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Editor

Albert Spillman

Table of Contents

Tuesday, October 26th
Morning Session
Moderators
Frank P. Achorn
Harold B. Blenkhorn

Tuesday, October 26th
Afternoon Session
Moderators
Frank P. Achorn
David Brochstein

Wednesday, October 27th
Morning Session
Moderator
Al. V. Malone

Program Continued. Turn Page
For Starting Wednesday Afternoon Session.

Wednesday, October 27th
Afternoon Session
Moderator
James C. Brown

Thursday, October 28th
Final Session
Moderators
Paul J. Prosser, Jr.
David W. Leyshon

INDEX OF PARTICIPANTS IN PROGRAM

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Resolution In Memory Of
Wayne W. King

Whereas the Fertilizer Industry Round Table owes a deep debt of gratitude to Wayne W. King for his loyalty, devotion, cordial encouragement and wise control over the many years of his active participation in the affairs of the Round Table, and

Whereas Mr. King was always distinguished by good humor, interest in others, service to his country in two wars, and the principles of Americanism, and

Whereas despite physical discomfort he never failed to be a good companion and unselfish gentleman,

Therefore Be It Resolved that the members of the Fertilizer Industry Round Table assembled in Atlanta, Georgia on October 26, 1982, express their appreciation to Mr. King for so much done in so many ways, and

Be It Further Resolved that this resolution be spread on the minutes of this meeting, and

Be It Further Resolved that a copy of this resolution be forwarded to the family of Mr. King, that they may enjoy the knowledge that his life and contributions were appreciated by his many friends throughout the United States and the world.

Tuesday, October 26, 1982

Morning Session
Moderators:

Frank P. Achorn
Harold D. Blenkhorn

Introductory Remarks
Chairman Achorn

It has been quite a year for the fertilizer industry — part of which has been a poor experience, and part that has been definately "up beat". Fertilizer sales were down this year, but this has inspired us to consider new technological developments in production and marketing. The purpose of this meeting is to discuss these new developments.

During the past year we were all saddened by the passing of Wayne King, a founder, board member, and outstanding leader of the Fertilizer Industry Round Table and the industry it represents. Director Edwin Cox has agreed to write a eulogy for Wayne, which will appear in the 1982 Proceedings of this conference. (note Front Page).

I am sure Wayne would have wanted us to proceed with our program with the enthusiastic approach which was always his trade mark. We will start the program this morning with a distinguished keynote speaker who will be introduced by Bill Sheldrick, who is employed by the World Bank, and is a member of the Round Table Board of Directors.

Introduction - Keynote Speaker
Director: William F. Sheldrick

This morning it is our good fortune to have with us an outstanding international expert as our keynote speaker. Mr. Pierre Latteur is Director General of Societe Prayon, and has had extensive experience with Trade Associations relating to the chemical and fertilizer industries. He has been chairman of the Common Market Liason Committee, of the International Cadmium Institute, and the International Zinc Institute. He has been chairman of I.S.M.A. (now known as I.F.A. -the International Fertilizer Association), and is presently Chairman of the Fertilizer Industry Advisory Committee (F.I.A.C.). These latter two positions are, in my opinion, the most important posts in international fertilizer industry circles. The fact that Mr. Latteur has occupied both of these positions is a mark of the high esteem in which he is held by the fertilizer industry.

The F.I.A.C. is concerned with helping to improve food systems and to increase productivity by using fertilizers. I know that Mr. Latteur is extremely active in this work at the present time, and we are all very important with the vigor with which he is pursuing this particular job. Our speaker today has an absolutely unique view of the international fertilizer industry. I might also note that this is the first time that we have had a keynote speaker from overseas. We are grateful and priveleged that he has made the long trip to talk to us. It gives me great pleasure to introduce Mr. Pierre Latteur. (Applause)

Meeting Future World Fertilizer Requirements The Challenge to The Industry
Pierre Latteur
Chairman
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F.I.A.C. — Rome

Introduction

To manage an enterprise is, above all, to develop its creative faculties, to strengthen its resistence to socio-economic constraints and, in particular, to develop its adaptability to change : this is what has been called "the strategy of change".

Although these aims of good management may finally amount to simple common sense, it is not obvious that all managers realize to what extent the phenomena which are ancillary to the classical strategic model have grown and diversified during the last ten years.

The structural problems confronting most of our industrial sectors — and fertilizer producers are certainly no exception — illustrate the extent to which our classical "strategic baggage" is unsuited to the nature of our present problems.

We have been trained in management methods which give priority to the confrontation of phenomena

— endogenous for the most part — which had relatively little effort on the structure and nature of the enterprise itself, still less on its end. Our respond has very often been to push ahead with successive increases in production capacity, in conjunction with technological progress.

However, the phenomena — exogenous now — which we must face today are such that they represent a fundamental challenge to our objectives and structures.

Let us take two examples.

THE INTENSIFICATION OF CONSTRAINTS on costs and prices, as well as on standards of production and consumption of produce. The chemical industry is daily confronted with this, and part of its problems can be attributed to the increased severity of legislation concerning environmental protection and public health.

In an interesting study, COLOMBO seeks to provide a suitable response to this tightening of constraints in the form of a "function-orientated chemistry", as opposed to the present chemistry which is a "product-orientated chemistry".

Immediately we can see the upheaval which such a redefinition of its activity would imply for an enterprise, if only because of the global nature of the questions and responses to which the analysis of the end use of a product would give rise. In terms of the strategy of change, this functional definition implies the development — amongst other things — of strategies of integration, localization and collaboration with public authorities, to which many of us are not accustomed.

The Permanence of a Situation of Crisis

If there is one risk which is most difficult to evaluate and which is, for this reason, generally neglected in the classical strategic planning, it is the insertion of a crisis in our time horizon.

But today it is not possible to approach such a reflection on the industrial situation without observing that we live in a world which is virtually in a state of permanent crisis.

Naturally, what springs to mind immediately are the economic and political aspects of this crisis. And yet one is tempted to state that these are only the most salient manifestations of a profound disintegration which threatens the whole range of principles shaping human existence and in the name of which we judge our actions : humanism, ethics, civilization, culture.

If, with the aid of the various disciplines which science puts at our disposal, we attempt to establish an objective inventory of our contemporary society, we are bound to appreciate that the world in which we live is not that which we thought it would be. But in spite of this, it is above all to the imaginary world that we refer in our prospective studies, in a kind of defensive reflex or "cultural myopia".

In fact, the majority of such studies are concerned with "linear projections" of past performances. In a world of inequalities and conflictsd such as that in which we live, this technique is inadequate, for, on the one hand, it must take on board a past which has beaten all records for totalitarianism and inhumanity and, on the other hand, it must underestimate the transformations and mutations of which we are vaguely aware today.

To accept such studies would imply the acceptance, for example, for the Africa in the year 2000, of a development model which would include "50 million starving persons, 200 million illiterates, 175 million unemployed, 100 million children with no school to go to, a death rate of 15/1000 and a life expectancy of 56 years" *(M. Elmandjra).*

The second method, that adopted by several institutions (O.E.C.D., E.E.C. and F.A.O. in particular) supposes a dynamic political environment and a sociocultural change which it tries to integrate into its scenarios. It demands "a large element of intuitive analysis and thus implies a certain subjectivity".

This type of forecast must be interpreted as a "message for creating awareness and inducing action" rather than a macro-economic reference framework. But as such, it already deserves to gain the attention of managers.

Whatever their imperfections (such as a tendency to ethnocentrism in some of them) these descriptions of possible futures are based on a certain number of general considerations which cannot leave us indifferent.

- man : "on the one hand the human species is basically motivated by old emotional responses which are full of danger and which . . . risk throwing one community against another at any moment, even in the name of grand sentiments . . .; and on the other hand (it is discovering) undefined vistas of knowledge and power without intellectual capacities being adequate to permit mankind to foresee all the consequences of his acts" *(Jacques Lesourne).*

The more we approach a satisfactory understanding of the psychological function of man, the more we are dismayed at the incapacity of human societies to govern themselves.

- science : "the scientific approach is characterized by logical rigor, but the result is irrational in relation to any human design. What is found is not necessarily what was sought, and the result obtained is often much more important for its multiple consequences than for the anticipated result which guided the research" . . . "To believe that it would be enough to draw from a reservoir of available knowledge is an enormous error which is unfortunately widespread. On the contrary, we should increase our resources for fundamental research by directing them away from probably useful fields to the resolution of certain critical, identifiable development situations. The science of the North has taken little account, so far, of such a specific approach, as expressed by the South, and research workers of the South, often qualitatively excellent but too few in numbers, have shown no more tendency to concentrate their work on specific questions relating to their geographical field, induced as they were to integrate themselves into the science of the industrialized countries" *(A. Danzin, I. Prigogine).*

- the world : the near future is hardly reassuring and the most likely outcome is far from satisfactory. Nevertheless, almost or over-simple speeches are uncalled for. Beyond the variety of scenarios there is a filligree outline of the major facts which make up the world of the turn of this century, a more complex, more diverse and much more instable world than that of the 80's:
  - — slow growth with permanent inherent unemployment and popular aspirations unsatisfied, the third world becomes less monolithic as the redeployment of activity intensifies in certain developing countries;
  - — from a bipolar situation, the world becomes multipolar, and the relative positions of different groups of countries in their share of gross world product change radically;
  - — interdependence will grow and increase the vulnerability of a given country to other states' actions. Whether in energy, raw materials, agriculture or financial movements, it would appear that competition between the industrial actors in the most developed countires will be all the tougher, the lower the rates of growth;
  - — the functioning of such a system does not, unfortunately, exclude either economic and political crises, or revolutions, or wars.
- under-development : according to the World Bank's latest Annual Report "on development", prospects for the 1980/90 decade are as follows:
  - — on the whole 50 countries will continue to reply for their progress nearly exclusively an official development aid. About 50 countries should be able to "reduce their dependence" on this aid;
  - — average-income countries would show a 2% yearly increase in income per capita which is "obviously inadequate";
  - — "should growth be inferior to this estimate", the experts warn us, "umemployment will grow", leading to serious problems and making social and political tensions worse. As a result, the control of the economy will become more difficult";
  - — economic growth in most low-income countries — except India and China - would be "negligible";
  - — as far as the African countries are concerned — those South of the Sahara - their prospects are still bad and many of them are in a "far more desperate situation than a year ago";
  - — oil-exporting countries would experience a "rapid expansion of their non-oil production capacities".

These rather gloomy prospects have led the experts of the IBRD to doubt whether the optimistic scenario could indeed come true. This scenario, designed for the 80's estimates that a real annual growth of 3.6% in industrial countries is the condition to reach a 5.7% average expansion in the Third World.

- international trade : "the progress of international trade will be highly susceptible to growth rates, North-South relationships and the options taken by the larger number of countries towards a greater liberalization or a new protectionism. The Third World's participation in commercial exchanges - excluding China - could grow from 12% at the beginning of the 70's to 18-22% at the end of the century *(IBID);*
- industry : "the internationalization of industry will constitute one of the major aspects of interdependence. In the devloped countries, the interaction between industry and scientific research and the complementarity between industry and services will progressively modify the concept of industrial activity . . . The third world including China, could account for 23 to 25% of world industrial production at the end of the century" *(Interfutures).*

There are few sectors presenting so much similarity with the industrial model described in most prospective studies as that of fertilizer production.

Hence our interest in briefly analysing in this paper the conditions for a satisfactory response from the industry to the challenge launched by the F.A.O. in its study on "Agriculture : towards 2000".

After stating the general objectives in the first part of this paper, we shall try to describe the main obstacles to their realization in the second part. In the third part, we shall examine the resources of the fertilizer industry which would be necessary for a positive response to an explosive demand, whilst in the conclusion we stress the principal collective obligations of our industry if it is to accomplish what may still seem today to be closer to Utopia than to reality!

Part One
The Challenge
The Scenario of the F.A.O.
"Agricultural: Toward 2000"

Twenty years ago the world population had not reached 3 billion; now it is 4.4 billion and will exceed 6 billion at the end of the century. Of these 6 billion people, 90% will live in the developing countries.

This means that we shall need to increase food production by 50% merely to maintain the present standards of nutrition which are far from satisfactory in certain parts of the developing world.

If we are to avoid the tragedy of a world abandoned to famine, it is in the next few years - and before 1985 in any case - that the main political decisions will have

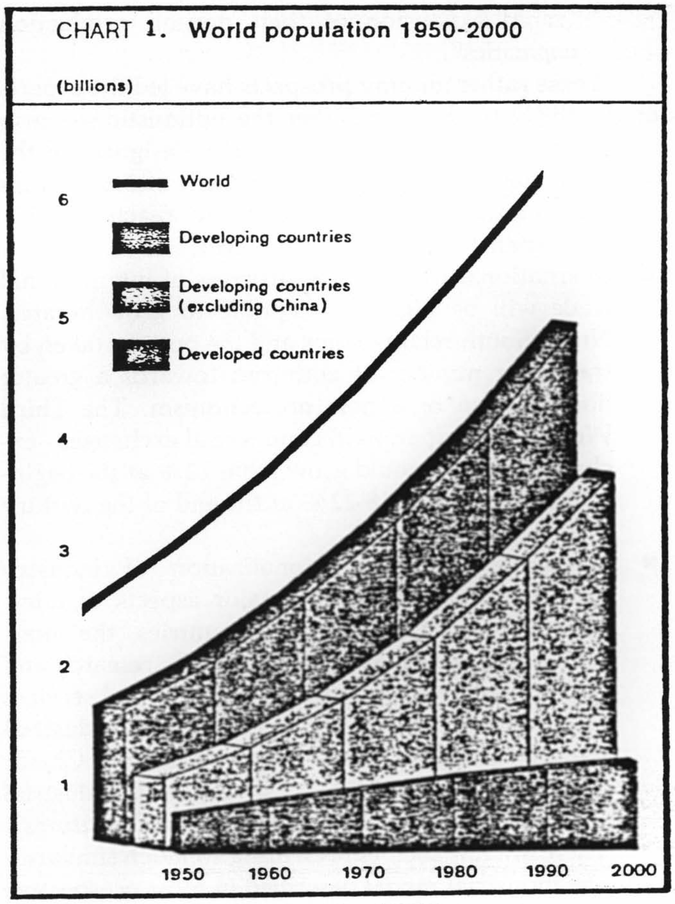


CHART 1. **World population 1950-2000**

(billions)

FAO : T. 2000

to be taken concerning the food situation at the end of the century.

Indeed, the formulation of any ambitious, realistic strategy will have to take account of the major constraints which will inevitably slow down its development :

- the long period of preparation which precedes the exploitation of additional natural resources;
- non-cultivated arable land is becoming scarcer and it is agricultural productivity which should be increased. But the resistence of the farmer, traditionally conservative to the introduction of new cultivation methods, cannot be ignored;
- the considerable lead time required to develop and experiment with new technologies and new varieties;
- the slowing down of the quantitative growth of the world economy as a consequence of the low anticipated rate of growth of the developed countries;
- the political, social and cultural obstacles to be overcome if the essential food requirements of the poorest people are to be translated into a steady, stable demand;
- the unreliability of the developed world's aid due to the conflictual nature of international relations.

Based on the impressive documentation accumulated over the last twenty years, the F.A.O. has constructed three development scenarios from now to the end of the century for agriculture in 90 developing countries representing 98% of the population of the third world not including China.

The first scenario is based on the extrapolation of the trend of agricultural production and consumption in relation to the growth of population. It leads to an alarming conclusion : between 600 and 700 million people will continue to suffer from a calory deficient diet.

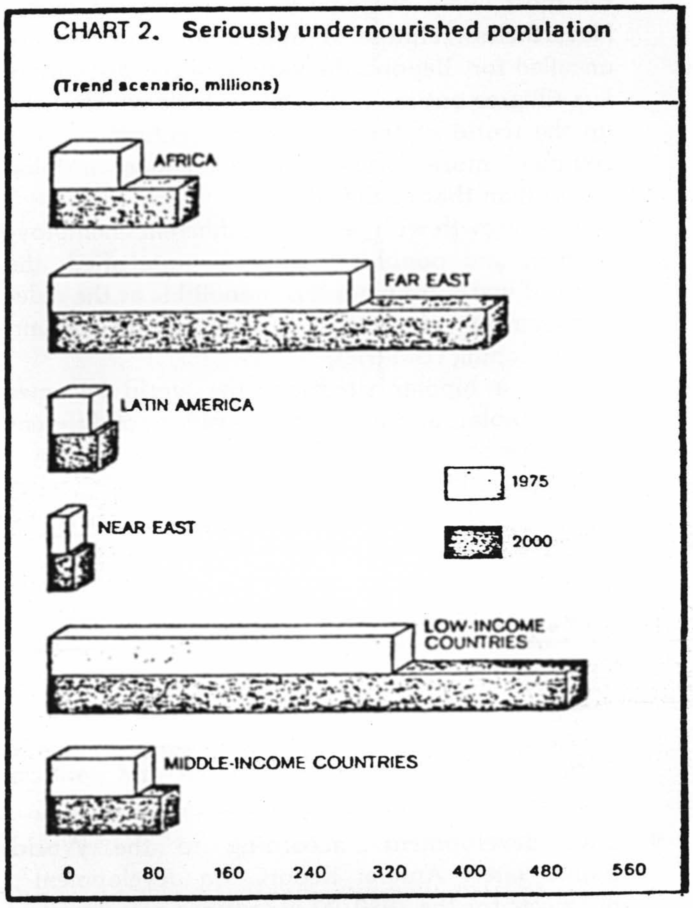


CHART 2. **Seriously undernourished population**

(Trend scenario, millions)

FAO : T. 2000

A realistic analysis of the problems concerning the international trade in agricultural produce shows that the large surpluses which continue to burden the markets of the developed countries could not, in practice, end malnutrition in the rest of the world. Moreever, it is clear that an agriculture so inadequately suited to the essential needs of the population would aggravate the threat of the degradation and exhaustion of natural resources as well as constituting an alarming factor tending towards political destabilization. The lesson is clear : the world can no longer be satisfied with its past performance.

It is gratifying to note that in its latest report the World Bank emphasizes "that in nearly every country which shows definite agricultural progress, there is a rapid economic growth. This had made it possible to suppress nearly completely the worst cases of utter poverty in numerous average-income countries".

The two normative scenarios - quantified evaluations of possible futures - are based, in the first case on a doubling of agricultural production over the next 20 years (scenario A), and in the other case on only 80% growth (scenario B). We shall refer mainly to this second scenario (principally to take account of economic crises and political accidents).

