatite concentrate (36% P_2O_5)	200 000 t/a

We have just started construction work on new extensions which will raise the capacities to:

Sulphuric acid	470 000 t/a
Phosphoric acid	180 000 t/a
Apatite concentrate	500 000 t/a

The Siilinjarven apatite deposit is large enough to allow exploitation at the increased capacity for over one hundred years.

Location of the works and water pollution control

Siilinjarven is situated in inner Finland, in a region rich in lakes. The lakes in the vicinity of the works belong to the Saimaa watercourse which is one of the largest in Finland. We are, however, at the northern end of the watercourse where lakes are shallow and water exchange limited. The lake from which the works take their raw water and into which they discharge the waste water in only a bay, seven kilometers long and less than one kilometer wide. The average flow is 0.15 m^3/s and as the works use 1.0 m^3/s, it is quite obvious that even small amounts of impurities will accumulate and result in lengthy alterations in the watercourse.

The eutrophication of the lake creates the biggest problem. Among the nutrients phosphorus is used in the manufacture of phosphoric acid and compound fertilizer at a rate of 200 t/d and as the phosphor discharges amount to 3 kg P/d, they represent only 15 ppm of the total used phosphorus. Since there is no other heavy industry at Siilinjarvi, the population was at first afraid of water pollution and therefore took a suspicious attitude to Kemira Oy. Now that they have noticed that the lakes are still good for fishing and bathing, we are starting to regain their confidence. Also the cattle continues to graze on the lake sides and to drink from the lake.

Waste water discharges

In 1964 a Water Act was passed in Finland. By virtue of this law e.g. a fertilizer plant has to apply the water court for a permit to take water from and to discharge waste water into a watercourse. The district body of the National Board of Waters sees to it that the terms of the permit are observed. This same body also has to give its consent to the plant's waste water and watercourse condition control programs.

In 1972 the water court of Eastern Finland granted the Siilinjarven works a permit fixing the limits of phosphor discharge: the daily mean, calculated on a six-month-basis, must not exceed 7 kg P/d. The discharge control results are to be monthly reported to the supervising authority. During the past decade and the commencing one phosphor discharges have always remained well below the limits. A minimum of 1 kg P/d was recorded in 1975-78. Since then the discharges risen to 2 - 3 kg P/d due to the increased manufacturing activity and to the aging of equipment. Leaks caused by aging are often very difficult to locate and to repair.

The Siilinjarven mine was granted the permit in 1980 and the production was started during the year. The waste waters differed considerably from the earlier effluents, but also the treatment techniques had been improved during the years. Naturally the terms of the permit were very strict.

The following table shows the terms of the permit of the mine and the results obtained in 1980 and during the seven first months of 1981.

	Discharge limits	1980	1.1 — 31.7.1981
QUANTITY	11 000 m^3d	4 400 m^3/d	7 057 m^3/d
P	0.4 mg/l	0.45 mg/l	0.38 mg/l
BOD7	10 mg/l	2.3 mg/l	3.8 mg/l
Solids	30 mg/l	48 mg/l	27 mg/l

During the first year the treatment techniques were improved and the results can be seen in the figures of the second year.

Condition of the watercourse

A control program was drawn up to allow the monitoring of the watercourse condition. Furthermore, fish, aquatic life in the lake bed and plankton have been analyzed. There are altogether 14 observation points, the most distant one being situated at 8 kilometers from the works. The observation points have been placed near sewer outlets, in lake hollows and in the streams bringing water into and taking water from the lakes in the region. Observations are recorded four times a year:

in winter and summer when water is in layers and in autumn and spring when water quality and temperature are even from the bottom to the surface. During the start-up of the plant there was a breakdown that resulted in increased phosphorus content at the northern end of the lake in 1970 and 1971. Thereafter no high phosphorus content figures have been recorded on a yearly basis. Before the construction of the works the phosphorus content of the lake was 20-30 u P/1. As to its water quality the lake provides a suitable environment not only for the local varieties of fish but also for lake trout that has been planted there and that seems to thrive in its new surroundings.

Water pollution control measures

Already in the design phase serious attention was paid to the pollution control problem. According to their nature the waters have been divided in three categories, each of which has its own treatment system. The arrangements are based on Kemira Oy's own research and design.

1) Cooling water

The works pump 3 600 M^3/h of cooling water from the near-by lake. This water is partly used at the power station for cooling the turbine and partly at the plant for different cooling purposes and for sealing vacuum pumps. The water flows in a closed circulation system and does not come into contact with process chemicals. Its temperature is slightly higher when it returns into the lake.

The same water is used for the preparation of the plant's domestic water and boiler feedwater. Although there are no contact points between the cooling water and the process chemicals, such undesirable contacts sometimes occur due to corrosion and breakdowns. To enable a quick location and reparation of leaks the sewer system is provided with an alarm device network. Thanks to this network it is possible to perceive and locate a leak immediately. The quality and the volume of the water returning into the watercourse are controlled daily through 24-hour sample analysis.

2) Waters with low nutrient content

Melting snow and rainfall on the plant area increase the amount of water containing some nutrients. This runoff water is collected through ditches, sewers and drains and then conducted to a chemical purification plant, which also receives the plant's domestic waste water after it has passed through a small capacity biological treatment plant. Here the phosphorous compounds are precipitated with lime. The amount of lime is controlled by means of the pH. the precipitate that is thus obtained will then be settled in the settling basins and pumped into the closed waste water circulation system. The amounts of phosphorus daily entering and leaving the purification plant are 20 kg and 100-200 g respectively, which means that the efficiency of the phosphor removal is 99.0 - 99.5%. Also the volume and the quality of water are daily monitored.

3) Acid and nutrient containing waste water

Waters containing acids and nutrients get onto plant floors during leakages and breakdowns. They are collected in a floor sump and led to circulating water basins. Process waters of the phosphoric acid plant are in a closed circulation system. In addition, runoff waters coming from areas where acids and fertilizers are stored and handled as well as waters from the gypsum waste dump area are conducted to the aforementioned basins. The basin water is used as make-up water in the process to maintain equilibrium in the closed circulation systems. Water leaves the system mainly in the form of phosphoric acid and gypsum waste and through evaporation in the fertilizer process.

Concentration plant area

Surface waters from the concentration plant area and leak water from the plant itself are collected in a settling pond in the yard and then reconducted into the process. The domestic waste water is pumped along with the refuse minerals to the attal dump where biological matter will decompose and oxidize.

Waste water from the concentration process

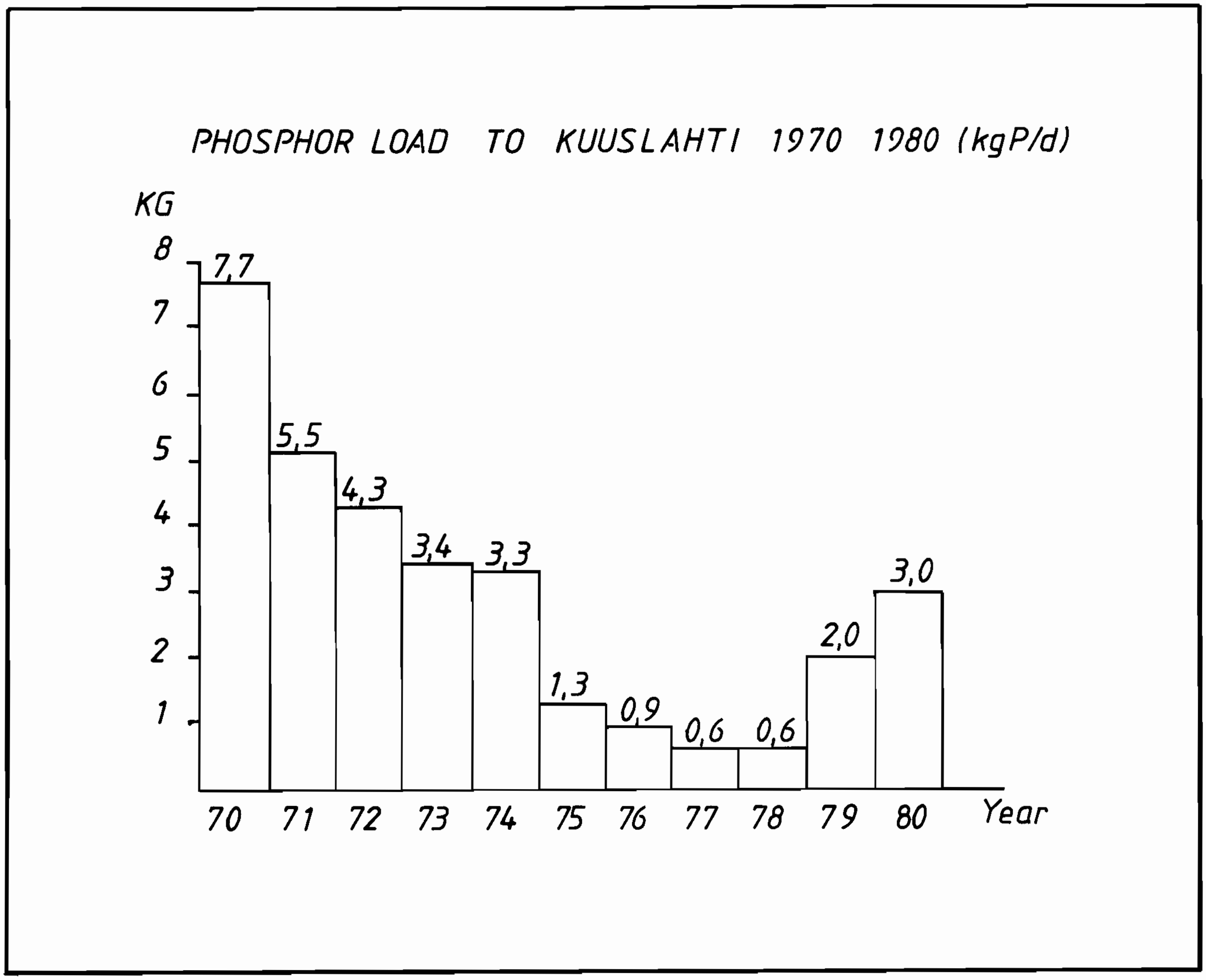
Considerable amounts of water are required in the concentration process for grinding and flotation operations. Once the useful minerals have been recovered, subordinate minerals are pumped as a water sludge to a 150-hectare dump area situated at a few kilometers' distance. There most of the rock material will settle and the flotation chemicals will decompose. Water that is now partly clarified is conducted into a settling basin where the settling goes on until the water can be recycled into the process. Due to melting snow and rainfall the basins contain, however, more water than is required for the process and as the rock material accumulating on the dump area decreases the storage capacity, the excess water is reconducted into the watercourse through a chemical purification plant. The quality and the volume of water are controlled by means of daily analyses.

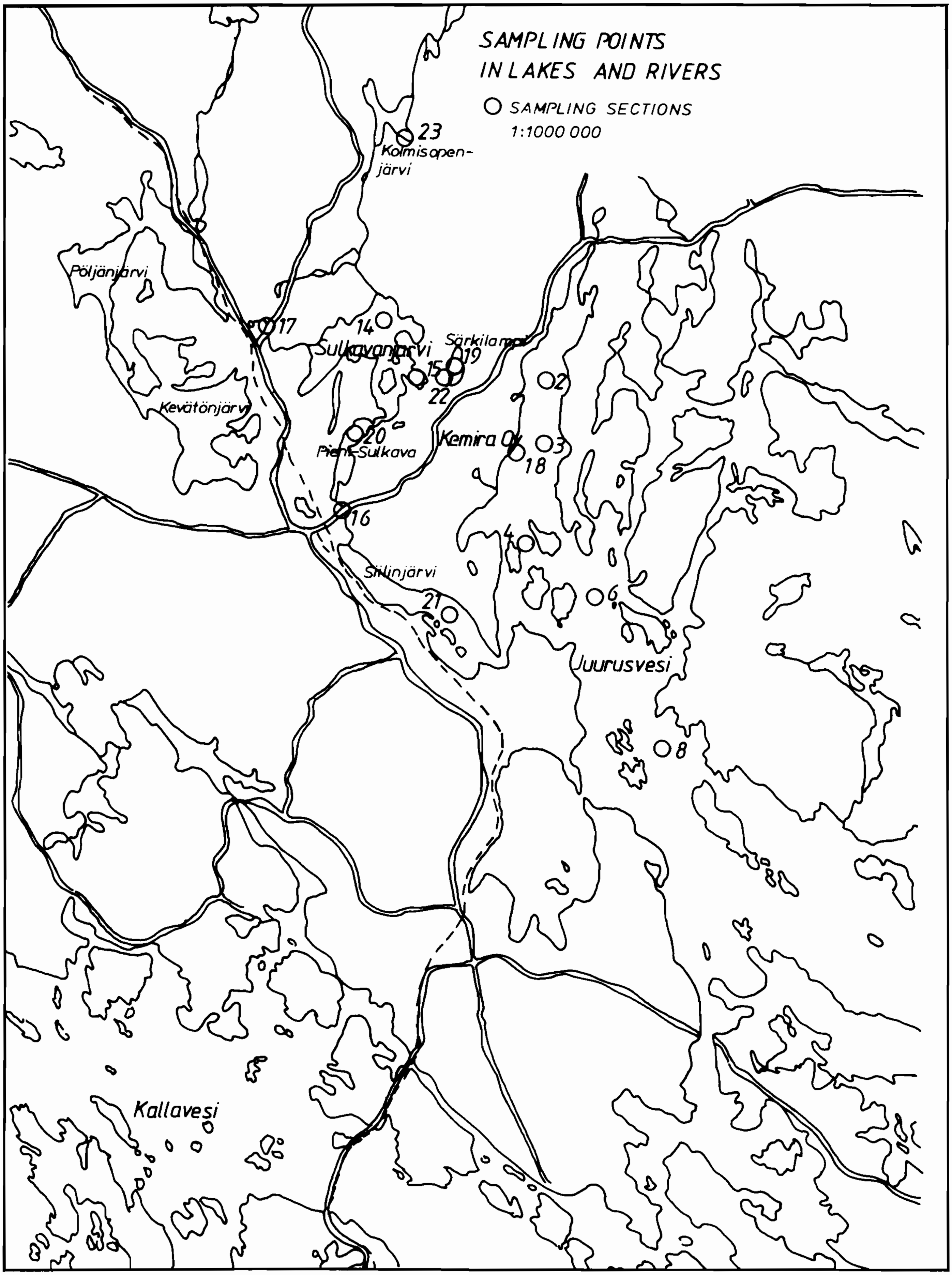
Conditions of success

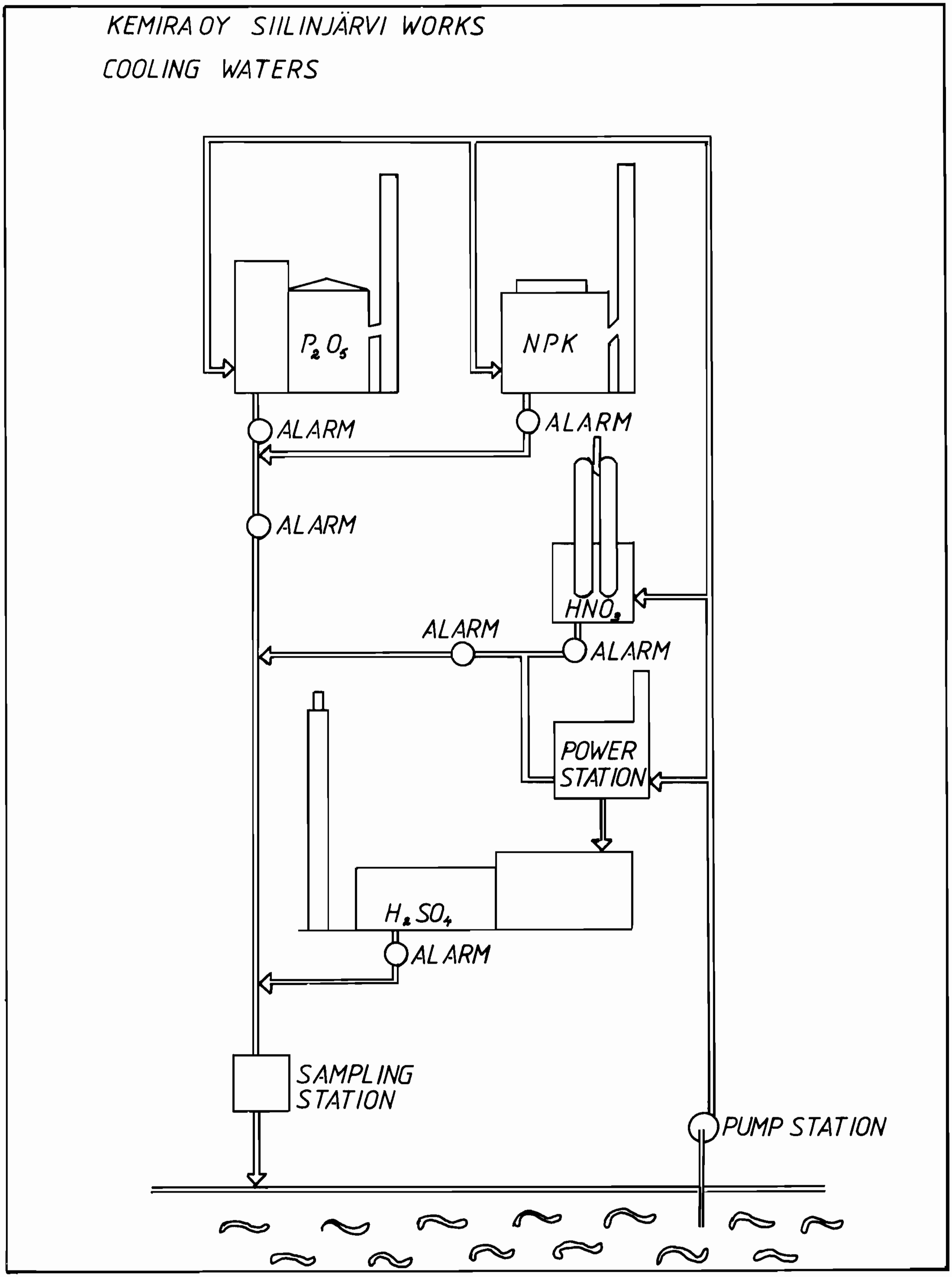
By adopting the best technical solutions and by improving them constantly according to the received feedback it has been possible to get good results. But not even the latest technology can guarantee the success unless there is a highly trained personnel with a sense of responsability and with a dedication to the environmental protection work, in other words people who wish to preserve their living environment healthy and comfortable.

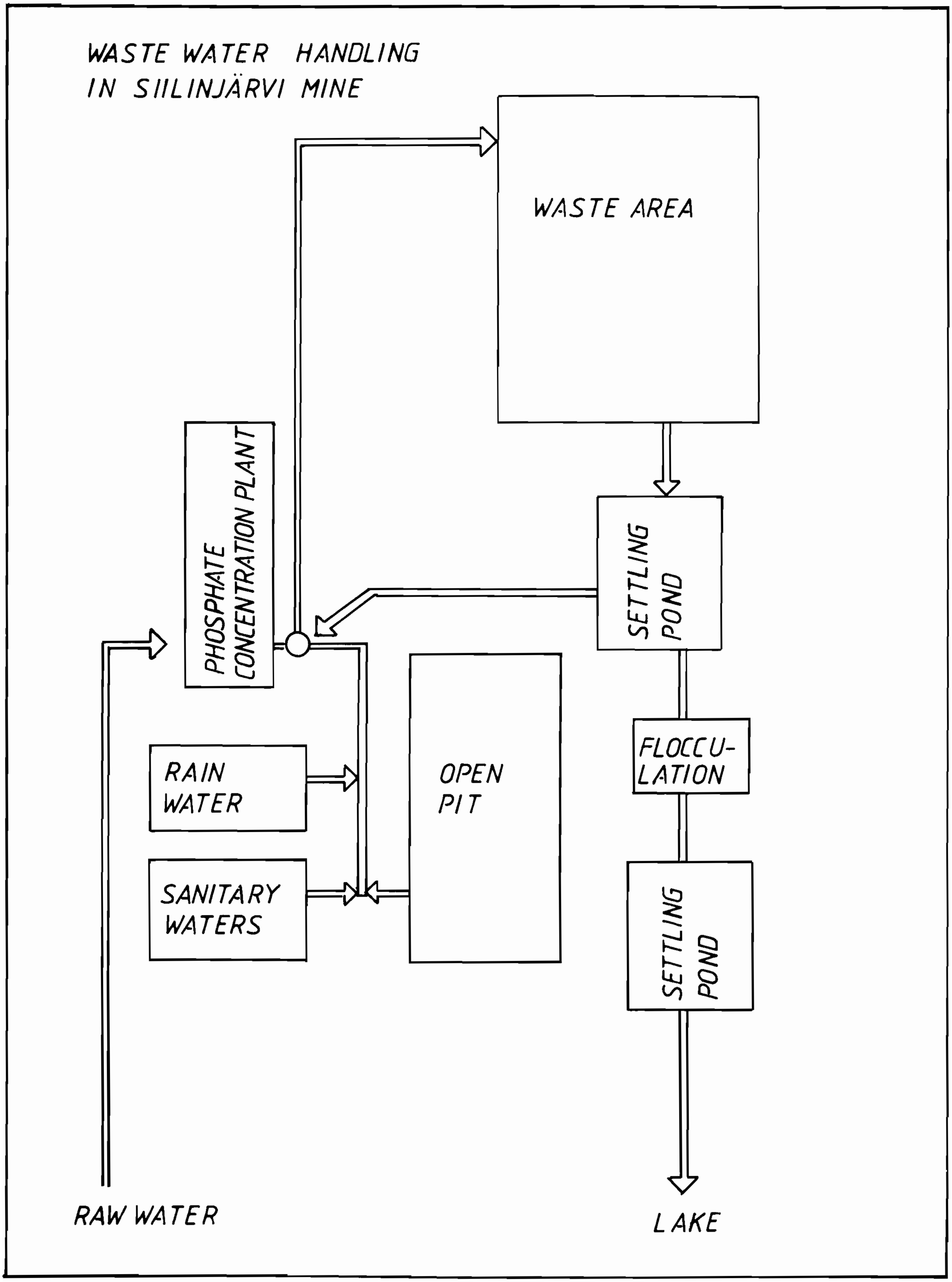
MODERATOR SMITH: Thank you Mr. Timo Karjalainen for that fine presentation. You can all understand why Kemira Oy is well known for its environmental programs. Are there any questions?

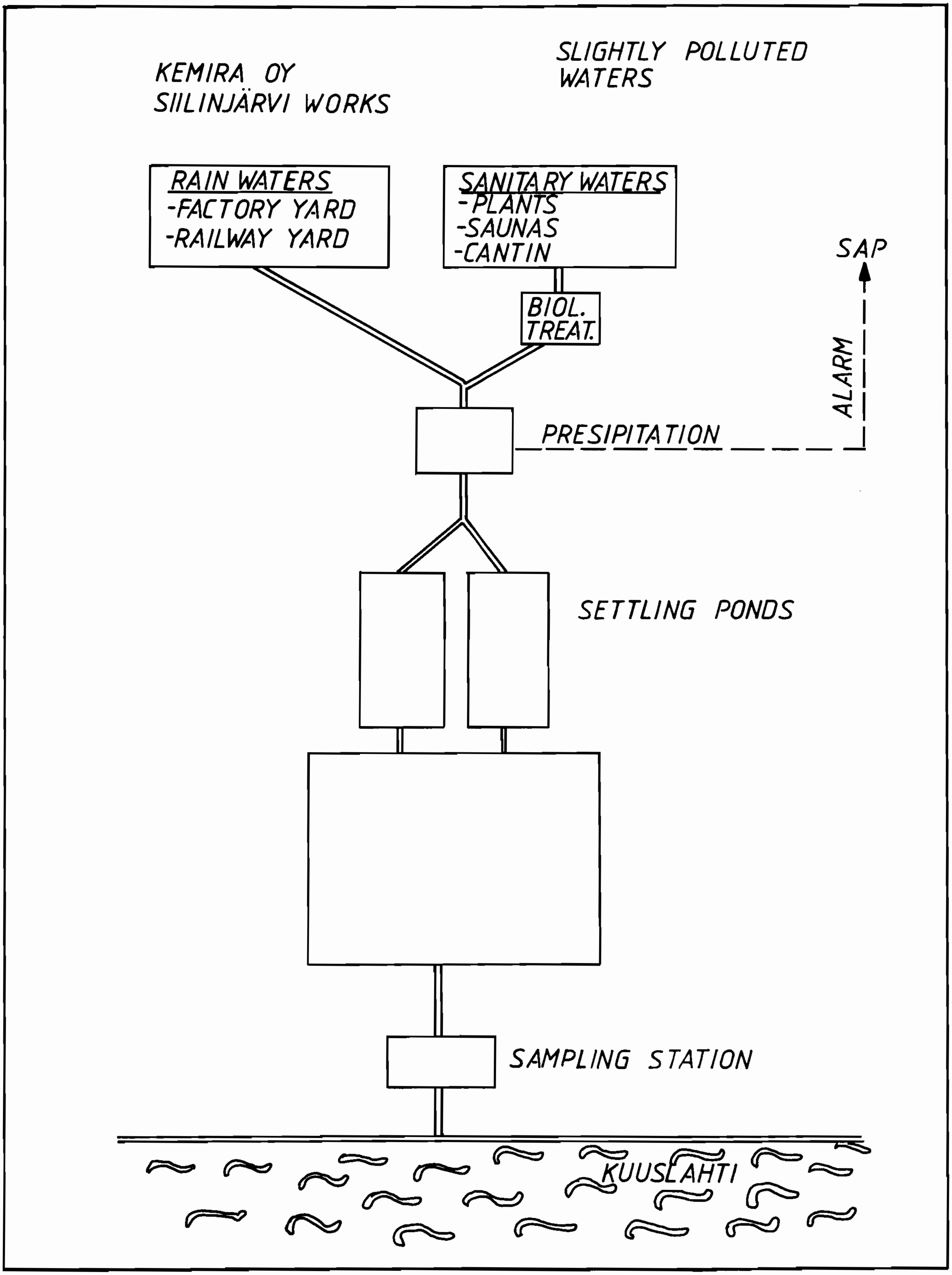
QUESTION FROM PIERRE BECKER—COFAZ FRANCE: What is the efficiency of your fluorine scrubbing system at the phosphoric acid unit? What sort of scrubber do you use and how many washing stages.