Table 1. **Growth rates of Scenarios A and B, 1980-2000**

	Assumptions		Results	
	Population	GDP	Total domestic demand for food, feed and agricultural raw materials	Total production of food, feed and agricultural raw materials
			Percent per year	
			A	
World[1] (124 countries)	1.9	4.4	2.3	2.3
34 developed countries	0.7	3.8	1.2	1.05
90 developing countries	2.4	7.0	3.7	3.7
			B	
World (124 countries)	1.9	3.6	2.0	2.0
34 developed countries	0.7	3.2	1.2	1.2
90 developing countries	2.4	5.7	3.2	3.1

FAO : T. 2000

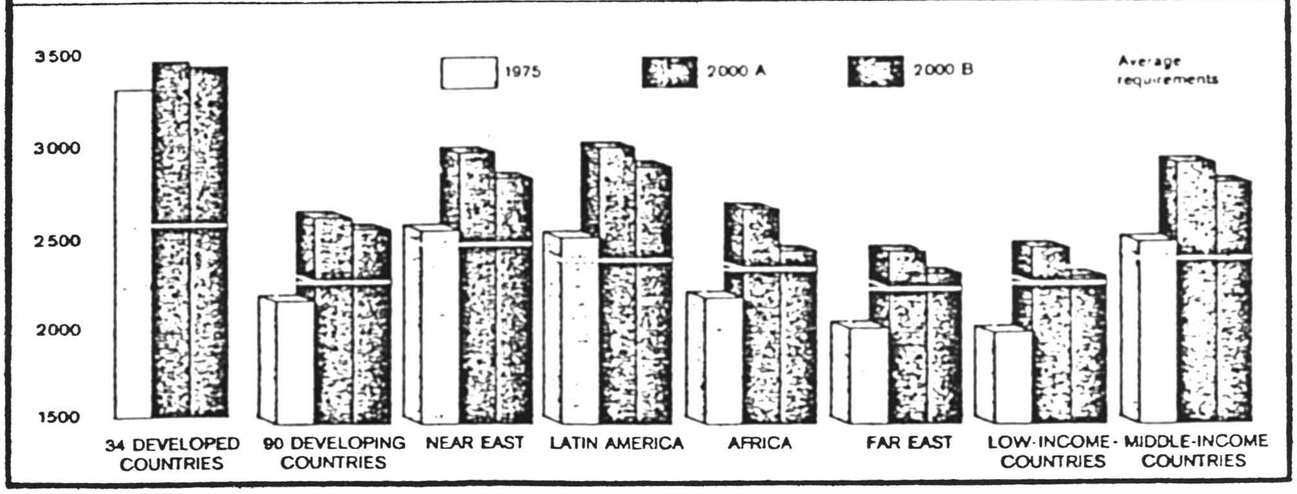


CHART 3. **Average calorie supply**

(calories per caput per day)

FAO : T. 2000

However ambitious these figures may appear, the number of under-nourished persons will still remain impressive: between 250 and 400 millions

This is despite the fact the additional amounts of food required to exceed the critical threshold of 1.200 calories would not even represent 5% of the total food production of these 90 countries.

Population growth calls for increasing agricultural productivity rates which means a genuine agricultural revolution with considerable investments in infrastructure, the practice of a great number of modern techniques, a strong injection of inputs and a thorough re-examination of most national agricultural policies.

A summary analysis of the condition on which the achievement of the objectives described by the F.A.O. depends on bringing out the preponderant role of the following factors : land, water and fertilizers.

Firstly LAND : the increase in the cultivated land area is expected to contribute a little less than 30% of the increase in agricultural production. At the end of the century, the shortage of arable land will have become the most critical constraint for 2/3 of the developing world.

More than 70% of the agricultural expansion will thus have to come from increased yields.

POSSIBLE CONTRIBUTION TO ACRICULTURAL PRODUCTION GROWTH - 1980/2000
TABLE 2

	Increased cultivated land (%)	Increased yield/Ha (%)
90 countries	28	72
Africa	27	73
Far East	13	87
Latin America	54	46
Near East	8	92

FAO: T.2000

And if the desired yields are to be achieved, the rate of growth of the use of inputs will have to be double that of agricultural production itself. (It may be noted that, according to the F.A.O. a significant increase in real agricultural product prices is not a necessary condition for stimulating the supply of these products).

Of all the inputs, WATER is undoubtedly the most important, since, after the land itself, it is the only absolutely indispensable element for plant growth. Despite the considerable investment recommended by the F.A.O. at the end of the century 60% of total agricultural production will still come from non-irrigated land representing 84% of the total arable area.

After land and water, FERTILIZERS are undoubtedly the main factor for increasing agricultural yields. Although fertilizer consumption in the developing countries has increased twice as fast as in the development countries over the last 10 years, the rates of use (average per hectare) still scarcely amount to 20% of the average amounts applied in the Western countries. This is why the two scenarios are based on annual growth rates of 7.5 to 8.5% per annum, which is both high, since it is more than double the expected growth rate for agricultural production, and also low since this rate is lower than previous growth.

One should emphasize that the F.A.O. relies on a spectacular increase of fertilizer use on irrigated land where the highest response is achieved.

The F.A.O. study also stresses the important role played in the achievement of its objectives by:

- the improvement of seed varieties to permit the cultivation of plants which are better adapted to the available inputs in a given region at a given time;
- the judicious use of pesticides and herbicides within the framework of an integrated campaign against parisites and diseases which are responsible for 20 to 40% of present losses;
- the intensification of agricultural mechanization even if, as is the case in the poorest countries, this development may lead to an increase in unemployment.

We should also note that this comprehensive study mentions numerous other agricultural components which are likely to undergo fundamental change before the end of the century (forestry, fisheries, livestock, agricultural research).

Wisely, the F.A.O. emphasizes that the increase in agricultural production is not an end in itself. It is a practical measure of the quantitative development of an economy but it is certainly not an indicator of the qualitative progress of mankind.

What should be radically re-examined are the social, cultural and institutional structures if they are unfit to offer each human being a decent living standard at a time when world resources are capable of securing those needs on a global basis.

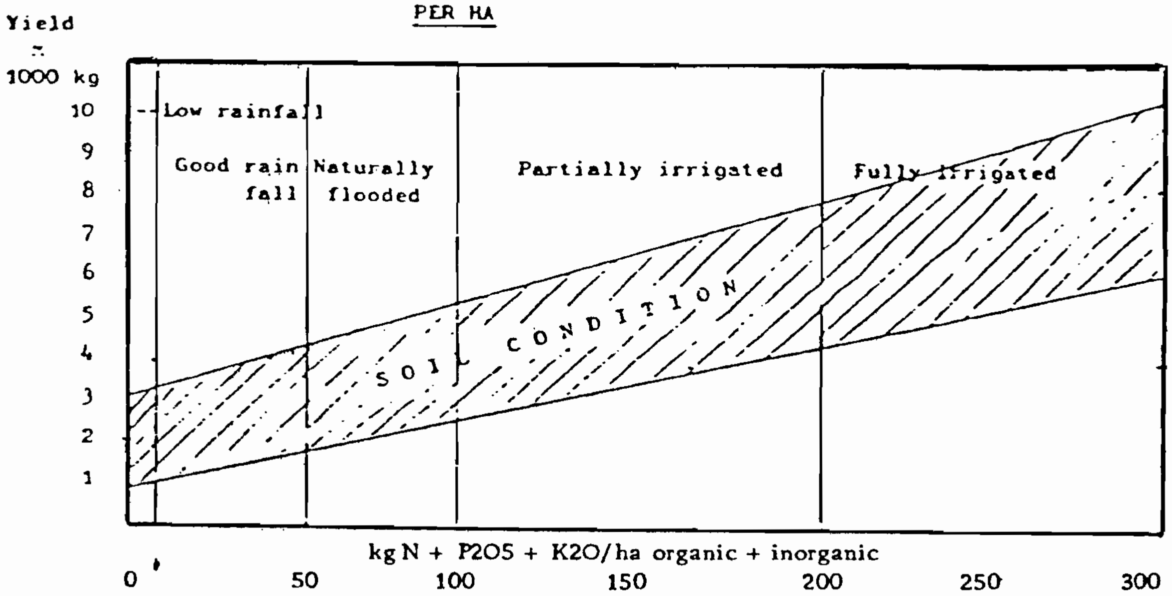
The F.A.O. also considers the future development of agriculture in the developed world, mainly in relation to the fact that its four main exporters (U.S.A., Canada, France and Australia) will continue to have to cover most of the external agricultural trading deficit of the developing countries. Based on an estimated annual growth of a little more than 1%, the result is quite positive.

For its part, the European Economic Community, in a study of its agricultural prospects to 1990, envisages only a very small increase in the consumption of agricultural products within its market of a little more than 300 million consumers. It estimates that the area of agricultural land and the number of farm holdings will continue to decline together with the active agricultural population which should lose 3.5 million persons.

The E.E.C. draws seven main conclusions from a certain number of prospective observations:

TABLE 3

POTENTIAL YIELDS (WATER, FERTILISER, SOIL CONDITION).
PER HA



Source:Van Monsjou

STATISTICAL SUMMARY - KEY GROWTH RATES (% per year)	1980/2000 (Scénario B)
. Population :	1.7
. Developed	0.7
. Developing (90)	2.4
. Gross domestic product :	
. Developed	3.2 - 3.8
. Developing (90)	5.7.
. Gross agricultural production :	
. Developed	1.1 - 1.5
. Developing (90)	3.1
. Inputs to crop production (90) :	
. Arable land total	0.7
. Arable land irrigated	1.3
. Fertilizer (NPK)	7.3
. Tractor park	7.4
. Draught animal population	0.6
. Labour use (man. days)	1.6

TABLE 4

FAO T. 2000

- The need for an acceptable level of agricultural income should lead to an intensification of agricultural production. Increased costs and a restrictive price policy will induce farmers to improve the productivity of their labour by increased use of production factors (fertilizers, compound feeding stuffs, machinery) and by applying new techniques. The result will be a built-in excess of agricultural supply over demand;
- the agricultural sector will need to make more intensive use of the capital market and will consequently have to bear higher financial charges. The level of agricultural investment will increase and will necessitate higher capital productivity;
- the economic importance of the agricultural sector will continue to decline. This will be compensated by an increase in the size of agricultural supply industries and food industries;
- the trend towards specialization and intensification will result in increased environmental risks, expressed in terms of product quality and pollution;
- the tendency of production to grow more rapidly than demand will probably necessitate considerable expenditure in the field of market support measures, either as intervention buying or as direct aid to farmers;
- demand within the Community for basis agricultural products from third countries will remain limited and the industrialized countries as well as the developing countries will engage in fierce competition on world markets;
- as for food aid to the third world, it will remain principally a development tool and an emergency resource for catastrophes. It is not considered to be a systematic means for disposing of the E.E.C.'s production surpluses.

A. The General Objectives of the F.A.O.

It is for the governments concerned to evaluate the degree of credibility of the quantitive development estimates put forward by the F.A.O. They, together with the intergovernmental organizations, must accept the dangerous mission of defining, selecting according to priorities and mobilizing the human, material and institutional resources implicit for the success of the gigantic humanitarian operation.

Without wishing to introduce a sceptical note, it is interesting to measure the magnitude of the development to be achieved by taking the example of a country with one of the largest agricultural growth potentials among the forty poorest countries. We refer to the Sudan which presents a case which is all the more interesting for the fact that the Arab World cherishes the hope of making it one day its breadbasket.

On a land area of about 1/3 of that of the U.S.A. live less than 20 million inhabitants, of whom 80% are illiterate. Sudan is a cultural and religious melting pot on the borders of the Arab and African civilizations, incorporating 500 tribes, both sedentary and nomadic, speaking 100 different languages. Over 26 years of independence, the country has already had 17 years of civil war.

Classified by the United Nations in the category of the forty "low income countries" i.e. countries whose gross domestic product per capita is less than 300 US dollars 1975, as well as in the list of the least developed countries, the Sudan is nevertheless considered as having abundant reserves of arable land.

This country whose agricultural production has grown at a rate of more than 3% per year, devotes 80% of its export revenue to the purchase of oil.

In recent years, important projects have been developed: the excavation of the JONGLEI canal which is designed to divert a stretch of 360 km of the white Nile (but at what cost for local ecosystem?); the largest irrigated farm in the world at EL GEZIRA between the blue and white Niles (but with what results?); the large sugarworks at KENAMA and the creation of a town of 50,000 inhabitants in the middle of the bled (but with what demographic problems?).

This example illustrates the enormity of the road to be travelled to achieve even the least ambitious objectives of the F.A.O. in a country whose population has survived so far more thanks to its resources of fatalism than to those of its agriculture.

B. Objectives in the Fertilizer Sector

The challenge which our industry is supposed to meet over the next 20 years may be briefly described as: IMPRESSIVE by virtue of its quantitative growth:

Nevertheless, the development of a programme of this magnitude raises four basic questions which should not be underestimated:

1. Apart from growing population pressures, the transition from a subsistence economy to a market economy implies the disappearance of itinerant agriculture in favour of permanent crops (the case of Africa, Amazonia, Central America and the coastal regions of South-East Asia and the Pacific). Moreover the increase in agricultural productivity generally results from the adoption of a range of improved techniques within which fertilizers, whilst being a decisive element, are only one among several.

   According to WORTMAN and CUMMINGS Jr. (1978) there are four conditions to be met if farmers on whatever size of farm holdings are to increase their yields:

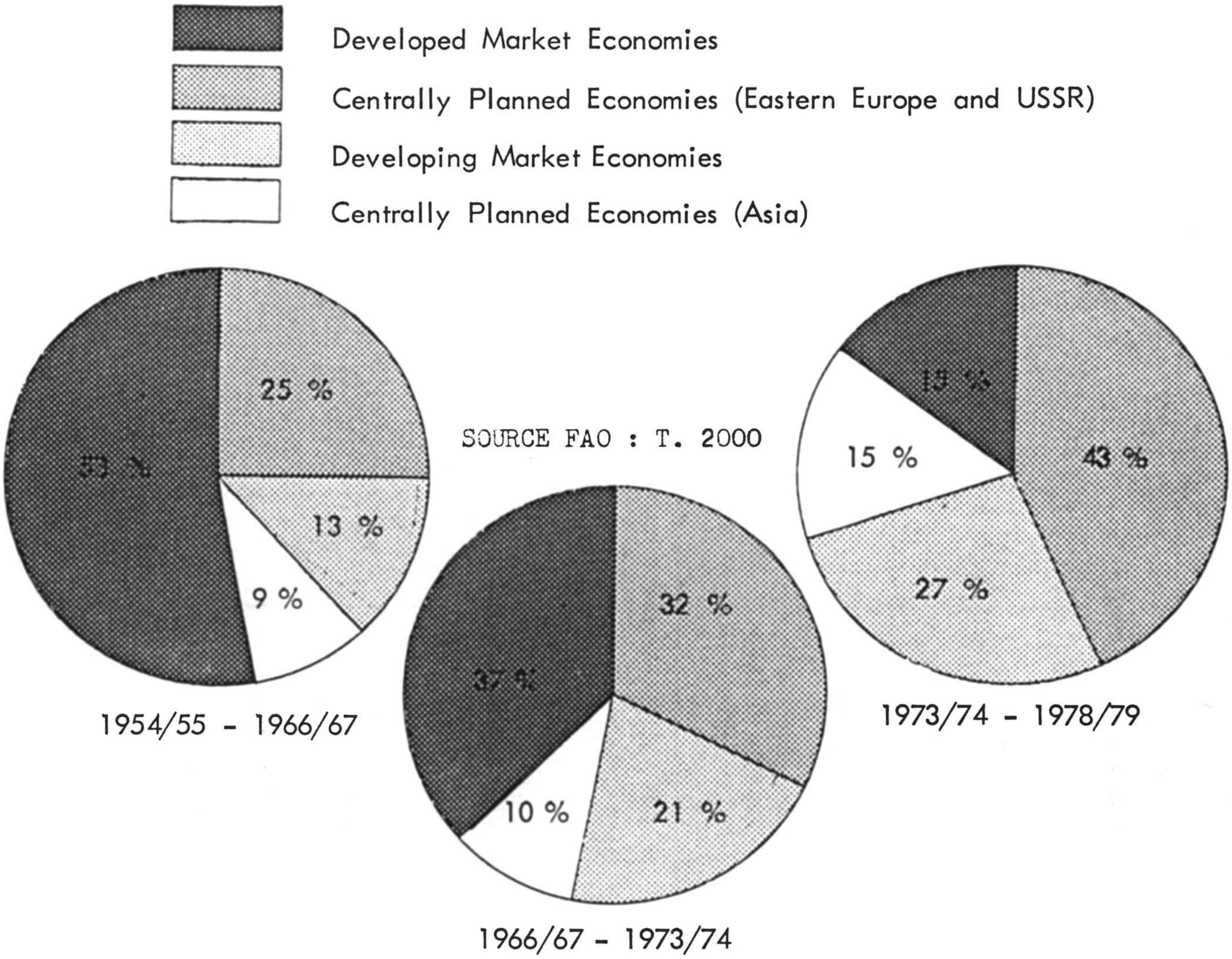
   The magnitude of the institutional problems arising from a rational development of fertilizer use could give fresh impetus to the dilemma between domestic production and the massive importation of food.

   Numerous studies have shown that this alternative is not realistic, firstly because international markets

continued on page 11

CHART. 4.

SHARE OF TOTAL GROWTH IN WORLD FERTILIZER USE BY COUNTRY GROUP



SOURCE FAO : T. 2000

TABLE 5 INPUTS AND YIELDS

90 developing countries

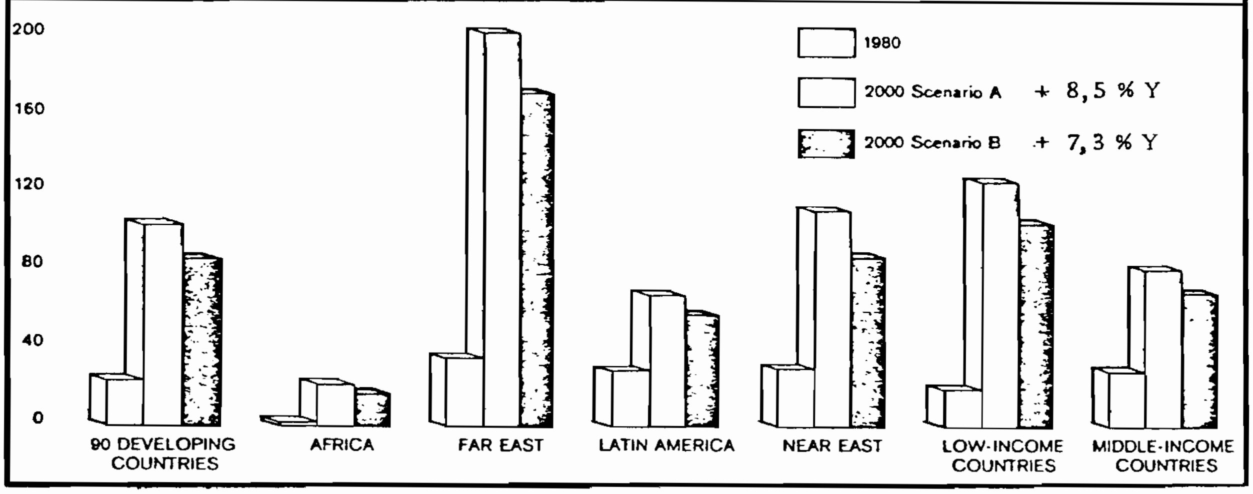
	1974–1976	2000 Scénario B
. FERTILIZER (thousand tons NPK)		
. Low income	5.227	45.273
. Middle income	8.258	30.279 (*)
Total	13.485	75.552
. WHEAT (tons/harvested ha)	1.29	2.20
. RICE (PADDY)	1.95	3.05
. COARSE GRAINS	1.02	1.55

(*) half of this tonnage will be used by cereals, of which 2/3 by wheat, rice and maize.

The challenge which our industry is supposed to meet over the next 20 years may be briefly described as :

IMPRESSIVE by virtue of its quantitative growth :

CHART 5. A. **Developing countries: fertilizer use per hectare of arable land, 1980 and 2000 (kg/ha)**



VERY ACCESSIBLE in terms of individual yields :

CHART 5.B. **Developing countries: cereal yield levels (tonnes/ha)**

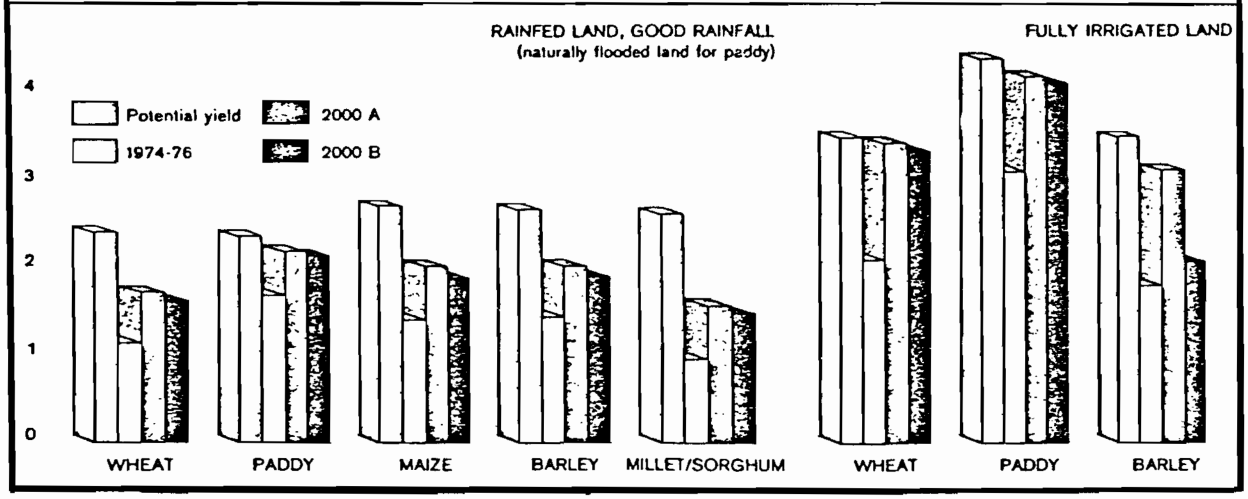


TABLE 6
CONDITIONS FOR INCREASED YIELDS

- OPERATING SYSTEM - LOW RISK IMPROVED MATERIAL AND METHODS.
- INSTRUCTION OF FARMERS BY SIMPLE AND PRACTICAL METHODS (Overcome the traditionalism of illiterates).
- COST OF INPUTS AND FINANCING COMPATIBLE WITH THE INCREASED VALUE OF THE CROP.

  (Ratio : $\frac{\text{Value}}{\text{cost}}$ "V.C.R")
- EXISTENCE OF DISTRIBUTION CHANNELS FOR CROPS

FAO: T. 2000

continued from page 8

are governed by essentially profit-making criteria and are not suited to such a demand, and could only be suited to it if the importing countries were to make ruinous investments in infrastructure which could be inflationary for the exporting countries.

A recent study by the F.A.O. estimates that, in the year 2000, the economy to be achieved annually by replacing cereals imports by fertilizer imports is roughly 20 billion dollars.

The case of certain countries such as India, where the population grows by half a million people every ten days, requiring 100,000 tonnes of additional food shows to what extent dependence on international markets could be suicidal[1].

2. Increasing agricultural productivity per unit area and per unit time not only permits an increase in the amount produced per hectare but also reduces the cost per tonne of harvested crop.

   The introduction of the concept of "maximum economic yield" (see the interesting reports of the P.P.I.) familiar in our developed countries necessarily implies a mastery over interactions between nutrient elements and a varied range of genetic and cultural factors.

   There can be no doubt today that the farming systems of many developing countries are potentially capable of progressively achieving a maximum yield, as has been shown in recent works on rice.

   One of the most decisive factors in achieving high yields is the determination of correctly balanced fertilization.

   Nevertheless, one should not underestimate the variety of controllable factors likely to reduce the efficiency of fertilizer use in the developing countries.

   The 3 most important factors are badly balanced fertilizer application (20 to 50% reduction), the use of an unsuitable variety (20 to 40%) and too great a delay in sowing (20 to 40%). However, the soils in most developed countries can respond quite satisfactorily to correct but still far from perfect methods or cultivation.

3. The main element which the farmer considers when he decides on the amount of fertilizer to buy is the relation between the cost of the fertilizer and the price which he expects to get for the crop on which he will put the fertilizer.

   A favourable ratio between these two elements obviously fosters a greater use of fertilizers. However, fertilizer prices which are derived from the costs of production, shipping, distribution, marketing and credit, as well as from the different governmental policies, vary greatly from one country to another.

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[1] One should not forget that a developed country's agriculture is very vulnerable when its income is directly related to the fluctuations of the World market for agricultural products. The spectacular drop in income suffered by the American farmer following 2 record crops confirms it (it should be noted that the production of about one third of the cultivated land in America is for exportation).

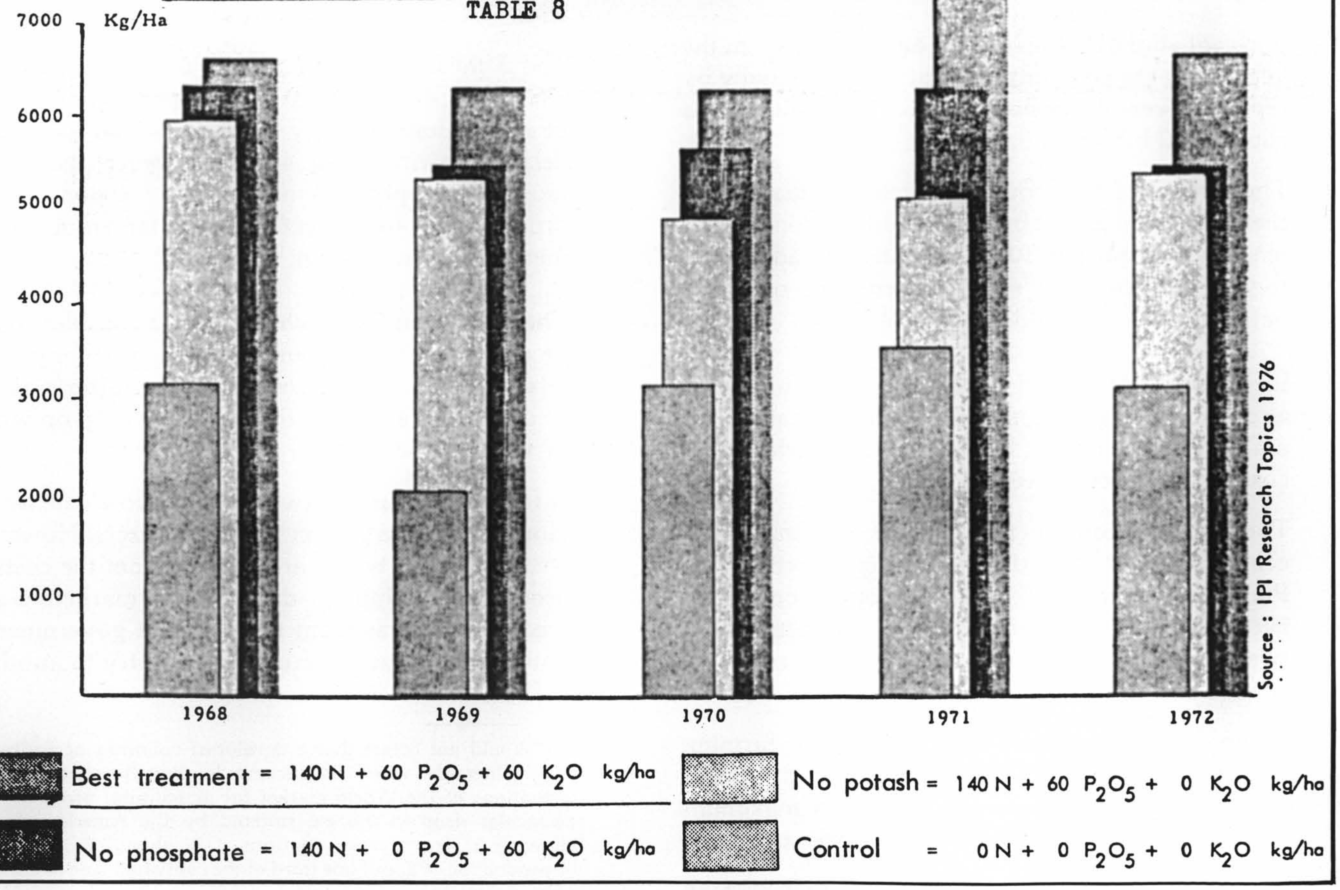
TABLE 7.
THE EFFECT OF PROGRESSIVE IMPROVEMENTS ON A HYPOTHETICAL FARM OF 1.9 Ha OF WHICH 1.5 Ha IS DEVOTED TO RICE
(derived from von Uexküll, 1978)

	Yield (t/ha)	Total farm production (t)	Domestic consumption (t)	Marketable surplus (t)
Traditional subsistence system	1.5	2.25	1.75	0.5
Improved varieties with irrigation and herbicides	2.2	3.3	1.75	1.55
As (2) plus pesticides and fertilizers	3.4	5.1	1.75	3.25
As (3) with additional fertilizers and multiple cropping	8.5	12.75	2.0	10.75

EFFECT OF NPK ON IRRIGATED RICE GRAIN YIELD CULTIVATED OVER FIVE CONSECUTIVE YEARS IN THE PHILIPPINES, DRY SEASON

AVERAGE OF 3 VARIETIES

TABLE 8



Source : IPI Research Topics 1976

Table 9

ESTIMATE OF POSSIBLE REDUCTION OF FERTILIZER USE EFFICIENCY RESULTING FROM CONTROLLABLE FACTORS

FACTORS WHICH REDUCE FERTILIZER EFFICIENCY	
Poor preparation of the seed-bed	10-25 %
Inappropriate variety	20-40 %
Delayed sowing	20-40 %
Bad sowing system	5-20 %
Inadequate plant population	10-25 %
Inadequate irrigation	10-20 %
Infestation by weeds	15-50 %
Attack by insects	5-50 %
Badly balanced fertilizer applications	20-50 %
Incorrect spreading	5-10 %

SOURCE: FAI SEMINAR 1976, NEW DELHI, INDIA.

TABLE 10

PRICE OF NITROGEN FERTILIZER DELIVERED TO THE FARM IN CERTAIN COUNTRIES

(US dollars/t of N in urea)

	1977/1978
Saudi Arabia	209
Egypt	248
Italy	281
Turkey	285
India	406
U.S.A.	407
Philippines	473
Japan	496
Netherlands	516
Brazil	526

TABLE 11

TRANSPORT COSTS IN SOME COUNTRIES

(US dollars/t of fertilizer)

Country-region	Type of fertilizer	Year	Cost of transport as % of TMC
AFRICA			
. Congo	Urea	1978	85.3
. Gambia	Compounds	1978	44.3
. Kenya	TSP	1978	36.2
. Lesotho	2-3-0 (15)	1978	6.6
. Sudan	Urea	1979	32.7
. Tanzania	Urea	1978	58.6
ASIA			
. Bangladesh	Urea	1978	41.0
. India	Urea	1980	16.4
. Indonesia	Urea	1978	21.0
. Nepal	Urea	1979	18.4
. Philippines	Urea	1979	31.8
. Sri Lanka	Urea	1979	20.4

SOURCE F.A.O.

TABLE 12.A.

SUBSIDIES IMPACT ON FERTILIZER CONSUMPTION GROWTH IN DEVELOPING COUNTRIES

(Average growth in % per year)

Direct fertilizer subsidies	Africa	Far East Pacific	Near East	Latin America
With	15.3	18.7	10.3	12.6
Without	8.8	-	6.5	7.4

Since the preponderant role of fertilizers has been recognized by governments, at least 2/3 of them have instituted systems for subsidizing the cost of fertilizers as well as establishing agricultural price support policies.

These subsidies take very varied forms but mainly consist in covering all or part of the distribution costs. They are of a precarious nature. Moreover, they do not necessarily succeed in overcoming other constraints limiting the regular, increasing use of fertilizers.

4. The 300,000 trials and demonstrations carried out by the F.A.O. Fertilizer Programme since 1961 have demonstrated that the average result of the best fertilizer application on each of the different crops results - in the worst of cases - in a benefit/cost ratio of 2.1, i.e. a profit of 100% on the money invested in the fertilizer. Thus there is no longer any shadow of a doubt as to the profitability of fertilizer use.

And yet a recent F.A.O. enquiry carried out in 15 countries shows that, although the delivered farm price of fertilizers generally fell between 1980 and 1981, and although the crop prices generally rose, thus increasing the benefit/cost ratio, more than half of the countries concerned indicated an inadequate supply.

This non-availability of fertilizer in the quantities and qualities required at the place and time when they are wanted, is the result of a whole set of causes such as the absence of everall planning, the lack of equipment in the ports and main distribution centres, defective transportation systems, inadequate resources at the last stage of distribution, i.e. the village and the farm, all resources showing the difficulty for developing countries to master simultaneously all the components of an apparently rational system.

TABLE 12.B.

EXAMPLES OF NUMBERS OF VEHICLES REQUIRED FOR ROAD TRANSPORT OF FERTILIZERS

Country			Thousands of vehicles required		
			1980	1990	2000
Kenya	:	lorries	1.5	2.0	2.5
The Gambia	:	lorries	1.5	4.5	7.5
India	:	lorries	2.0	15.0	25.0
		carts	80.0	150.0	100.0
Philippines	:	lorries	3.5	4.7	6.0

Source: FAO - Fertilizer Marketing Requirements

In addition to these logistic obstacles, we may add defective conditions of credit and inadequate coordination between research and extension.

The specific constraints on the harmonious development of fertilizer use may be described in four words: institutional, cultural, financial and logistic.

Dream or Reality:

The Indian example should give us cause for optimism, although from the point of view of its general situation, agriculture in India does not differ so much from that in Africa. About 1/3 of all forms are of less than one hectare, and available land is scarcer than in Africa. However, during the last 15 years, the production of cereals has increased by more than 50% on an agricultural area which has grown by only 5%. However, India still uses an average of only 30 kg/ha of $N + P_2O_5 + K_2O$, i.e. 8 times less than in Europe and 10 times less than in Japan and Korea. Wheat and rice yields are about 1.5 to 1.3 t/ha compared to 6 tonnes in Japan. And yet there is reason to think that India has become self-sufficient in cereals.

In the same way as fertilizer is only one input among several, the fertilizer policy of a nation is only one element of its agricultural policy which, in turn, cannot be dissociated from its overall governmental policy. Unfortunately there is more than one step to be crossed between the seat of a government and the farmer in his village.

Nevertheless, examples exist to persuade us that if a government adopts a coherent policy, develops it and controls it wisely, and when the main stages of the operation are identified and begin to be mastered, the near term objectives of 1987/1988 and the more distant objectives of 2000/2001 are not in the field of Utopia.

TABLE 12.c.

EXAMPLES OF ESTIMATED FERTILIZER MARKETING TRAINING REQUIREMENTS AT RETAIL, WHOLESALE AND POLICY LEVELS IN 1980 AND 2000

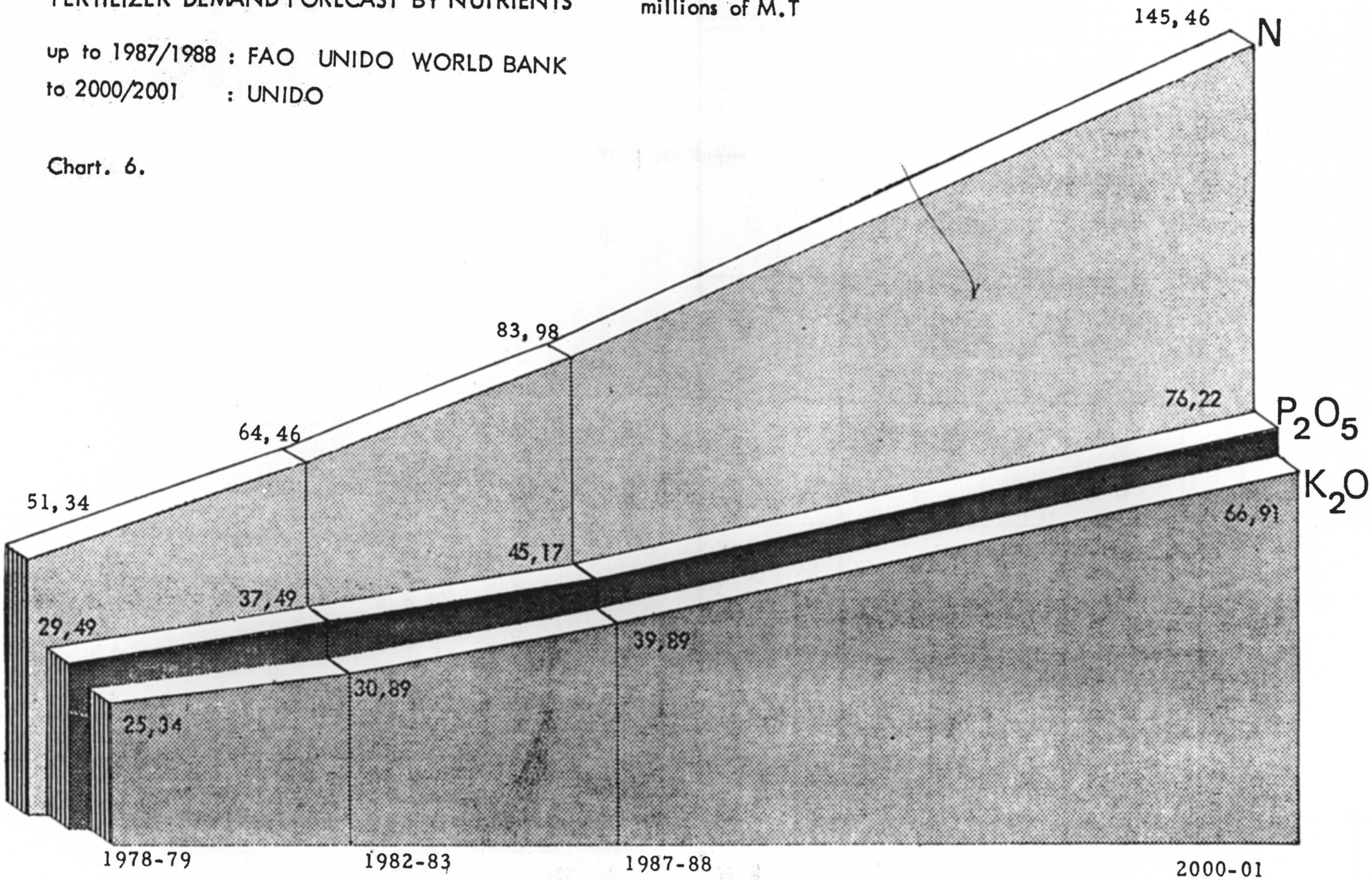
Country	Retail		Wholesale		Policy level	
	1980	2000	1980	2000	1980	2000
Kenya	1.200	4.500	30	90	20	40
The Gambia	300	1.500	30	80	10	20
India	23.000	31.000	2.500	3.100	250	350
Philippines	3.210	4.500	120	200	60	60

SOURCE: FAO FERTILIZER MARKETING REQUIREMENTS

FERTILIZER DEMAND FORECAST BY NUTRIENTS

up to 1987/1988 : FAO UNIDO WORLD BANK
to 2000/2001 : UNIDO

Chart. 6.