PHOSPHOR LOAD TO KUUSLAHTI 1970 1980 (kgP/d)
KG
8
7
6
5
4
3
2
1
7,7
5,5
4,3
3,4
3,3
1,3
0,9
0,6
0,6
2,0
3,0
70
71
72
73
74
75
76
77
78
79
80
Year


SAMPLING POINTS
IN LAKES AND RIVERS
○ SAMPLING SECTIONS
1:1000 000
23
Kolmisopen-
järvi
Pöljänjärvi
17
14
Sulkavanjärvi
Särkilampi
19
15
22
2
Kevätönjärvi
20
Pieni-Sulkava
Kemira Oy
3
18
16
4
Siilinjärvi
21
6
Juurusvesi
8
Kallavesi

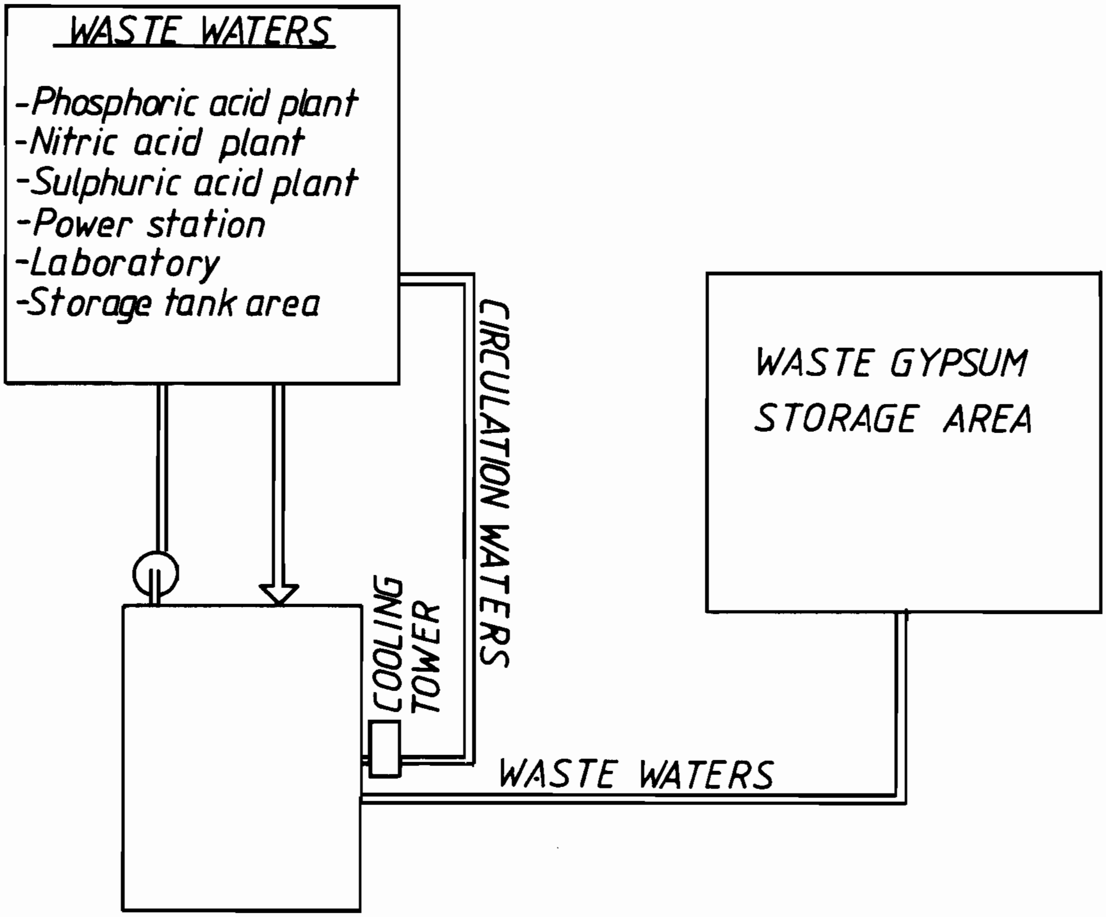

KEMIRA OY SIILINJÄRVI WORKS
COOLING WATERS
P_2O_5
NPK
ALARM
ALARM
ALARM
HNO_3
ALARM
ALARM
POWER STATION
H_2SO_4
ALARM
SAMPLING STATION
PUMP STATION

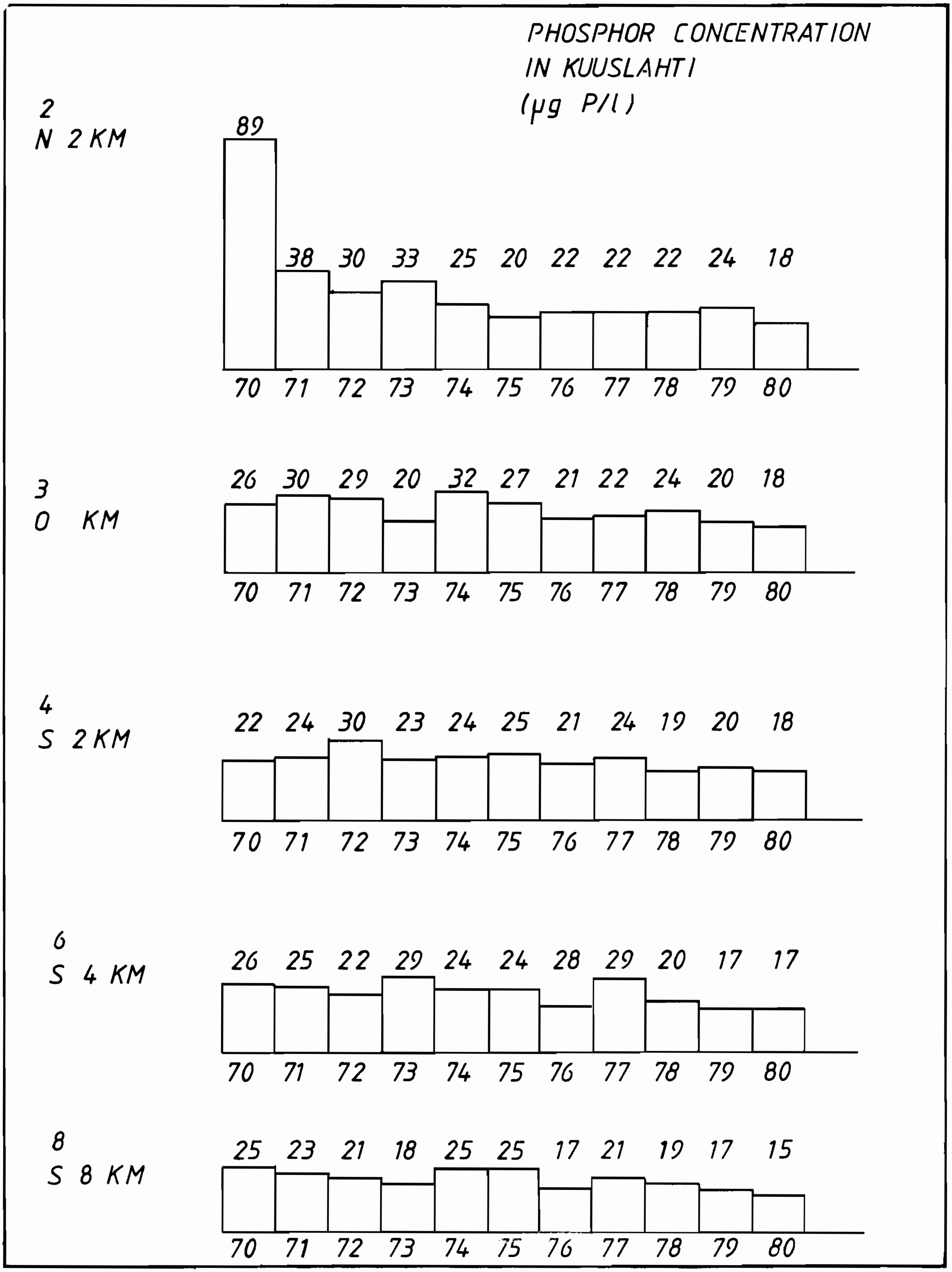

WASTE WATER HANDLING
IN SIILINJÄRVI MINE
WASTE AREA
PHOSPHATE CONCENTRATION PLANT
SETTLING POND
RAIN WATER
SANITARY WATERS
OPEN PIT
FLOCCU-LATION
SETTLING POND
RAW WATER
LAKE


KEMIRA OY
SIILINJÄRVI WORKS
SLIGHTLY POLLUTED WATERS
RAIN WATERS
-FACTORY YARD
-RAILWAY YARD
SANITARY WATERS
-PLANTS
-SAUNAS
-CANTIN
BIOL. TREAT.
SAP
ALARM
PRESIPITATION
SETTLING PONDS
SAMPLING STATION
KUUSLAHTI

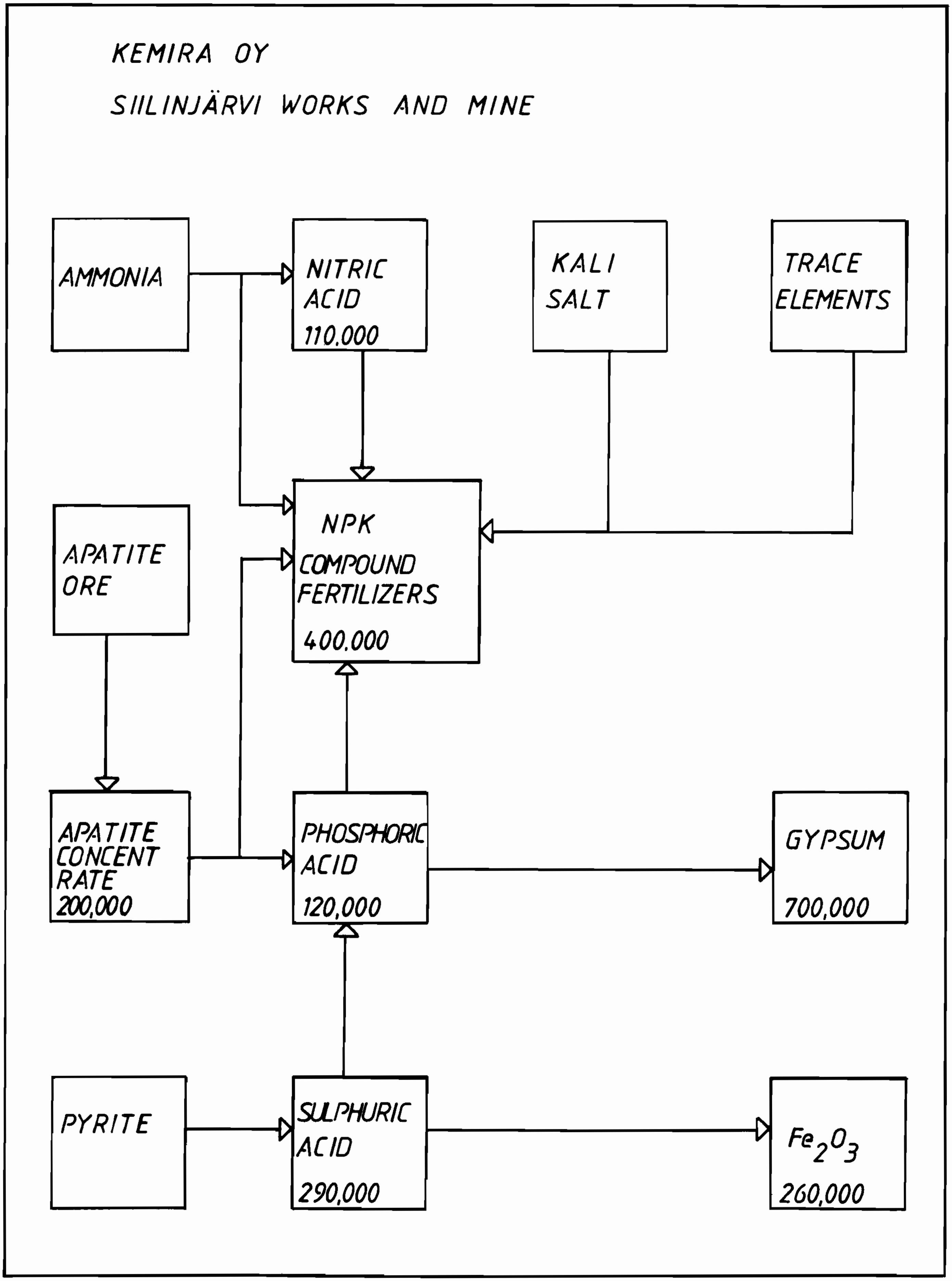
KEMIRA OY SIILINJÄRVI WORKS

CLOSED WASTEWATER SYSTEM OF PHOSPHORIC ACID PLANT





PHOSPHOR CONCENTRATION IN KUUSLAHTI (μg P/l)


KEMIRA OY
SIILINJÄRVI WORKS AND MINE
AMMONIA
NITRIC ACID 110.000
KALI SALT
TRACE ELEMENTS
APATITE ORE
NPK COMPOUND FERTILIZERS 400.000
APATITE CONCENT RATE 200,000
PHOSPHORIC ACID 120,000
GYPSUM 700,000
PYRITE
SULPHURIC ACID 290,000
Fe_2O_3 260,000

TIMO KARJALAINEN: In the phosphoric acid plant we are making silicitic acid and we can say that it is one step of washing. It contains droplet remover and condensor. Making dilute phosphoric acid we have both Venturi and so-called ball scrubbers. The amount of fluorine from phosphoric acid plant to air is about two grams per hour.

QUESTION—WILLIAM SHELDRICK - WORLD BANK: What sort of overall phosphoric acid efficiences do you get? If you recover all of your phosphates you must have apretty high efficiency. Is it possible to relate this in terms of the initial investment?

TIMO KARJALAINEN: The amount of phosphoric fifteen TPM of phosphoric handled.

QUESTION—ALAN ANDREWS –– CF INDUSTRIES: Are you regulated by Nitrogen and Fluorides as well as total phosphorus outfall or discharge?

TIMO KARJALAINEN: No, but the amount of fluoride is about 15 kilos per day.

MODERATOR SMITH: Thank you. We certainly appreciate your contribution and your being here. (Applause)

MODERATOR SMITH: During the past six years I have been working, primarily, in the field of phosphates. One of the genuine professionals in "Phosphate Technology", that I have met, is our next speaker for whom I have developed great respect for his methodical approach to "Phosphate Technical Questions and Problems." He is the author and editor of a soon to be published book on "Phosphate Technology". Pierre Becker commenced his career in fertilizer as "Phosphoric Acid Plant Production Superintendent" from 1951 to 1962. While with Chemiebau, an engineering company, he was involved in the engineering and construction of seven phosphoric and triple superphosphate plants. He then was Technical Manager-Consultant on phosphates in France, Germany, Brazil and Tunisia. Since 1976 Pierre Becker has been Assistant to the Technical Manager responsible for phosphoric acid and fertilizer with Cofaz-France. He will speak to us on the subject: "From Bench Scale And Pilot Plant Test to Industrial Applications Proven Extrapolation Techniques". It is a pleasure to introduce to you Pierre Becker. (Applause)

From Bench Scale And Pilot Plant Test To Industrial Applications Proven Extrapolation Techniques

Pierre Becker

I. The Need for Bench Scale and Pilot Plant Operations for Phosphoric Acid Technology

Phosphoric acid is on important intermediate chemical product which is mainly used by the fertilizer industry. In 1980 worldwide phosphoric acid production totalled more than 30 million tons of P_2O_5 equivalent. In order to produce such large tonnages, it is evident that phosphates, the raw material of phosphoric acid production, will be mined in many parts of the world. The most easily mined phosphate deposits are found in the great sedimentary basins. Derived from matter associated with living creatures, phosphates are subject to many variations due to the different sources and even to differing compositions within the same source.

Because of the increase in demand, the original sources of high grade ore (essentially Morocco, U.S.A. and U.S.S.R.) are no longer sufficient and new deposits are being mined in some 25 different countries. There is considerable variation in the quality of the ore mined, with most of them, requiring beneficiation.

Also, the general rise in raw material prices in 1974 means that certain phosphate deposits and qualities which had previously been considered uneconomic or to low in quality are now exploited. Consequently lower priced lower quality phosphates, began to find a growing market.

Added to this, although most phosphates are of sedimentary origin, about 5% of world production is derived from igneous rocks. Not containing any organic matter, showing different physical qualities and some variation in chemical composition, the igneous phosphates behave very differently when they are used for phosphoric acid production, thus introducing a further variable into the desparities in sources of raw material.

At the beneficiation stage, different techniques may be used to treat the same ore for removal of the gangue and associated inpurities. This gives rise to further variations in the finished ore concentrate product because each technique leads to its own purification degree.

The first conclusion that can be drawn from the aforegoing is that phosphoric acid technology, having to rely on raw materials of such a great variety and of permanently fluctuating composition, has to readapt itself constantly.

In terms of phosphoric acid producers, this constant readaptation of technology means experimentation. Each new ore has to be tested, bearing in mind the various possible beneficiation techniques, in order to choose the most economic one with a marketable product quality. New construction materials have to be tested for corrosion. The different phosphoric acid processes have to be tested with the individual ores.

It is obvious that for economic and technical reasons these experiments cannot be done in the operating production units. This is where the bench scale and the pilot plant unit will play their role. Their small size offers, the required economic and technical flexibility.

II. Definition of Pilot plant and Bench Scale Unit

1) *Pilot plant*

A pilot plant can be considered as a reduced size version of a large industrial plant with geometrical similarity. The quantity and type of equipment is comparable with large sized plants.

The data obtained from pilot plan operation can be used for phosphate rock assessment as well as for equipment sizing. For example the agitators of the pilot plant reactor can have geometrical similarity with those of a large plant. Specific power consumption and pump flow of the agitator can be extrapolated to the large one. Pilot plants operate with several tons of rock per day. Their investment costs can be considerable. A pilot plant is necessary when equipment or process technology is to be tested. It can only be used when large amounts of ore are available.

2) *Bench Scale*

A bench scale unit is too small to be built as a reduced equivalent. Some of the dominating extrapolation factors necessitate different technical conceptions. to give an example, a large reactor has to be cooled, a bench scale unit has to be heated. (Fig. 1) (2)

Phosphoric acid bench scale units operate usually between 1 and 4 pounds of rock per hour. They can be installed in an ordinary laboratory room equipped with a good air hood and the capital investment needed will not exceed 10 000 US $. Bench scale is used when phosphate rock assessments are needed. Only reasonable small amounts of ore samples are necessary.

One of the major reasons that have often led to the choice of bench scale tests is their small phosphate rock sample consumption.

In fact, bench scale test services are required to serve as a guide to the ore beneficiation process studies. The results of the bench scale test, concomitantly running with the beneficiation test, will reveal the optimum economic conditions for beneficiation which will also produce a good marketable product.

It is obvious that for those studies, only small amounts of sample are available; quick and flexible operating is required.

Furthermore, a phosphoric acid plant often has to be calculated and designed at the same time as experiments on the beneficiation of the ore are carried out. Here also, only small samples are available.

III. *Bench Scale Information and Services*

The most frequent case where bench scale services are required is that of a potential new mine from where a great number of small samples are to be tested. The next most frequent case is that of an engineering company which has to make its process calculations, material and energy balances and equipment specifications of a plant to be designed for a specific rock.

Another frequent case is that of an existing phosphoric acid plant which is to use an available rock quality it has never used before.

Bench scale tests nevertheless are also called for in many other studies, mostly related to operating plants: process debottlenecking (when crystallization is involved) corrosion problems related to the ore, checking of consumption figures, etc. . . . .

A typical bench scale test program can be listed as follows:

1. Crude phosphoric acid production for chemical analysis and further test works, general study about phosphate rock behaviour.
2. Crystallization qualities, filtration rates, filtration tests with additives.
3. Yields of recovery of P_2O_5 from the phosphate rock.
4. Specific sulfuric acid consumption (material and heat balance).
5. Specific calcium sulfate production.
6. Corrosion test with 30% acid.
7. Concentration test, physical properties and chemical composition corrosion rates at 40 and 50% P_2O_5.
8. Sludge formation test with concentrated acid.

In the case of a new ore the results of such a study gives to the phosphate rock producer the necessary elements to estimate the potential marketability of his rock.

A phosphoric acid technician will be in a position to prepare his process engineering calculations for the plant he has to operate.

IV. *Reliability of a Bench Scale Unit*

In the late 50s and early 60s the few operating phosphoric acid bench scale units were often regarded distrustfully. In fact, because of the simple design, the small size, the hand operated filter funnel, bench scale units can make the outside observer suspicious. The skill and the experience of the operator which is of great importance, is not visible.

Nevertheless these units, operating in parallel with large units, have proven to produce the same quality crystals, the same acid, and can simulate an industrial filtration.

Phosphoric acid slurries with comparable filtration rates can be produced under consideration of the following similarities and conditions:

1. Continuous operating.
2. Similar specific reaction volume or feed rate (reagents/reaction volume ratio).
3. Similar agitation energy input (similar micro-agitation).
4. Same reaction temperature.
5. Same or comparable filter cake thickness and filter cycle times.

6. Same or comparable impeller tip speed for corrosion test.

Today, some of the large integrated mining and phosphoric acid projects have been designed on the bases of bench scale studies.

This has been the case for the VALEFERTIL project in BRAZIL (2 million tons of rock per year, 2 phosphoric acid plants) (Fig. 4) where bench scale tests have been operating for TAPIRA rock assessments. No pilot plant tests have been made in this case, equipment technology has been applied (Fig. 5)

Today many companies operate a phosphoric acid bench scale unit almost continuously:

• PRAYON	BELGIUM
• PAULO ABIB	BRAZIL
• KEMIRA OY	FINLAND
• COFAZ	FRANCE
• RHONE POULENC	FRANCE
• NEGEV PHOSPHATES	ISRAEL
• NISSAN	JAPAN
• GERPHOS	MOROCCO
• SIAPE	TUNISIA
• OCCIDENTAL	U.S.A.
• AGRICO	U.S.A.
• I.M.C.C.	U.S.A.
• T.V.A.	U.S.A.
• JACOBS ENG.	U.S.A.
• MONTEDISON	ITALY

V. Design of a Bench Scale Unit

1. Size of a Bench Scale Unit (reaction volume)

The choice of the size of a bench scale unit is affected by 3 components:

A. Sample quantities generally available.

B. Sized for easy handling and standard equipment available.

C. Accuracy of the test operations when unit size becomes too small.

In practice values between 4 and 30 litres are the most usually encountered volumes (2 to 15 kg of P_2O_5 in 24 hours).

2. Shape, Size and Number of Reactions Compartments

Generally, baffled cylindrical tanks are used, but square shaped tanks are also encountered, the latter do not need baffles. The bench scale reaction has to be considered as a volume element of the large tank. In this volume element the same nucleation number and the same crystal growth potential should be maintained. This means that we have to operate with the same supersaturation value. To obtain this, comparable specific feed rates, similar dispersion, consequently similar shear or micro agitation energy input has to be provided. The small reactor is to be considered as a volume element of the large reactor. (Fig. 6)

Most of the bench scale units operate as a single tank unit oven though they simulate a multicompartment system. Once the same persaturation conditions have been calculated, the best crystal formation similarity (and filtrability) is adjusted by trial and error.

Two or multiple tank systems can also be used. Nevertheless they are less flexible and need more operating time.

3. Agitation — Agitation energy input

Agitation is one of the most important factors to be properly designed and operated in a bench scale unit.

The Agitator controls several functions:

a) quick and efficient dispersion of phosphate rock and sulfuric acid in the slurry (agitation flow and shear agitation).

b) maintain solid/liquid suspension.

c) breaking of foam and emulsion resulting from the rock conversion.

d) maintain chemical homogeneity throughout the reaction media — flow and shear agitation.

These functions are controlled by DIFFERENT mathematical models as shown in TABLE 1.

The problem was to select those functions which have to be respected and those which can be neglected.

It could be demonstrated by trial and error that in the case of a single tank system microagitation was the dominant effect. This is probably because of the porous structure of the phosphate particles and the necessity for rapid and highly extended dispersion of the sulfuric acid fed into the system.

Micro or shear agitation is proportionally related to the total agitation energy input (it all ends as heat which is molecular agitation).

This means that the specific multiplication factor for the agitation extrapolation is n^3D^2 or the total power input $P = K_p n^3 D^5 P$ to be calculated with the same specific energy input as for the large reactor.

where	P	Power in Watts
	K_p	Power number of agitator (dimensionless)
	n	Revolution speed (r.p. second)
	D	Impreller diameter (metre)
	p	Specific gravity (kg/m3)

Having choosen the n^3D^2 multiplication factor to extrapolate our bench scale unit for crystallization similarity we cannot use it to study other tests like foam breaking or corrosion. For every other test the system geometry has to be changed.

4. Temperature Control or Heat Balance

In a large plant (500 - 1 000 t/day) about 190 000 Kilogram calories have to be evacuated by cooling for each ton of sulfuric acid (98% H2S04) fed into the system.

A bench scale unit has a much higher surface to volume ratio and will consequently evacuate much more heat by ordinary surface cooling. An 8 litre bench scale will compare with a 1 000 m^3 reactor.

	8 litres	1 000 m^3
Surface to volume ratio m^2/M^3	40	0.8
Kilogram calories to be evacuated, compared to reactor surface KCal.m2	280	14 000
Kilogram calories to be evacuated per degree C Δ t and per m2 reactor surface (Δ t total ≃ 55°C)	5	250
Production t P205/day	0.016	500

The fact that the large plant has thick, brick-lined walls will strengthen the difference of the heat transfer coefficient for the bench scale. In fact, up to 10-30 litres, the bench scale plant will have to be heated; the accurate size limit depends on the amount of ventilation air which will be used to remove the fumes.

It is evident that a heat balance extrapolable to a large plant will not be directly measurable from the bench scale. Nevertheless, the amount of heat to be removed from a large plant for a given rock can be calculated from the specific sulfuric acid consumption, which is measured with the bench scale unit.

5. *Bench Scale Filter*

Small continuously operating belt filters, with effective filtration areas of 0.01 or 0.02 can be purchased as standard equipment; but they operate with a much thinner filter cake than the large plants. (Fig. 7).

Because of the filtration equations, a cake of 10 millimetres thickness compared with the usual cake thickness of 50 to 100 millimetres would dry up with in 1/25th to 1/100th of the time needed for the thicker cakes.

Furthermore, the cake washing with the filter wash water would be less efficient because of the large surface distribution effect (Fig. 8) and the edge effects of such a small filter.

Also it is not possible to conceive a continuous filter operating with a cake that would show more height than width. Consequently the most similar filtration operation is that in a simple, hand operated, funnel (Fig. 9). The funnel is fitted with a similar bottom and uses the same filter cloth as the industrial sized equipment.

The same cake thickness and the same filtration cycle time can be operated and the extrapolation becomes the simple surface multiplication.

6. *Feeding Equipment*

For the liquids, H2504 and return acid, peristaltic metering pumps are very suitable.

It is mor difficult to have accurate ground rock feeding. The most common device is a small hopper with a vibrating feeder. The hopper is loaded every 30 minutes with preweighed loads so that the material flow, on a long-term basis, is very accurate.

7. *Corrosion test equipment*

For corrosion tests we have to change the system geometry. Higher tip speed has to be used. Corrosion tests will be made with a specially designed agitator in order to reproduce the peripheral speed of the blades of a large impeller (Fig. 10).

Corrosion rates are measured by weight loss of the blade samples.

The bench scale reactor has to be rubber lined to prevent it from a corrosive action that would alter the corrosive action that would alter the corrosion rates on the samples. (Fig. 11)

8. *Bench Scale Concentration Unit*

Phosphoric acid is usually produced within the range 28-30% P_2O_5. Most of its uses involve a more higher grade, hence a bench scale concentration equipment is necessary to extend the studies to specific problems linked with the concentration of acid.

Some of these important aspects are listed below:

a) Sludge formation
b) Volatilization effects
c) Behaviour of concentrated acids
d) Corrision

Sludge formation depends on the grade of the final acid, on its impurity content and on its cooling rate.

Due to higher viscosities, sludges separate slowly and their formation is often very time consuming. When acid must be clean for merchant grade purposes, a good control of this step is needed with minimizing P_2O_5 losses in the sludge.

the bench scale concentration unit allows us to produce continuously any desired grade of concentrated acids, and, starting from them, to quantity the sludge formation under similar conditions to those existing in large agitated or settling tanks.

Ventilization effects of the concentration can be correctly estimated if temperature, holding time and continuous operating conditions are joined together. Impurities concerned are mainly fluorine but also chlorine, sulfur and arsenic.

Volatilization of these impurities and their abatment in condensers and scrubbers belong to the environmental impact of a concentration plant.

Behaviour of concentrated acids must be tested mainly when they are used in TSP and ammonium phosphates.

- TSP bench scale studies need concentrated acid issued from the same secondary phosphate rock.
- Some important aspects of ammonium phosphate production such as preneutralization step (NH3 dispersion - water vapour and heat emission — Foaming) need concentrated acid whose grade must be adjusted similar to its industrial feed level.

Description of the bench scale concentration unit (Fig. 12)

Main similarities with industrial conditions are:

- Continuous operation

  - Boiling temperature (and corresponding pressure)
- Holding Time
- Tip speed for corrosion tests.

Product and acid is continuously introduced into a reactor by means of a volumetric pump, from a graduate head tank.

The reactor itself is a 4 "diameters — 15" height agitated, side and bottom — jacketed material -Hastelloy C".

Heating is provided by external circulation of oil from a thermostatically regulated bath (2.500 Watts) — Vacuum needs are provided and controlled by standard laboratory means.

Concentrated acid overflows from the reactor to a collecting tank through an intermediate cell enclosing a densimeter to control the grade.

The desired grade is obtained by adjusting pressure level and the acid flow through the reactor when operating within 78-80°C.

Volatile emissions are condensed by cooling, collected and analyzed if necessary.

The described bench scale unit evaporates about 1,5 kg/h of water; it corresponds to a concentration of 1, 2 kg/h P_2O_5 from 28% to 54% P_2O_5 in a single step.

9. Sludge test

The sludge formation test is operated in a slightly agitated, 30 to 60 litre tank, where a temperature of 50°C is maintained.

VI. Bench Scale Operating and Results for Phosphate Rock Assessments

1. Phosphoric Acid Production, Filtration Rates and P_2O_5 Losses in Filter Cake

The bench scale unit is operated as similarly as possible to the large plant. The production should be started in closed cycle with water, rather than with an acid originating from another rock, introducing impurities with unknown influences.

Three shift operating is the most accurate procedure but since it is expensive in labor costs, most laboratories operate only two shifts, leaving the slurry to settle and cool overnight without agitation. Much controversy is still about this subject, but apparently only small result from it, and not in all cases.

The slurry produced is periodically batch filtered with the hand operated funnel — each filtration operation is recorded.

Regular microscope observation of the crystals as well as periodic sulfate and P_2O_5 concentration analysis should also be recorded on a graph.

The main variables exploring affecting the filtration rates are:

- H2S04 excess
- P_2O_5 concentration
- Reaction temperature
- Solid content

To test a new rock, several weeks of operation are necessary unless exexpected problems appear, where additional time may be required.

Great care has to be given to the filtration test. Once the filtration cycle time has been decided (according to the large filter cycle under comparison a preliminary test has to be made.

If for example a 4 minutes cycle is to be operated it will be subdivided, as on a large filter, into 3 stages. (Fig. 13)

1. Product acid recovery (about 30% of total time: 1'10")
2. Cake washing with weak acids about 40% of total time: 1'40"
3. Cake washing with water and drying about 30% of the total time: 1'10"

To achieve a proper filtration, phase one has to remove about 60% of the total acid contained in the slurry (1 litre of slurry contains 750 cm3 of acid). A preliminary test will indicate the load of the filter funnel to be taken so that the liquid portion will be removed within a railroad time of about 1 minute and 10 seconds. Once this load is known the proper filtration test will be operated.

The cake wash acid taken will be 3% P_2O_5 acid. the 3% P_2O_5 wash acid is a simple and equivalent substitute for the two system operating with most industrial filters. It has been found by trial and error.

For both product acid removal and tail wash with water, time allowance for deep cake drying will be given. The intermediate 3% acid wash requires only superficial cake drying to avoid wash liquor mixing. The actual time to complete the test with its contraints as described will be recorded. To calculate the equivalent filtration rate for a standard cycle time of ts second the following equation is used:

Rateat standard time t = (Measured filtration rate)
(measured time) ¼ (ts)

After the cake removal, P_2O_5 filtration losses are measured in order to confirm the quality of the filtration tests.

2. *Consumption figure test — heat removal*

a) Specific sulfuric acid consumption : H2S04 / rock or H2S04 / produced P_2O_5

b) Specific calcium sulfate production : CaS042H20/rock

c) Specific cooling rate : Kcal to be removed/produced P_2O_5

The purpose of this test is to determine exactly the specific sulfuric acid consumption of a given phosphate rock by a reactor operating in closed cycle because theoretical determination from analysis is not very accurate.

a) and b) are operated concomitantly; c) will be calculated from a).

To operate a) and b) the bench scale reactor will operate for a short time as a closed system. No slurry outflow will be allowed, the level difference will compensate the feed. The reactor is filled with 30% P_2O_5 acid and only 50 grs of seed crystals per litre, weighed exactly before introduction.

A one kilogram sample of phosphate rock is weighed exactly and fed under normal operating conditions, into the bench scale system for continuous conversion.

During and after the rock conversion, the sulfate level is checked and adjusted to its desired level.

The sulfuric acid consumption is weighed exactly as well as the filtered calcium sulfate cake after water and acetone washes, followed by drying at 50°C.

3. *Corrosion test*

The corrosion test can be operated simultaneously with filtration tests provided the rubber lined tank and the special agitator is used. The total power input nevertheless has to be checked especially to make sure of operating with comparable microagitation conditions.

After every operating day, the stainless steel samples have to be removed and weighed, they have to be periodically exchanged.

Weight losses after 8 hours operation are high enough to be significant, provided they will be repeatedly operated.

4-5. Concentration Test — Corrosion test with concentrated acid

Concentration and corrosion tests have to be operated simultaneously. A number of corrosive impurities have a limited life during concentration (chlorides, fluorides).

To operate a comparable evaporation corrosion test there must be similarity of:

- Temperature
- Mean detention time
- Concentration
- Comparable tip speed of steel samples.

6. *Sludge Test*

The sludge test is to measure the amount of solids precipitating from concentrated acid during further storage time. The minimum test time is 2 weeks where most of the sludge formation occurs. Nevertheless, care has to be taken to check the absence of further precipitation during the following weeks.

This test can be made by maintaining the acid at 50°C with suspension agitation. Usually 30 to 50 litre samples are used.

Periodically, by thorough sampling, a representative sample is taken for solid content determination.