FERTILIZERS DEMAND FORECAST BY REGION
(millions of MT N P2O5 K2O)

Table 13	N		P2O5		K2O	
	1987/1988	2000/2001	1987/1988	2000/2001	1987/1988	2000/2001
Developed countries						
. Market economies	28.28	40.60	16.69	21.03	16.85	25.28
. Centrally planned economies	23.00	41.41	14.00	27.26	16.40	29.28
Total developed countries	51.28	82.01	30.69	48.29	33.25	54.56
Developing countries						
. Market economies	22.70	45.54	10.73	21.05	5.63	10.63
. Asian centrally planned economies	10.00	17.91	3.75	6.88	1.01	1.72
Total developing countries	32.70	63.45	14.48	27.93	6.64	12.35
Total World	83.98	145.46	45.17	76.22	39.89	66.91

Up to 1987/1988 FAO/UNIDO/WB
To 2000/2001 UNIDO

Briefly, these projections indicate:

- for the developing world, an annual growth rate of 5% or slightly more for each of the 3 plant nutrients;
- for the developed market economies, a rate of 1.8% p.a. for P_2O_5 , 2.8% p.a. for nitrogen and 3.2% p.a. for K_2O. In the centrally planned economies, these figures are respectively 2.4, 3.7 and 3.9% p.a.

These figures show that the developing countries could, by 2000, use 40% of world nitrogen consumption, about 1/3 of P_2O_5 consumption and 20% of potash consumption.

Part Three
Industry's Response

The question which springs immediately to mind is whether the fertilizer industry will be able to meet such a very considerable demand in good time.

Obviously, it is impossible to reply correctly to this question today, but this does not exclude reflection on the three basic factors which will condition the achievement of a satisfactory global supply in the medium to long term (capacities, raw materials, capital).

1. *Available production capacities and additional capacities needed for the achievement of the global objective*

F.A.O. and UNIDO consider that, apart from potash, where the developed countries will continue to hold more than 90% of world capacity, the developing countries could be able to ensure their overall self-sufficiency in nitrogen and could come close to self-sufficiency in phosphate fertilizers.

Supply capacity for regional self sufficience is calculated as follows:

- N = 1.685 time the nitrogen demands for developed countries and 1.52 time for developing countries.
- P205 = 1.29 and 1.22 time respectively.
- K20 = 1.24 and 1.36 time respectively.

The logic of self-sufficiency which - in the case of nitrogen - approximates to a postulate which still deserves some fine critical analysis, masks a more subtle reality:

This table shows that in the developing world only the Near East could become self-sufficient in all 3 major plant nutrients. Latin America and the Far East would remain large importers of phosphate and potash fertilizers, whilst Africa is distinguished as an exporter of phosphate together with certain developed countries.

Chart. 7.

FERTILIZER DEMAND FORECAST BY REGION

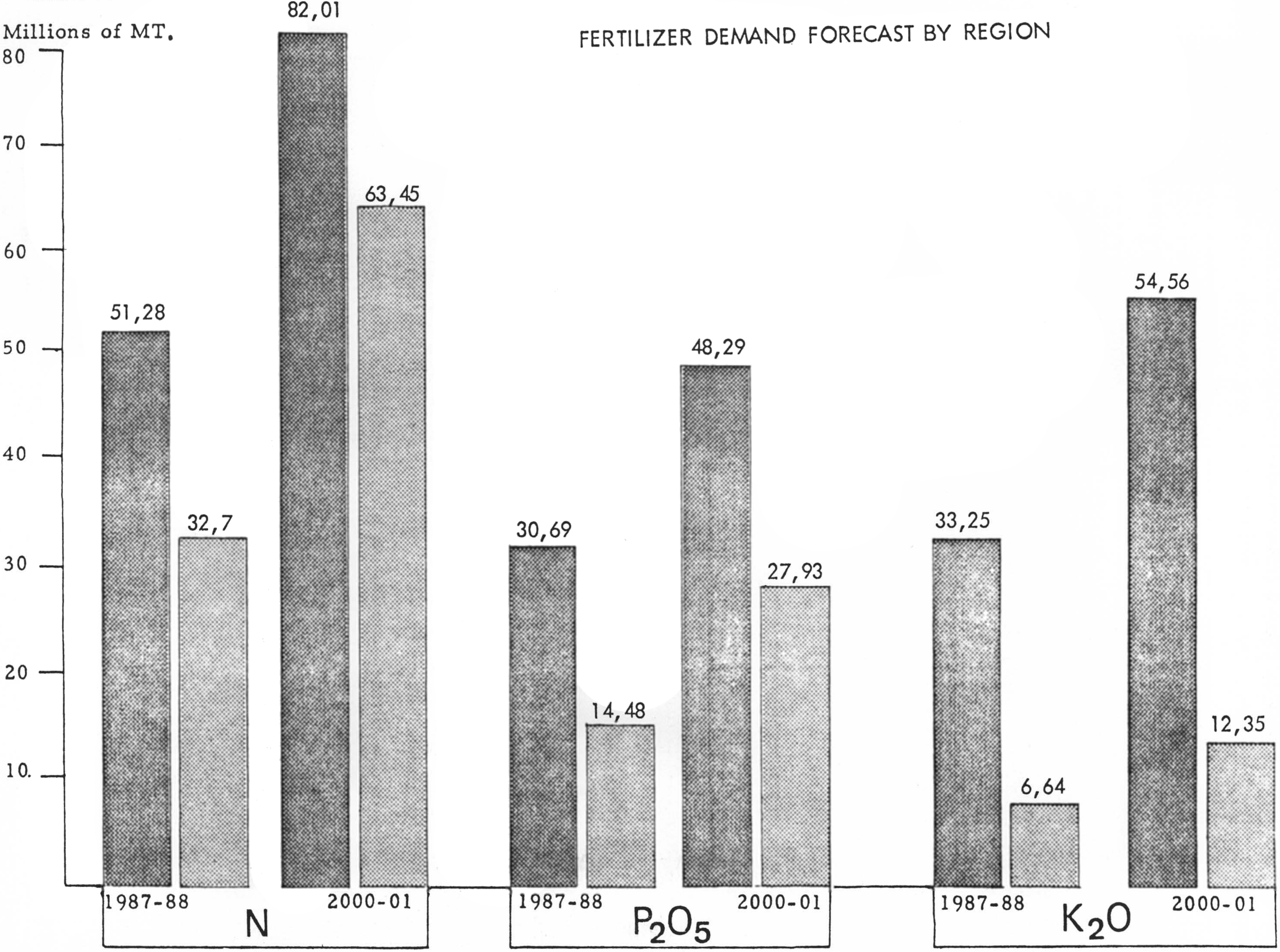
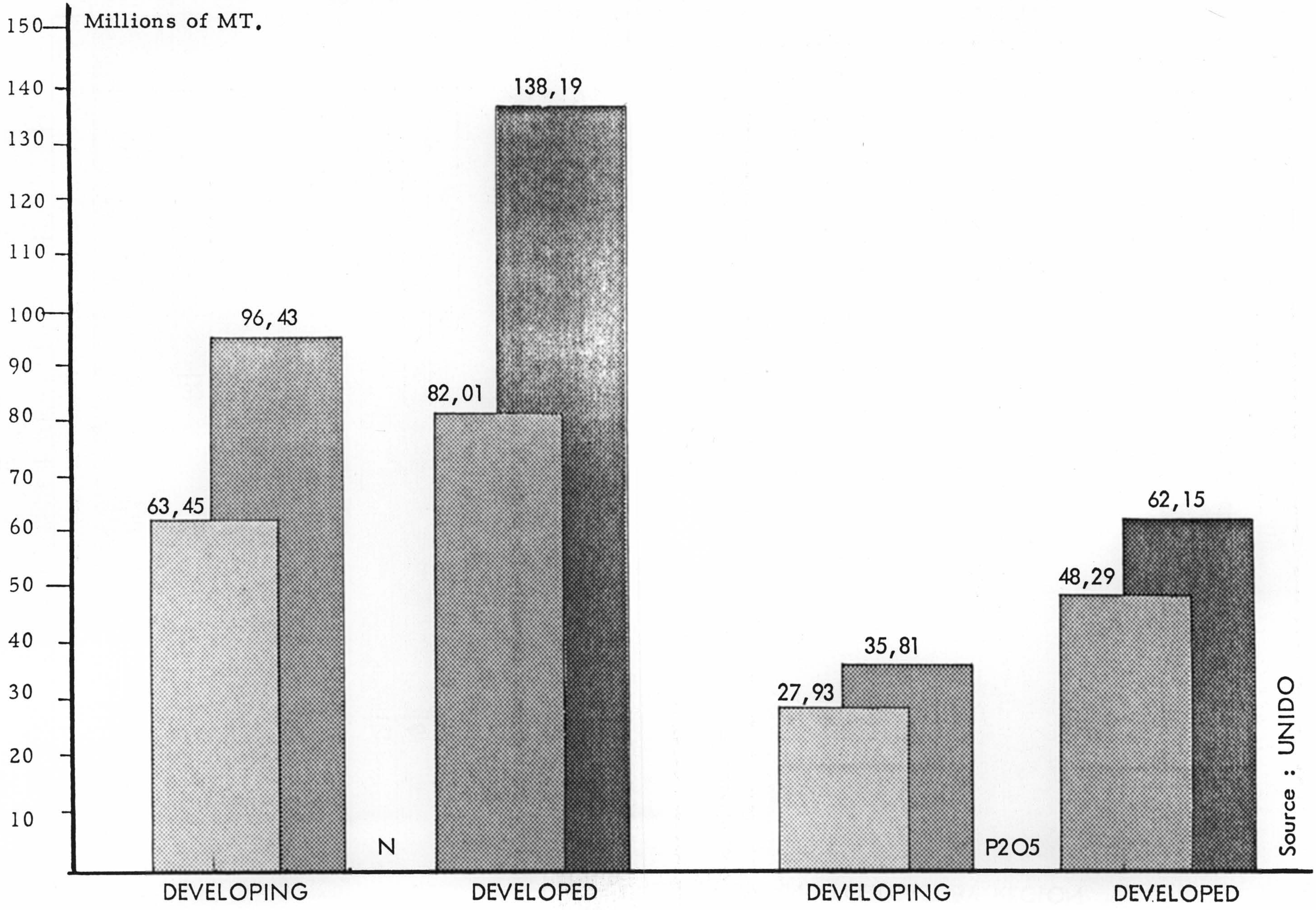


CHART. 8 NITROGENOUS AND PHOSPHATE DEMAND AND CAPACITY Years 2000/2001



Source : UNIDO

TABLE 14

FORECAST OF NITROGENOUS PHOSPHATE AND POTASH CAPACITY

(million of MT N P2O5 K2O)

Year 2000/2001

	N	P2O5	K2O
Developed countries			
. Market economies	68.41	30.24	36.94
. Centrally planned economies	69.78	31.91	41.90
Total developed countries	138.19	62.15	78.84
Developing countries			
. Market economies	69.21	25.68	2.32
. Asian centrally planned economies	27.22	8.39	2.35
Total developing economies	96.43	34.07	4.67
Total World	234.62	96.22	83.51

Source : UNIDO

TABLE 15

SUPPLY DEMAND BALANCE BY REGION

Regions	N	P	K
. Market economies	S.S.	Exp.	Exp.
. Centrally planned economies	S.S.	Imp.	Exp.
. Africa	S.S.	Exp.	Imp.
. Latin America	S.S.	Imp.	Imp.
. Near East	S.S.	S.S.	S.S.
. Far East	S.S.	Imp.	Imp.
. Asian centrally planned economies	S.S.	Imp.	S.S.

Even in those parts of the world where the movement of goods would not appear at first sight to be necessary, the fertilizer market will continue to be characterized by substantial inter - and intra-regional trade, with al that this implies in the way of incidents, surpluses, shortagesand tensions. We may recall that in 1980/81, the developing countries (excluding China) had net fertilizer imports amounting to nearly 45% of their total requirements.

The estimated number of fertilizer complexes to be constructed is quite impresive. According to UNIDO, more than 500 nitrogen (ammonia and urea) and phosphoric acid (phosphoric and sulphuric acid and DAP) units are needed, of which somewhat less than half will be in the developing world.

The F.A.O. estimates that, to maintain the balance between nitrogen and phosphate supply and demand in 1984 and the 4 following years, and to replace outdated plants, 90 nitrogen plants and 25 phosphoric acid plants will have to be constructed, i.e. more than 4 nitrogen plants and 1 phosphoric acid plant every 3 months.

The situation of these plants will probably continue to be determined by the proximity of the main raw material, although the development of new phosphate reserves threatens, in certain cases, to involve infrastructural investments which it would be difficult to justify (production costs of between 50 and 60 dollars per tonne).

2. *Raw materials requirements*

The case of potash raises no problem of availability.

Even tho 35 countries have been indentified to-date as having workable phosphate deposits, nearly 90% of identified resources and located in 5 countries only and more than 60% in Morocco alone. The availability of this raw materials poses no problem.

The case of sulphur is more worrying, to the extent that the known, economically exploitable reserves do not cover the projected demand[1]. Thus, by virtue of its cost or its physical availability, sulphur may be the major limiting factor on the use of highly soluble concentrated phosphate fertilizers.

The production of nitrogen fertilizers requires only a tiny proportion of the world raw materials production necessary for this industry (less than 5% of natural gas - less than 1% of oil and coal production).

The problem of the expansion of our industry over the next few decades will therefore be less that of availability than of access to the most competitive sources of supply, as governed by current technological developments (the example of the deregulation of gas prices in U.S.A. deserves to be mentioned, since, with a gas price at 6 dollars/mcf in 1985, the price of ammonia could reach 400 to 430 dollars/t).

3. *Capital requirements*

A . On the basis of production capacities which seem to be outmoded by today's standards (1.000 tpd ammonia and 1,725 tpd urea - 600 tpd phosphoric acid - corresponding 1,600 tpd sulphuric acid and 1,275 tpd ammonium phosphate) UNIDO estimated in 1978 that the total investment over the last 18 years of this century should amount to 83 billion US dollars 1977. This amount included neither the investments in the development of additional resources nor the capital needed for the improvement of replacement of existing units, nor the local expenditure needed to handle the fertilizer, transform it into products corresponding more precisely to domestic demand and distribute it. Consequently we may estimate today that the total capital requirement of our industry in the context of the F.A.O. and UNIDO studies amounts to between 150 and 200 billion dollars. The developing countries should absorb about half of this amount.

B . However impressive these figures may be, it is not their magnitude which should concern us but the probability of their profitability, since it is after all in relation to profitability that investments are in principle financed.

In general, our industry has only one customer: the farmer. For him, the cost of fertilizer must be compared either with the anticipated increased value of his crop or with a possible higher profitability of other inputs. Although he may partially command the resources needed to improve the productivity of his farm, he has scarely no control over the ex farm prices of his produce (which fluctuate according to commodity exchange quotation or state regulation) nor over that of his delivered farm purchases, since these are very often regulated as well.

For his part, the fertilizer producer who is only rarely totally integrated or in a monopolistic position, has only a relatively limited influence on the policy of his raw materials and energy suppliers.

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(1) The exploitation of new pyrites deposits, the intensification of sulphur recovery from hydrocarbons and coal and the processing of residual gypsum sulphate are additional potential resources.

TABLE 16.A
WORLD PHOSPHATE ROCK CAPACITY AND RESOURCES

	Capacity		Reserves (*)		Total identified resources	
	1980		millions	%	millions	%
	millions	%				
North America	56.6	35.4	2,200	8.1	8,100	12.0
. U.S.A.	56.2	35.2	2,200	8.1	8,000	11.9
. Others	0.4	0.2	-	-	100	0.1
Latin America	1.5	0.9	450	1.7	950	1.4
Europe	33.15	20.7	1,415	5.2	3,445	5.1
. U.S.S.R.	33.0	20.6	1,400	5.2	3,400	5.0
. Others	0.15	0.1	15	-	45	0.1
Africa	49.1	30.7	22,180	82.1	51,450	76.3
. Algeria	1.2	0.8	50	0.2	550	0.8
. Egypt	(**)	-	100	0.4	1,000	1.5
. Morocco	33.0	20.7	18,400	68.2	41,600	61.7
. Senegal	2.0	1.2	130	0.5	200	0.3
. South Africa	3.0	1.9	3,000	11.1	7,000	10.4
. Togo	3.0	1.9	(**)	-	(**)	-
. Tunisia	6.0	3.8	300	1.1	700	1.0
. Others	0.9	0.6	200	0.7	400	0.6
Asia	14.5	9.1	660	2.4	1,350	2.0
. China	6.0	3.8	100	0.4	200	0.3
. Israel	2.0	1.2	60	0.2	100	0.1
. Jordan	3.0	1.9	100	0.4	300	0.4
. Viet Nam	1.5	0.9	100	0.4	150	0.2
. Syria	(**)	-	200	0.8	400	0.6
. Others	2.0	1.2	100	0.4	200	0.3
Oceania	5.0	3.1	100	0.4	2,130	3.2
. Australia	1.0	0.6	-	-	2,000	3.0
. Pacific Islands	4.0	2.5	100	0.4	130	0.2
World (***)	160.0	100	27,000	100	67,425	100

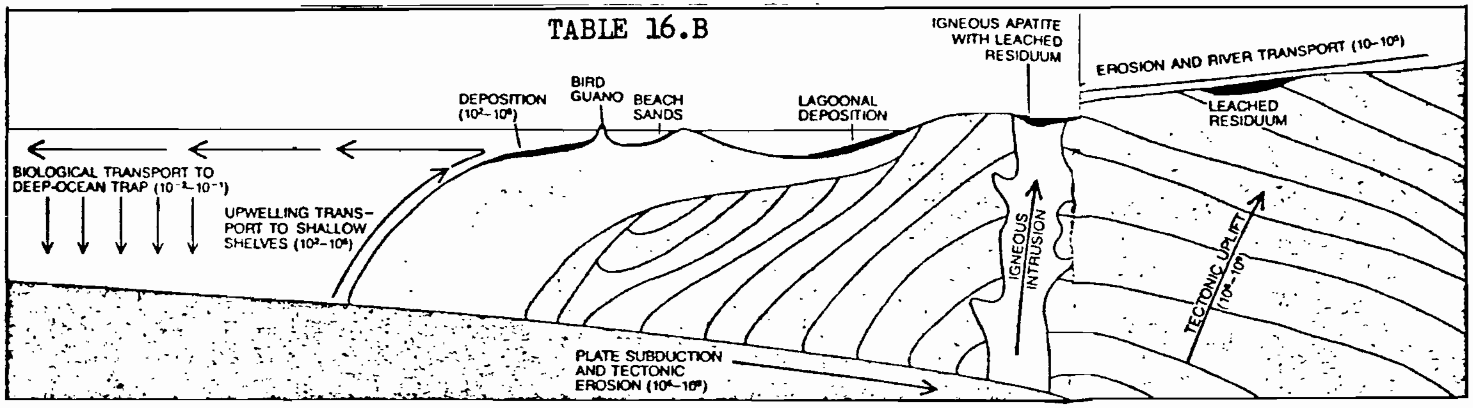
(*) Estimated reserves at 1977 costs/prices

(**) Included in "Others"

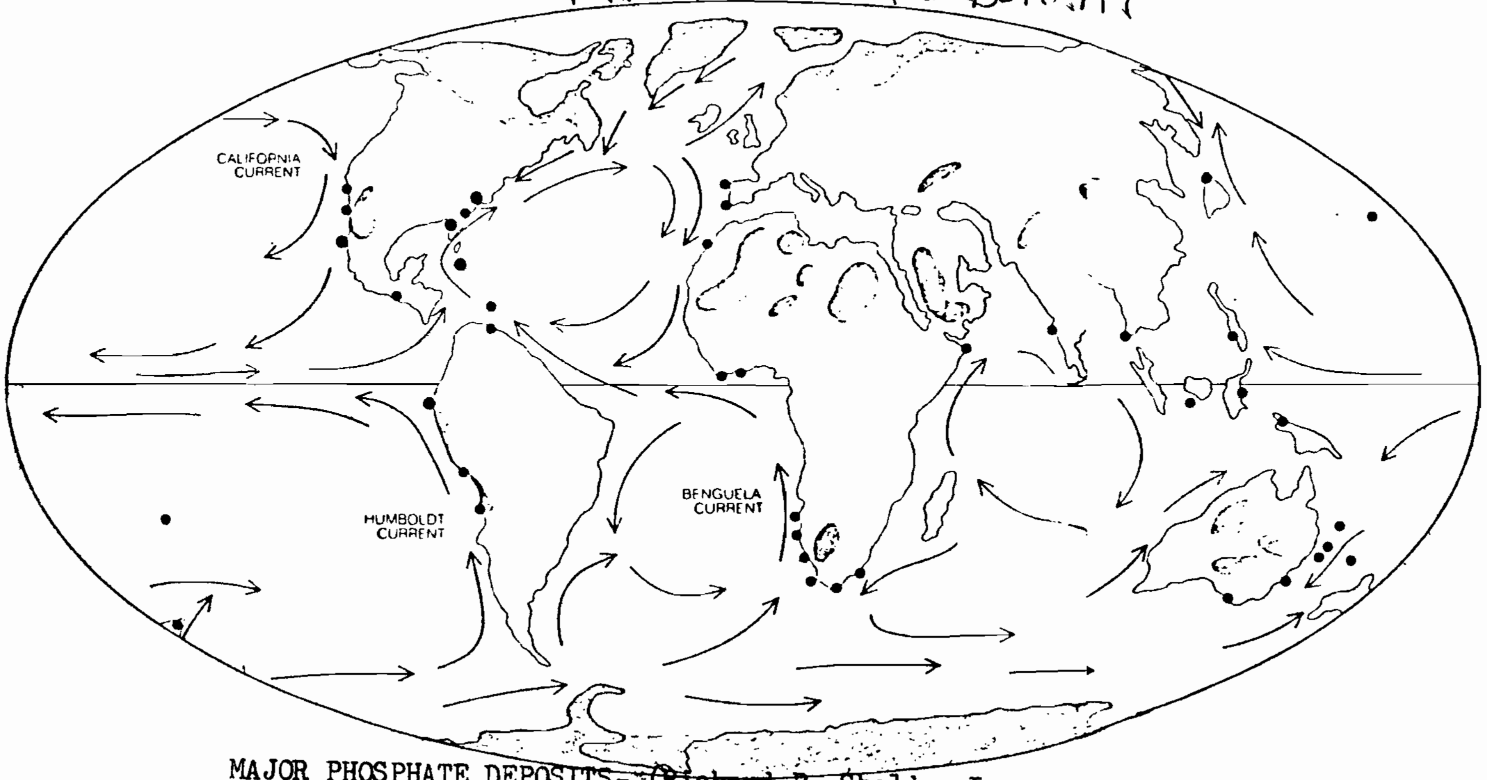
(***) Figures have been rounded, hence totals may not correspond to the sum of their components.

Source : Phosphate, Mineral Commodity Profits MCP, January 1979, Bureau of Mines, Ministry of the Interior of the U.S.A.

TABLE 16.B



MAJOR PHOSPHATE DEPOSITS



MAJOR PHOSPHATE DEPOSITS-- (Richard P. Sheldon In Scientific American-- June 1982

TABLE 16 C.
IDENTIFIED WORLD RESOURCES

(% of total)

	Natural gas	Phosphate	Sulphur (potential production)	Potash
Developed countries	56	22 - 30	84	94
. Market economies	16	17 - 25	45	57
. Centrally planned economies	40	5	39	37
Developing countries	44	70 - 78	16	6

Consequently, the commercial dialogue between the large primary producers and the farmers - the final consumers - is not effective in the determination of a so-called "normal" price for fertilizers, in view of the cascade of events and interventions which disturb the price fixing mechanisms at the farm level both for fertilizers and for crops. Hence, it is perfectly useless to try to construct hypothetical ratios between "fair prices" and ideal profitability", since the amount of fertilizer consumption finally depends on a value relationship at the level of the farm itself, the terms of which are almost entirely outside the control of the operators. Here we are probably facing the major unknown factor in the prospective work of the F.A.O.

C . One of the major features of our industry is its large need for capital for increasingly identical plants to produce massive quantities of relatively undiversified products which can sometimes even be easily substituted one for another and which resemble raw materials or intermediate products more than end products. Thus the price fixing mechanism of the main fertilizers in the competitive markets is similar to the one of mineral raw materials and the main agricultural products, except that, since there is no international commodity exchange for fertilizers and their raw materials, and hence no possibility of hedging operations, brutal short term fluctuations can ravage the profitability of enterprises, the more so since the use of fertilizers is essentially seasonal.

We can never emphasize too strongly in the circles of the intergovernmental organizations that one of the main obstacles to the steady growth of fertilizer use is not regular increases in its price[1], to the extent that such increases are justified in relation to a state of healthy competition, but excessive price volatility resulting from the multiple imperfections of the market.

It is not by means of price intervention that we shall achieve a healthier market performance and more regular consumption but by the correction of the most disturbing constraints.

Consequently, in order to assess the probability of achieving the gigantic investments implied by the normative scenario of the F.A.O., we have only one remaining resource: our appreciation of the impact on potential demand of the probable development of the realization price of the product from new plants, always supposing a return to more reasonable levels of energy cost and inflation.

If we consider the various estimates of realization prices established recently with great care by the World Bank for new plants, we observe that to justify profitable investment on developed sites we should have to have a urea price of between 275 and 300 dollars (1981) per tonne, for phosphoric acid between 425 and 450 dollars per tonne (with sulphur at 160 dollars CIF) and for TSP between 200 and 230 dollars per tonne.

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[1] Obviously, we are alluding here to fertilizer price increases contained within the limits of a moderate inflation (4 to 8%) which is perfectly acceptable to agriculture.

These figures show the potential competitiveness of battery limit units - of a reasonable size and with satisfactory technical performance -with grass roots plants, even when the latter are situated near abundant reserves of a given raw material. Thus, in a perspective of average profitability, it is still worth setting up additional capacities in developed countries.

Nevertheless, except for a few markets showing strong growth, the new industrial complexes will be concentrated in countries with raw materials resources (natural gas, phosphate).

D . Even a brief analysis of the industrial problems poses by the realization of the normative scenario of the F.A.O. reveals to what extent the decision to invest - particularly on sites without infrastructure or even with rudimentary infrastructure - should undergo longer consideration and correspond with much more accurate criteria than in the past, however honourable the end in view. This "moment of reflection" would undoubtedly constitute the most effective cure against the endemic surplus which affects our industry.

The alternative which is always latent in developing countries between importing fertilizer and local production should be the subject of a much more satisfactory response from the moment when the deciding nation, faced with the magnitude of the financial package required for a coherent, effective fertilizer programme, has to decide simultaneously on the type of industry to be established and the sequence of investments to be made. In certain cases, this should lead to the complete reversal of the classical cycle: primary production, processing and distribution which is a mythical conception and generates the overcapacity responsible for the wastage of capital.

E . Sooner or later we should be prepared for basic changes in the nature and form of certain fertilizers. According to M. DEPREZ, the increase in agricultural productivity (in France one bushel per acre per year for wheat over the last 30 years) will make it compulsory for fertilizer producers to "change their fertilizers and take into account minor elements which are not scarce to-date because of the natural riches of the land and a slow consumption level, but whose level in the soil will become insufficient". He also predicts that a conflict of interests may arise between nitrogen fertilizer producers and seed-breeders since "geneticians" no longer despair or breeding new plants which can recover nitrogen from the atmosphere in the way leguminous plants do".

4. *The short term*

Such considerations should not let us overlook shorter term prospects.

The opinion of experts from intergovernmental organizations is illustrated in the following table which shows on the one hand the large availability of potash and natural phosphate and on the other hand the possibility of a progressive reduction in the availability of nitrogen and phosphate fertilizers leading to a tight situation and scarcity towards 1984/85 for the former and 1985/86 for the latter. In addition, over the next four or five years, we do not expect any upheaval in the major components of the market as was the case during the previous decade. We expect a less chaotic development of energy costs, a more reasonable rate of inflation leading to a progressive return of the major developed economies to a better balance, a relief of the accumulated deficits of the developing oil importing countries, little remarkable progress in the field of applied research as related to our industry, with the exception of energy economies in the nitrogen sector and the improved processing of low grade phosphates.

In Western Europe we may see a continuation of the concentration of the fertilizer industry around national poles or international groups commanding one or other of the essential natural resources. This movement should increase the public nature of the fertilizer sector which has already grown very considerably during the previous decade.
What will be the attitude of the European Community Commission towards this phenomenon of concentration and participation by non-Community interests?

We must hope that the concern to preserve in Europe an efficient fertilizer industry capable of competitively ensuring the major part of the supply to its agriculture will guide the Commission towards a policy of realistically applying the rules of the Treaty of Rome both in the case of concerted rationalization and with regard to self-defensive measures in case of damaging competition.

Conclusion
An Interdependent World

The international dimension of our industry results not only from the large proportion of international trade in the global volume of its business or from the serious nature of the obstacles which inhibit its development. It also flows directly from the universalization of the agricultural phenomenan.

Agriculture is probably the most highly protected sector in the world, and it would be quite unrealistic to imagine an abolition in the near future of the arsenal of restrictive measures which have been set in place to defend it.

And yet, of all the problems to be resolved if the inequalities between peoples of the world are to be diminished, the main one - for it is the motor element in any decent development of the less favoured economies - concerns the expansion of trade between developed and developing countries.

Realism indicates that it should be the developed economies who not only take the initiative but play a preponderant role. How?

A. Firstly by moderating their protectionism and multiplying international tariff arrangements. This does not exclude the developing countries from also seeking to increase their reciprocal agricultural trade (this represents only 10% of world trade today, compared with 60% for trade between developed economies).

B. Secondly by transferring towards the agriculture of the developing world the capital, technology and technical assistance which its modernization implies, to the extent that the recipient countries recognize the preponderant role of their own agriculture and adapt their defective structures.

   However, it would be unrealistic to believe in a "Marshall Plan" to save the Third World. No development can be set into motion by another power but its own. This is probably the reason why those countries of the Third World who have relied in an exaggerated way on external money-lenders are now faced with serious financial difficulties: uncontrolled urbanization, unbridled armaments expenses leading to heavy debts which come into light with the crisis.

C. Finally, by getting involved in an aid programme -bilateral or multilateral - more thoroughly than in the past. The F.A.O. estimates that total aid in the year 2000 should amount to 15 billion dollars (1975) i.e. 3 times the present aid level and this amount will only be reached if the developed countries agree to devote at least 0.7% of their G.N.P. to developing countries. Such an aid should include free fertilizers to the 41 poorest countries (particularly in Africa) whose requirements have been estimated at 4.3 million tons fertilizer nutrients for the year 2000 i.e. 15% of aid to agriculture (present fertilizer aid is only 477,000 tons whereas the irreducible minimum is one million tons).

D. However, an aid of this magnitude cannot have an effect commensurate with the effort it implies unless we become aware of the need to fight waste, both in the management of inefficient or unsuited plants and in actual farming (in the rate of nitrogen assimilation by the plant could only be increased from 25-40% to 60%, this alone could represent a saving of 21 million tonnes of N per year, equivalent to a value of 11 billion dollars). In comparison, according to professor Peter Timmer of Harvard, the fight against hunger would need only 30 to 50 millions tonnes of grain more each year -costing between 8 and 16 billion dollars - out of a total production of 1.860 million tonnes.

E. Finally, developed countries - particularly the U.S.A. - should act in a responsible way and look for a better equilibrium between the monetary and budgetary policies adopted to fight price increases. M. Jacques de Larosiere, Director General of the International Monetary Fund believes that a one point increase in international interest rates causes a 2 billion dollars increase in the debt of developing countries.

If all fertilizer producers could have observed the phenomenon of the universalization of their industry in time - if they could have appreciated the redistribution of roles which this anticipated - our profession would probably have avoided several sharp setbacks.

In an interdependent, multipolar world, no company can reasonably aspire to expansion in isolation, or even in confinement. The all too numerous failures in the search for improved market stability should have convinced us of the need to participate actively within our professional organizations -conserving our independence and respecting the rules of competition - in order to elaborate a more reliable information system on the probable development of the constraints which handicap our expansion. Similarly, we should intensify our contacts with governments and more particularly with the intergovernmental organizations (F.A.O., WORLD BANK, UNIDO, UNCTAD, etc. . . .) to alert them as much to the political and economic factors which threaten our exchanges as to damaging consequences of precipitous intervention or inadequate initiatives on their part.

The merit of the normative scenario as compared with the trend scenario is precisely to show up the obstacles which we risk running into and to suggest the structures and behaviour likely to overcome them.

The place occupied by our industry in the front line of the battle against under-development also puts us under obligations from which we can hardly escape without discrediting ourselves in the eyes of international opinion. In the forefront of our duties towards society we see an active participation in expertise, in men and in kind in the transfer and aid operations which comprise the programmes of solidarity of our governments within the framework of the North-South dialogue.

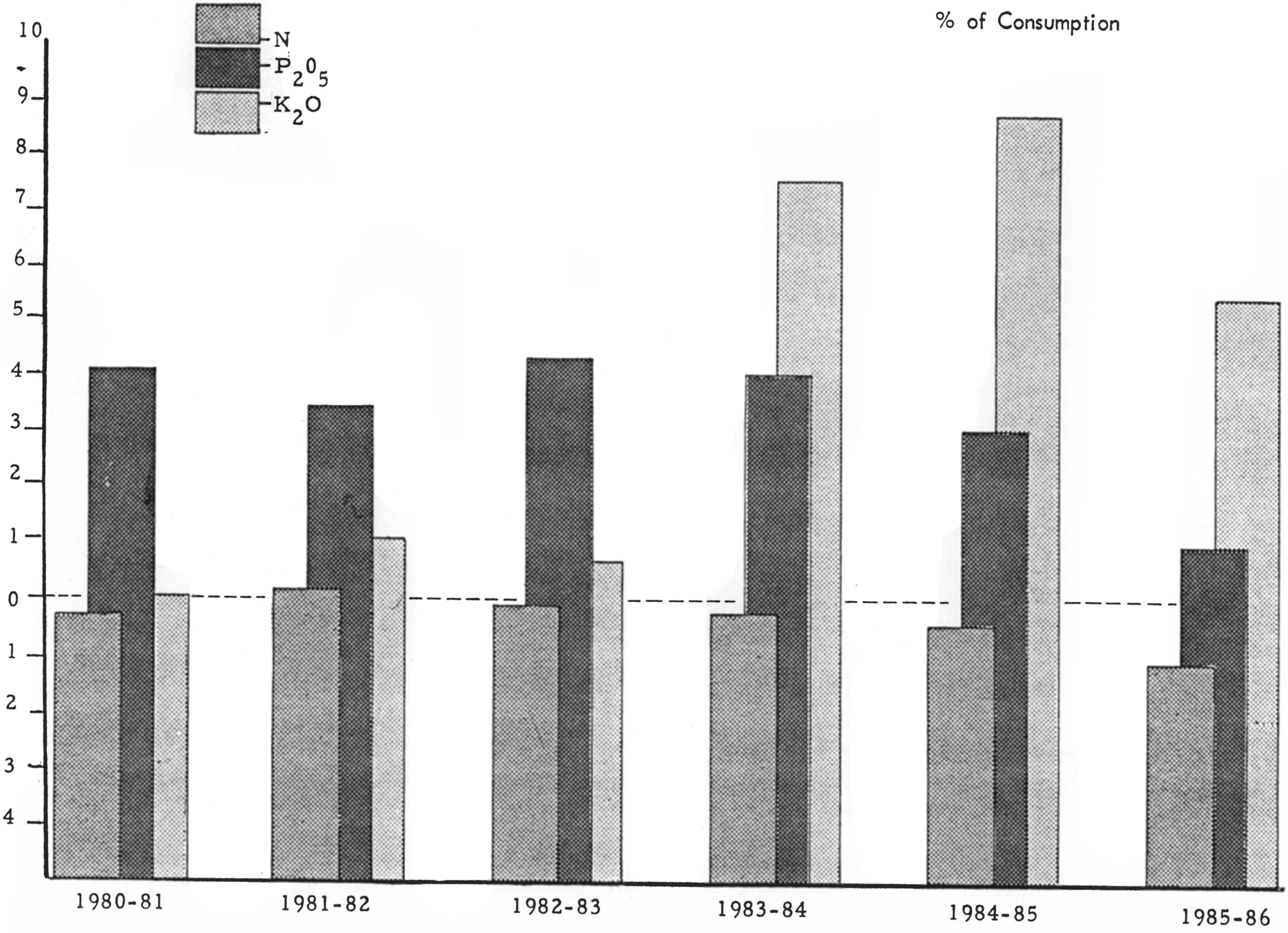
Philanthropy does not figure in the forefront of industrial priorities. We even question whether it belongs to the genetic legacy of man!