TABLE 1

EXTRAPOLATION FUNCTIONS FOR AGITATED SYSTEMS

FUNCTION	SPECIFIC RATIO	SPECIFIC MULTIPLICATION FACTOR
Agitation flow	$\dfrac{\text{Flow m3/h}}{\text{Tank volume m3}}$	(n)
Foam breaking	$\dfrac{\text{m3 of foam broken}}{\text{Tank volume m3}}$	$(n^3D^{1/2})$
Vortex formation	$\dfrac{\text{Depth of vortex}}{\text{Liquid level in tank}}$	(n^2D)
Total power input (shear agitation or micro	$\dfrac{\text{Power KW}}{\text{Tank volume m3}}$	(n^3D^2)
Corrosion	$\dfrac{\text{Vol. of material lost mm3}}{\text{Equipment surface mm2}}$	$(nD)^x$

LIST OF FIGURES

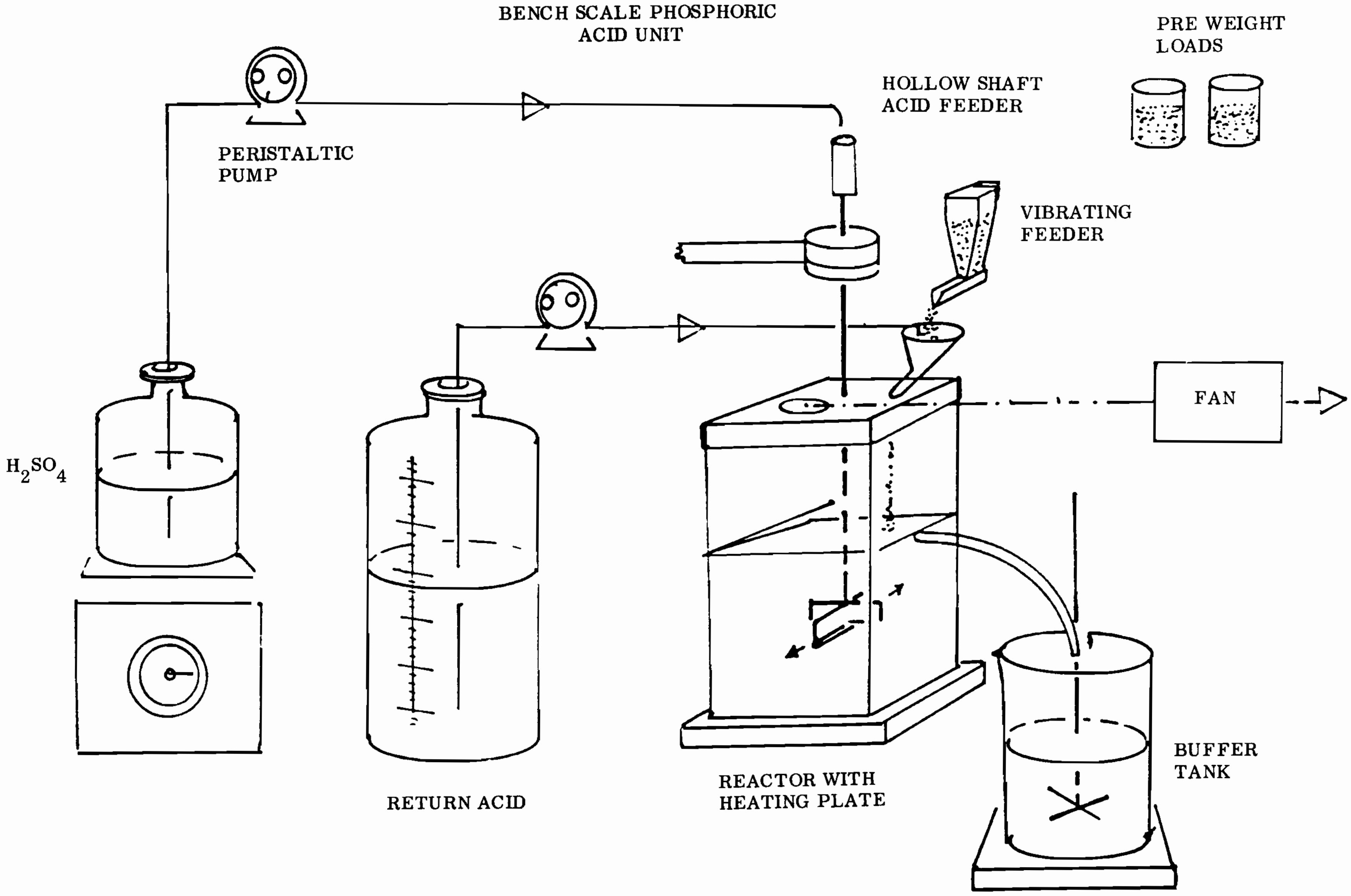

BENCH SCALE PHOSPHORIC ACID UNIT
PRE WEIGHT LOADS
HOLLOW SHAFT ACID FEEDER
PERISTALTIC PUMP
VIBRATING FEEDER
FAN
H_2SO_4
RETURN ACID
REACTOR WITH HEATING PLATE
BUFFER TANK

FIGURE 2

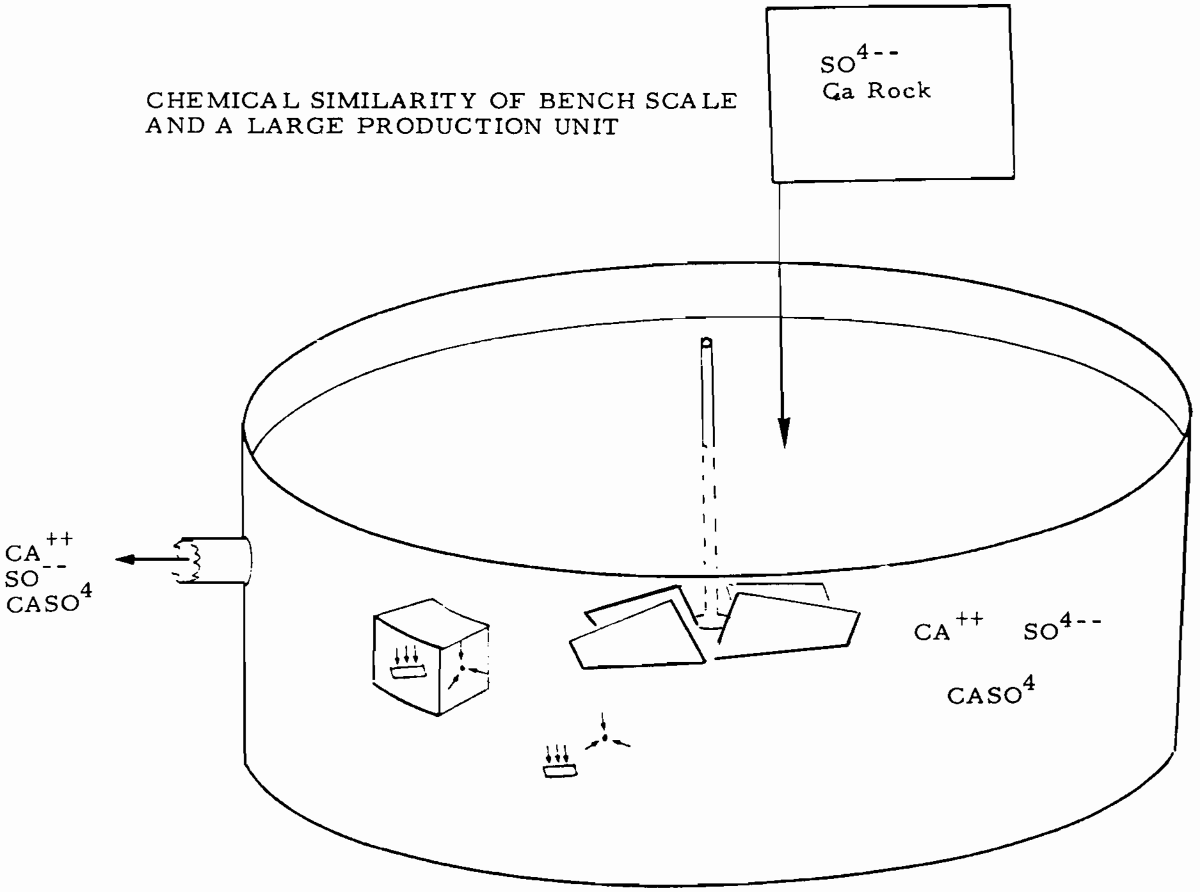
CRYSTALS FROM PRODUCTION PLANT

CRYSTALS FROM 8 LITRE BENCH SCALE REACTOR

EARLY BENCH SCALE TESTWORK
(1954 TUNISIA)

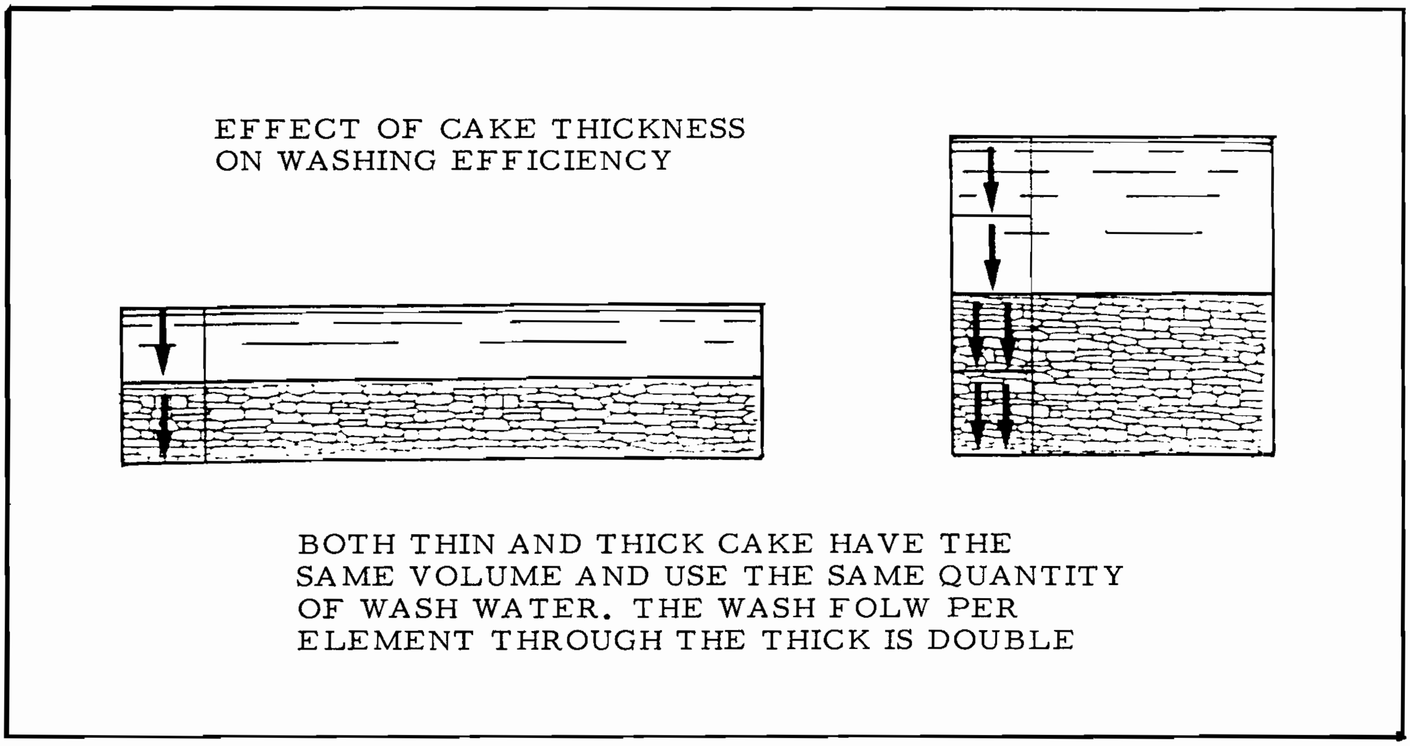
FIGURE 3

CHEMICAL SIMILARITY OF BENCH SCALE AND A LARGE PRODUCTION UNIT



THE BENCH SCALE UNIT SHOULD BE CONSIDERED AS A VOLUME ELEMENT OF THE LARGE SIZED TANK WITH A SIMILAR CRYSTALLISATION BALANCE

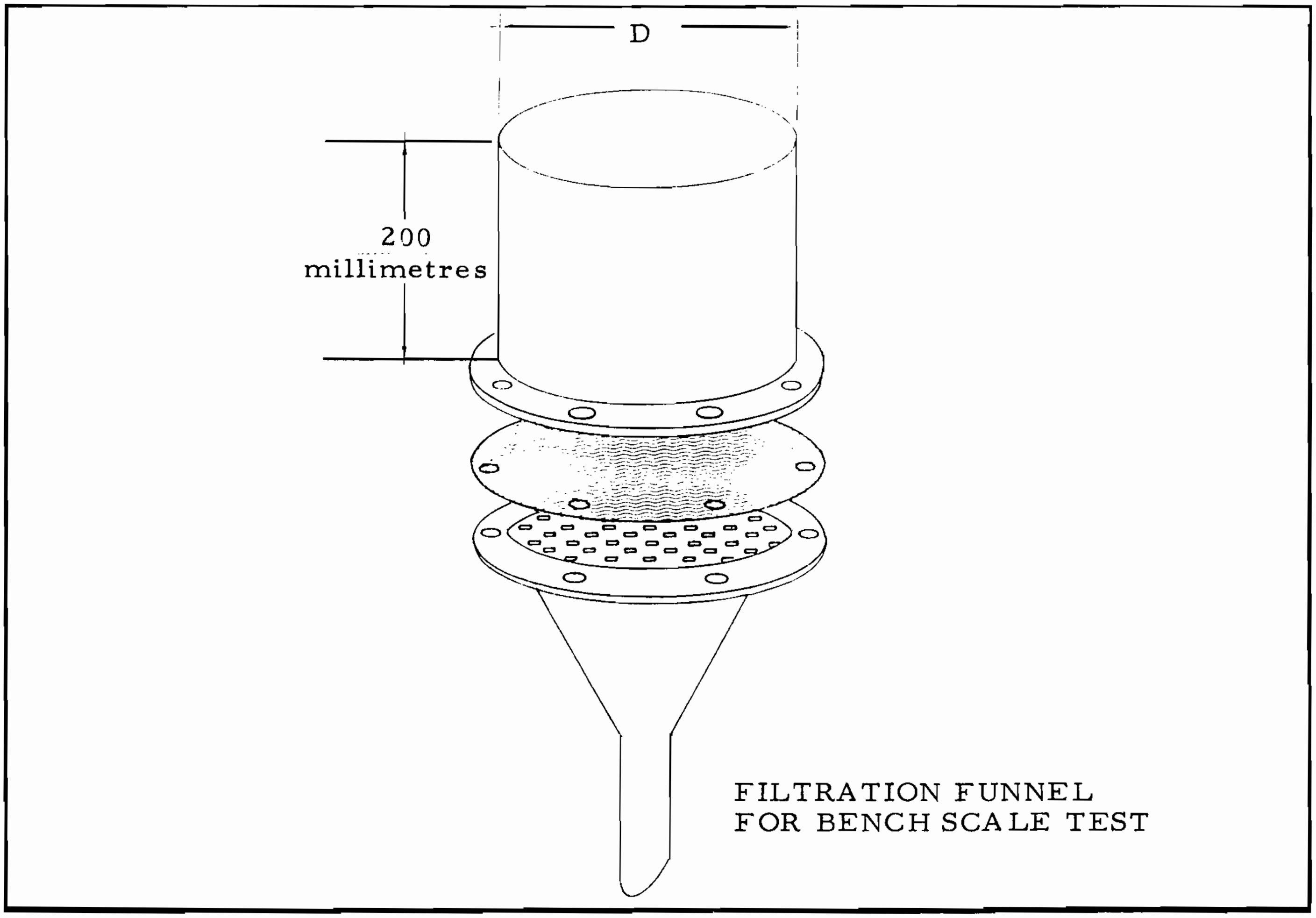
FIGURE 6



EFFECT OF CAKE THICKNESS ON WASHING EFFICIENCY

BOTH THIN AND THICK CAKE HAVE THE SAME VOLUME AND USE THE SAME QUANTITY OF WASH WATER. THE WASH FOLW PER ELEMENT THROUGH THE THICK IS DOUBLE

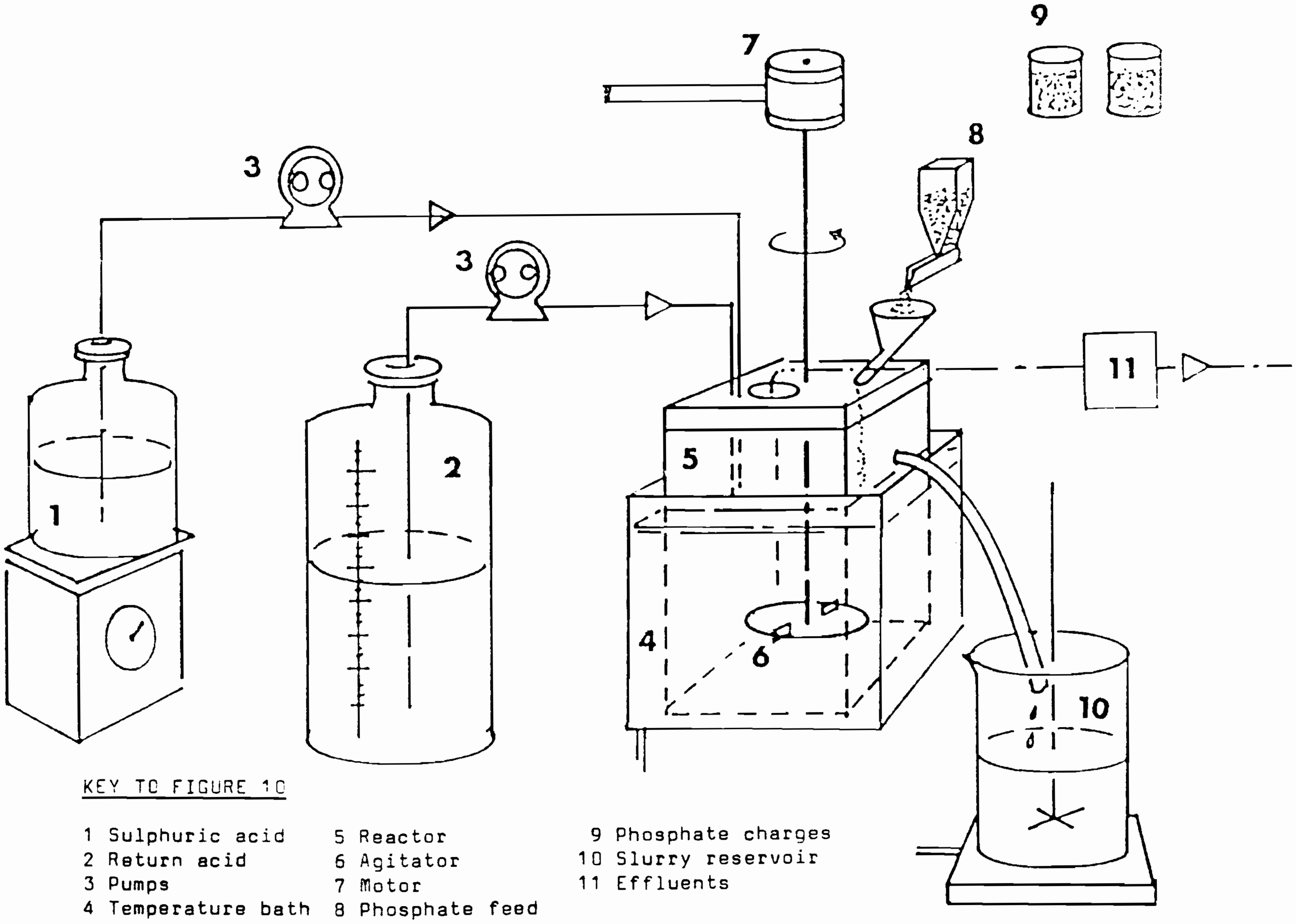
FIGURE 8



FILTRATION FUNNEL FOR BENCH SCALE TEST

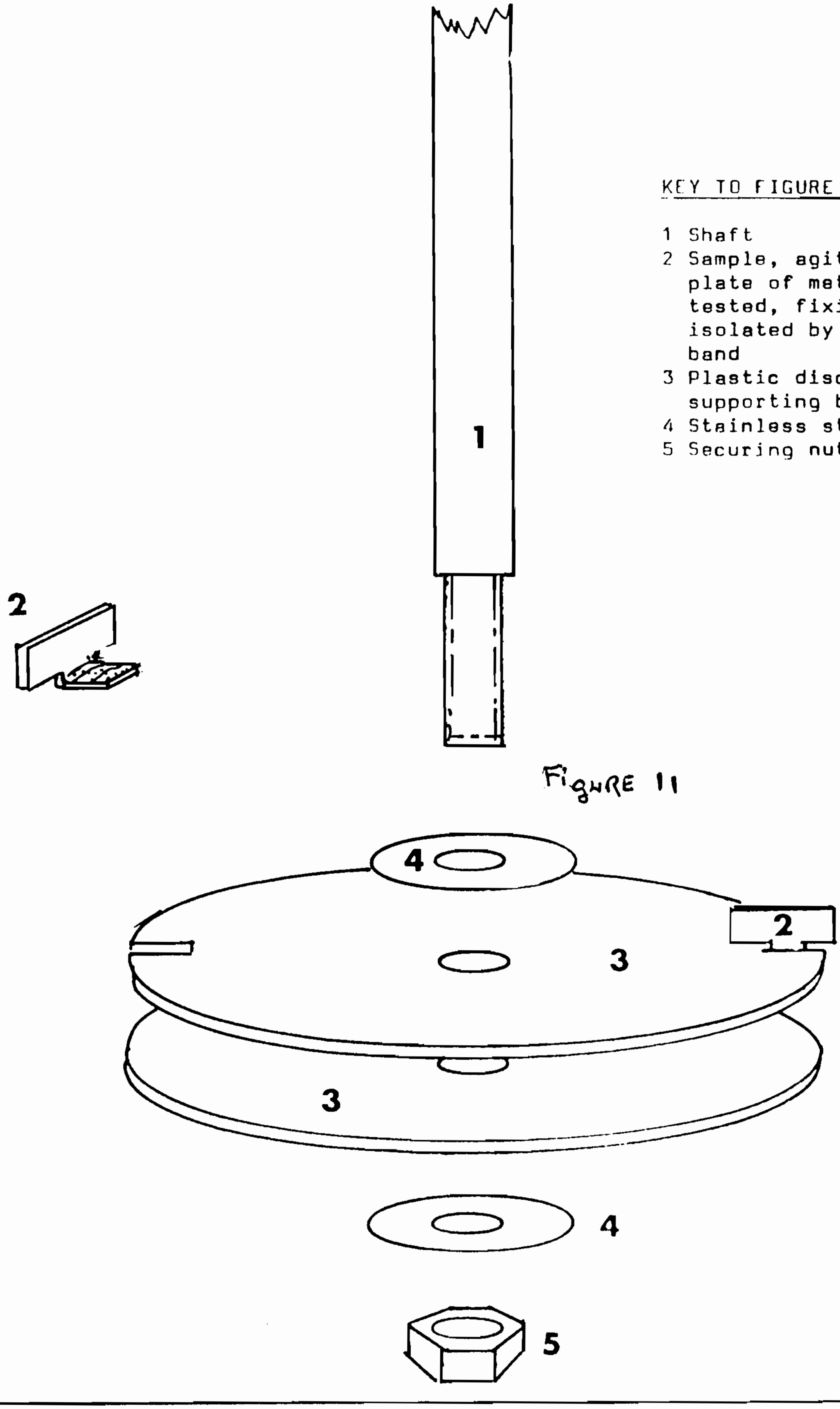
FIGURE 9

FIGURE 10



KEY TO FIGURE 10

1 Sulphuric acid
2 Return acid
3 Pumps
4 Temperature bath
5 Reactor
6 Agitator
7 Motor
8 Phosphate feed
9 Phosphate charges
10 Slurry reservoir
11 Effluents



KEY TO FIGURE 11

1 Shaft
2 Sample, agitator plate of metal to be tested, fixing plate isolated by teflon band
3 Plastic discs supporting blades
4 Stainless steel washer
5 Securing nut

FIGURE 11

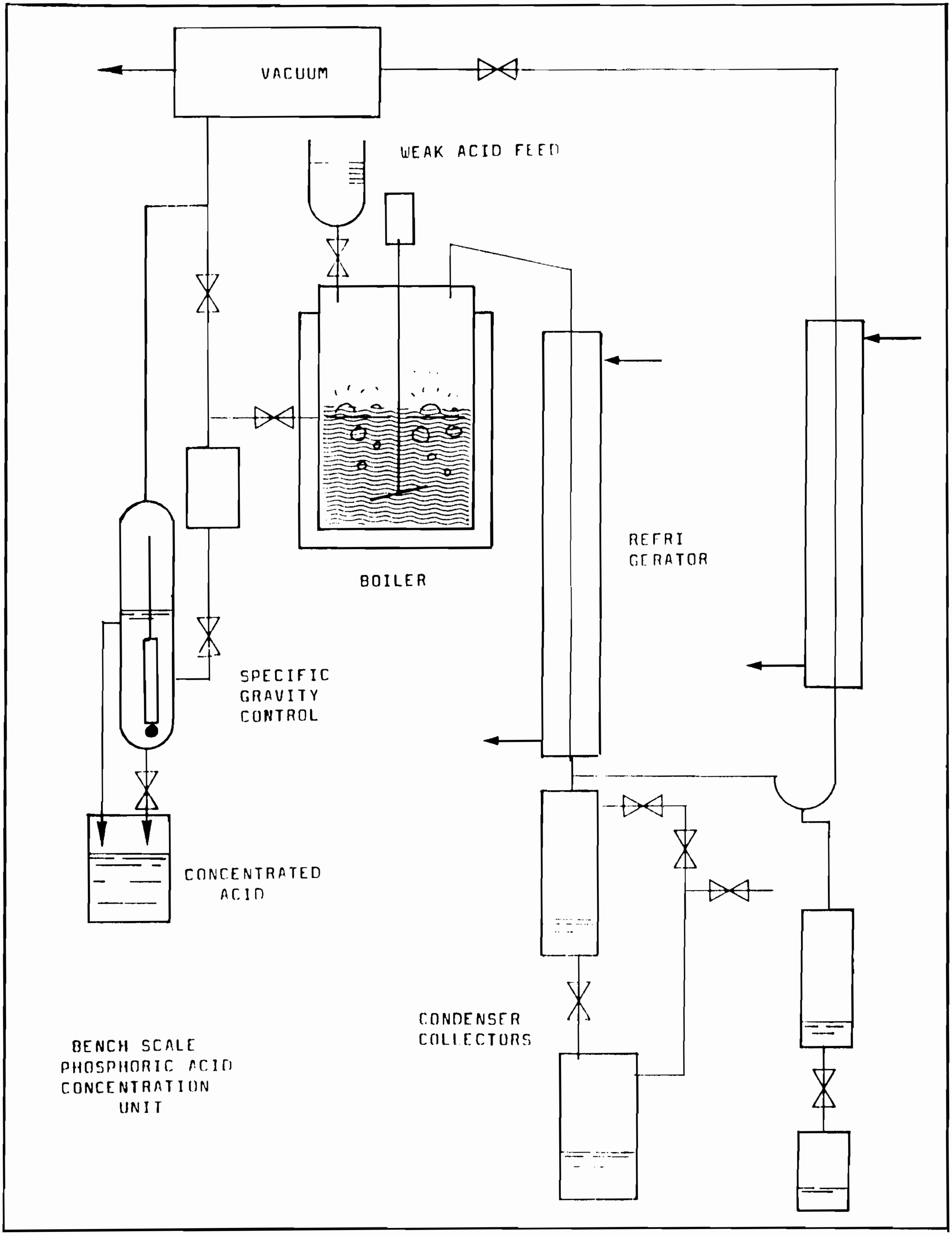

VACUUM
WEAK ACID FEED
BOILER
REFRI
GERATOR
SPECIFIC
GRAVITY
CONTROL
CONCENTRATED
ACID
CONDENSER
COLLECTORS
BENCH SCALE
PHOSPHORIC ACID
CONCENTRATION
UNIT

FIGURE 12

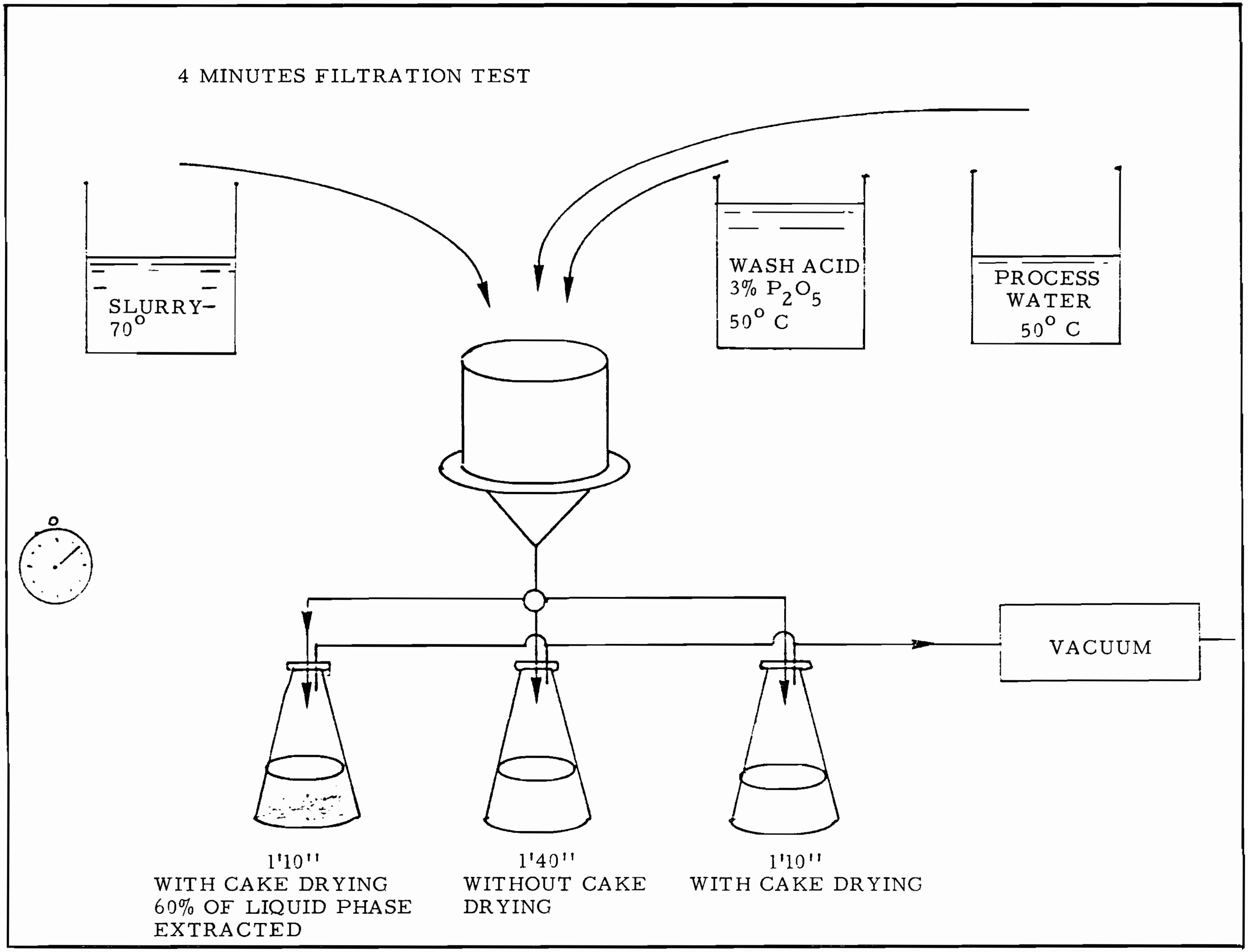

4 MINUTES FILTRATION TEST
SLURRY– 70°
WASH ACID 3% P_2O_5 50° C
PROCESS WATER 50° C
VACUUM
1'10''
WITH CAKE DRYING 60% OF LIQUID PHASE EXTRACTED
1'40''
WITHOUT CAKE DRYING
1'10''
WITH CAKE DRYING

FIGURE 13

MODERATOR SMITH: If you have not had the occasion, in your work, to work with phosphate rock; phosphate rock is not necessarily phosphate rock in the same sense that muriate of potash or ammonium nitrate, for example, are. It is a highly variable material. It is a natural occurring material with a degree of benefication and varies greatly in both chemical and physical characteristics. So it is impossible with a degree of certainty, to look at a product characteristic sheet and be certain how it is going to operate in a phosphoric acid plant. For that reason the techniques that Pierre Becker has described, have been developed in order that you can, in advance, evaluate what part of recoveries you are going to get, what sort of conditions, and how much sulphoric acid it is going to require and so on. That is what is behind this thing. It saves a lot of pain and strain and cost in an operating plant by doing this sort of work in advance. Are there any questions for Pierre Becker? Thank you for a most valuable discussion. (Applause)

QUESTION BILL SHELDRICK - WORLD BANK: Some people use apecific surface area as a measure of indicating the stability of these reactions. In fact, if you use an air permeability method, you can also measure porosity and permeability which they also think is a very good measure of filtration. What do you feel about this technique?