At first sight, the contribution demanded of the fertilizer industry shows all the characteristic of a gratuitous act which is incompatible with the objectives of an industry seeking a capricious profitability at the borders of dream and reality.

For my part, my present function as Chairman of F.I.A.C. bears witness to my preference for a generous participation rather than an egoistic isolation. Because reason ordains it but also because I could not exit satisfied from a "world where action is not the sister of dreams" (Ch. Baudelaire).

TABLE 17.

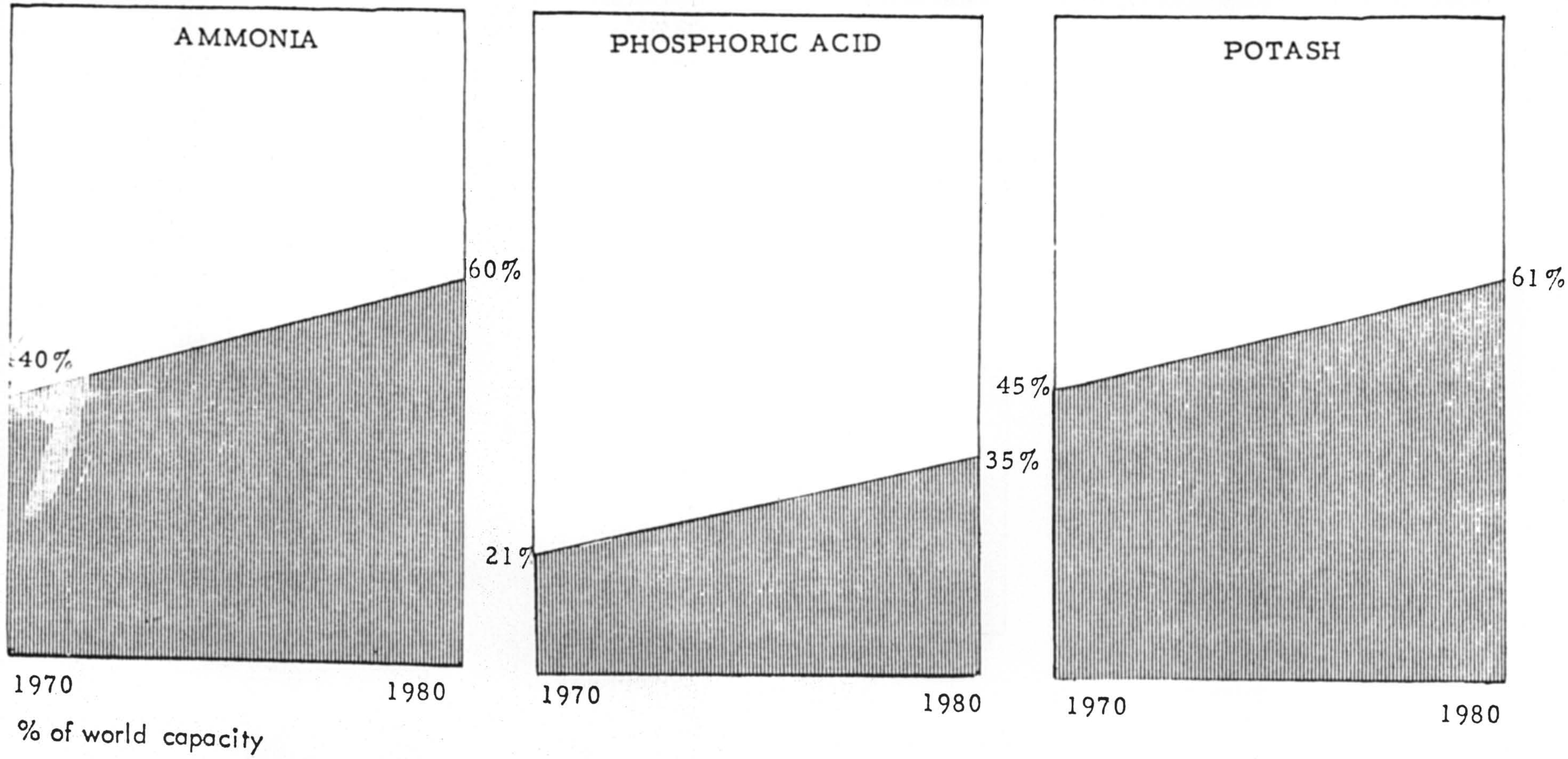
PROJECTED NUTRIENT SURPLUSES AND DEFICITS, 1980/1981 - 1985/1986



Source : FAO/UNIDO/WORLD BANK Working Group on Fertilizers. 1981
Current Fertilizer Situation and Outlook, Rome, Italy.

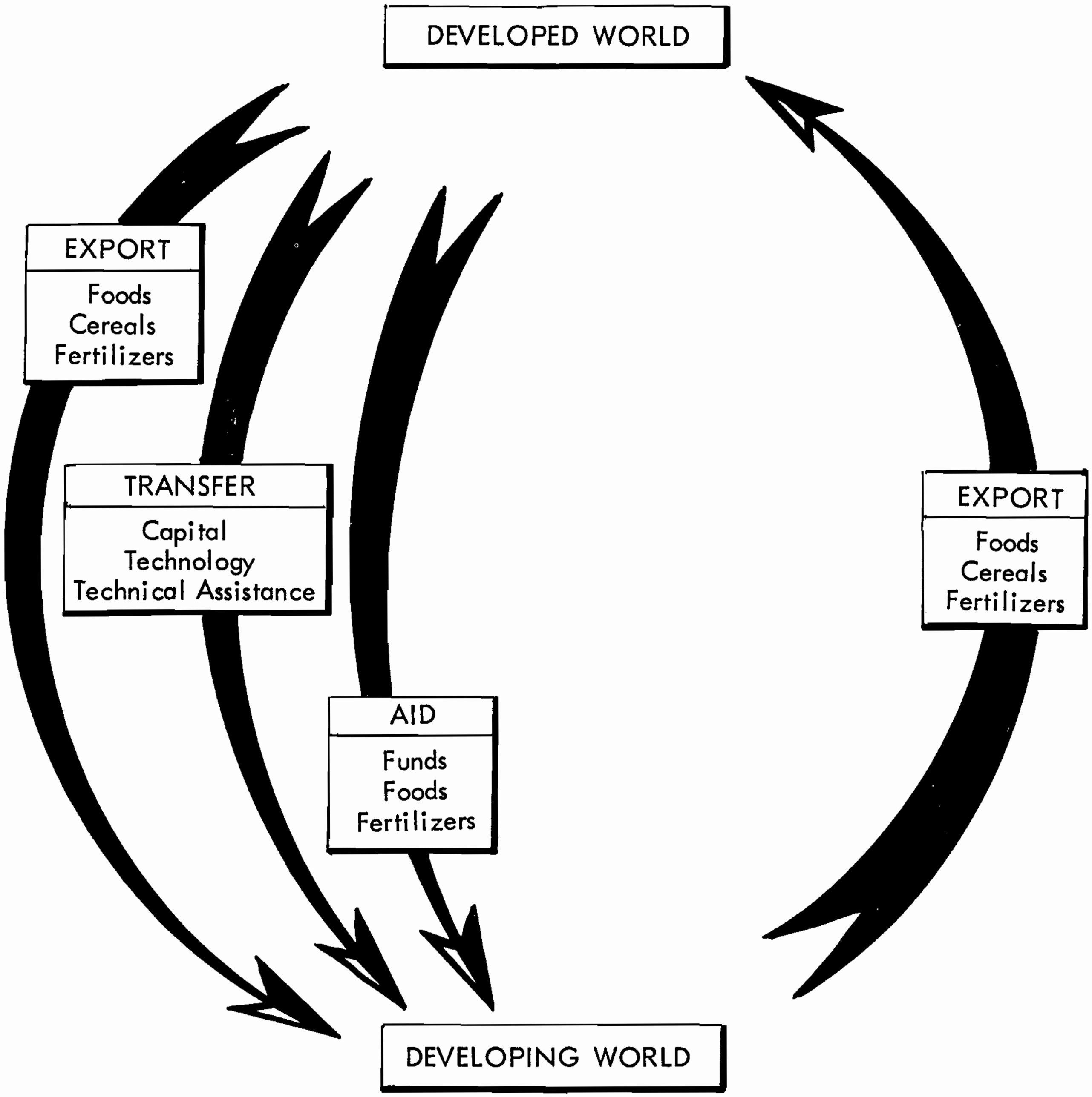
TABLE 18.

STATE-OWNERSHIP DEVELOPMENT, 1970-1980, AS A PERCENTAGE OF WORLD CAPACITY IN MAJOR PRODUCTS



Source : Tennessee Valley Authority. 1981

CHART 19


DEVELOPED WORLD
EXPORT
Foods
Cereals
Fertilizers
TRANSFER
Capital
Technology
Technical Assistance
AID
Funds
Foods
Fertilizers
EXPORT
Foods
Cereals
Fertilizers
DEVELOPING WORLD

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Thank you. (Applause)

CHAIRMAN ACHORN: Thank you very much, Pieree Latteur, for giving us such excellent insight into the part that fertilizer has to play in the world production of food. You have certainly brought home to us the challenge that faces our industry, and the need for international co-operation.

The moderator for this morning's program is Harold Blenkhorn. Harold is a Canadian. He is located in Montreal, where he is employed as Manager of Technical Services for Nitrochem Inc. He is also vice-chairman of the Round Table. (Applause)

MODERATOR BLENKHORN: This morning's session is devoted to presentation on the outlook for nitrogen, phosphates, potash, sulphur, and transportation. Those who give outlook papers usually have a background in economics. This is a profession which people make jokes about, most of which are rather poor. It is time some new ones were devised. I will only mention that ancient proverb: "He who lives by the crystal ball must occassionally be prepared to digest broken glass".

Our speakers this morning are called upon to make some predictions, and perhaps give us some advice. This can be dangerous. I am reminded of a gem of wisdom which comes from a teacher who asked her junior high school class to write an essay on Socrates. One of them went like this: "Socrates was a great man. He was a Greek. He went around telling people what to do. They poisoned him". (Laughter)

We will proceed with the program. Our first speaker, well known to Round Table audiences, is Gene Graves of Agrico. Gene is a native of Kansas, has a MBA from the University of Chicago, and has been employed with Agrico since 1971. His present position is Vice-President, Planning and Economics. Gene will speak to us on the Nitrogen outlook. (Applause)

Outlook For Nitrogen

E. B. Graves

The nitrogen industry has undergone significant changes over the past two decades. The steady increase in nitrogen fertilizer consumption is not likely to continue at its same growth rate and farm incomes have fallen three years in succession, and real net farm incomes are at their lowest rate in fifty years. Approximately one fifth of the U.S. ammonia capacity has been shut down since the start of the current fertilizer season, and the export growth in nitrogen for the U.S. appears to be over. Rising debts in the developing world force nations to devote more cash to debt repayments and less to food imports, and to upgrade their own industries to become more self-sufficient. Barter deals are increasing, and trade embargoes as a political tool make countries reluctant to depend too heavily on one source. The developed countries will face stiff competition from new producers in LDC's who have a very low alternative value for their natural gas feedstock.

It is against this background that I give you my outlook for nitrogen.

World Fertilizer Nitrogen Consumption (Slide 1)

This slide shows the historical and projected world fertilizer nitrogen consumption. Nitrogen consumption in 1970 was 28.9 million metric tons, an increase of nearly 20 million tons from the 9.9 million of 1960, a growth rate of 11.3 percent per year. By 1980, consumption had increased to 57.2 million tons, a growth rate of 7.1 percent for the decade. By 1990 we are now looking at consumption of 87 to 88 million tons, a growth rate of 4.4 percent per year.

This slide also shows where the biggest growth is likely to occur. In terms of absolute growth, Russia and the Eastern Bloc show the biggest change. However, in terms of growth rates, we believe that China and Latin America will be the highest. The developed countries of the U.S., Western Europe and Japan show the lowest growth rates.

Given these growth rates, where are we likely to see new supply come from, and what are the factors influencing this supply?

Since most of the new nitrogen production will be based on natural gas, let us take a look at who has this gas.

World Proven Gas Reserves (Slide 2)

By a wide margin, Russia has the most gas, with 38% of the world's proven reserves. However, much of their gas is used for heating and other use. Iran follows with 18%. The U.S. has only 7%. It follows that those countries having a comparative advantage in captive natural gas supplies and having limited alternative uses for the gas will be the likely sources of new nitrogen production in the future. In the U.S., the big concern is the future price of natural gas.

Natural Gas Price Trend (Slide 3)

This slide dramatizes the pricing outlook for gas. Most people have little problem projecting the gas price to and even beyond 1983. In fact, most would predict that it would be in the $5-6 range by 1985.

However, the expiration of the NGPA, or alterations made to it even prior to its expiration date, may lead to a much higher pricing level. Nevertheless, the trend in the natural gas prices, and thus the cost to the ammonia producer, is certainly up, and by 1990 we could easily see a price level which might be somewhere between $10 to perhaps even $20 per MMBTU.

Typical Plant Construction Cost (Slide 4)

In meeting the demands of the future, the fertilizer industry will also be facing substantial increases in construction costs. This slide summarizes what has already transpired for some of the major units, such as an ammonia plant which in 1970 cost approximately $25 million. By 1980 the cost had escalated to $125 million. This includes all of the necessary offsites to make an ammonia plant run. By 1985, our best estimate is $180 million.

Likewise we see urea plant construction costs escalating to $100 million by 1985. Offshore plants, particularly those in new areas, would be significantly higher.

World Ammonia Capacity Projections (Slide 5)

Because of the factors such as those that we just saw, capacity projections on a worldwide basis are generally optimistic. This slide shows capacity forecasts which were made by the British Sulfur Corporation in 1979, 1980 and 1981. By connecting the bottom point of each forecast, we get an idea of how much the forecast falls short of actual design capacity.

World Ammonia Capacity Projections and Production (Slide 6)

The impact of these delays is shown by this slide. It also shows our forecast of capacity and for comparison both historical and projected production. This indicates that worldwide production is about 75 percent of design capacity. There are several reasons why new capacities fall short of earlier forecasts. We already saw the magnitude of the uncertainty regarding feedstock costs and of the ever increasing costs of construction. In addition, governments are becoming more involved in nitrogen construction and this generally means more time elapses between plans and execution, particularly in lesser developed countries.

World Nitrogen Supply and Demand (Slide 7)

Taking into consideration the various things that affect new capacity, this slide compares our projected forecast in consumption with available supply. This highlights some of the surplus capacity which the industry experienced during the middle 1970's. However, the data for current operations indicate a fairly balanced outlook despite the fact that the current level of pricing suggests a rather severe surplus situation. We believe that the current situation is temporary in nature, and in all probability was brought about more by a slow down in demand than in a build-up of new capacity.

Both our data, as well as that prepared by the FAO/World Bank/Unido Working Committee, indicates a tightening of the supply/demand balance within the next few years. This, to some extent, is due to the delay of new nitrogen projects which we have already mentioned. Just to put the new supply capital in perspective, we estimate that about 100 new ammonia plants will have to be built before 1990. And if you include the cost of urea, the total cost of this is somewhere between $40 to $45 billion. Thus, someone will have to make a rather sizeable committment in order to supply the nitrogen needs of the future.

By 1990 we anticipate that about 40% of total nitrogen consumed will be in the form of urea, up from 30% in 1976.

The increased use of urea as a nitrogen source has already led to a substantial change in the world trade of urea and it is likely to change even more in the future.

World Urea Exports (Slide 8)

This slide underscores the change which has taken place in the traditional suppliers of urea for the world markets. As shown, Japan has virtually disappeared, where at one time they were a very dominant factor in the world supply of urea. This is due to their high priced feedstocks which no longer permit them to compete against producers in areas where feedstocks are still quite low. West Europe has been able to increase to some extent its supply of urea, however, in the future we anticipate that they will eventually lose their dominance. The big change has been in Eastern Europe, particularly if you add Russia to that category. In 1972/73, they accounted for only slightly over 500 thousand tons, and by the mid-80's are expected to account for a much bigger share of the total urea exports.

World Urea Imports (Slide 9)

The major importers of urea, however, remain relatively unchanged from what it has been during the past ten year period. India and China are still the major importers, as they were ten years ago, and are likely to become even bigger in the years to come. The U.S. is likely to become a bigger importer that what it has been in the past. Currently the U.S. imports about a million product tons, while exporting anywhere from a million to 2 million tons, however, as we saw in the previous slide, the level of exports out of the U.S. is likely to diminish while imports increase.

Switching now to the U.S. outlook, my projections are based on a fertilizer consumption level for this past year of 11.3 million tons, down 4% from that of last year. For the current fertilizer year, that is the fiscal year that began this past July 1, we see consumption relatively unchanged ranging from a small decrease of 100 thousand tons to a high of only up 200 thousand tons over that of 1981/82.

With that as a background, let's look at the near term forecast for individual nitrogen products in the U.S. starting first with ammonia.

U.S. Ammonia Balance (Slide 10)

Ammonia production for the 1981/82 Fertilizer Year was 17.7 million tons, down from 19½ million the previous year. The big fall-off occurred during this past spring. This past spring we only produced 8.5 million tons compared to 9.8 million tons produced last spring. Imports for 1981/82 were 2.2 million tons, unchanged from the prior year. The big change for 1981/82 vs. the prior year was in domestic disappearance, that is ammonia used for upgrading and for direct application. Total domestic use was down by 2.4 million tons due to reduced urea and ammoniated phosphate production and to a lower demand in the industrial area as a result of the current recession.

For the 1983 Fertilizer Year, the production of ammonia is expected to remain relatively low due to the extremely low prices which prevail on the Gulf Coast. In fact, the level of 18 million tons indicated is probably quite optomistic in light of the industry's performance through September, 1982. All indications are the production level will now be in the 15-16 million ton range. The current price is about $110-115 per ton, far below the cost of gas for many ammonia producers. In fact, if it were not for the take or pay gas contracts, it is quite likely that we would see more than the current 20% of the ammonia production curtailed. As a result we anticipate imports increasing by 300,000 tons to 2.5 million. Exports, however, are likely to be down slightly. Domestic use for this fall will be about the same as last fall while next spring domestic use is likely to be up reflecting the industry's need to produce more products for spring shipment. This simply means that the dealer will not be building his inventories this fall. For the year domestic disappearance is expected to be up 1.3 million tons.

We see some improvement over the next several years. However, as you can see the biggest change is in the level of imports, increasing to 4 million tons by 1985.

Where will these imports of ammonia come from?

U.S. Ammonia Imports by Country of Origin (Slide 11)

This slide summarizes where imports have been coming from and potentially where they could come from through 1985. Beyond 1985, assuming that nitrogen demand will continue to grow, we will have to look for other areas, or the U.S. will increasingly become dependent upon the U.S.S.R. for our nitrogen.