PIERRE BECKER — COFAZ - FRANCE: Yes, I know. At present, I think we are talking about Fison's. I know this method. Presently they are not yet standard. Each company has its own standards, so, I do not say it is better in one case than in another. The skill of the people is very important. I think whether you operate with porosity or filtration tests, if it is done by experienced people, I would say it is equivalent.

QUESTION FRANK ACHORN: Pierre it concerns me that it is making a rather large stop to go from just a bench scale equipment to a large scale plant. Is the predictability of your data enough? What are the largest plants that you have gone to from bench scale? For example, on your filtration rate and designing the size filter that you need? It looked you were using a standard funnel to obtain your filtration rate. I might not have understood it correctly. It is rather a big step and I am amazed that you can do it.

PIERRE BECKER — COFAZ - FRANCE: I understand your concern. First I want to underline that I do not want to say that the bench scale allows to extrapolate everything. It certainly does not allow to extrapolate equipment. It concentrates on what we can consider as phosphate rock (assesment). Your specific question was about filtration rates: Whatever the size of the large plant will be. Provided the sample you get is the good sample, I forgot to tell you, in many cases, and this was the case in Brazil, when we started working on the project, we had to work on the mine, the benifiction plant and the phos acid plant, and there was not enough sample any way to use a pilot plant. We only had a few kilos of sample. So, the big risk is not the error you make with the pilot plant. The big risk is how representative is your sample.

MODERATOR SMITH: Thank you, Pierre. We appreciate your cooperation and your discussion very much. (Applause)

MODERATOR SMITH: Now we come to the last paper of the afternoon. Once again, we reach across the Atlantic, this time for a report on a thorough investigation of Anti-Caking and Anti-Dusting Treatment" although these problems are minimal now compared to the conditions that prevailed before the advent of granulation, prilling and compaction, it is still a challenge to maintain the level of fertilizer product perfection anticipated by customers. The paper that you are about to hear, is the result of considerable investigation of materials and equipment to prevent fertilizer caking or dust evolution. You will find this paper useful. Our Speaker is a Chemical Engineering Graduate of the University of Ghent, Belgium. Following military service, he was Manager of Quality Control and Research for an Yeast Manufacturer. He is now Manager of Laboratories for Nederlandes Stikstaf Mantschappij (N.S.M.) at Sluiskil in the Netherlands, wholly owned by Norskthydro of Norway. We welcome Dr. Wille H. P. Van Hijfte. (Applause)

The Coating of Straight Nitrogen Fertilizers

Willie H. P. Van Hijfte

A. *Introduction*

This paper deals with the N.S.M. innovations on coating of straight nitrogen fertilizers, developed in the seventies. The Nederlandse Stikstof Maatschappij (N./S.M.) is a Belgian Company with headquarters in Brussels, operating a single large factory at Sluiskil, in the southern part of the Netherlands. The only shareholdedr is the Norwegian Norsk Hydro. The plant, with its own harbour facilities on the Ghent-Terneuzen Canal, and loading facilities for ships up to 50.000 tons, has direct access to the North Sea and the European system of inland waterways.

The current NSM production capacities are:

Ammonia	700 000 MTPY
Urea solution	750 000 MTPY
Nitric acid (as 100%)	700 000 MTPY
Ammonium nitrate solution (as 35%N)	880 000 MTPY

The urea solution produced can be diverted alternatively to the manufacture of finished products in facilities with capacities of:

46% N prilled urea	700 000 MTPY
46% N granulated urea	275 000 MTPY
32% N liquid fertilizer	800 000 MTPY.

The ammonium nitrate solution produced can be diverted to the manufacture of the following products:

26% N prilled calcium ammonium nitrate	800 000 MTPY
33,5% N prilled ammonium nitrate	400 000 MTPY
32% N liquid fertilizer	800 000 MTPY.

B. *Bulk Transport Needs Better Quality.*

Seventy percent of our production has to be exported all over the world. A major part of this export is realized by bulk transport and bulk shipment.

The first experience with bulk shipments of urea in 1970 were poor; rapidly it became clear that bulk loading, bulk transport and bulk storage needed products with higher quality standards than available at that time.

The most urgent objectives in 1970 were to realize the following goals:

1. The product must be dust-free from producer to user.
2. In bag storage and in bulk storage under dry conditions, the product should not cake at all, even after prolonged storage.
3. In bulk storage the humid top layer should be reduced to a fraction of the depth of the humid top layer of a product with powder coating.
4. No powder should be used in coating of pellets.

C. *General Considerations About Coating.*

1. *Powder coating.*

In the seventies and even up to now the common treatments to overcome caking were:

- a powder coating of the fertilizer pellets;
- no coating for some qualities of ammoniumnitrate containing an internal drier as $Mg(NO_3)_2$;
- no treatment at all for prilled urea.

The most usual way to reduce the tendency of fertilizers to cake during storage has been to coat them with mineral powders. To maximize adhesion, very finely ground powders such as diatomaceous earth, limestone, dolomite and different types of clays have been and still are used. The results are unsatisfactory: the finer the powder used the better the adhesion but also the greater the problems with clouds of dust during handling in general and particularly during bagging and bulk loading. Working conditions at best are very bad. To overcome the dustiness of the products some producers oil them so as to improve adhesion of the powder coating. Most oiled products give less problem with dust when bagged, but in bulk loading and unloading the clouds of dust have persisted.

The scale of the problem has increased in the last ten years because of higher production rates, larger shipments in bulk over log distances and more attention to working conditions and environmental regulations. At the same time, in Western Europe as well as the USA and especially in the Netherlands, there has been an increased trend towards bulk storage. In the very humid climate of the Netherlands more than 95% of calcium ammonium nitrate is shipped, handled and stored in bulk.

As fertilizers are often stored in buildings from which it is impossible to exclude humid air, the practice of storing ammonium nitrate-containing fertilizer in bulk under humid conditions has generated a need for a new method of protection against moisture penetration into the piles.

NSM has performed intensive studies of the bulk storage problem of these fertilizer types under humid conditions, using the TVA test procedure : storage in open bins.

In the case of a conventional coating with powder, moisture penetrates into the prills and passes partly by direct contact from one prill to another. In this way, a wet cake is formed at the surface of the pile during storage : its hardness increases with time and depends on atmospheric conditions. Depending in the duration of storage, this crust can vary in depth from 5 cm to 80 cm (after 4-6 months). During periods with less humid air the wet layer is transformed into a hard crust, which is very difficult to break.

2. *Use of organic coatings.*

When N.S.M. abandoned the principle of coating with fine mineral powders it was clear that investigations had to be directed towards an organic coating.

After intensive investigation N.S.M. developed:

1. a process for coating prilled urea (US-patent 4.160.782)
2. a process for coating ammoniumnitrate pellets (US-patent 4.150.965).

In each case the major difficulties to overcome were:

- finding a good anti-caking agent
- realizing a homogeneous distribution of the coating agent all over the surface of the pellets.

The type of coating agent and the process of application will be described in chapter D . . . and E . . .

First we will talk about how to cover, all kinds of pellets with a homogeneous film of the anti-caking agent.

Coating pellets with a relatively slight amount of a liquid coating agent, for example in a proportion of 0,02 - 0,2% so that the pellets are provided with a uniform, substantially complete coating, on an industrial scale, for example at a rate of up to 50 t/h pellets, has hitherto always proved to be difficult to achieve. Spraying the coating agent in finely divided form on to the pellets on a conveyor belt, in a chute or in a conventional coating drum seldom leads to acceptable results. NSM has studied the coating process and the factors which play a role in it by using coating drums made of transparent acrylic resin in which pellets were sprayed with a liquid coating agent to which a coloring agent had been added. In the light of numerous experiments it was found that a more uniform coating is produced over the entire surface of the pellets when there is a more intensive rolling of the pellets during spraying with the coating agent. The rolling has been found to be essential for spreading the coating agent over the surface of the pellets. Any measure tending to reduce rolling, for example, lifting the pellets with built-in flights, turned out to delay or prevent the spread of the coating agent.

Very good distribution of a liquid coating agent is obtained in a concrete mixer. Observing the rolling of the pallets in a concrete mixer, NSM developed a continuous coating drum in which the movements of the pellets are similar to those in the concrete mixer. In this type of drum, described below, the rolling and rubbing obtained is comparable with the rolling and rubbing of the pellets in the concrete mixer. The apparatus for coating pellets comprises a cylindrical, obliquely disposed drum containing partitions arranged transversely to the axis of rotation, dividing it into compartments. For most purposes 4-6 compartments have been found to be effective. The perpendicular distance between two immediately succeeding partitions is preferable not greater than the interior diameter of the drum. Each of the partitions has a passage opening located off the axis of rotation; passage openings in two immediately succeeding partitions must be peripherally offset in relation to each other by approximately 180°, and the width of each passage opening in the radial direction relative to the axis of rotation must be less than half the interior diameter of the drum. During rotation this coating drum causes surprisingly intensive rolling of the pellets inside it. The liquid coating agent which is sprayed, for example, onto the pellets in the first compartment of the drum is thus spread into a uniform, substantially closed coating on the surface of the pellets. During rotation the pellets transverse a helicoid path through the passage openings which are in their lowest position. The passage openings filled with pellets close the various compartments in groups of two for most of a revolution so that the sprayed coating agent, being confined between the partitions and thus usable to pass through the passage openings filled with pellets, is forMed to come into contact with the pellets. It is this feature which gives the drum the extemely important advantage that the liquid coating agent is almost completely utilized for coating the pellets, and at worst can escape from the drum to the working spaced in small quantities only.

In practice, excellent results are obtained with a continuously operating coating drum having a capacity of approximately 1,200 t/d pellets, a length of 10 m and a diameter of 2 m. the drum is fitted with five interior partitions equidistantly spaced from one another and containing eccentric round passage openings having a diameter of 900 mm. In each pair of directing succeeding partitions these passage openings are peripherally offset through 180°F. The drum has a discharge opening of 900 mm, is disposed at an angle of inclination of a few degrees and is rotated at a rate of 6 rev/m. The layer of pellets in the drum is approximately 500 mm high. In the first compartment adjacent to the supply end of the drum the liquid coating agent is sprayed over the pellets of the two sprayers, and in the other five compartments the coating agent is spread over the surface of the pellets by the rotation of the drum.

D. *Anti Caking Treatment of Prilled Urea.*

Up to 1970 the NSM prilled urea was not coated and showed a strong tendency to cake, even in our own warehouses. This caking, resulted in a gradually deformation and degradition of the prill structure and in transformation of the stockpiles in very hard masses. When such a product is reclaimed and loaded, heavy formation occurs with relevant product losses and unhealthy environment for the workers involved in the operation.

Depending in the storage period in the producers warehouse the quantities of fines originated by reclaiming could range from 2 to even more than 10% and a final sieving between reclaiming and loading of a ship was not enough to remove all these fine particles. These fines loaded in a ship caused a more intensive caking during the trips and unloading of the first bulk shipped urea had to be done with the aid of a bulldozer, entraining more losses and product deterioration.

I remember very well the time that after nine months of storage of urea prills with 0.2-0.3% of moisture the whole stockpile had caked to such an extent that even the use of carbon dioxide cartridges was not sufficient to break down the stockpile.

The NSM research on an efficient anticaking treatment started from the evaluations of the effect of the product characteristics on caking tendency and the evaluation of treatments used for different bulk products. The following parameters and treatments were considered:

1. *Humidity:* the study demonstrated beyond any doubt that urea with very low humidity (0.1%b.a.) has the same caking tendency as the regular commercial product (0.25-0.30% humidity).

2. *Temperature of the product feeding the stockpile:* urea being fed to the stockpile at 50° to 70° will definitely form strong cakes. The lower the feed temperature, the lower the tendency to cake and the hardness of the formed cakes will be. The conclusion of the study was that if the prills are cooled below 30°C (86°F) before entering the storage, there is less agglomeration and, mainly, the agglomerates are softer.

We would like to mention at this point that a large stockpile of urea maintains its temperature for months: accordingly the feed temperature is much more important than the warehouse temperature.

3. *Coating with inorganic powders:* like kaolin, diatomaceaous earth, bentonite, talc etc., was found slightly effective only at very high rate (3 to 4% kaolin). Coating at a low rate, seemed to favour the caking tendency as was confirmed by others. In general the

Fig. 1: Longitudinal Section of NSM Fertilizer Coating Drum

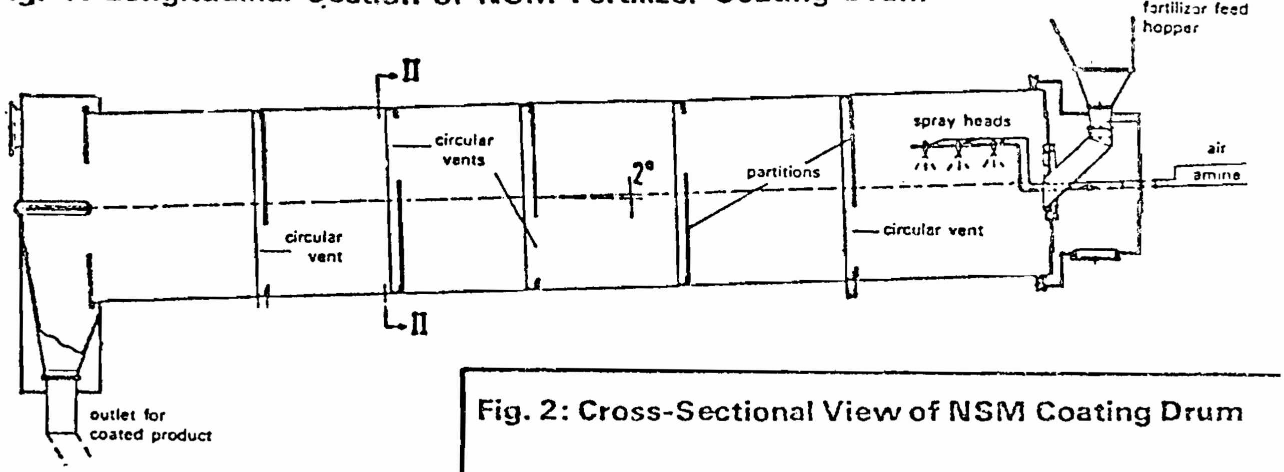
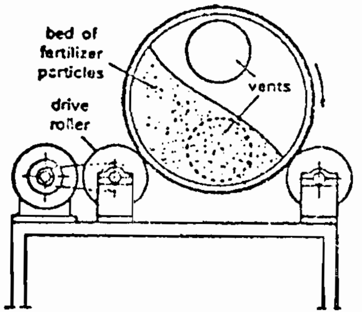


Fig. 2: Cross-Sectional View of NSM Coating Drum



adherence of this powders on prills was very poor and heavy dustiness was not to overcome.

4. *NSM Coating Of Prilled Urea:*
   1. *The coating process.*

After this thorough examination of the existing treatment in 1970, NSM *developed a new anti-caking treatment* (covered by USA patent 4.160.782 dd 1979-06-10) consisting in:

- spraying the prills with 0.1 to 0.2% of a concentrated solution of methylolurea (an addition product of urea and formaldehyde prepared in alcalin medium, containing 23% urea and 57% formaldehyde of which approximately 50% is present as trimethylolurea).
- cooling the product to 30°C with partially dried air before storage.

With the development of a special designed coating drum, NSM found that a uniform substantiality closed coating on the surface of the ureaprills is easily performed. The coating drum is described in chapter B, on page 6.

2. *Advantages of the NSM coating.*

This coating agent gives a thin uniform tacky film. This tacky film minimizes abrasion and hence dust formation during stockpiling, reclaiming, loading, unloading.

the coating completely eliminates the odour of ammonia in the storage, handling facilities and on the ship.

At Sluiskil the ammonia content in the air in the loading area was reduced from 10-15 mg/m^3 to less than 1 mg/m^3. In the atmosphere of the ship holds ammonia is undetectable. The elimination of dust and ammonia odor together have improved dramatically the environmental conditions in the storage and loading areas of the plant, as well as on the ship. The free flowing product can be loaded at very high rate (at Sluiskil 6000 tons/dag) due to the total absence of agglomerates. Minimum abrasion and minimum prills breakage mean better product quality for the customer.

The product keeps free flowing during the sea voyage, provided that some simple precautions, such as cleaning the holds and covering with plastic sheet the hatches, are taken.

At the arrival, the product is easily discharged, at a rate controlled by the unloading facilities used. Care should only be taken to avoid unloading under heavy rain. The urea can be stored at the terminal in bulk in conventional warehouses or in steel tanks.

NSM is supplying several terminals in North America and some other in India and the Far East. In North America the material has been stored in steel tanks in wintertime for several months, undergoing temperature changes from +15°C (59°F) to —25°C (—13°F). Even in these extreme conditions the material keeps its excellent flow properties and can be discharged from the bottom of the bins as easily as fresh product; most of the product is shipped, still in bulk, to the farms, when needed.

As far as technical grade urea is concerned, the treatment is compatible with most of the end uses of the product. To mention the last, but by no means the least advantage to the final user, good flow properties ensure even fertilizer distribution over the agricultural land, i.e. better crop yields per unit of nutrient applied.

NSM now has about 10 years of experience with this type of coating. During these 10 years NSM never received complaints about caking or dustiness of the urea.

3. *Anti-caking treatment of granulated urea.*

In the successful fluid bed granulation for urea, which NSM developed in 1979, the same anti-caking agent (methylolurea) is added to the 95-96% urea solution, just before granulation. Surprisingly we found that addition of 0,8% of this product not only warranted non caking urea granules, but moreover made, due to its crystallization delaying capacity, the granulation of urea much easier. Delaying crystallization means more mother liquor in the granules during the granulation step with the consequence that this growing granules have a largely greater plasticity, which results in less breakage during granulation and to well round shaped granules.

E. *The NSM Process for Coating Ammonium Nitrate-Containing Fertilizers.*

1. *Introduction.*

The use of alkylamines and alkylamine-oil mixtures. At the beginning of the seventies the use of alkylamines containing 12-18 carbon atoms was not unknown, but complete covering of ammonium nitrate pellets with small quantities of amine (0.01-0.05%) was hard to achieve. In order to increase the amount of coating agent without increasing the quantity of amine, solutions of alkylamines in an mineral oil were proposed.

Several producers offered such products, mostly consisting of a 20-30% solution of amine in oil. Some fertilizer producers tried with variable success to apply this coating both on straight ammonium nitrate and on binary and ternary fertilizers.

In pellets thus treated the tendency to moisture absorption and caking is decreased, but seldom to the extent that the product is free flowing after prolonged storage. To improve the storage properties still further, the pellets are normally dusted with a fine inorganic powder such as kaolin, diatomaceous earth or limestone. A disadvantage of this procedure is that the product evolves dust, which is objectionable during such industrial manipulations as repacking, bagging, sealing of plastic bags, bulk loading and pneumatic transport.

Whether coating only with amine or with a mixture of amine and oil, the film of amine is sensitive to abrasion. During the manipulation of loose fertilizer pellets, owing to the pellets rubbing and striking each other, dust is formed, a proportion of which is so fine that it will become airborne. If the pellets have been sprayed with a mixture of amine and oil, the fine fly-dust will contain amine particles liberated by mutual friction of the pellets. This amine-containing fly-dust can cause skin complaints in operating personnel. NSM tried out this coating method up to an industrial scale; the results were unsatisfactory.

2. *The NSM coating process.*

Process description

After intensive investigations NSM developed a process for coating ammonium nitrate pellets. This process has been described in US Patent n° 4,150,965 (24 April 1979) and the equipment, a special coating drum, has been described in US patent application n° 898,530. The NSM coating process is characterized as follows. Ammonium nitrate containing fertilizer pellets are successively coated in a first stage with a uniform and substantially continuous layer of molten C_{12}—C_{18} alkylamine(s), cooled in a second stage to a sufficiently low temperature to bring said coating entirely to the solid state, and coated in a third stage with a thin layer of mineral oil.

In the first stage, the alkylamine melt is sprayed, in a rotary coating drum, over the fertilizer pellets, the temperature of which is above the melting point of the amine. The fertilizer pellets to which the process can be applied may consist of ammonium nitrate, alone or in a admixture with fillers such as limestone or dolomite (for example, 28-35% N ammonium nitrate prills and pellets; 20.5-23% and 26% N calcium ammonium nitrate prills and pellets); binary mixtures of ammonium nitrate and ammonium and calcium phosphates (for example, a mixture of monoammonium phosphate and ammonium nitrate such as 20-20-0 and 23-23-0); and ternary mixtures of ammonium nitrate, phosphates and potassium salts, possibly supplemented with any other plant nutrient.

Suitable amines are primary alkylamines, in which the amine group is terminal and the alkyl group contains 12-18 carbon atoms, preferably in a straight chain. Generally speaking mixtures of such amines will be used. Excellent results were obtained using so-called technical grade octadecylamine, which is a mixture of unbranched C_{10}—C_{20} alkylamines, containing approximately 65% C_{18} alkylamine, approximately 30% C_{16} alkylamine and minor percentages of C_{12} and C_{14} alkylamines. The amine is sprayed in the molten state over the fertilizer pellets to be treated in a rotary coating drum designed so that the pellets are provided over their entire surface with a uniform and substantially continuous coating during their passage through the drum. The drum used for this purpose is described in a later section of this paper. The amount of alkylamine needed to produce a substantially continuous coating over the entire surface area of the pellets is 0.03-0.04% of the weight of the pellets. For best results both the alkylamine and the fertilizer pellets should be at a high enough temperature to ensure that the amine will remain molten all the time the pellets are in the coating drum so that it will be spread uniformly over their surface as they roll in the drum. In general, the amine will be 25-30°C and the pellets at least 5°C above the amine melting point at the moment of spraying.

In the second stage, the coated fertilizer pellets are air-cooled to a temperature of 27-28°C to completely solidify the coating. The cooling air should be dry enough to prevent the pellets from absorbing any moisture. A fluidized-bed cooler or a suitable-designed rotary drum cooler can be used.

At this point the fertilizer pellets have a substantially continuous solid coating, which effectively protects the pellets from moisture penetration. So as to protect this coating from friction damage during handling and thereby to reduce dust formation and lessen still further the caking tendency, a further coating of a mineral oil is then applied at ambient temperature (15°-30°C) by hydraulic or air-spraying in a rotary drum similar in type to that used for applying the amine coating. It is important that the oil, which is applied in a proportion of 0.03-0.1% of the product weight, should not dissolve the amine at temperature up to at least 28°C. Thin mineral lubricating oils with a high paraffinic hydrocarbon content and only minor proportions of aromatic and naphthenic hydrocarbons are highly suitable.

Even after much handling, the treated product retains its favourable properties: greatly reduced moisture absorption, greatly reduced caking tendence and no dusting tendency, as illustrated by the following examples, in which coating tests, carried out on industrial scale, have been described.

3. *Experience in commercial operation of the NSM coating process.*

The introduction of the process in NSM's own ammonium nitrate plants in 1974 caused considerable changes, as can be seen from the following description of the company's experience before and after 1974.

Before 1974

Much investment and many unsuccessful trials in preparing finely crushed and air classified limestone or dolomite powder to coat the pellets to prevent caking.

Caking of the products in NSM's warehouses and in those of distributors.

Crushing of 5 to 10% of the pellets by the scraper in loading, and consequent recycling of this quantum in the production.

Clouds of dust in the production, in warehouses, in loading bays, in ships and at distributors.

Formation of thick hard humid top layers in bulk storage at the distributors with subsequent difficulties in breaking these layers, and subsequent caking in the bags when mixtures of wet and dry products were bagged.

This all resulted in many complaints and claims for damages by distributors and users.

After 1974

Products are dust-free from production to user.

Bagged and bulk storage under dry conditions give no caking at all, even after prolonged storage.

In bulk storage the humid top layer is reduced to a fraction of what it was with powder coating.

No more crushing of product while loading and unloading.

Products resist very well bulk storage under the very humid conditions in the Netherlands.

Products are shipped in bulk all over the world.

No complaints or claims for damages because of bad quality.

Process requires only small investments in apparatus in relation to the total investment for an ammonium nitrate plant.

Very low cost coating agent.

Comparing the costs of the present NSM coating process with the cost of the former process, without quantifying the results, which depend on every particular case; and considering particularly:

the cost of investment in plant to prepare fine powders;

the quantum of products to recycle, due to caking; and taking into account in the actual process;

the absence of complaints and claims for damages by the users;

the clean working conditions;

the satisfaction of the clients with these products.

It is evident that the present coating process yields greatly increased profits and many considerable advantages.

Appendix

DETERMINATION OF THE CAKING TENDENCY OF FERTILIZERS

The pellets are packed in polyethylene bags of 50 kg which are stored for a certain period (2 weeks - 1 month - 3 months) under a pressure of 0.35 kg/cm^2 in a room in which a constant temperature of 27°C is maintained. Subsequently the amount of lumps (caked product) in a bag is determined by carefully placing the bag on a 1 cm mesh screen, cutting it open and removing the cut-open bag. When the screen is lifted the free-flowing pellets flow through the screen; the lumps remaining behind on the screen are collected and weighed. The weight of the lumps is expressed as a percentage of the bag contents (50 kg). Subsequently, blocks of 7 x 7 x 5 cm are cut from the lumps, and the load under which the block breaks is determined using a dynamometer. This weight is termed "Hardness" and is expressed in kg required to break the block.

Rating:

Percentage of lumps

0 % = free flowing
<15 % = good
15-30 % = moderate
>30 % = unsatisfactory

Hardness of lumps
<1kg = virtually free flowing
<3kg = good
3-5kg = moderate caking tendency
5-10kg = considerable caking tendency
>10kg = "hard baked"

MODERATOR SMITH: Thank you very much Willie Van Hijfte. Those pictures of caking and co-crystallizing bring back rather unsatisfactory memories for many of us. It is evident that N.S.M. has an example here of a very definit advancement in conditioning of fertilizer materials. Are there any questions?

QUESTION FROM DR. PONA SARMA: I have two questions. The first one is: Do you have any cost data on the coating of Ammonium Nitrate and Urea? The second question is: Did you study if the coating of Urea has any effect on the ammonia volatilization losses. What I am asking is: Does it effect the Urea's inhibition at all?

ANSWER WILLIE VAN HIJFTE: We are not making a slow release fertilizer. Our Urea is soluble like normal Urea. Our Urea as we coat it can be applied to make practically all technical products of Urea. As to your first question, I have no costs.

QUESTION FRANK ACHORN: We have observed a use of Amine and Oil on coating Ammonium Phosphate Nitrate Fertilizers and on Nitric Phosphate Fertilizers, however, this is the first time I have noted the use of a special drum to do this in. Is the objective to obtain effective coating with less Amine and less Oil? Did I understand you correctly when you said it was the rolling action, rather than the spray pattern that counted the most?

ANSWER - WILLIE VAN HIJFTE: Spraying is without importance. You should never try to spray very fine. Then you have a mist. What is important is rolling and rubbing.

QUESTION - PIERRE BECKER: What is the retention time in your coating drum. What is the peripheral speed to make your granules run?

WILLIE VAN HIJFTE: The retention time is practically six to seven minutes. I do not have the speed.

MODERATOR SMITH: We certainly thank you Dr. Van Hijfte. Our thanks to all of the Speakers. They have all made an excellent contribution. Let's give them a hand. (Applause)

We can recess first to our Cocktail Party at 6 P.M. and please report to our Final Session tomorrow morning. Thank you and have a good evening. (Applause)

Thursday, November 5, 1981

Final Session
Moderators:
Paul J. Prosser Jr. - Barney A. Tucker

MODERATOR PROSSER: Good Morning. The normal process, as you know, is to begin by reading the "Treasurer's Report."

FINANCIAL STATEMENT

October 25, 1980 to October 28, 1981

CASH BALANCE — October 25, 1980		$10,999.54
Income October 25, 1980 - October 28, 1981		
Registration Fees — 1980 Meeting	$18,389.13	
Sale of Proceedings	1,452.85	
Total Receipts October 25, 1980 to October 28, 1981		$19,841.98
Total Funds Available October 25, 1980 — October 28, 1981		$30,841.52
Disbursements October 25, 1980 — October 28, 1981		
1980 Meeting Expenses	$ 2,455.89	
1980 Proceedings Including Printing, Postage, etc.	10,533.02	
Miscellaneous Expenses Including Postage, Stationery, Etc.	888.81	
Directors Meetings	1,036.66	
1981 Meeting — Preliminary Expenses	1,043.91	
Disbursement Cocktail Party Fund	236.25	
Advertising	804.27	
Capital Purchase (Scriptomatic Addresser)	1,464.75	
Total Disbursements October 25, 1980 to October 28, 1981		$18,463.56
CASH BALANCE — October 28, 1981		$12,377.96
Less Reserve for Cocktail Party Fund		298.03
Total Cash Available October 28, 1981		$12,079.93

Respectfully submitted,

Paul J Prosser

PAUL J. PROSSER, JR.
Secretary-Treasurer

Just to say a word about The Financial Statement. We have, as you will note, a $12,000 cushion. You will also note that last year's expenses amounted to $18,500.00. Obviously the receipts, from this meeting, will not be sufficient to take care of one year's expenses, so, we will be digging into the reserve to some extent.

When I came into this meeting room a couple of minutes ago the total registration, including some who had registered in advance but had not appeared, was 310. Last year's registration, as I remember, was 376. This shows that we have about a 20% reduction.

We will now proceed with the rest of the Business Meeting.

As you know and you have heard, since your arrival here, that Our Nominating Committee Chairman, Wayne King, is seriously ill and will not be with us at this meeting. Chairman Achorn is going to take care of this part.

Nominating Committee Report

Chairman Frank Achorn

Thank you Paul. Normally, Wayne King, tells a joke before he makes his report of The Nominating Committee. I fail so horribly in jokes that I will not attempt to give one this morning. That is my joke.

Our Nominating Committee has had several meetings during the past 6 months at Our Board Meetings in Baltimore and a meeting here yesterday. The Committee recommends and nominates to join Our Board of Directors:

Jean Cheval, Operating Manager
Crops Division
United Cooperatives of Ontario
Missiseauga, Ontario, Canada

Dean R. Sanders, V.P.
The Espoma Co.
Millville, N.J.

Jean and Dean have been very active in our Round Table for a number of years. Please stand up. (Applause)

Do we have a second Okay from our Audience here? Yes we do, many seconds. Any opposition? Silence. Jean and Dean you are elected members of Our Board of Directors. (Applause)

The meeting is back to you Paul. (Applause)

MODERATOR PAUL PROSSER: I offer my congratulations to "Our New Board Members". (Applause) We will now have Our Chairman, from our other Committees, give us their reports:

Meeting Place and Dates Committee

Tom Athey, Chairman

Thanks for your kind welcome.

As we have done for a number of years: On the even years we have been going to Atlanta, Ga. I have made arrangements for Our Round Table 32nd Annual Meeting to be held in Atlanta— Sheraton-Atlanta Hotel— Meeting Dates-Tuesday, October 26, Wednesday, October 27 and Thursday, October 28, 1982. Registration will start at 6:00 P.M. Monday, October 25th.

MODERATOR PROSSER: Thank you Tom. (Applause) Tom Athey is also Chairman of Our Entertainment Committee and reports.

Entertainment Committee Report

Tom Athey, Chairman

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 the evening very much. (Applause)

HOSTS:

ATLANTA UTILITY WORKS
BARNARD AND BURK, INC.
C&I/GIRDLER INCORPORATED
DAVY POWERGAS, INC.
FEECO INTERNATIONAL INC.
FESCO, INC.
HAVER FILLING SYSTEMS,
  BEUMER CORP.
  DIVISION KRUPP INTERNATIONAL
J&H EQUIPMENT, INC.
THE M. W. KELLOGG COMPANY
KIERNAN-GREGORY CORP.
PETROCHEMICALS COMPANY, INC.
THE PROSSER COMPANY, INC.
EDW. RENNEBURG & SONS CO.
ST. REGIS PAPER COMPANY
  BAG PACKAGING DIVISION
THE A. J. SACKETT & SONS CO.
SINGMASTER & BREYER, INC.
STEDMAN FOUNDRY AND
  MACHINE CO., INC.
UREA TECHNOLOGIES, INC.
WEBSTER INDUSTRIES, INC.
WHEELABRATOR-FRYE, INC.

MODERATOR PROSSER: Thank you again Tom. You and our Hosts did a magnificent job organizing and arrangements made with the Hotel, etc. etc.

Walter Sackett, Jr. will now report to you as Chairman of:

Public Relations Committee

Walter J. Sackett, Jr. Chairman

Thank you Paul. I will be brief. I think we have maintained good relations with most of the domestic and foreign publications, at least the ones that I know of. If anybody is aware of any publication that we are not contacting, on a regular basis, I wish they would contact me. We advertised in Farm Chemicals and Fertilizer Progress again this year. The cost was something over $600.00 I would like to thank everybody on The Board for their support. I would also like to thank my Secretary, Pat Rampmeyer, who runs my end of the show pretty well. (Applause)

MODERATOR PROSSER: We have completed our Business Session. Are there any questions? If there are no further questions I will turn the remainder of this morning's meeting to Chairman Achorn. (Applause)

CHAIRMAN ACHORN: Barney Tucker is our man from Kentucky. Whenever I hear people say that NPK mix plants are going to disappear and we will never see them again. I think of Barney Tucker. He laughs all the way to the Bank! Barney does a tremendous job with NPK mixtures and also with other agricultural activities. He has been very active in the Fertilizer Industry Round Table and a strong supporter of it. He is a member of The Fertilizer Institute. I could go on and on with many more of Barney's activities, however, time will not permit. Barney come on up here and take over as Moderator to cover the remainder important discussions. (Applause)

MODERATOR BARNEY TUCKER: Thank you Frank. It shows real interest and fortitude to see this many of you present this morning after you have been here two long days participating in programs with excellent, interesting discussions.

Frank, noting the remarks by our Secretary- Paul Prosser - that our attendance for this meeting is down by about 20%, I think the Executives have just spent the money out in Palm Springs this week. I just came from the T.F.I. Board Meeting out there. They have been there since Sunday. Maybe their budget just goes so far. They probably do not realize how business-like this particular program is.

Our first speaker, this morning, is a Gentleman I just rode with last night, all the way across the country, coming from the T.F.I. Board Meeting at Palm Springs, Florida.

Bill White is a Senior Vice President of T.F.I. He has a little bit of action on practically all of the programs, including E.P.A., OSHA and T.F.I.'s Energy Program. Bill grew up on the farm in Amelia County, Virginia, attended V.P.I. and Ohio State specializing in Soil Fertility and Plant Nutrition. Somewhere along the line he got injected with a bit of Energy Information and he is going to present a paper on The T.F.I. Energy Survey and the Energy Situation. With no further ado, and to move the program along, it is my pleasure to call on William C. White. (Applause)

Energy Survey

William C. White

There is hardly a more fascinating, more far-reaching subject than energy. It is the essence of life itself.

Take, for one example, the presence of this 200-person group during this 30-minute discussion. At 2,500 calories per person per day, the metabolic energy consumption of the group during this half-hour period will be 10.4 kilo calories, or about 41 Btus. Such a consumption is equivalent to the energy in 10.5 lb. of hamburger (992 cal/lb), or for those on a liquid diet, 69 cans of Pabst Blue Ribbon (150 cal/12 oz. can).

Whether we use the food chain, space heating or cooling, transportation or manufacturing processes, man is the most energy-consumptive form of life of which we are aware. His list of energy uses is nearly endless. Among this list, however, we should recognize that in the U.S., agricultural production currently accounts for nearly three percent of total energy consumption annually, on the order of 78 quads.**

And, of that amount, energy in applied fertilizer accounts for about 0.4 quad, one-sixth of that used in agriculature, or approximately 0.5 percent of the total energy consumption, 78 quads, in 1980. When all ammonia and phosphate production is counted, energy consumption for fertilizer production exceeded 0.5 quad in 1980.

This subject of energy consumption is one of the four I want to discuss related to fertilizers. The other three are conservation, curtailments and costs of energy used in fertilizer production.

Energy Consumption

Ten years ago, The Fertilizer Institute conducted the first survey in this country on energy used in producing key fertilizer products. TFI has made a continuous effort to improve this base of information, and the survey published in 1980 for CY 1979 represents the best accumulation of data on this subject to date. Table 1 presents these results in summary form.

Natural gas clearly is the energy workhorse in the fertilizer industry. Of the energy used in ammonia production (centrifugal plants) in 1980, natural gas provided 97 percent of the total (40.3 million Btu's per ton). For liquid urea production, natural gas provided 31 percent of the total energy requirement and 56 percent of the total for muriate of potash.

Phosphate production, however, depends on the electric plug. Electricity provided 95 percent of the energy for mining and reclamation of phosphate rock and 97 percent of the energy for wet beneficiation. For wet process phosphoric acid, electricity and imported steam each provided approximately half the energy needs.

Converted to representatively quantities of energy per pound of nutrients, one obtains results shown in Table 2. Admittedly, such values depend on product mixes used, but those shown are sound for quickly calculating energy equivalents in fertilizer production and in fertilizer consumption. The latter is used for its

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** One Quadrillion Btus (1,000,000,000,000,000 Btus) value in making comparisons for fertilizers with other agricultural inputs.

Table 2
Representative quantities of energy used in producing nutrients applied in commercial fertilizers in the U.S. in 1980

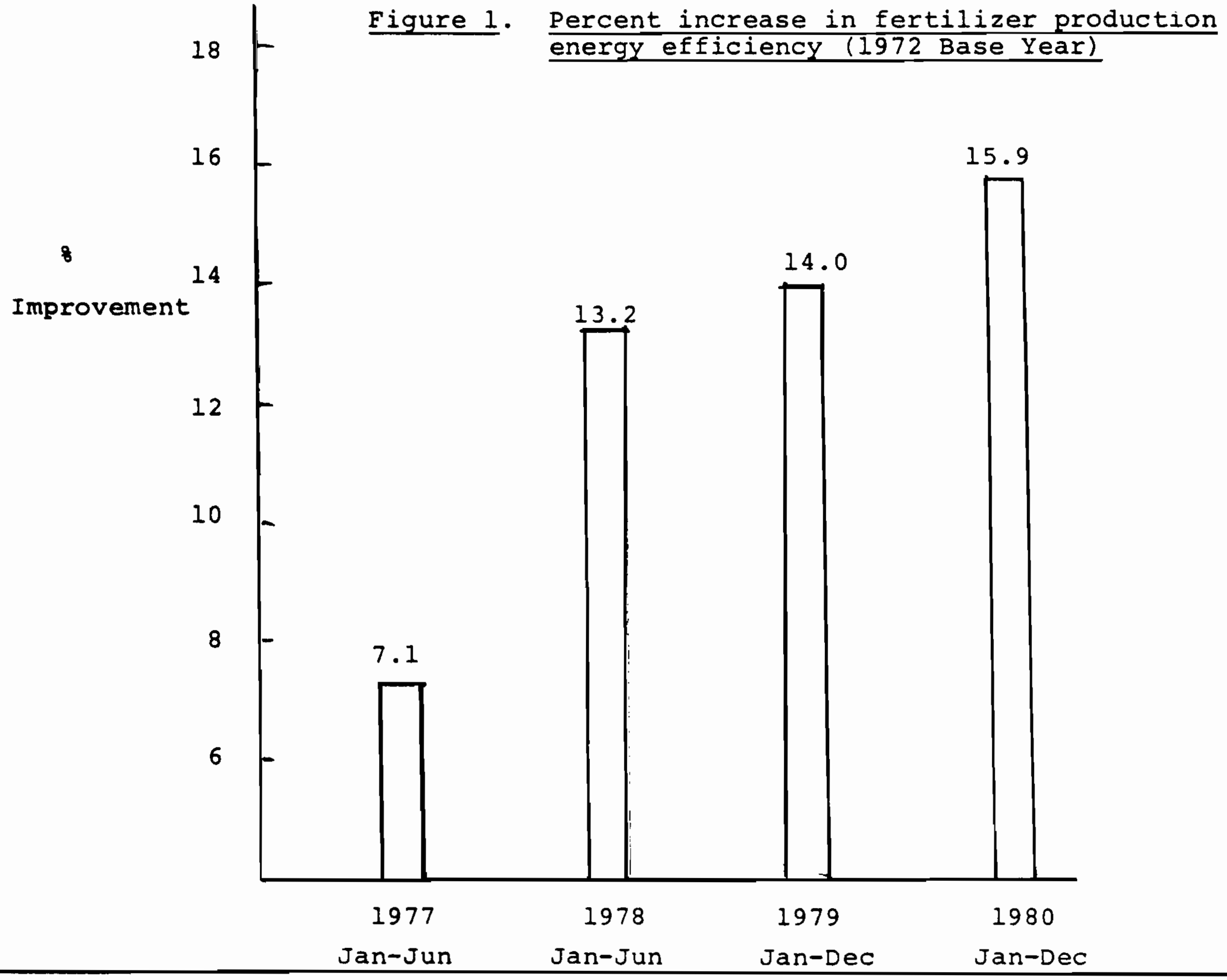
	Nutrients Applied (million tons)	Energy Used (Btu's/lb)	Total energy (Trillion Btu's)	% of Total
N	11.4	30,000	342	87
P_2O_5	5.4	7,000	38	10
K_2O	6.1	1,800	11	3
			391	

Of the energy consumed in producing the nutrients applied in 1980, nitrogen represented by far the largest share — 87 percent. Phosphates consumed 10 percent of the total. As shown in Table 1, energy consumption in phosphate production includes large quantities of imported steam, primarily as recovered heat from sulfuric acid production. Muriate of potash, at 1,800 Btu's per pound of K_2O, represented three percent of the total.

Energy Conservation

In the mid-seventies, the federal government initiated a program for designated industry groups to report progress in energy conservation, with 1972 as the reference or base year. Industry groups were designated by two-digit SIC Codes, with fertilizer production (nitrogen, finished phosphate and mixed fertilizers) included in SIC Code 28. Mining of phosphate, sulfur and

Figure 1. Percent increase in fertilizer production energy efficiency (1972 Base Year)



potash, in SIC Code 14, was not "designated." Rather than being amalgamated with dozens of other industries in SIC Code 28, the fertilizer industry decided early to report its record separately.

Figure 1 shows this record for calendar years 1976-1980. Beginning with the first report, feedstock energy was excluded, thus, only process and other manufacturing energy is included in these reports. Progress in energy conservation (energy used per ton of product) has been rather steady during the period. In the most recent report, for CY 1980, fertilizer production consumed 15.9 percent less energy per ton of product than in 1972.

As Cliff Twaddle* of Agrico Chemical Company has described, the grains in energy efficiency in fertilizer production have been a result primarily of five practices:

1. Recovery and conservation of process heat.
2. Process improvements and innovations.
3. Use of computer controls and analyzers.
4. Redesign and replacement of existing equipment.
5. Utilization of by-products and waste steam.

For the 20 fertilizer producers participating in TFI's energy conservation report, energy savings in 1980 amounted to more than 49 trillion Btu's, equivalent to 8.5 million barrels of oil, or more than the average day's import in the U.S. of crude oil. Such a savings, expressed in other terms, were equivalent to the energy for residential and commercial energy needs of Houston for more than a year.

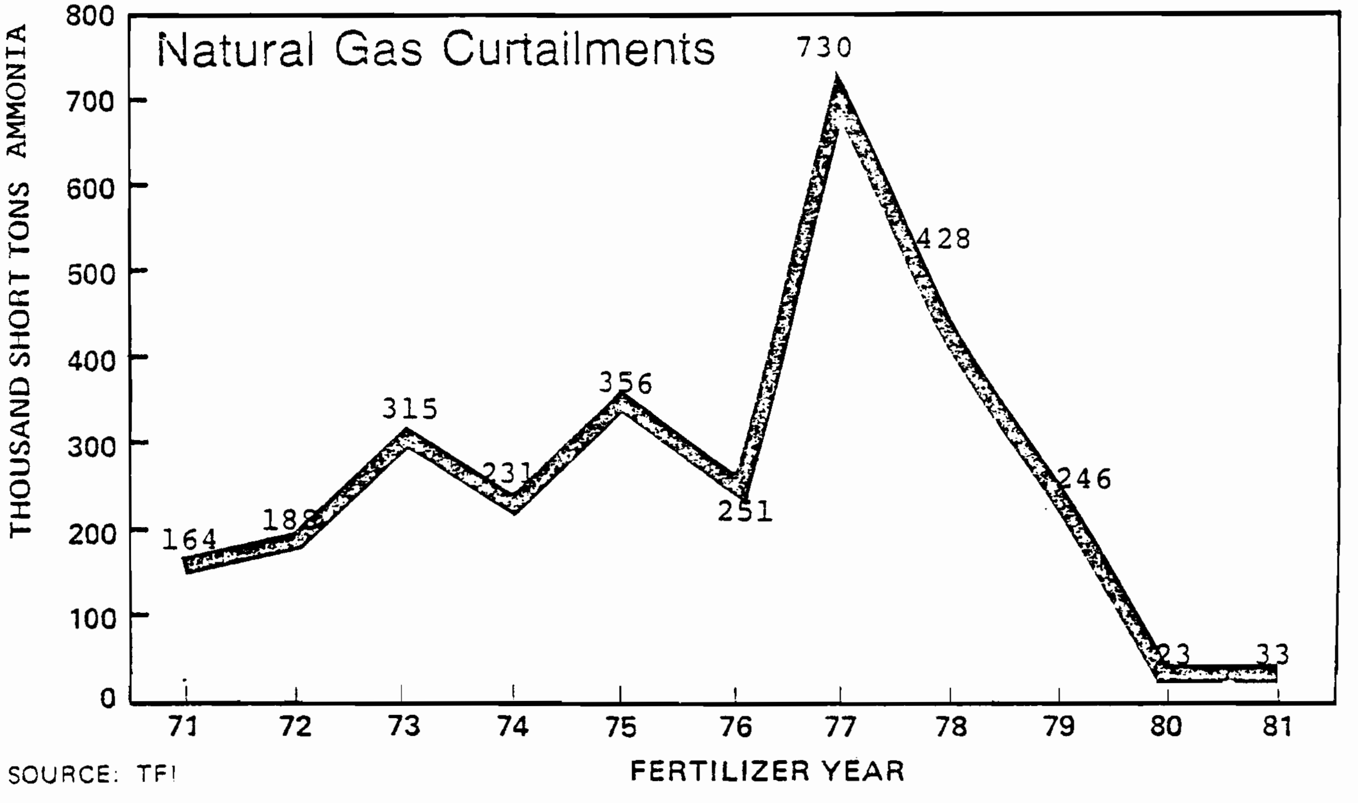
In 1975, the federal government, through contract studies, set energy conservation goals for 1980 against 1972 for each of the 10 two-digit SIC Code industry groups. In 1980, most industry groups, in coordination with DOE, undertook determining goals for 1985, with 1972 as the base year. Results of this for the fertilizer industry published by TFI May 1981 are in Table 3.

Again, feedstock energy was excluded. The results show efficiency of energy use (including OSHA and EPA energy) in producing fertilizers in 1985 will improve 21.2 percent over 1972. *Excluding* energy used to meet OSHA and EPA requirements, an improvement of 23.9 percent is expected. Using energy equivalent data, the former represents a savings of 14 million barrels of oil in 1985.

Energy Curtailments

Aside from electrical power curtailments in the early seventies, energy curtailments have centered on natural gas. Electrical curtailments peaked in 1973 in Florida at the phosphate mines, cutting production by at least a million tons of phosphate in 1973. Since then, electrical curtailments have been negligible.

Figure 2.



SOURCE: TFI

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*The Fertilizer Handbook, 1981 edition (in press).

The record for natural gas curtailments is shown in Figure 2. Curtailments peaked in 1977 with a loss of 730,000 tons of ammonia. Since then, with increasing supplies of natural gas, ammonia production losses from gas curtailments have declined sharply.

For the immediate future, gas curtailments do not appear to be a problem. Reduced projected demand is resulting in certain pipeline companies having gas they do not anticipate selling in the next year or two through their system. Thus, the sales of "off-system" gas which reflect the temporary excess gas situations.

Title IV of the Natural Gas Policy Act provides for Priority 2 for natural gas used as feedstock or process heat in fertilizer production. Natural gas for boiler fuel would presently fall in Priority 5 during periods of natural gas curtailment. In recent years, wherecurtailments have been almost non-existent, the principal activity of industry has been to file certificates of priority use with their gas suppliers.

Energy Costs

No energy subject has more uncertainties than future costs of natural gas. These, in turn, depend on what role the federal government will exercise over interstate gas prices in the future.

Since 1954, the federal government has exercised control over interstate gas prices, primarily at the wellhead. The result in recent years has been lower costs for energy in natural gas than in other energy sources. In 1978, recognizing the inequities of the situation, congress passed the Natural Gas Policy Act (NGPA). The Act sought to remedy the situation through gradual decontrol of *wellhead prices* of *new interstate* gas (from wells with drilling beginning on or after February 19, 1977) *by 1985* to a price equivalent to *$15/barrel of crude oil at '78 dollars.* The escalations of wellhead prices allowed by the NGPA simply have not fulfilled the Act's objective, namely, to raise interstate gas prices, at the wellhead, to a level comparable to crude oil by January 1, 1985. Hence, the quandary of national leadership as to what to do. Until the decision is made, one can only speculate what natural gas costs will be in the future.

Past records, however, can be cited with confidence. They clearly show skyrocketing energy costs for fertilizer production, just as for other purposes. Electrical costs today are on the order of three to four cents a kw-h compared with less than a cent in 1970. And, natural gas has increased even more sharply, as shown in the following table:

Table 4.
*Natural gas costs for ammonia production**

CY	$/mcf	mcf/Ton	$/Ton
1980	1.96	36.2	71
1979	1.62	36.4	59
1978	1.34	37.3	50
1977	1.14	36.8	42
1975	0.62	37.1	23
1973	0.36	38.9	14
1970	0.28	39.3	11

*TFI Ammonia Production Cost Surveys

The average price of natural gas (inter and intrastate) of $1.96/mcf was seven times that of 1970 ($0.28/mcf). In a more recent TFI survey (October 6, 1981), the average cost of natural gas for ammonia for FY 81 had increased 16 percent from CY 80 to $2.28/mcf.

Future gas costs will depend largely on what happens to the NGPA. Will it continue unmodified? Will it be advanced ahead of 1985? Or, will total decontrol (old andnew gas) take place? Nobody knows the answer. Whatever the option played, costs will go up. If crude oil prices become the determinant, there is agreement among most of the energy experts that natural gas wellhead prices will be about 80 percent of the crude oil price. With this assumption, and 5.8 million Btu's/barrel of oil, one gets the following figures:

$ Barrel Oil	$ mcf gas
30	4.14
35	4.83
40	5.52
45	6.21
50	6.90
55	7.59
100	13.79

In addition to current conditions of the market pushing up energy costs, there is Title II of NGPA — Incremental Pricing. This section of NGPA prescribes that natural gas used under industrial boilers will have an "incremental pricing surcharge" added to the bill. The purpose is to discourage natural gas use under industrial boilers, and where used to generate additional revenues, supposedly to reduce the impact of decontrol on nonindustrial gas consumers.

The fertilizer producers, this surcharge would be about $25 million annually (primary to urea and ammonium nitrate producers) if there were not exemptions. Initially, fertilizer production was exempted under an agricultural category. FERC terminated this exemption effective August 31, but September 24, 1981, FERC exempted fertilizer production under another section, Section 206(d), of NGPA. This latest exemption is scheduled to be effective November 1. As with Title I of NGPA (wellhead price controls) Title II of NGPA likely is up for heavy overhaul, or, more likely, termination, by the present Administration.

Summary

This survey of energy issues is far from complete. Its purpose is to highlight developments in only four areas relating to fertilizer production . . . consumption, conservation, curtailments and costs.

Increased production of fertilizer, essential to supporting increased future agricultural production, most likely will call for more total energy, even with our best conservation record. We have reviewed information showing that energy to produce fertilizers presently applied in the U.S. annually is about 0.4 quad, 0.5 percent of the total energy used last year in the U.S. Conservation in energy, or improved efficiency in energy use, in 1985 may result in a savings of five to 10 percent over 1980. At projected growth rates in production, these savings will fall short of meeting future energy needs for fertilizer production.

Natural gas provides the predominant share of energy for fertilizer — from ammonia to potash. Electricity is the major source, however, for phosphate products as a group. Hence, the focus on natural gas regarding curtailments — which presently are negligible — and costs.

Energy costs are one of the largest expense items, probably exceeding transportation cost now, in fertilizer production. Costs per unit of energy in 1980 amount to many multiples of 1970 costs, three to five for electricity and six to 10 for natural gas. In 1980, the total energy bill for fertilizers consumed (for production the bill would be even greater because of net export positions for nitrogen and phosphates) exceeded $1 billion (0.4 guad at $2.50/million Btu).

For the future we anticipate natural gas prices to increase by dollars/mcf, not cents/mcf, and impacts on fertilizer costs will be major. An increase of $3/mcf, definitely in the realistic range, in the next several years will increase ammonia costs $117 per ton (39 mcf/T). Consevation of energy, at even eight percent in the next several years, will share only about $9.00 from this increase. So, large costs increases for energy per ton of fertilizer are strong suspects for the future.

Perhaps the engineers will come through with new processes that will cut energy use per unit of product, but at the present no quantum leaps in this area are in sight. This may be the case for the very short term, but for the longer term we have to turn to ingenuity and innovation for solutions to our energy supply and cost problems. I have no clues for which road to travel in this direction, but counsel from Francis Bacon more than a century ago would be sound to follow:

> *"He that will not apply new remedies*
> *must expect new evils, for time is the*
> *greatest innovator."*

Table 1. Energy Use Survey, The Fertilizer Institute, CY 1979

NATURAL GAS SOURCES FOR AMMONIA PRODUCTION

Anhydrous Ammonia Production 13,762,000 Tons*

Natural Gas Source and Type of Contract

Interstate Source		Intrastate Source		Total
Firm	33.3%	Firm	55.8%	89.1%
Interruptible	5.9%	Interruptible	5.0%	10.9%
	39.2%		60.8%	100.0%

AVERAGE ENERGY CONSUMPTION IN ANHYDROUS AMMONIA PRODUCTION

A. Reciprocating Plants: Based on 2,402,000 Tons Production

1,000 Btu/T of Ammonia

	Feedstock Energy	Reformer Process Energy	Other Process** Energy	Total
Natural Gas	21,521	12,957	582	35,060
Electricity	-	632	4,460	5,092
Fuel Oil	-	204	86	290
Imported Steam	-	-	1,416	1,416
Other	276	-	-	276
Total	21,797	13,792	6,544	42,134

B. Centrifugal Plants: Based on 11,450,000 Tons Production

1,000 Btu/T of Ammonia

	Feedstock Energy	Reformer Process Energy	Other Process** Energy	Total
Natural Gas	22,368	14,542	2,181	39,091
Electricity	-	-	708	708
Fuel Oil	-	215	(178)	37
Imported Steam	-	-	408	408
Other	-	102	-	102
Total	22,368	14,859	3,119	40,346

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*All tonnage data refer to tonnage of participants in the survey, not to industry-wide tonnages.

**Energy such as electrical, import steam, fuel for turbine and engine driven compressors of pumps, etc.

Product	Production 1,000T	Natural Gas	Electricity	Fuel Oil	Imported Steam	Total
		1,000 Btu/T				
Urea						
Total liquid	4,791	1,516	864	187	2,188	4,755
Prilled	1,487	222	636	1	2,640	3,499
Granulated	2,438	463	479	3	1,231	2,176
Ammonium Nitrate						
Liquor	5,038	541	568	(3)	392	1,498
Prilled	2,601	113	443	45	1,913	2,514
Granulated	528	643	315	75	1,025	2,058
Phosphate Rock						
Mining & Reclamation	58,814		249	12		261
Beneficiation (wet)	34,944		347	9		356
Calcining	2,771	447	282	173		902
Rock drying	35,078	178	37	186	1	402
Wet Process, Filter Grade Phosphoric Acid (P_2O_5)						
Wet rock feed	2,515	--	1,462	17	1,660	3,139
Dry rock feed	5,524	66	1,650	30	1,852	3,598
Wet Process, Merchant Grade Phosphoric Acid (P_2O_5)	3,706	22	681	62	4,567	5,332
Superphosphoric Acid (P_2O_5)	940	1,296	428	–	972	2,696
Sulfuric Acid	22,985	23	162	27	(1,343)	(1,131)
Normal Superphosphate*						
Unground rock	295	–	215	6	--	221
Ground rock	246	278	212		--	490
Concentrated Superphosphate						
ROP	440	143	170	19	19	351
Granular (Slurry)	2,755	505	527	287	180	1,499
Granular (Reclaimed from ROP)	222	423	414	21	13	871
Diammonium Phosphate	9,179	223	344	70	173	810
Monoammonium Phosphate, Granular	1,537	492	440	–	79	1,011
Potash (Shaft Mining)						
Standard, Coarse and Granular	8,193	1,230	964	1	–	2,195
Mixed Fertilizers						
Granulation	5,059	372	380	121	28	901
Bulk Blends	566	109	35	10	–	154
Mixed Fluids	1,961	309	140	2	90	541

*Use of unground phosphate rock usually consumes less energy than use of ground rock. However, the relatively small number of participants in this survey reported the reverse.

Table 3. Energy conservation goals, fertilizer products in SIC 2873, 74, 75*

	Million Btu (Excluding Feedstock)
1. Projected Total Energy Consumption, CY 1985	335,831,230
2** Total Energy Consumption, Base Year (CY 1972)	426,051,138
3. Projected Total Energy Consumption for 1985 for OSHA and EPA Requirements _not_ in effect in base year	11,409,017
4. Projected Total Energy Consumption for CY 1985 _less_ OSHA/EPA figure above	324,422,213

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5. Percent Reduction in Energy Consumption in 1985 with OSHA/EPA Energy _Included_

$$\frac{2-1}{2} \times 100 = \quad 21.2\%$$

Median 18.7% Mid 50% Range 10.5% – 32.3%

6. Percent Reduction in Energy Consumption in 1985 with OSHA/EPA Energy _Excluded_

$$\frac{2-4}{2} \times 100 = \quad 23.9\%$$

Median 23.2% Mid 50% Range 12.3% – 32.5%

* SIC 2873 – Nitrogenous Fertilizers
SIC 2874 – Phosphatic Fertilizers (Phosphate Mining is SIC 1475)
SIC 2875 – Mixed Fertilizers

** Calculated by multiplying Btu/T in 1972 by projected tons of product in 1985.

MODERATOR TUCKER: Thank you Bill White for that excellent report on T.F.I.'s Energy Survey. (Applause) Are there any questions for Bill?