U.S. Solid Urea Balance (Slide 12)

Turning now to urea, production for 1981/82 was 4.5 million tons, down 500,000 tons from 1981. All of the decrease occurred during the spring of 1982. Imports were up about 100,000 tons while exports were down about 300,000 tons. Domestic disappearance too was down by about 200,000 tons.

For 1982/83 we anticipate production of 4.5 million tons, almost equally split between the spring and fall. Imports are likely to be about even with 1982, while exports are expected to drop from 1.7 million tons to 1.2 million tons. Domestic disappearance, that is, shipments to both fertilizer dealers and for industrial use, is expected to be 4.2 million tons, up about 400,000 tons, which with much of the increase coming during the spring six month period.

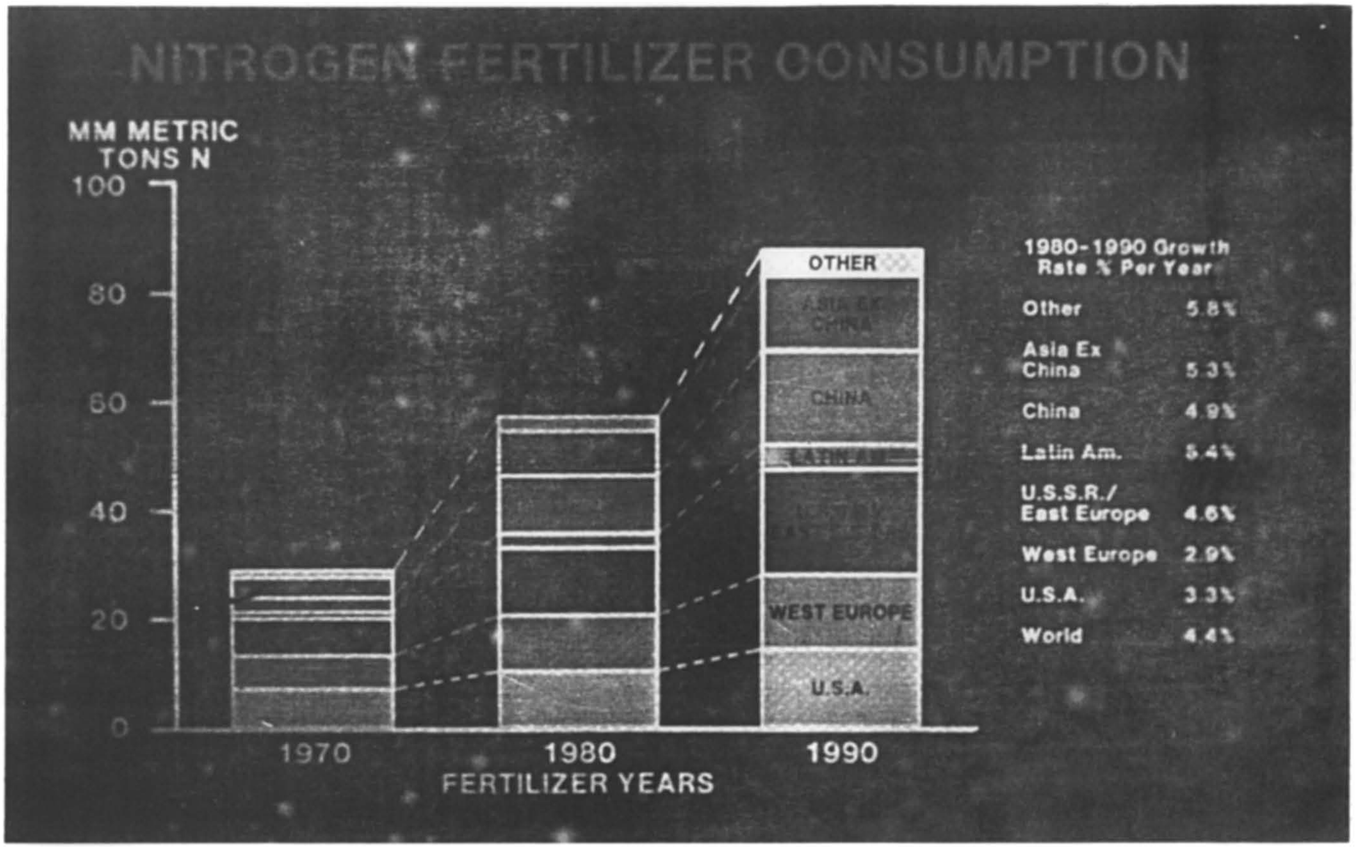
Longer range we see a significant increse in domestic urea demand. In part this reflects the replacement of the ammonium nitrate that had been coming from facilities that are now shut down.

U.S. UAN Balance (Slide 13)

The outlook for UAN is somewhat better than either ammonia or urea. Production during 1981/82 was 7.5 million tons, down only 200,000 tons from the prior year. Domestic disappearance, that is product that was shipped to the dealer, was down only 300,000 tons. For the Fertilizer Year 1982/83, we see production reaching 7.8 million tons and domestic disappearance 7.5 million tons, up 200,000 tons, and almost equal to the record level of 1980/81. Producer inventories remain a relatively comfortable 1.4 million tons, up just slightly over that over the last couple of years.

In summary, the longer term outlook for nitrogen will be dictated to a large extent by how quickly countries that have never had nitrogen production before can implement their construction plans, and how willing the major existing producing areas, such as the U.S. and West Europe, are to become dependent upon imports. Near term, we may see a number of countries reduce their own consumption in order to increase exports to generate hard currency. Meanwhile, in the U.S. we should not be surprised to see a number of ammonia producers shut down even though they have take or pay natural gas contracts. (Applause)

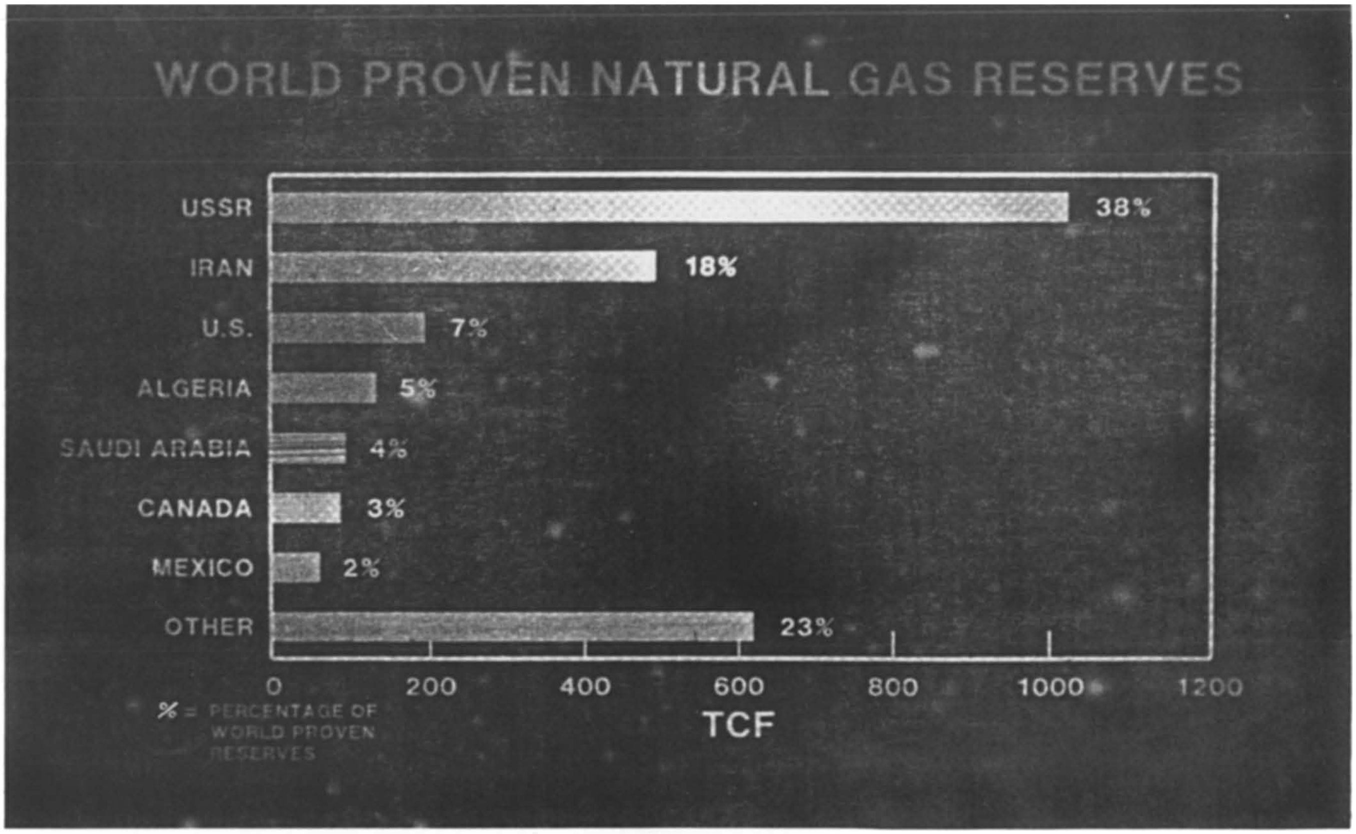
Slide 1



NITROGEN FERTILIZER CONSUMPTION

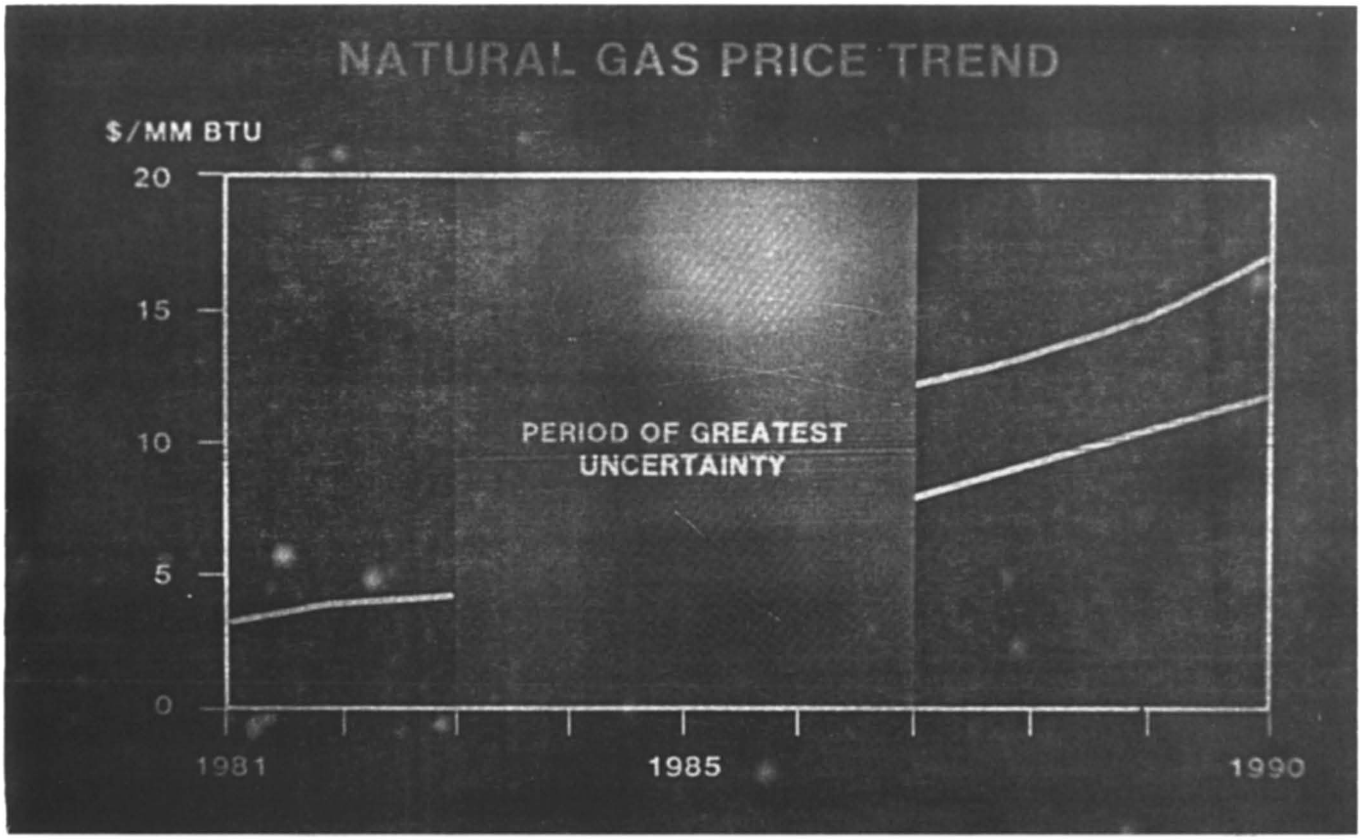
1980-1990 Growth Rate % Per Year	
Other	5.8%
Asia Ex China	5.3%
China	4.9%
Latin Am.	5.4%
U.S.S.R./ East Europe	4.6%
West Europe	2.9%
U.S.A.	3.3%
World	4.4%