QUESTION—BUD DAVIS -T.V.A.: Bill you have done an excellent job defining and monitoring the Fertilizer Energy Situation, and, certainly The Fertilizer Industry has a very impressive record of decreasing the Energy Consumption. A number of studies have been published where there are some differences in the numbers that are quoted for the energy requirements for various processes. Even during this meeting a question was raised, I believe to Russ Jones, about why the numbers that engineering firms were using for the energy requirements to make ammonia, differed from T.F.I.'s numbers. I do not think the question was really answered. Bill, would you care to comment?

Answer—BILL WHITE: Bud, I wish I had a real good answer. I wish I were an Engineer. Someone, like Travis Hignett, could give the answer real quickly. All that I can say, is, the numbers we have are numbers actually experienced, that is, after you read the gas meter and after you pay the bill. We realize there is a difference between those numbers and what the engineering companies might say are the design numbers. We hear of the new plants, for ammonia, being built in Canada, are in the neighborhood of 27 mcf per ton. I hope they will run that way. We need that sort of advancement, but so far, I do not know of any plant that is producing ammonia, after having read the gas meter, at 27 mcf per ton. All that I can explain is that these are actual numbers consumed. These are not design numbers. Again, they are 1979 figures.

QUESTION—FRANK ACHORN-TVA: Bill, the subject on gas supply in the country is very confused. Some of the technical magazines (Petroleum Institute, National Gas Association and several others) are reporting some pretty big findings of natural gas at deep levels. In fact, in many cases, they are drilling for that gas. I agree we are going to continue to have gas shortages, but have you had any reports of increased gas supplies and a leveling of gas prices recently?

ANSWER—BILL WHITE: Frank, we have had information, certainly, on icreased gas supplies and to the contrary, all we hear about are increasing gas prices. Union Oil, at the meeting this week, advised something like a 75¢ increase and by next spring pushing their gas prices way up there. We hear about gas price increases everywhere we turn around. I do not know how all of this ties in, but Interstate Pipelines today are making what they call "Off System Sales". Interstate Pipeline Companies, and I am no expert, are now selling gas that they have not turned back to Interstate markets. We have one report, that in Louisianna alone, up to twenty percent of the Intrastate gas in Louisianna, is gas Intrastate buyers are getting thru Intrastate pipelines. It is real "mixy-moxy." All that I can reply is, all we hear about, is gas supplies are increasing. You drill deeper than 15,000 feet and you can take what ever you can get for it and that is where so much of our new gas is coming from because it is decontrolled. These people with gas at 10,000 feet to 10,500 feet are sitting on it.

MODERATOR TUCKER: Thank you Bill. Really, I think the natural Gas Policy Act is so complicated that it just makes for a lot of "hanky-panky". I do not think it will be resolved until the whole thing is either redefined or decontrolled. (Applause)

MODERATOR TUCKER: Out next Speaker is John Rednour, Production Manager, Mississippi Chemical Corporation. Most of you, who have ever had experience with granulation of Fertilizer, know that the granulation of O-X-X grades is a problem. John is going to give a paper on the Conversion to Slurry of O-X-X mixtures. John's hometown is Gastonia, North Carolina where he attended High School. He had his college experience at Jackson County Junior College and the college of Business Management at L.S.U. He has been priviledged to attend the Leadership Dynamic School of The Wharton School of Finance and Accounting. He is a member of The American Institute of Chemical Engineers and is active in his community. He is a Board Member and Past President of The Boys Club Of America, he is a member of The Civil Service Commission and a member of The Chamber of Commerce. He holds a patent on Ammoniated Related Check Valve System. His hobbies are golf, gardening, fishing and civil recovery. He is one of the "old pros" of World War Two where he spent three years in the Army and rose to the rank of Captain. That is one of his greater accomplishments, I would say. Please come to our rostrum John Rednour.

Mississippi Chemicals Conversion To Slurry For O-X-X

John Rednour

Mississippi Chemical Corporation manufactures many different grades of NPX fertilizer in a finished granular form for direct field application. Among the grades produced are those called O-X-X, which contain no nitrogen constituents. Various grades of O-X-X are normally made with available P_2O_5 values ranging from 17% to 38% and K_2O values ranging from 8% to 34%. The O-X-X grades produced in the greatest quantity are 0-17-34, 0-24-24, and 0-20-20.

Prior to the conversion to the slurry process the O-X-X grades were made by granulating potash and enriched run of pile superphosphate. The "Super" was produced by a "Den" conveyor process and sent to a storage area where it cured for several days before being reclaimed and sent in a dry powder form to our #1 NPK granulation plant. In the #1 plant the powdered "Super" and potash were granulated with water and steam.

The #1 NPK plant was modified in 1973 by the installation of a pug mill system designed to be operated in series with a drum granulator-ammoniator. Both nitrogen and O-X-X grades were recycled through the pub mill, which discharged into the granulaor-ammoniator. On nitrogen grades the slurry was split between the pub mill and the granulator-ammoniator with ammonia sparged into both units. On O-X-X grades the recycle through the pub mill was treated with water and steam then fed to the granulator-ammoniator. The pug mill system proved to be of very limited benefit to granulation and product quality. However, the associated high maintenance cost, long downtimes, and frequent need for cleaning the paddles and shaft led us to bypass this unit and use the granulator-ammoniator exclusively.

There were several problems associated with this method of producing O-X-X grades. These included bin storage space for the intermediate "Super", which was not sold in the powdered form, fume scrubbing equipment for the "Den" conveyor and the storage building, as well as the operating and maintenance requirements for the reclaiming equipment. Production schedules sometimes meant the production of O-X-X grades from uncured "Super", with resultant high unavailable P_2O_5 levels.

In early 1979 the decision was made to experiment with a process for making O-X-X from slurry on a production scale. The existing equipment for feeding and weighing rock into the "Den" system was modified by the addition of a screw conveyor and relocation of the rock mixing cone to allow rock and acid to be introduced into an existing agitated reaction tank at our #1 NPK plant. This tank is one normally used in the ammoniation of nitrogen grade slurries.

Soon after experimental production runs began it became apparent that the rock mix cone was not suitable for this application. The cone did not sufficiently disperse the rock into the slurry, resulting in lumps of unreacted rock (mud balls) in the reaction vessel. The level of agitation in the reaction tank was not high enough to reduce the lumps. The slurry in the reaction tank experienced great and rapid changes in viscosity, sometimes resulting in a large crust of build-up around the tank walls and on the agitator shaft. The high viscosity slurry was often impossible to pump into the granulator. This problem was also aggravated by large amounts of gasses being released from the slurry.

The pumps used in pumping this O-X-X slurry are open impeller, dynamic seal, centrifugal types normally used on nitrogen slurries with minimal difficulty. Build-up in the expeller region of this type pump caused seal leakage and bearing failures. The use of sealed pumps with packing or mechanical seals was not successful due to the gasses being liberated from the reacting slurry. The gasses lower the suction head available to the pump and cause cavitation and loss of pumping. dynamic seal designs allow the gasses to be purged through the expeller.

Early slurry problems were not limited to the reaction system, but caused difficulty in the granulation circuit as well. A sticky, wet granulation circuit resulted in frequent blinding of screens, balls in the granulator, chute pluggage, and build-up in the dryer and cage mills. The build-up in the cage mills was a particular frustration, since the O-X-X build-up is extremely dense and hard to chip out, in comparison with that associated with nitrogen NPK grades. In addition the unavailable P_2O_5 levels in the product was quite high.

Over a period of time several changes have been made which have dramatically improved the operation. In order to obtain better rock and acid contacting, the rock mix cone was replaced with a small rock mixing tank which was fitted with a 300 rpm agitator. The small rock mixing tank contained an underflow section which allows the homogenized slurry to maintain a constant level in the mixing section and flow by gravity to the large reaction vessel. In addition to this the sulfuric acid was diverted from the rock mixing area directly to the large reaction vessel. Later the phosphoric acid concentration used in the rock mixing tank was reduced from 50% to 42% P_2O_5 and process make-up water was reduced.

The small rock mixing tank produced a much more uniform dispersion of the rock into the slurry. Because of the more homogeneous nature of the slurry from the rock mixing tank, the changes in viscosity in the large reaction tank became less radical. The pumpability of the slurry increased and build-up problems were greatly reduced. The reaction of the rock was improved resulting in lower unavailable P_2O_5 levels. Improvements were seen in the granulation circuit, subsequently production rates were increased, cage mill pluggage and screen blinding reduced.

In spite of great improvements in the operation, cage mill build-up and build-up in the reaction vessel were still significant problems. The problem of build-up in the reactor led us to relocate the rock mixing tank on a smaller existing reactor vessel which was equipped with an agitator similar to that in the original reaction tank. In changing to the smaller reaction system the retention time of the slurry was not reduced since build-up in the larger reactor reduced its capacity after a short period of operation. With the smaller system the level of slurry agitation was effectively increased and build-up in the tank was reduced to an acceptable level. The increased agitation led to increased slurry pumpability and reduced pump seal build-up problems. Additional reductions in unavailable P_2O_5 levels were also seen.

The problem of cage mill build-up was largely eliminated by the installation of rubber flaps on the interior of the cage mill housings. These were cut from conveyor belting material and hung in the housings in such a way that they were free to flex and dislodge build-up material in thin flakes of scale instead of building into a massive accumulation of concrete-like material in the mills.

O-X-X slurries have varying percentages of free acid when fed to the granulator. This free acid reacts with potassium chloride in the granulation circuit and emits HC1 fumes. These fumes cause corrosion of metal surfaces. The dryer duct and cyclone plenum chamber have experienced severe deterioration. FRP has been used to replace the dryer duct and is showing satisfactory performance. The dryer cyclone equipment will also be replaced with FRP. Other pieces of equipment experiencing HC1 corrosion are primarily the upper surfaces of chutes, screens, and screw conveyor housings. Various materials are under investigation to determine cost effective substitutes for steel in high corrosion areas.

Let me say a little about process parameters and controls. The particular grade being produced sets the available P_2O_5 levels necessary as well as the K_2O. Thus the slurry includes phosphate rock, phosphoric acid, sulfuric acid and water. The P_2O_5 content can be balanced between rock and phosphoric acid with sulfuric acid added primarily as a filler. However, the sulfuric acid is also a reactant in the process. In addition to available and unavailable P_2O_5 and K_2O analysis performed on the product, the quality control lab also runs tests on the slurry; these are P_2O_5 /Ca0 and P_2O_5/H_2SO_4 ratios. In grades like 0-17-34 and 0-24-24 the P_2O_5/Ca0 ratio is in the range of 1.8-2.0 while the P_2O_5/H_2SO_4 ratio is in the range of 4.0-4.35. These ratios are variable and are adjusted in response to the quality of granulation, unavailable P_2O_5 levels and free acid levels. The phosphate rock used is usually 68 BPL and is ground to 80-90% minus 200 mesh. The reaction temperatures are maintained between 180 degrees F and 190 degrees F in the rock mixing tank and between 200 degrees F and 220 degrees F in the reactor. The addition of water in the mixing tank allows the slurry density and viscosity to be adjusted as needed to maintain a pumpable slurry. the specific gravity is monitored by operators in the control room and is usually in the range of 1.70 to 1.90 when corrected to room temperature. A defoaming agent is added in the rock mixing tank to reduce excessive foaming of the reacting slurry.

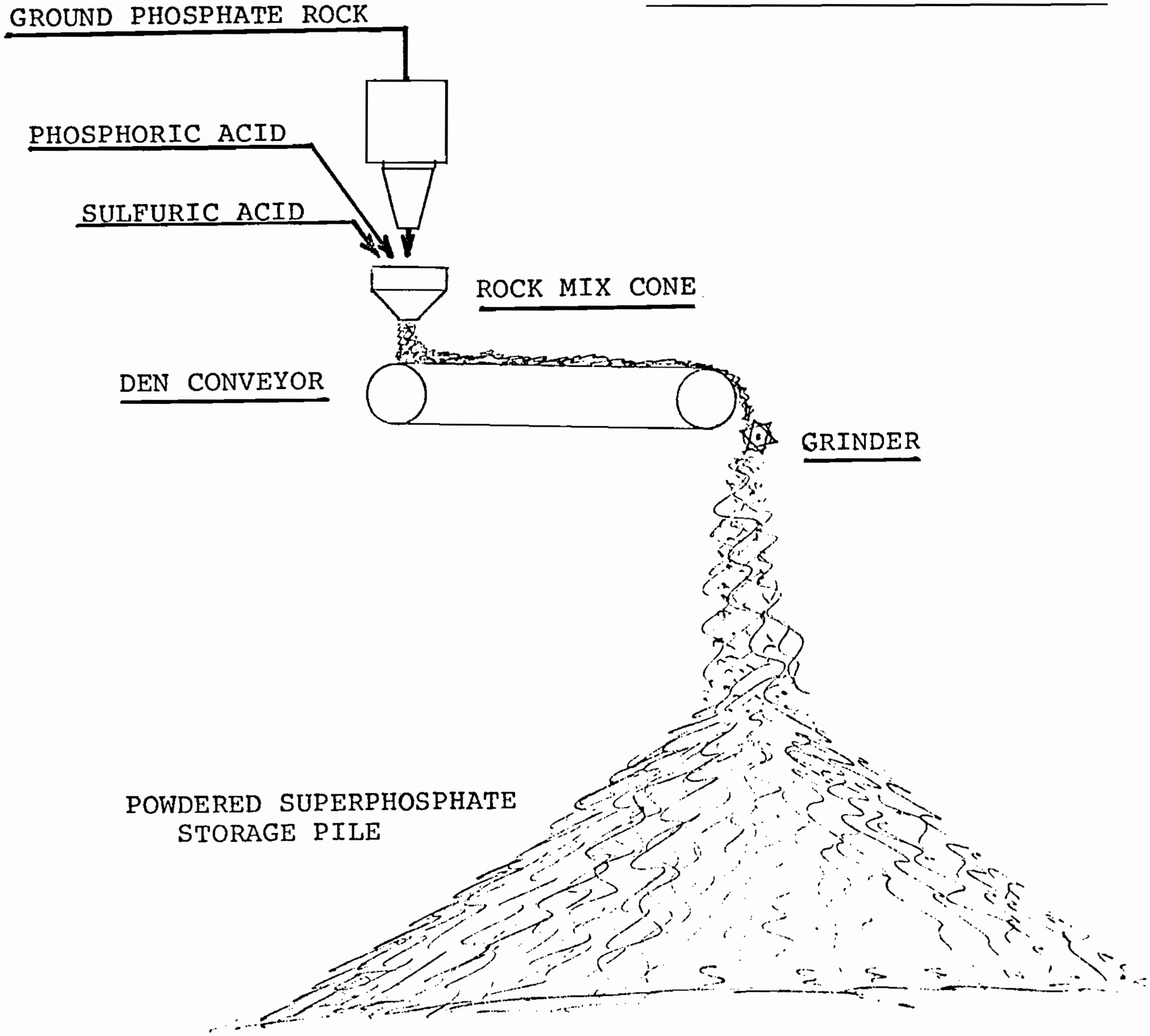
To summarize the feelings we have about O-X-X production with the slurry system, let me say that the process has exceeded our expectations. Producing both O-X-X and nitrogen grades of fertilizer the #1 NPK plant set a new production record in the 1980-81 fiscal year. This new record reflects a 13% increase in production of all grades at #1 NPK plant over the 1979-80 year, which was also a record year.

The production rate on O-X-X grades like 0-17-34 and 0-24-24 is normally between fifty and sixty tons per hour with the slurry system, compared to thirty to forty tons per hour with the "Den" conveyor process. The highest rate with the slurry system has been seventy tons per hour. At this production rate the recycle ratio was 2.7 to 1.

The product quality of O-X-X produced from slurry is superior to that from powdered "Super".The granules are more dense, more uniform, less dusty and have greatly improved handling and storage properties. Cost savings have resulted from higher available P_2O_5 ratios in the product and increased production rates. Corrosion problems have increased in the #1 facility, however, these are off-set by the elimination of operation and maintenance expenses of the "Den" conveyor and reclaim system. Granulation of O-X-X grades can now be more easily scheduled to suit the requirements of customer needs and the logistics of storage and shipping.

Let me close by saying that MCC is grateful to the #1 plant operations and maintenance personnel for their support and persistance in the face of many difficult and frustrating situations. We would also like to thank the folks at TVA and many Fertilizer Institute members for their helpful advice in our conversion to the slurry system.

DEN CONVEYOR PROCESS
FOR POWDERED SUPERPHOSPHATE Figure 1



AGITATED ROCK MIX TANK USED BY MCC

Figure 2

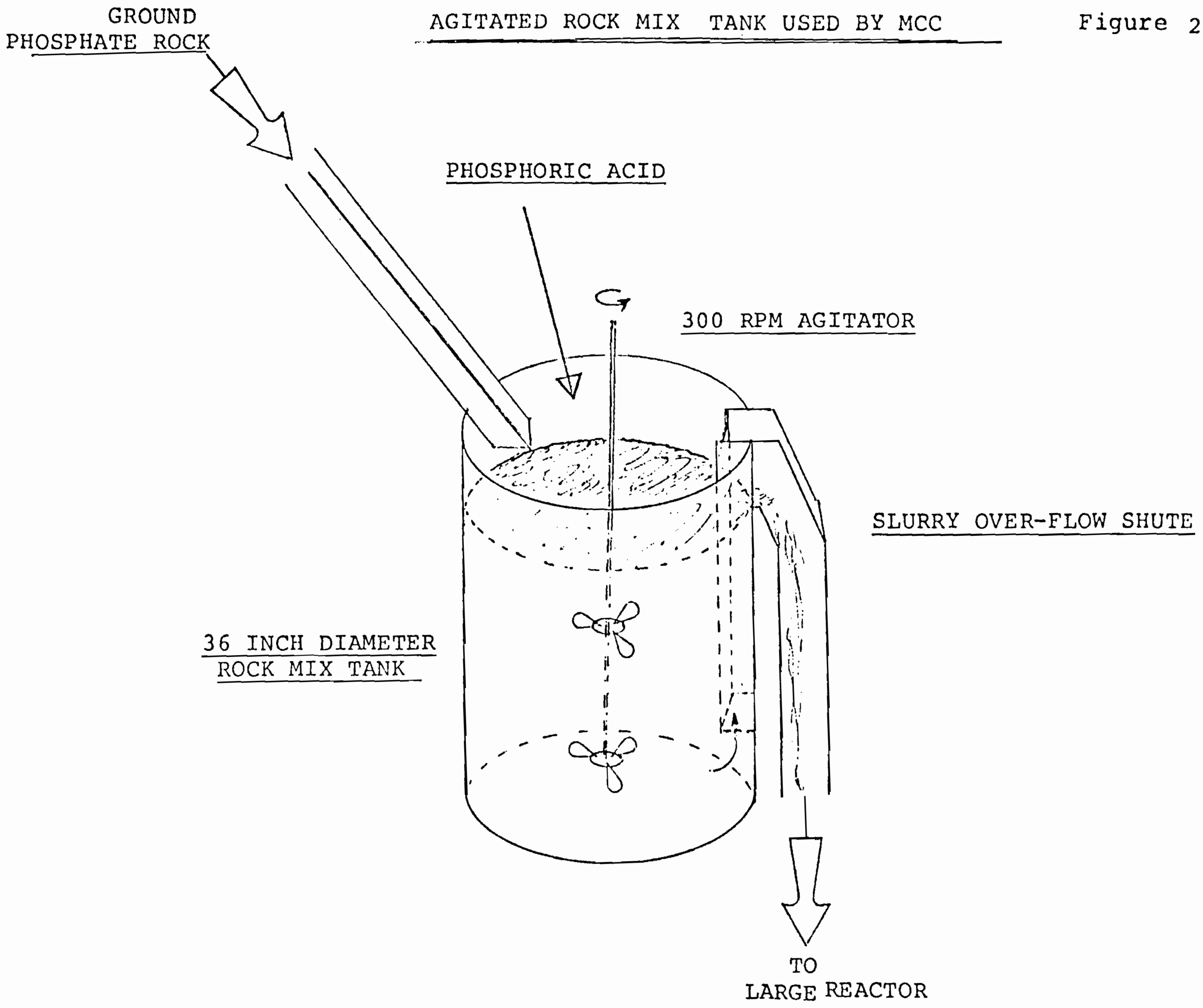
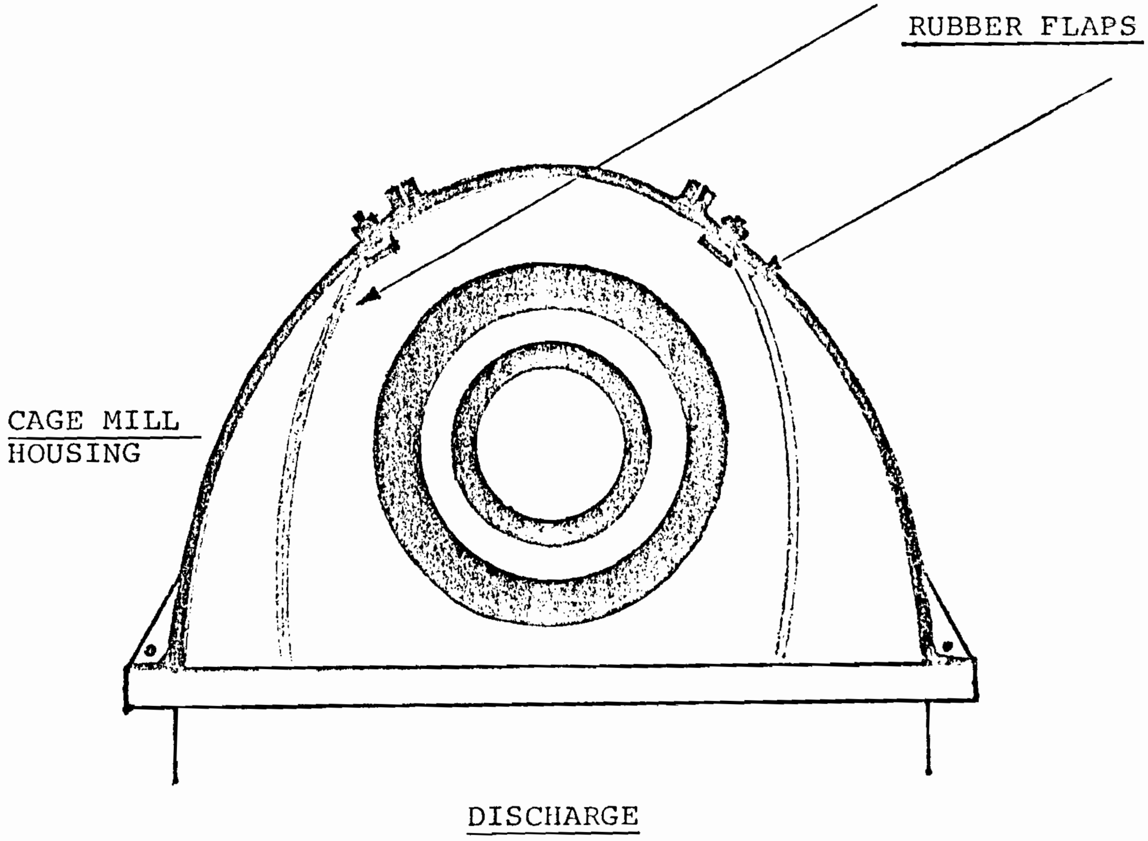


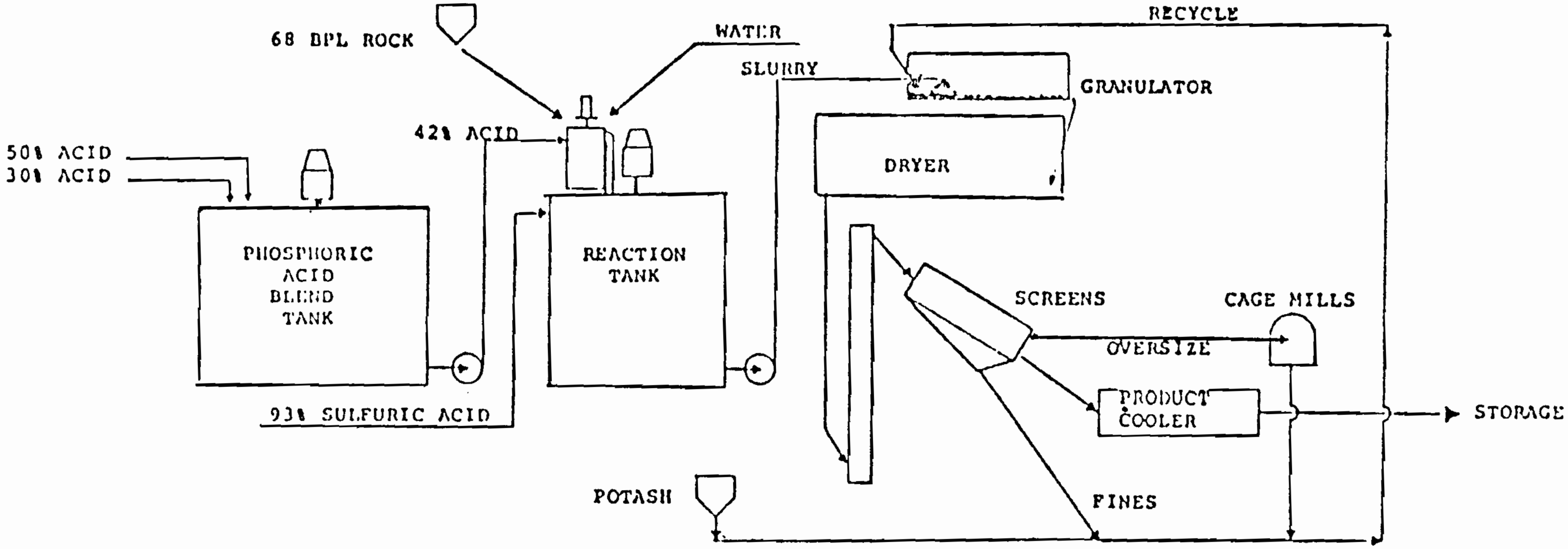
Figure 3

CUTAWAY DRAWING OF CAGE MILL

SHOWING

RUBBER FLAPS





BASIC ELEMENTS OF NPK FACILITY

Figure 4

TYPICAL 0-X-X FORMULATIONS

# ROCK	# P_2O_5 FROM H_3PO_4	# H_2SO_4	# KCl	P_2O_5 / CaO RATIO	P_2O_5 / H_2SO_4 RATIO
0-24-24					
530	325	80	800	1.9-2.0	4.5-5.0
0-19-34					
410	227	90	1135	1.85	3.73
0-20-20					
685	200	280	667	1.3-1.4	1.4-1.5
0-30-15					
670	400	100	500	1.85-1.95	4-4.5
0-34-8					
783	450	160	266	1.9-2.0	4.8-5.5
0-14-28					
553	130	240	940	1.15-1.25	1.2-1.3
0-28-14 S/S					
696	370	150	466	1.84	3.25

MINERAL FEED 60 LBS. % BORON .15

Figure 5

MODERATOR TUCKER: Thank you John. (Applause)

Are there any questions: Yes.

QUESTION—BUD BALAY - TVA: I would like to know what the pH of the final product is and if there are any corrosion problems in handling the final product in exess of those of handling a product with nitrogen in it?

ANSWER—JOHN REDNOUR: Bud, we have not experienced any corrosion problems. I really do not know what the pH of the material is, but I will be glad to get it for you later. Anyone else who wants any information like that, you can call me on the telephone and I will get it to you. Our product handles well and we have not experienced any corrosion problems. A very good product.

QUESTION FROM THE AUDIENCE: Can you bulk blend this material with urea?

ANSWER—JOHN REDNOUR: We have not tried it. I do not know.

QUESTION FROM JOHN MEDBERY - I.M.C.: Did you make an energy consumption comparison of the old method and the new method on a per ton basis. That of course, would include all of the associated equipment that you would use with both processes.

ANSWER—JOHN REDNOUR: John, we did not. There is a lot of equipment and a lot of motors with the old system that we are not using now. We are not using any more in the new system. I am sure we are much better off energy-wise. The slurry is hot. It takes less gas ans less fire in the dryer to dry this product. You know granulating with water and steam, it takes a lot of heat to get that water back out. I do not have the figures, but I know we are much better off energy-wise.

JOHN MEDBERY: I have one more question and that is: extraction of the P_2O_5 in the rock. That is the coversion from insoluble to soluble. Do you have a number, a percentage?

JOHN REDNOUR: The C.I. runs about 1.3%.

QUESTION—FRANK ACHORN - T.V.A.: You talked somewhat about the loss of choride—hydrochoric acid coming off from the product. I believe I understood you to say you are using fiberglas hoods. You also have fluorine coming off. What have you done to protect the fiberglas?

JOHN REDNOUR: That is right. Extra resin over top. We sure do.

QUESTION—FRANK ACHORN: One other question: Do you bag any of the product at all, or is it all shipped in bulk.

ANSWER—JOHN REDNOUR: Most of it has been shipped in bulk. We have bagged a small amount but not very much.

QUESTION—FRANK ACHORN: Have you run any bagged storage tests with this product?

ANSWER—JOHN REDNOUR: Let me tell you something, Frank. When you go to pick it up in the bin it rolls down like shell corn. It will not set-up.

QUESTION—FRANK ACHORN: What the worry would be is bag deterioration. Will it destroy the bag?

ANSWER—JOHN REDNOUR: I know what you are talking about. We have not run a test on it. It would be easy to run one.

QUESTION—JOHN T. PROCTER - U.K.: Can you give me any comparison between the critical relative humidity of this higher homogeneous product compared to the previous system with the inter-reaction which may not have given quite so much calcium chloride double D. composition. The absorption from the atmosphere is always a problem in my country, where the relative humidity is very often very high when PK fertilizers are being applied. We have been trying almost to go in the other direction to reduce the completion of the reaction between the components of PK fertilizers. You seem to have gone completely in the wonderful direction of homogeneity, but I am wondering about the critical relative humidity of such a product.

ANSWER—JOHN REDNOUR: I am not sure, but we are down there on the coast, you know. The humidity is high down there. We know what it is to have fertilizer in bins and humidity in the air, and it gets on the fertilizer and you have wet sticky fertilizer. We do not have that problem with this O-X-X. Like I told Frank Achorn— it is like shelled corn. It holds up real well. It does not pick-up a lot of water.

MODERATOR TUCKER: Are there any other questions? Thank you John for your excellent paper and thanks to all of you for your questions. (Applause)

MODERATOR TUCKER: Our next speaker, Kenneth Sharples, is on the production of mixed fertilizer by extrusion, incorporating by-product materials. He is from the United Kingdom, living on the East Coast of that area. He was educated at various schools in the United Kingdom. He is a Fellow of The Royal Institute of Chemistry. He spent five years working with cellulose acetates, cellulose ethers and ethelene oxide and 15 years with Fisons Fertilizer Limited. In 1963 be became a consultant to small Fertilizer plants in the use of Animal By Products and lately Biological Methods for Effluent Disposal and Odor Control. It gives me great pleasure to have Kenneth Sharples, who came all the way from Our Mother Country, to present his discussion, a new process they are working on in England.

Production Of Mixed Fertilizers By Extrusion Incorporating By Product Materials

Kenneth Sharples

Properties of Pelleted Fertilizers

In many respects this type of fertilizer is archaic and made by a method unusual to the fertilizer industry. I am initially discussing the product in that it may be unfamiliar. The product is cylindrical in shape with a mean length of 9 mm and a mean diameter of 3 mm. This length to diameter ratio of 3:1 is not ideal and for many reasons the preferred ratio is a maximum of 2:1. Regretably the shorter pellet can significantly reduce the life of the die through which the pellet is extruded. So the pellet size is really a compromise which has been accepted because of the machines in use.

The pellet is not dried like conventional fertilizers and has a moisture content of up to 5-6%. There is intrinsic merit in this in that the organic content retains the mositure in the interstices of the organic matrix. To vigorously dry to 0.3-0.5% moisture would denature the organic content of the pellet and reduce its function as a fertilizer.

The keeping quality of the pellets is good, provided that free moisture is evaporated. It is not a common practice to apply a surface coating. To spray with any oil, other than one with a very high viscosity, say 3600 Redwood seconds, would be ineffective. Low viscosity oils either slightly emulsify or are sucked into the pellet and so have no adhesive value to hold china clay, talc or Kieselsuhr.

The crushing strength of the granules, whether measured latitudinally or longitudinally, is low at 1.3 to 2.3 kg compared with 3.5 to 6 kg for good NPK granules. There is a marked difference in the behaviour of pellets compared to normal granules, in that the pellets bend under pressure (particularly when the organic content and moistures are at satisfactory values) rather than fracture.

Pelleted fertilizers are generally of low analysis. A representative list of commonly marketed pellets is as follows:—

Typical Analyses of Organic Compounds for Agriculture (Cereals, Rootcrops, Fodder and Grassland)

Plant Food Ratio	N	P_2O_5			K_2O
	Total	Soluble in Water	Soluble in NAC + Water	Total	Soluble in Water
1:1:1	10	9.5	10	10	10
1:1:1	7	6.5	7	7	7
2:1:1	14	5.0	6	7	7
5:1:1	20	3.0	3.5	5	5
2:1:3	10	4.0	4.5	5	15
1:1:3	5	4.5	5	5	15
1:5:5	3	13.5	14	15	15
1:1:2	7	5	6	7	14
1:2:4	1	11	11.5	12	22

Apart from this selection from the standard range, there is a whole spectrum of compounds made to the farmers' particular requirements.

Examples are as follows:—

Plant Foods.	Semi Organic Compounds.				
	1	2	3	4	5
Total N	7	9	18	20	5
W/Sol P_2O_5	5	2	0	0	5
Total P_2O_5	6	3	0	0	9
K_2O (S/Potash)	14	-	0	0	0
K_2O (M/Potash)	0	10	0	0	10
Magnesium	0	3	2.4	0	0
Trace Elements	0	-	yes	0	0
Boron (PPM)	0	0	0	0	2000

Evaluation of Semi-Organic Fertilizers for Agriculture.

Pelleted semi-organic fertilizers appear expensive when compared on unit plant food values with normal granular compound fertilizer. Some idea of the difference in price is shown in Table III

Ratio	Semi Organic Compound			Normal Granular Compounds.		
	Analysis	Farm D/D Price		Analysis Farm D/D Price.		
1:1:1	7: 7: 7	£148	(274$)	7: 7: 7	£ 95	(176$)
1:1:1	10: 10: 10	£146	(270$)	15: 15: 15	£137	(253$)
2:1:1	14: 7: 7	£148	(274$)	20: 10: 10	£132	(244$)
1:1:2	7: 7: 14	£136	(252$)	10: 10: 20	£128	(237$)
N:0:0	20: 0: 0	£110	(205$)	26: 0: 0	£ 88	(163$)

(These are February to May prices in 10 ton lots. The money conversion is 1.85 dollars to the pound)

The price difference is the added organic material. This organic content is derived from composted wastes, dried poultry manure, dried sludge from sewage farms, tobacco dust, activated sludge, residue from maggot farms and various meals. After suitable preparation a mixture of some of these goes into the pellets to a variable extent but is usually 25-30%.

The theory, borne out in practice, is that the inorganic salts held in a matrix of organic matter allow sequential feeding of the plant foods to the growing plants. The organic matter can be looked upon as humus which breaks down to form complexes with organic phosphates and becomes more readily available to higher plant life. Both available phosphorus and nitrogen can be stored, in that reversion of Phosphate to tricalcium phosphate in calcium bearing soils is inhibited and Nitrogen converted to bacterial protoplasm is rendered less soluable.

When the bacteria mortify and decompose, then the nitrogen is released. The effect is to reduce the amount of nitrogen leached from the area of the growing plant and so enhance eutrophy. The "binding" effect of nitrogen in the form of microbial protoplasm prevents nitrification (mineralisation) particularly of urea. There is, in terms of environmental care, a good point in that nitrogen as nitrate is not eluted into streams and rivers.

On sandy soils the semi-organic fertilizer scores in that it tends to promote aggregation and allows water to be retained at the root level of the crop.

Independent field trials have been extensive and results show that with semi-organic fertilizers the nitrogen intake can be 90% compared with 50-60% for a variety of inorganic fertilizers. A three-year comparative experiment on barley showed that semi-organic fertilizers gave up to 15% better germination.

As with all applications of fertilizers, the soil, the pH, the rainfall and the sun are important. Agriculturalists and agronomists all know that choosing the fertilizer to get the best results possible (NOT best possible results) needs analysis of the requirements of the soil and crops. Semi-organic pellets have a role in the U.K. and there are many lands where a similar approach could have handsome returns.

Semi-Organic Fertilizers for Turf and Horticulture.

A reasonable tonnage of semi-organic pellets is used for pre-seeding or dressing turf on soccer and rugby pitches, golf fairways, parks and playing fields. Typical formulations are shown in Table IV.

N	P_2O_5			K_2O
	Sol	Insol	Total	
12	4.5	1.5	6.0	6.0
7	10.0	1.0	11.0	7.0
3	6.0	4.0	10.0	10.0

These pelleted fertilizers are also used for garden crops, (Lettuce, brassicas, legumes, rootcrops, flowers bulbs, annuals perennials) and fruit (berries, apples, peaches, plums) and hops, both early and late. They are safe horticultural compounds with very little chance of producing scorch or trouble with over-feeding.

The Production of Pelleted Fertilizers Raw Materials.

YEAR	KCl	K_2O EQUIVALENT	K_2SO_4	K_2O EQUIVALENT	TOTAL K_2O
1978	108	68	53	29	97
1979	99	62	55	30	92
1980	110	69	62	34	103

To make pellets it would perhaps be assumed intuitively that powders would be the best form of the salts. Experience has shown that a spectrum of sizes of materials gives the best results. Hence, the practice of using a proportion of the material as granles. If the formulation does not warrant the use of MAP, DAP or GTSP, as for low value NPK fertilizers, then the powdered sulphate of ammonia and powder SSP would be allied with coarse grade potash (0.5 to 1.6 mm particles) The organic material has an importance and is a mixture of:—

a) *Composted Material.*

This ia mostly vegetable matter and roots (e.g. liquorice) It is composted either naturally or by addatives such as ammonium nitrate. A new source is to take waste from maggot farms and mix with activated sewage sludge and allow to compost. Provided that the humidity of the heap is kept towards 80% and the mass is turned over to allow free access of oxygen, then the blood, fish and bone comes down to a non-odorous compost ($N=3\%$, $P_2O_5=8\%$, $H_2O=14\%$) Worm casts are another possibility.

b) *Sewage Sludge*

This is received in two forms:

1) *Wet.* The material is taken from the sewage beds, pressed, treated with sulphuric acid and put into sheltered pits so that it consolidates and partially dries. It is received into the factory at 17-20% moisture.

2) *Dry.* This is the same sludge but dried to a 4-5% moisture powder which is fibrous in texture.

Analyses from Two Samples (Different Sewage Units)

Wet		Dry	
Water	35.0%		14.0%
Nitrogen	0.7%		2.3%
P_2O_5	0.3%		2.7%
K_2O	0.1%		0.4%
Cr ppm	3300	Mg ppm	2350
Cu	380	Cu	330
Ni	30	Fe	20800
Zn	750	Zn	1750
Cd	7	Mn	900
Pb	70	Ca	13800

The cost of the dried sludge collected ex works is about 24 $ ton compared with the wet sludge at 11 $ ton. The haulage costs are high at about 9-11 $/ton.

c) *Dried Poultry Manure*

This was used extensively but the energy costs of drying it have made the material unviable, so now-a-days it is seldom used.

d) *Other Organic Material*

Tobacco Dust
Ground Cocoa Meal/Coffee Husk
Ground Linseed Husk
Ground Leather Meal

The objective of having very wet and also dry organic material is to exercise some control on the moisture of the initial mix before pelletizing.

Formulations

These are all traditional in that the mixing is calculated to give the necessary concentration of plant foods plus the residual moisture in the product. Some skill is needed to get the best mix. Since the nitrogen concentration can be accommodated by increasing the urea concentration this can allow more or less organic material in the pellets.

Another factor to be considered when formulating is that if the mixture has a lot of urea (over 15%) and high moisture, then since the temperature of the mix rises as pellets are formed, there is generation of a liquid phase. This can both help and hinder in that, although pelletizing may be easier, but the product is more difficult to screen and cool.

The inclusion of Kieserite - intrinsically $MgSO_4.H_2O$ which hydrates to Epsom salt, $MgSO_4$. 7H20 is useful as an internal drying agent. Experiments with anhydrites and clays are being made to harden the pellets.

To make a straight nitrogen fertilizer such as N20 requires prilled urea and very fine sulphate of ammonia crystals andorganic material adjusted to 15% moisture. By maturing this mix for 4-5 days before pelletizing the urea permeates the mass and dissolves into the organic material and so give a consistent material to be pelleted.

Process of Producing Pellets.

The unit processes are as follows:—

1. Proportioning the ingredients.
2. Mixing the ingredients. Maturing the mix.
3. Screening and milling the mix.
4. Feeding the Pelletiser(s).
5. Pelletising.
6. Cooling the pellets.
7. Screening the pellets.
8. Packing to 50 Kg P/E bags or valve sacks.
9. Palletising and either shrink or stretch wrapping.

1) *Proportioning the Ingredients*

The usual method is by automatic gravimetric units. A bin is fitted with a vibrating tray discharging into a weigh bucket. The feed, ex bin, occurs whilst vibration is in action. The vibrator is cut off at the balance point and the contents of the weigh bucket discharge to a collector belt. Three to five of these bin weighers set up in series with dual hoppers can handle up to ten ingredients. The whole operation is in sequence so that once the weighers are given the set points the proportioning is automatic. Load cells controlled by a potentiometric system can also be used.

The collected material is fed over a coarse vibrating screen to take away any tramp material. There may or may not be a crude hammer mill in this circuit — it depends on how good the raw materials are. A batch usually weighs one tonne.

2) *Mixing and Maturing*

Getting the mass homogeneous is important and is one of the controlling factors in getting good production of the best quality pellets. The form of the mixer can be a conventional vertical mixing drum or a horizontal rotating drum with paddles (virtually a concrete mixer). The mix is discharged to pens and allowed to stand for up to 7 days. During this time the moisture (5-6%) takes up soluble chemicals. According to some producers, maturing the initial mix is essential to give satisfactory pelleting.

3) *Screening and Milling the Mixture*

The matured mix may cake into clods so a coarse screen is needed to separate them (mesh 25.4 mm square). The oversize is disintegrated by a flail mill or a conventional cage mill. An alternative is to mill the whole of the mix prior to pelletizing.

4) *Feeding the Pelletiser*

This operation appears to be easy, but considerable thought is needed to ensure that the pelletiser is fed at a constant rate. Over-feeding or continued feeding when a pelletiser is overloaded leads to blocked dies. A vibrating tray feeder is usual but there should be a measure of the power being consumed by the pelletiser and if the amps rise above a certain value, then the feed needs to be cut off. On large pelletisers there is overload protection provided by a friction disc on the main shaft which is normally held stationary by brake calipers, hydraulically activated at the correct torque. Exceeding the torque activates a micro-switch to isolate the motors.

5) *Pelletising*

The pelletising machines are standard as used in the production of animal feed pellets (sometimes known as "cubers"). Basically, there is a vertically mounted die ring which rotates and 2 or 3 press rollers on the inner perimeter of the die to guide material and force it into the die holes. A doctor knife shaves off the pellets after extrusion. The know-how of the process is really contained in the following points:—

Size of machine The smaller pelletisers producing 1-1.5 tonnes per hour are marginally more successful than large units producing 5-6 tonnes/hour. The reasons for this are:—

a) If a die blocks then the down-time in cleaning the die holes is lengthy and cumbersome on a large machine and there is a disproportionate loss of production.

b) The energy requirements are not linear; to produce at one TPH uses motors of 100 HP, whilst 2 TPH requires 250 to 300 HP.

c) The die has to rotate at optimum speed and is usually about 6.5 m/second. There are constraints on the speed, depending on the pellet size.

d) The press rollers with universal positioning have to be set precisely. This is guesswork and experience rather than a calculated setting.

e) The ratio of land to void area on the dies is very important. More disc holes give larger output but the die life is lessened.

f) The doctor knife setting is critical so that pellet lengths are regular.

g) The profile of the die holes can materially alter production rates. The die hole can be parallel or provided with taper reliefs. The angle of the relief had to be judged. If the relief is on the die-hole discharge, then too much taper allows the pellet to break before being cleanly doctored. A taper of 1 in 48 is about the maximum to be tolerated. In the experimental work it was found that the greater the length of the parallel shank of the die, the greater the overall strength of the pellet.

h) The diameter of the press rollers affects the performance.

i) The metal of the die needs to be a ferrochrome stainless steel with high polish.

j) Given all the correct attributes of the machine, then the final constraint is the chemical and physical qualities of the mix and its initial moisture content. The press action can raise the temperature in the die to 80°C or even higher, dependent on the feiction developoed by the abrasiveness of the materials in the fertilizer.

With urea, as stated, a liquid phase is generated but there is no decompostion of the urea. (It is obvious that with these conditions, using a nitrate with the organic material present would form a safety hazard.) Sintering is an important agglomerating effect and is qualitatively proportional to the ratio of solid temperature (degrees Kelvin) to temperature of solid at melting point (degrees Kelvin). This has been extensively studied (Reference 4 and 5). The actual pressure developed to force the material through the die is difficult to measure accurately but is over 10 t/sq.in.

To obviate voidage the mixture being pelletised is at least a collection of multi-sized particles to maximixe the packing density. Some theoretical aspects of compaction have been studied by W. Peck[1], Kurtz and Bardulin[2], and Komarek[3]. Cohesive strength has been studied by Pirani and Kee[4].

6) *Cooling Pellets*

This is usually a louvre static cooler intrinsically the same as for animal feed pellets. Fluidized bed coolers are not acceptable as for animal feed pellets. Fluidized bed coolers are not acceptable in that the residence time is usually too short. In private, with pellets entering the cooler at say, 70°C with 5% moisture, then the residence time should be about 30 minutes to reduce the temperature to 25°C and moisture usually drops by 0.5% to 4 to 4.5% and evaporation occurs at the surface. Failure to cool properly leaves a temperature gradient between the interior and the surface of the pellet. Temperature equilibrium is reached with nuisance effects on storage in sacks.

7) *Screening Pellets*

This is conventional screening on flat deck, out-of-balance actuated machines. With good pelletising the amount of "fines" is less than 2% so that the recycle is extremely low. One is only concerned with fines, but if there is concern about over-size or misshapes, then another screen for oversize is inserted into the system. (It would be disasterous to use double-deck screens when urea is in the pellet due to the difficulty of cleaning the screen cloth.) Screening has been more successful since using either nylon, plastic or rubber screens — they plug less and stay clean.

8) *Packing to 50 Kg P/E Bags or Valve Sacks*

Open-mouthed pillow sacks are best. Packing in valve sacks tends to break down the pellets by the rather rough handling of the filling mechanism. It is best practice to pack pelelets of ambient temperature.

9) *Palletising and Shrink or Stretch Wrapping*

This is conventional practice but it is worth noting that if the palletised material is shrink-wrapped, it should not be stored outside in direct sunlight. The "greenhouse" effect can cause problems with these high moisture bearing pellets.

Costs — Capital and Revenue

Capital

Setting up a pelletising factory has a much lower capital cost than a granulation plant of similar capacity (U.K.)

10 TPH Pelletising Plant ca 325,000 $
10 TPH Granulation Plant ca 500,000 $

The storage areas for raw materials and finished product are about the same. The actual area of the processing units (preparation unit, pelletisers, packing units) can be quite small, 12,000 square feet with buildings to height of 30 feet to the eaves.

The fringe benefits with pelletising are:—

a) No steam raising equipment.
b) Very modest water requirements
c) No elaborate wash towers, since there is no pollution of the atmosphere by gaseous emissions.
d) Dust extraction is relatively simple and the working environment is reasonable and can be kept clean.
e) No exhorbitent drying costs with use of coal, oil or gas.
f) No elaborate recycle system.

Drawbacks

a) For a given tonnage the installed electrical power is much greater for pellets than granules.

For 10 TPH Pellets Installed House Power ca 900
For 10 TPH Granules Installed House Power ca 450
This could mean a larger sub-station.

Revenue Costs

1) *Labour to Operate Plant*

The number of men engaged and their duties to produce 10 TPH of pellets is as follows:—

Raw Material Shovel Operator	1
Mixer Operator	1
Pelletiser Operator (Foreman)	1
Packing, Palletising	3
Fork Lift Operator	1

2) *Maintenance Costs*

The largest single factor is the cost of dies. A die for producing up to 1.4 TPH costs about 650 - 740 $; in ideal conditions this will give (with care) 400 tonnes of pellets, so the capital cost appears to be 1.6-1.85 S per ton. It is not as straightforward as this because dies block and have to be skimmed down. The norm is 70% performance. When dies block, the only way of clearing them is by drilling them out individually. Hence, die cleaners are usually part of the maintenance force. Typically, the maintenance of a 10 TPH plant would be covered by:—

2 Fitters
2 Die Cleaners
1 Electrician
1 Oiler / Greaser.

Thus, the total direct force is 13 men / shift if there is online packing. By producing to bulk heaps and limiting the packing to day hours, this force can be cut. Like most conventional granulation plants, one could increase the rate of production up to say, 18 TPH without having to increase the labour force.

Conclusions

—Producing fertilizers by extrusion is practical and has value for the particular operation of incorporating organic by-products. It is not a cheap method of production but has the virtue of not being a continuous process so that fertilizer prescriptions can be dispensed according to the need of the soil, the plant and the idiosyncratic desire of the farmer. The fertilizers so produced are efficient and effective.

—These types of organic fertilizers are produced in the U.K. and Europe for agriculture and particularly for the horticulture and for turf dressing.

—Pelleted fertilizer for agriculture is best applied by a spreader and not drilled into the ground. Hence, there is some limitation in its application to cereal crops.

—The process is capable of development by improving both the pelletiser and the die performance, as these apply to producing fertilizers.

—The capital cost of pelletising plants is low compared with an equivalent granulation plant. The plant is compact and light-weight so that the housing and civil work involved is not onerous.

—The largest single criticism of the process is the very heavy utilization of electricity.

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Stoneferry,
Hull.

MODERATOR TUCKER: Any questions for Kenneth Sharples?

QUESTION—FRANK ACHORN - T.V.A.: If you use this to compact micronutrients, would it be practical to use if for a ore materials like boron, powdered zinc-oxide, or materials like that where you have relatively small amounts, to extrude them into a pellets?

KENNETH SHARPLES: Yes. There is quite a trade in putting the micronutrients into pellets.

MODERATOR TUCKER: Any other questions? Kenneth Sharples: We certainly appreciate your being with us this morning and we enjoyed listening to your most interesting discussion. (Applause)

MODERATOR TUCKER: Our next presentation is by Luis Corominas, Manager of Research, Fertilizantes Mexicanos, S.A. He is a Chemical Engineer who graduated from Madrid, Spain, in 1954. From 1954 to 1956, he did research work in welding at the Welding Institute of Madrid. From 1956 to 1960, he did research work on rayon in Cuba. From 1960 to 1962, he was Development Superintendent for Celanese Mexicanos, Mexico. From 1962 to 1964, he was Process Superintendent of Fertilizantes Del Ismo, Mexico. From 1964 to today he is Manager of a Research Subdivision of Fertimex of Mexico. We are happy to have our neighbor from the South, Luis Corominas, present the next paper. (Applause)

Potassium Chloride In Mexico

Luis Corominas

Ladies and Gentlemen:

The present report has been made with the intention of giving information about the potassium situation in Mexico. A series of slides ars also been prepared to enlight this and copies of such illustrations, will be available at the end of this presentation.

At the present time, there is no production of potassium salts used on both the fertilizer and chemical industries in Mexico, so all of the potassium is being imported from the United States and from Canada.

Main imported salts are potassium chloride and potassium sulfate, which meant a total amount of 103 000 metric tons of equivalent K_2O imported in 1980. These salts are mainly used in the fertilizer industry. Consumption of both, potassium chloride and sulfate as raw materials for NPK fertilizers production, represent about 75% of the total figure.

Potassium chloride consumption in Mexico has been increasingly changing through the years, an outlook of such consumption gives a figure of about 300 000 metric tons per year in 1990. In order to satisfy this demand, two K_2O production projects are being developed in Mexico nowdays. Fertimex, S.A., the government owned fertilizer company, will produce 80 000 metric tons per year of KC1 by late 1983, while Exportadora De Sal, S.A., will be producing about 200 000 metric tons per year of K_2SO_4 in 1984.

The Fertimex project is based on the KCL removal from a residual brine obtained by Comision Federal De Electricidad (CFE), in their Cerro Prieto Geothermal field, North Baja California.

The Geothermoelectric Project started up in 1973, with two 37.5 megawatt turbogenerators. The present power generation is 150 megatt, with four turbogenerators a 400 megawatt capacity is expected in 1984.

Power generation from geothermal energy is based on geothermal wells. The output consists of a mixture of water and steam which, to be exploited, needs to be separated so as to send the dry steam into the turbines of the power plant.

The separation of the water steam mixture is achieved by letting the flow of the well pass through centrifugal separators where water adheres to the separator walls and descends to its bottom, from where it goes to the silencer, while steam, rises in the separator and it is extracted through a central pipe towards the collecting net, to be conducted to the plant.

Separated water is presently discharged into an evaporation pond and a drainage channel from both of which it is finally disposed into the hardy river. Separated water, commonly known as brine, has a flwow of about 3200 metric tons/hour with 1.78% NaC1 and 0.33% KC1. This and the high evaporation rate in Cerro Prieto which averages about 100 inches/year encouraged Fertimex to develop a process for potassium chloride exploitation from the geothermal brine.

This process is based on solar evaporation of the initial brine up to precipitation of NaC1, and concentration of KC1 to its saturation point. This saturated brine will be the raw material for the mechanical part of the process. The first evaporation step will be achieved in a 14 km^2 pond which will be built with no special treatment, except for the bottom soil, which will be compacted.

A problem found during previous works is the high soil permeability, which averages about 1×10^{-3} meters/second. The predicted permeability rate in the evaporation pond is of 1×10^{-5} meters/second, with compacted soil. This rate is the maximum which can be allowed in order to obtain the NaC1 saturated brine in amounts large enough to feed the consecutive steps of the process.

The second step is a crystallization pond in which residence time will be enough to allow the preceipitation of about 87 000 metric tons/year and to obtain a KC1 saturated brine. This pond will be 0.8 Km^2 large and since very little loss can be allowed in this point, it will be built using a compacted clay treatment in the bottom and the outer borders. The expected permeability rate in this pond will be of 5×10^{-9} meters/second. The KC1 saturated brine will be the raw material for the extraction steps, which consist basically of the following operations:

1.— Concentration of saturated brine in three evaporation stages to bring up the precipitation of sylvinite (NaC1-KC1 mixture).

2.— Hot leach separation of NaC1 and KC1, using a hot NaC1 satured brine as leaching fluid.

3.— Centrifugation and drying of NaC1.

4.— Crystallization of KC1.

5.— Centrifutation and drying of KC1.

KC1 production will be 80,000 metric tons/year which is equivalent to 50 000 K_2O metric tons/year with a grade similar to that presently imported.

NaC1 production will be about 159 000 metric tons/year which, added to that obtained by solar evaporation, will make a total production of 246 000 metric tons/year.

A diluted calcium chloride solution is obtained as a by-product from the mechanical evaporation stages. This solution will be concentrated by means of another evaporator and will mean the obtainment of some 180 000 metric tons Ca $C1_2$/year as a 17% strength solution.

A small amount of residual brine (bitterns), no longer able to be recycled to the process neither to the solar evaporation ponds nor to the mechanical stages, will be obtained as a purge to the system. This bitterns will be discharged to the hardy river, its final disposition site being the California gulf.

Finally, I would like to give a general idea on what the costs of this project will be: the ponds and piping investment will be of U.S. $ 10 mm. The plant (mechanical process) will mean a figure of U.S. $ 18 mm. Total investment will be of about U.S. $ 28 mm. An estimate of the operation cost gives U.S. $ 26.00 / metric ton KC1.

POTASSIUM SALTS MEXICAN IMPORTS

(THOUSANDS OF METRIC TONS)

POTASSIUM SALT	SOURCE
K Cl	U.S.A., CANADA
$K_2 SO_4$	U.S.A.

POTASSIUM CHLORIDE CONSUMPTION OUTLOOK IN MEXICO (IN THOUSANDS OF METRIC TONS)

CONSUMPTION OF POTASSIUM SALTS IN MEXICO

POTASSIUM SALT	AS DIRECT APPLICATION FERTILIZERS	AS NPK FERTILIZERS	OTHER USES
K Cl	33 %	67 %	—
K_2SO_4	5 %	88 %	7 %

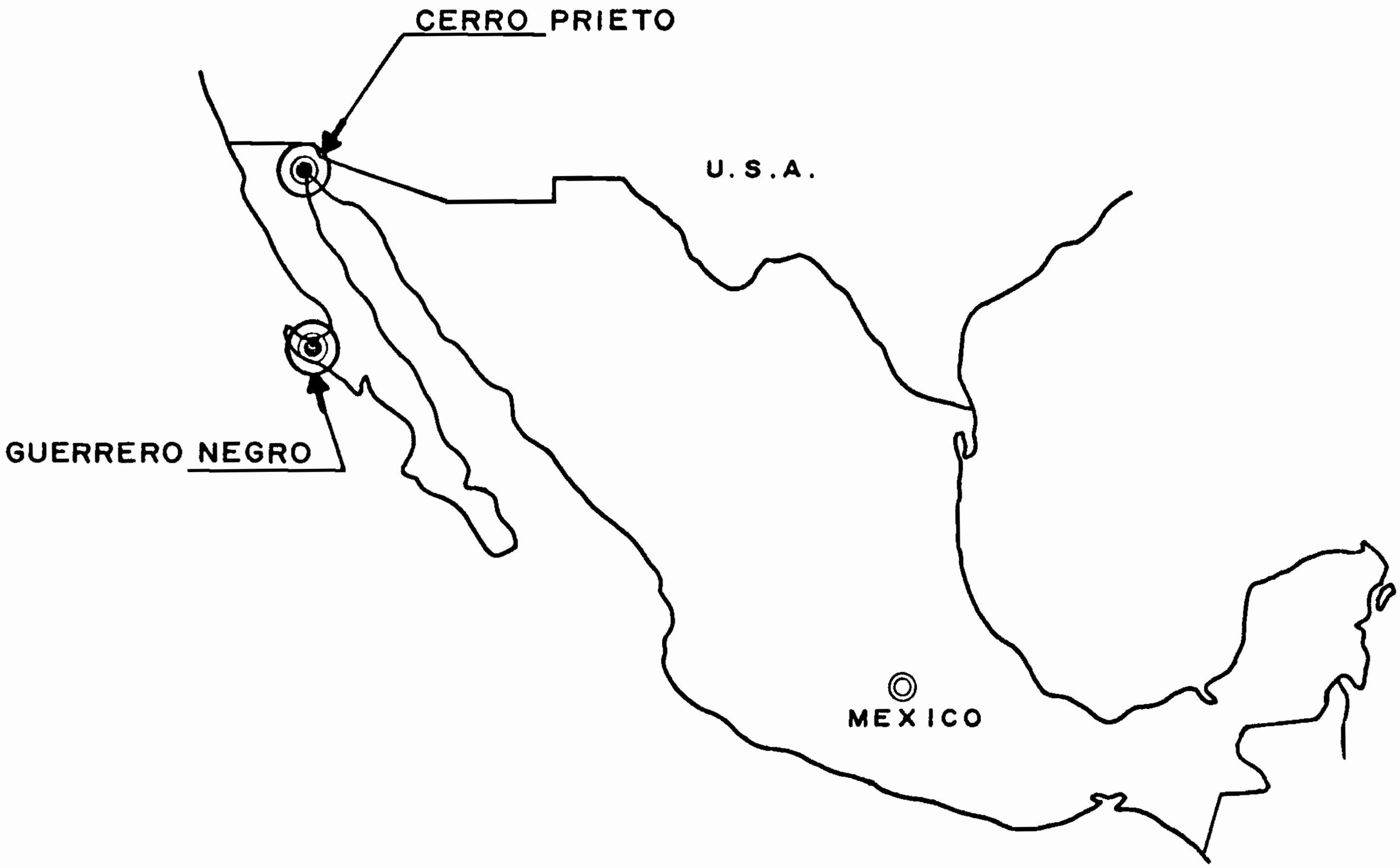
CONSUMPTION OF POTASSIUM IN MEXICO
(THOUSANDS OF METRIC TONS)

POTASSIUM SALT	AS DIRECT APPLICATION FERTILIZERS	AS NPK FERTILIZERS	OTHER USES	TOTAL CONSUMPTION
K Cl	36 (23 as K_2O)	74 (46 as K_2O)	—	110 (69 as K_2O)
K_2SO_4	3 (2 as K_2O)	55 (30 as K_2O)	4 (2 as K_2O)	62 (34 as K_2O)

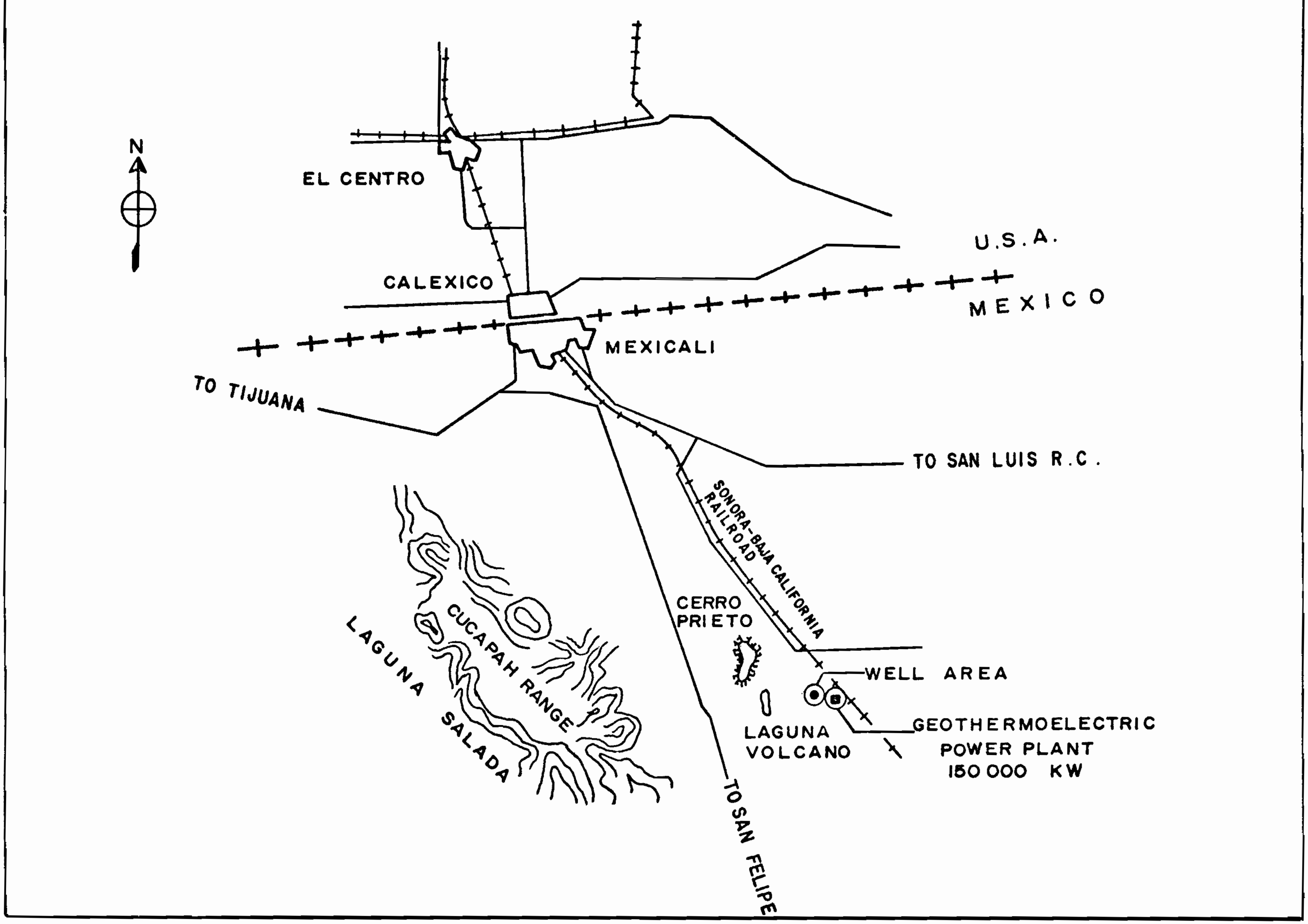
K_2O PRODUCTION PROJECTS IN MEXICO

COMPANY AND LOCATION	ANNUAL CAPACITY (THOUSANDS OF METRIC TONS K_2O)	START UP	PRODUCT
FERTIMEX, S. A. CERRO PRIETO, NORTH BAJA CALIFORNIA	50	1983	KCl
EXPORTADORA DE, SAL, S. A. GUERRERO NEGRO, SOUTH BAJA CALIFORNIA	108	1984	K_2SO_4

GEOGRAPHICAL LOCATION OF CERRO PRIETO AND GUERRERO NEGRO PROJECTS



GEOGRAPHICAL LOCATION OF CERRO PRIETO FIELD



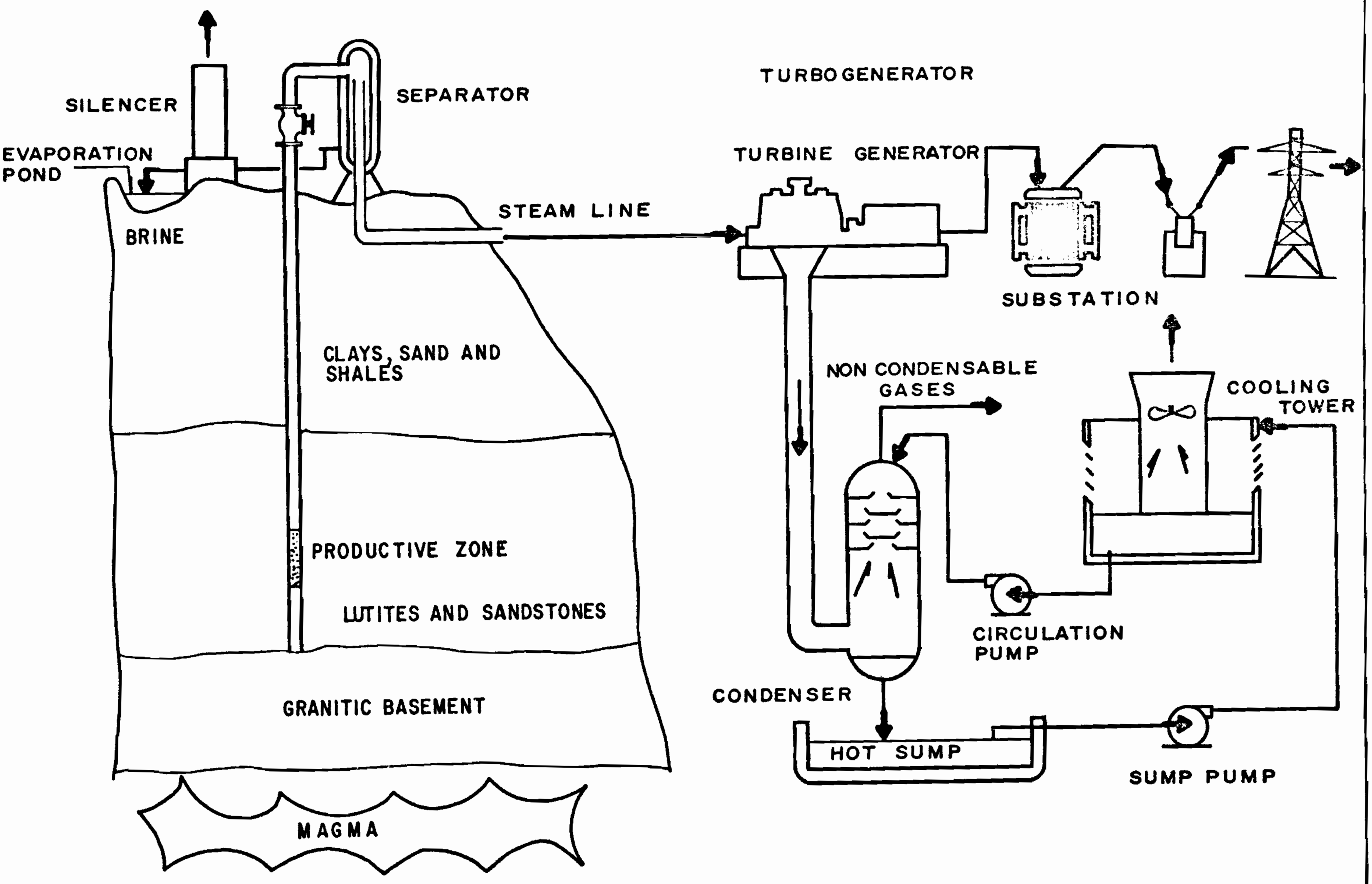
DEVELOPMENT ON POWER GENERATION IN CERRO PRIETO

PLANT	UNIT	MW	START UP
CERRO PRIETO I	1	37.5	1973
CERRO PRIETO I	2	37.5	1973
CERRO PRIETO I	3	37.5	1979
CERRO PRIETO I	4	37.5	1979
CERRO PRIETO I	5	30.0	1982
CERRO PRIETO II	1	55.0	1982
CERRO PRIETO II	2	55.0	1982
CERRO PRIETO II	3	55.0	1984
CERRO PRIETO II	4	55.0	1984

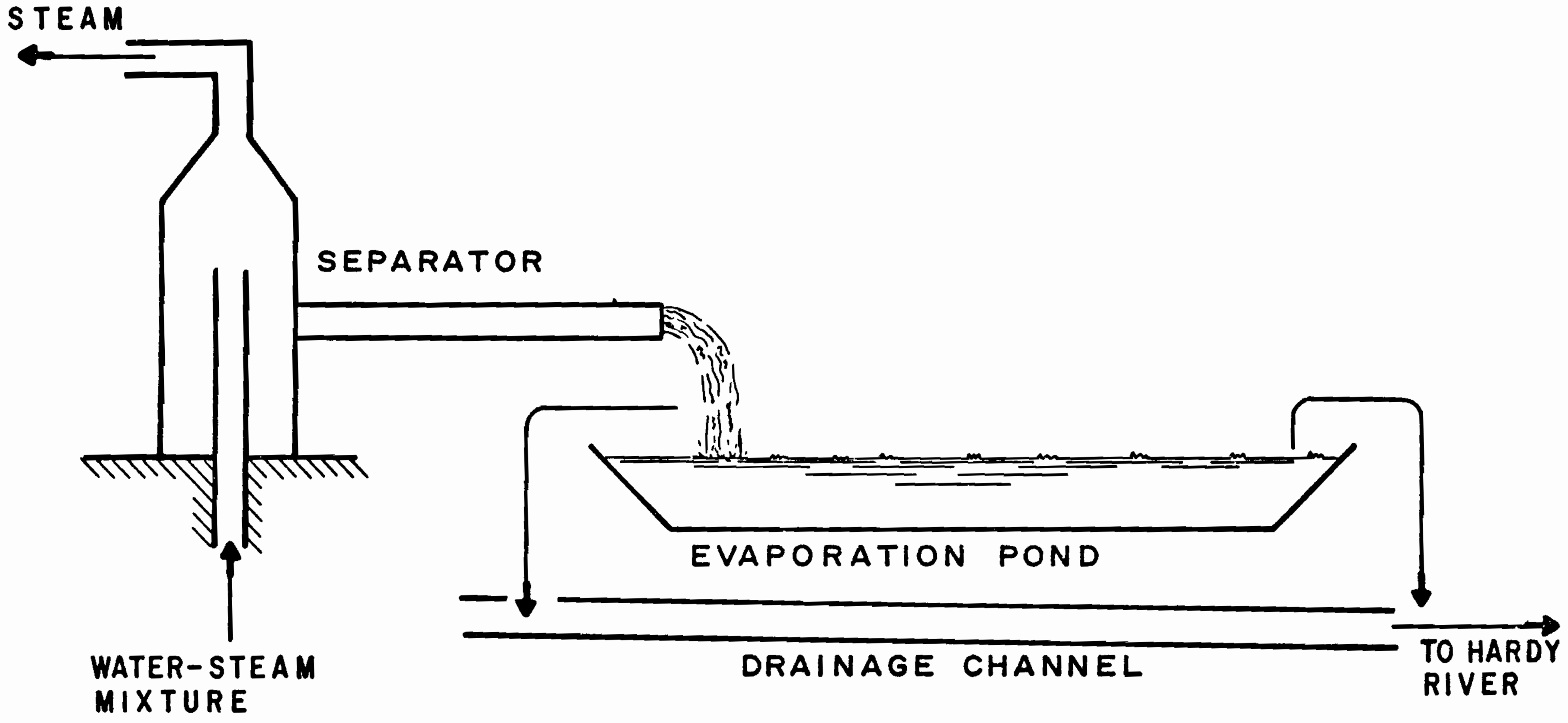
PRESENT CAPACITY: 150 MW

PROGRAMMED CAPACITY IN 1984 : 400 MW

POWER GENERATION FROM GEOTHERMAL ENERGY AT CERRO PRIETO



PRESENT BRINE DISPOSITION AT CERRO PRIETO GEOTHERMAL FIELD



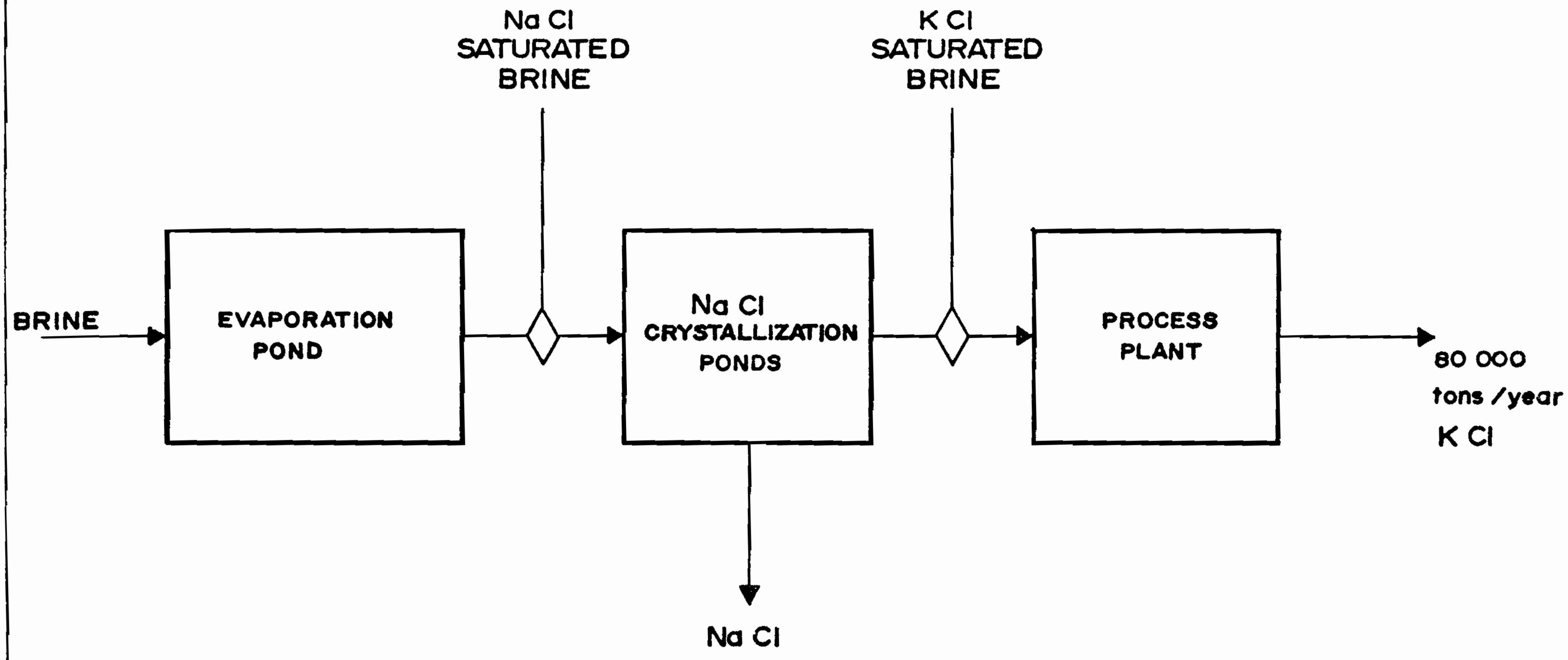
BRINE FLOW AND COMPONENTS FROM CERRO PRIETO GEOTHERMAL WELLS (1980)

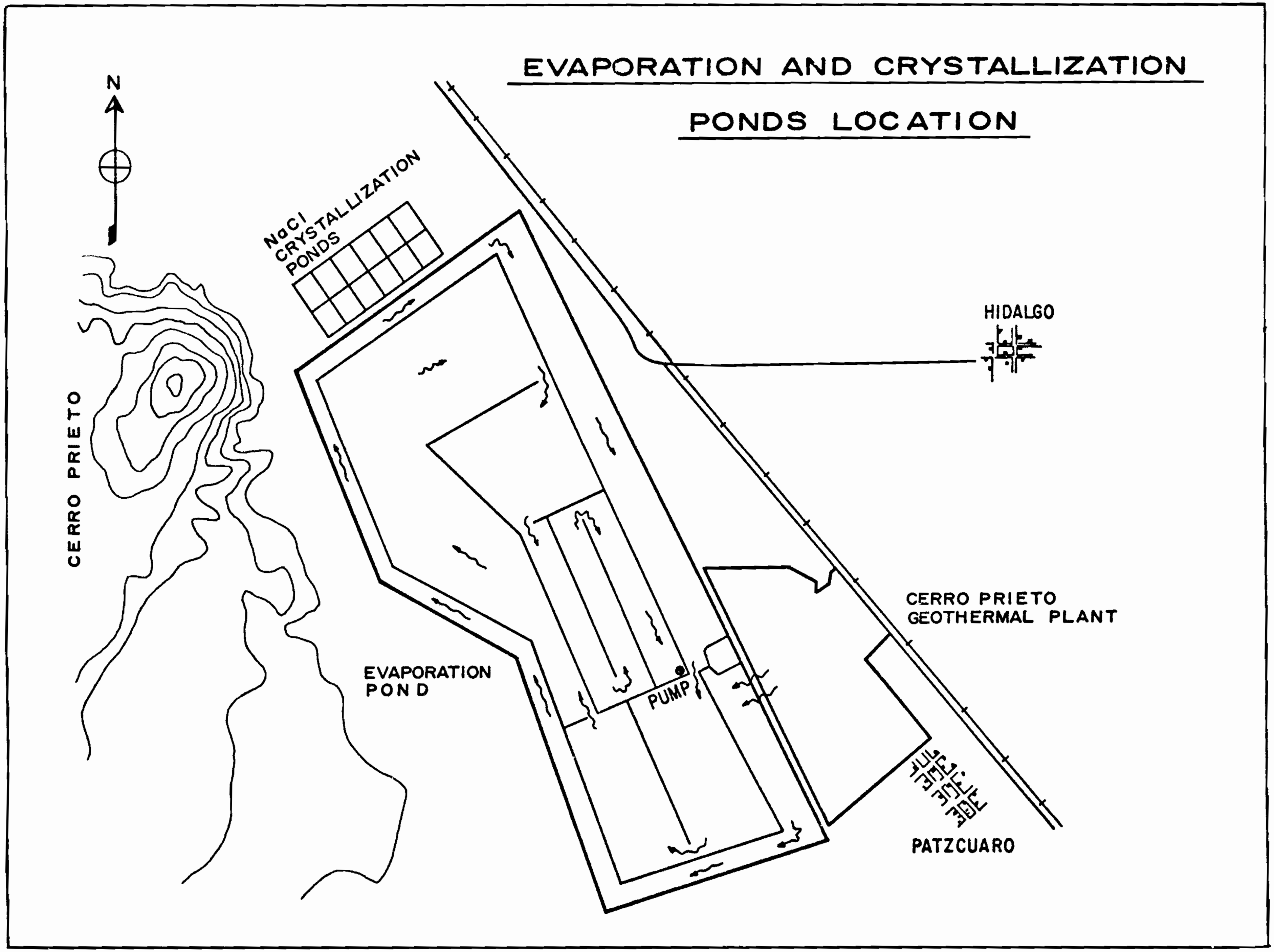
$0.89\ m^3/s = 3236$ ton/hr

1.7822 %	$NaCl$
0.3339 %	KCl
0.0121 %	$LiCl$
0.1235 %	$CaCl_2$
0.0002 %	$MgCl_2$
0.0900 %	SiO_2

CERRO PRIETO K Cl PROJECT

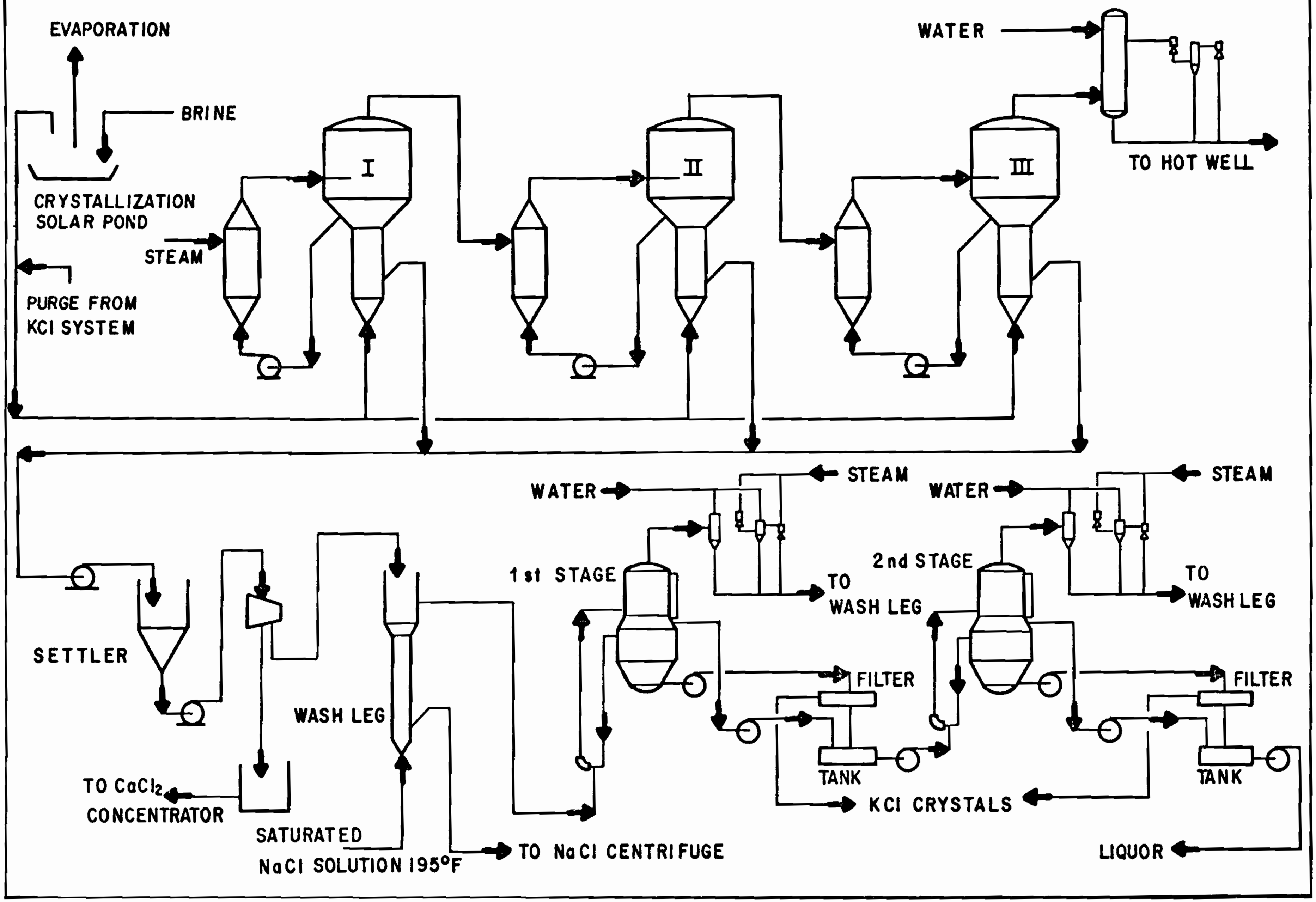
EVAPORATION PONDS - PROCESS PLANT GENERAL ARRANGEMENT





EVAPORATION AND CRYSTALLIZATION PONDS LOCATION

KCl EXTRACTION PROCESS FLOW DIAGRAM



POTASSIUM CHLORIDE GRADE TO BE OBTAINED AT CERRO PRIETO

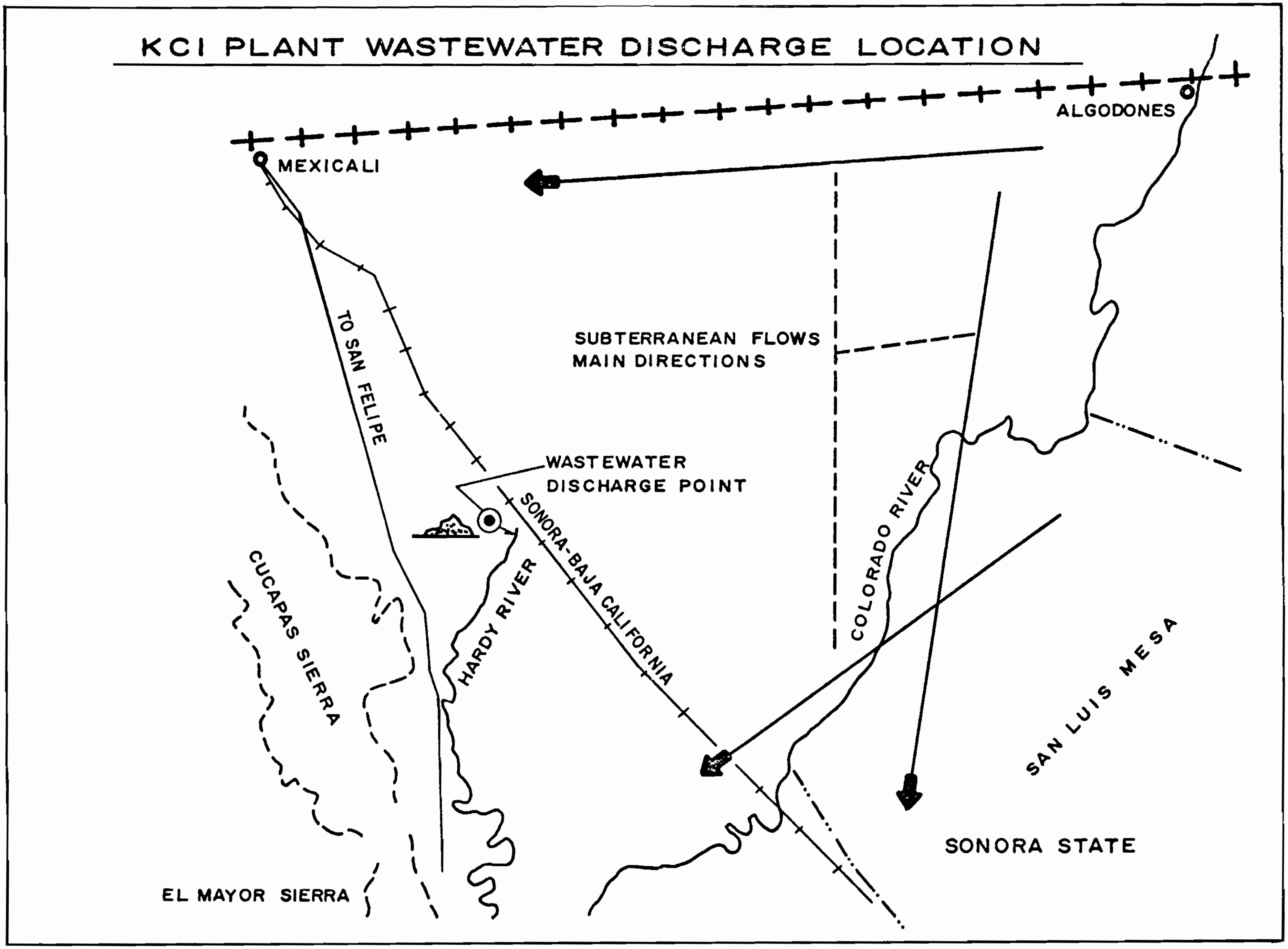
60 % K_2O (95 % KCl)

1 % Na

0.2 % SO_4

0.4% moisture

97% + 100 U.S. Sieve



KCI PLANT WASTEWATER DISCHARGE LOCATION

MODERATOR TUCKER: Are there any questions on this very interesting development?

QUESTION—FRANK ACHORN: In this potash, that you are going to make, is it going to be large crystals in size? Would it be considered a "granular potash," too?

ANSWER—LUIS COROMINUS - FERTIMEX: No, the crystals will be the same that we are importing now. It means a Standard Grade.

MODERATOR TUCKER: Are there any other questions? Thank you Luis Corominus. Your discussion was most interesting. One of the attractive things, about your paper, is the cost that you have enumerated, twenty eight million for a "Plant" and a production cost of "$28 per metric ton." I would like to express our appreciation to our four Speakers this morning and particularly Kenneth Sharples, who crossed the Atlantic, to present his discussion and Luis Corominas who came from our good neighbors to the South. They were all excellent papers. Let's give them a hand. (Applause)

As far as the formal Program is concerned that concludes it for this morning. I will now turn it back to Chairman Achorn to see what he has for the future. (Applause)

CHAIRMAN—FRANK ACHORN: Thanks to all of you who stayed late and heard all of these wonderful papers. I was quite impressed with our session this morning. I agree with Barney Tucker and we certainly want to thank our Speakers who came from "overseas," as well as our Speakers from "the U.S." We seem to be getting a lot more interaction between Mexico and our Canadian friends, and certainly, the European people and the people who came from India and halfway around the world just to visit "Our Round Table." This recognition is very "commendable to all of our Speakers.

You have "the word" — Our 32nd Annual Meeting will be held the last week in October in Atlanta — at Sheraton-Atlanta Hotel — October 26, 27 and 28, 1982. I know you are going to have a good spring season, so we will probably have an increased attendance. Thank you all. Have a save return home. Lots of Standing Applause.

Comments By Albert Spillman

Editing Chairman

My pleasure, as it has been for many years, to have had this responsibility, to "prepare and edit these Proceedings covering Our 31st Annual Round Table Meeting".

We had another outstanding, interesting and excellent meeting. Our Speakers' discussions carried up-to-date information on most of "our day to day operations."

We had a good "Attendance at each of our five sessions." Everyone present seemed to show much interest and acknowledged with much Applause and Compliments, showing their thanks, to "Our Speakers and for Our Well Planned Meeting".

It takes a lot of work to "organize and properly prepare our printed proceedings." We try to do the best possible job. We delivered to our printer approximately 540 thoroughly checked "script sheets" covering all of the Meeting Activities, Discussions, Slides, Questions and Answers.

All of my contacts with our Speakers, Chairman Achorn, Moderators, Secretary Paul Prosser, his very able Secretary, Miss Alice L. Blount, The Prosser Organization, our printer Tom Sabia, Manager of Quickee Offset, Inc. in Baltimore, Maryland, his most accommodating office. To all of you thanks and much appreciation for your replies to additional information we needed. I am sure your cooperation, with the answers requested were given at your earliest opportunity. I am sorry receipt of your copies of these Proceedings were delayed. Our Thanks again.