Slide 2



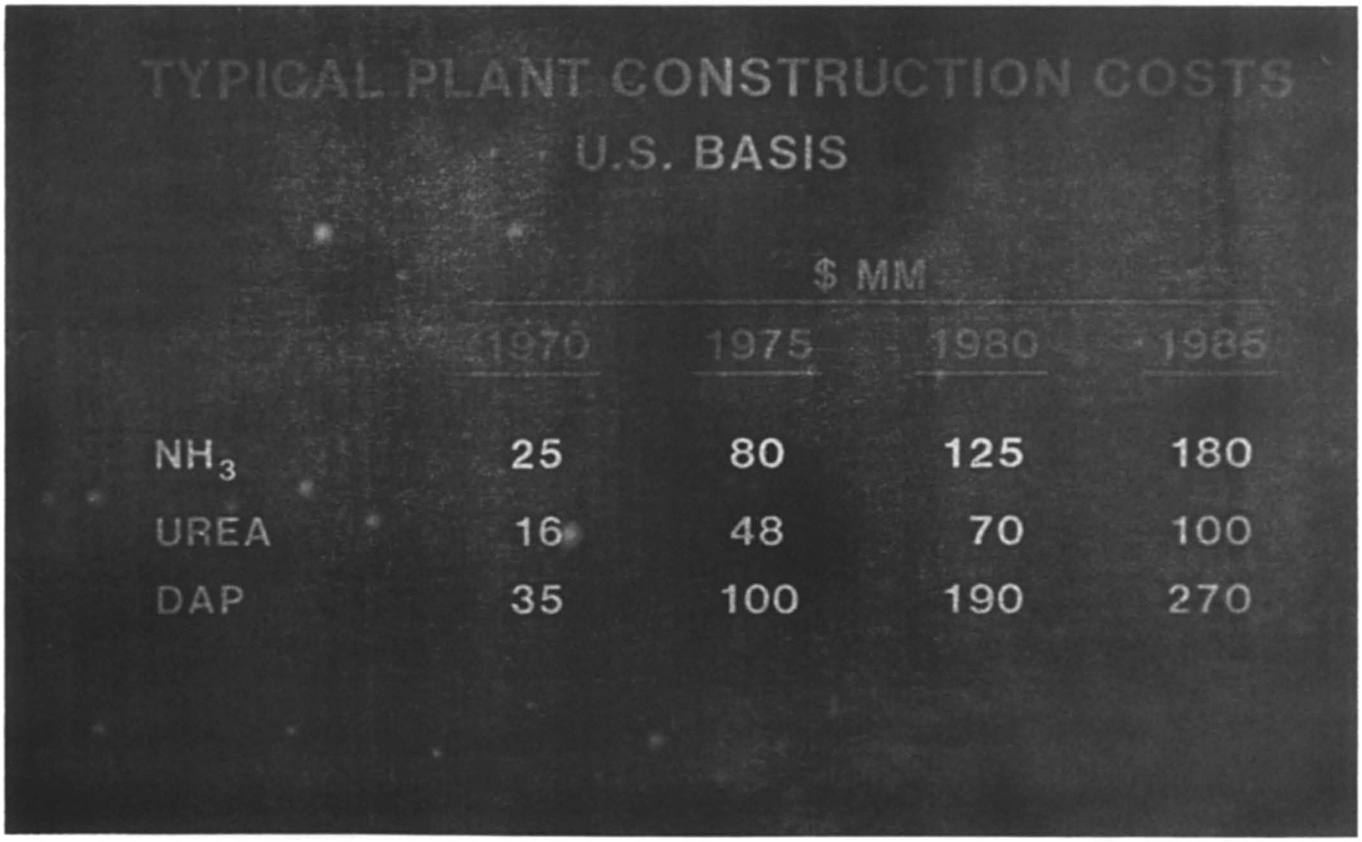
WORLD PROVEN NATURAL GAS RESERVES

Slide 3



NATURAL GAS PRICE TREND

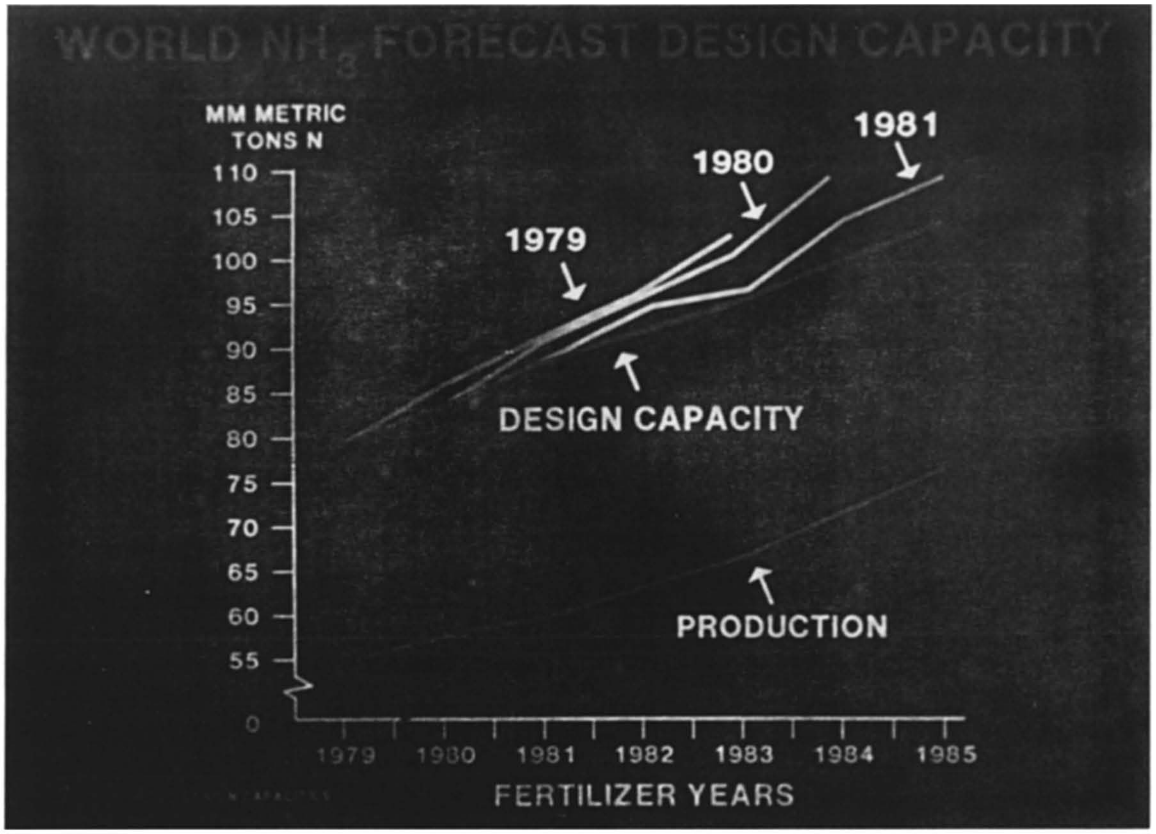
Slide 4



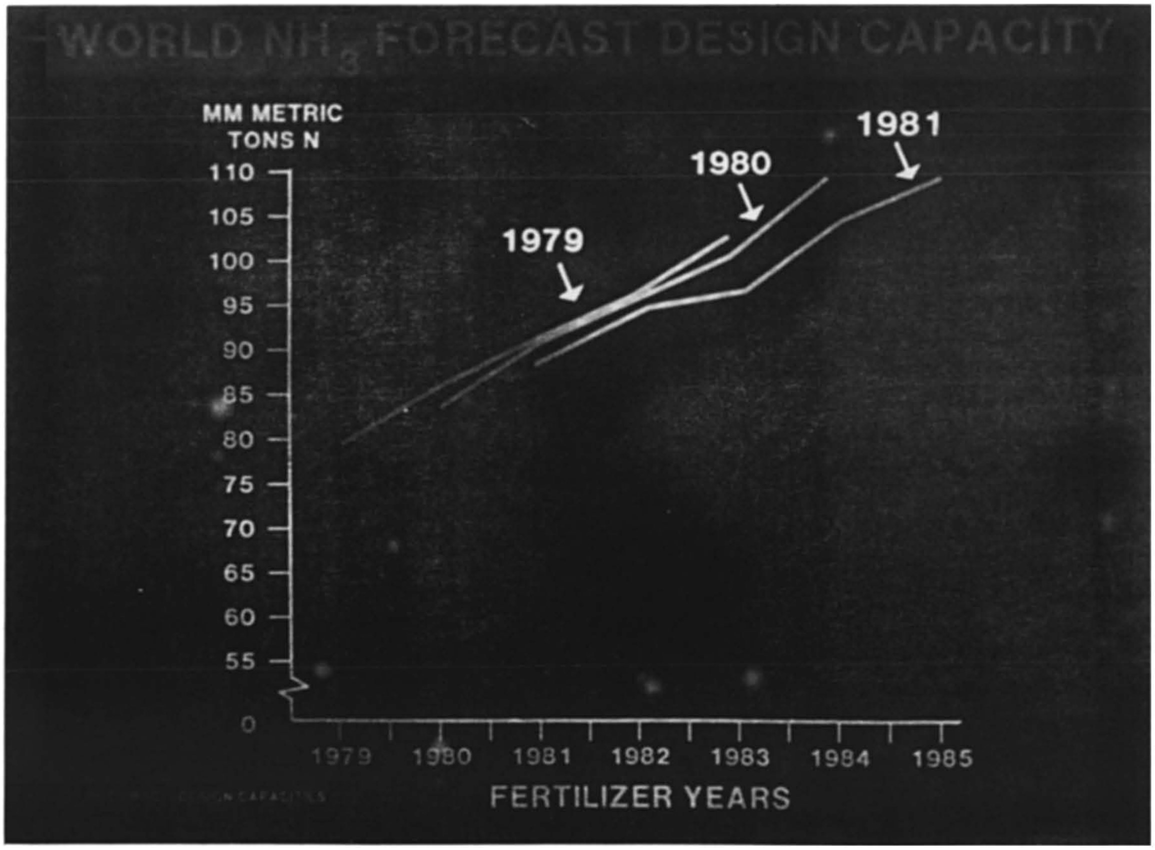
TYPICAL PLANT CONSTRUCTION COSTS
U.S. BASIS

	$ MM			
	1970	1975	1980	1985
NH_3	25	80	125	180
UREA	16	48	70	100
DAP	35	100	190	270

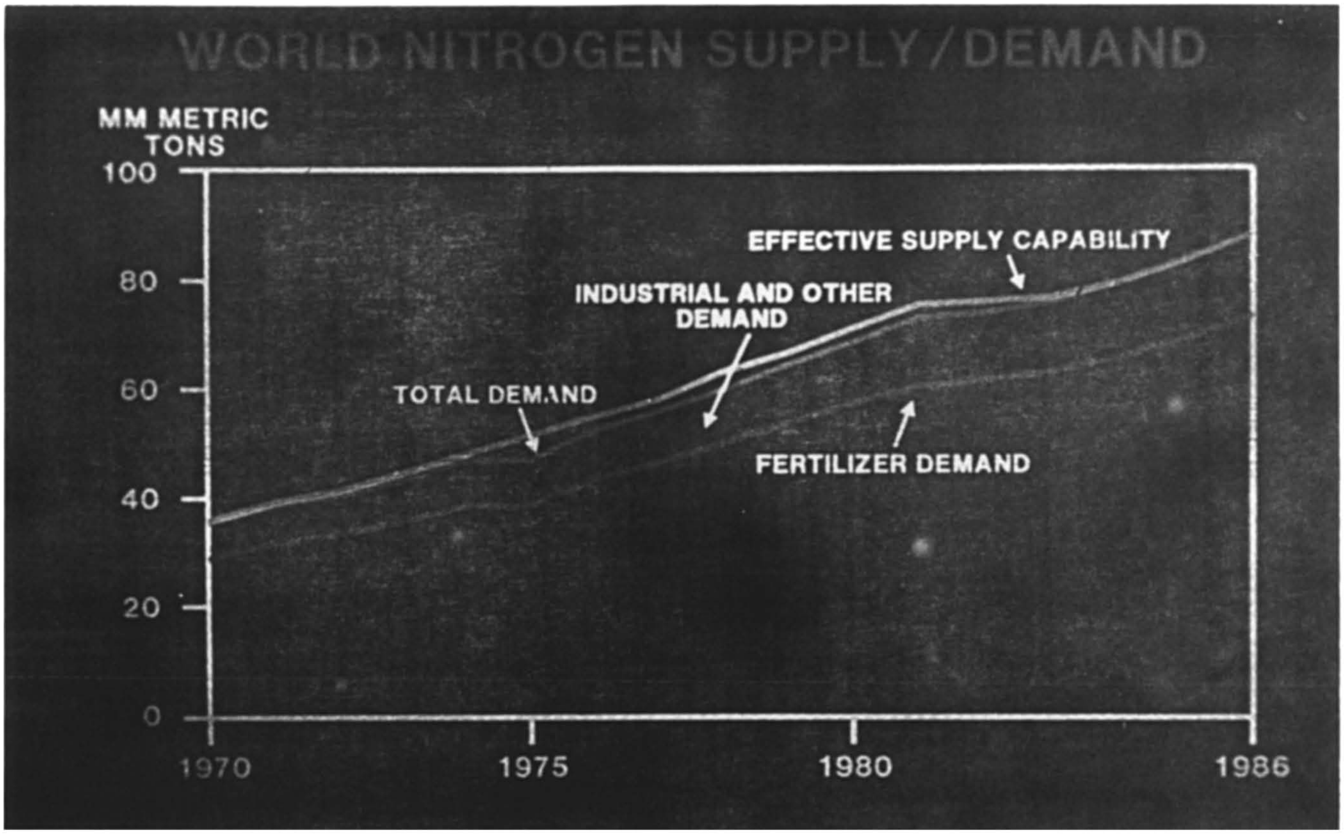
Slide 5



Slide 6

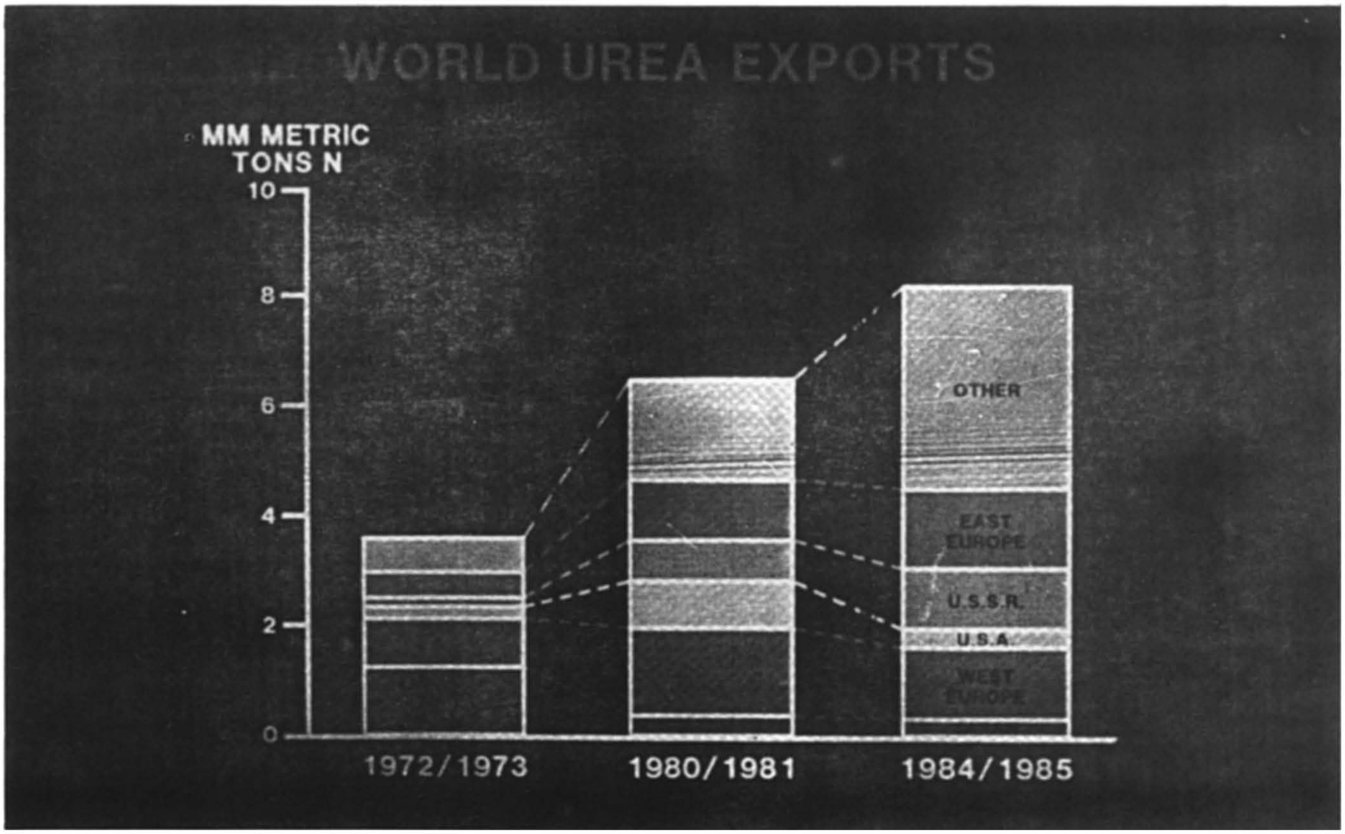


Slide 7



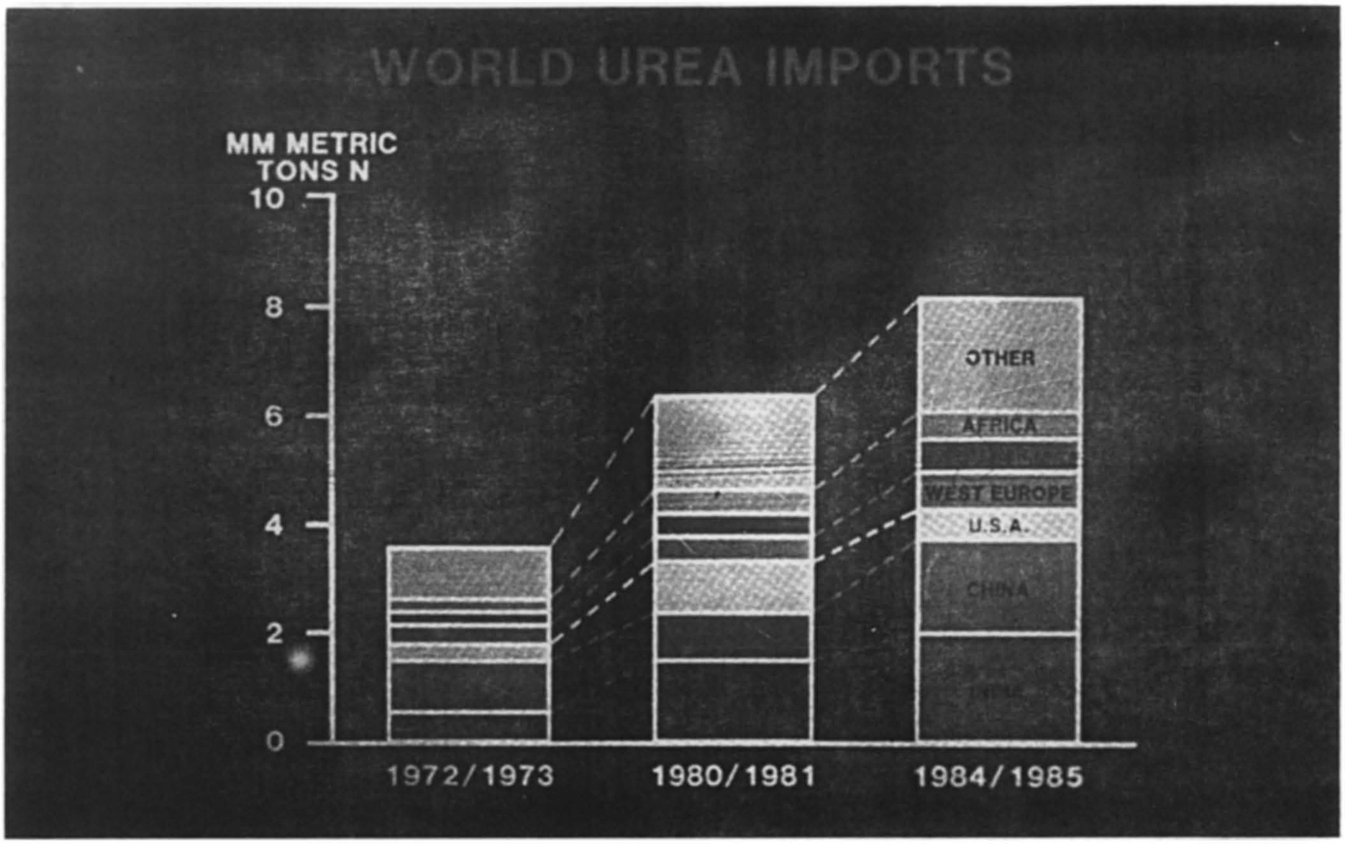
WORLD NITROGEN SUPPLY/DEMAND

Slide 8



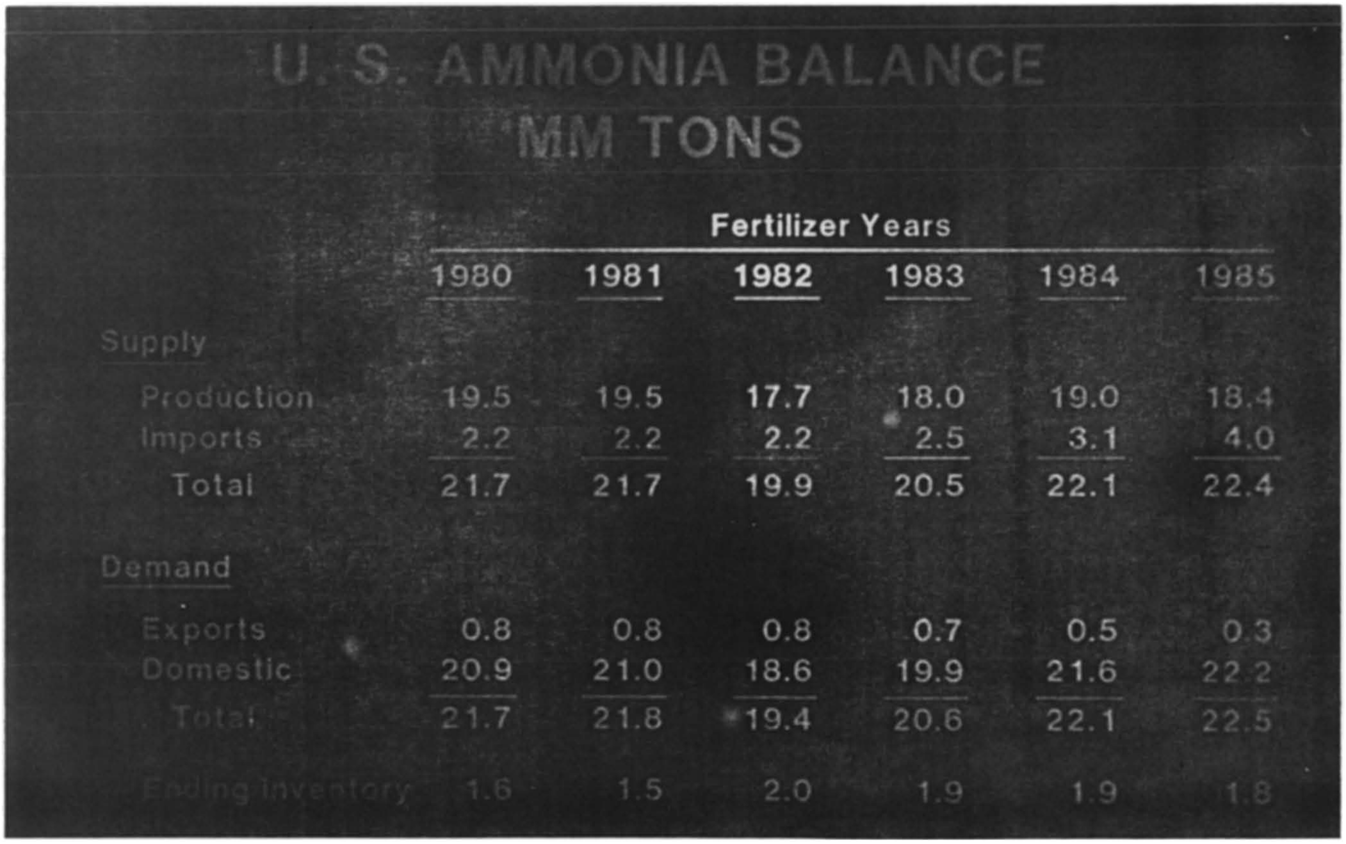
WORLD UREA EXPORTS

Slide 9



WORLD UREA IMPORTS

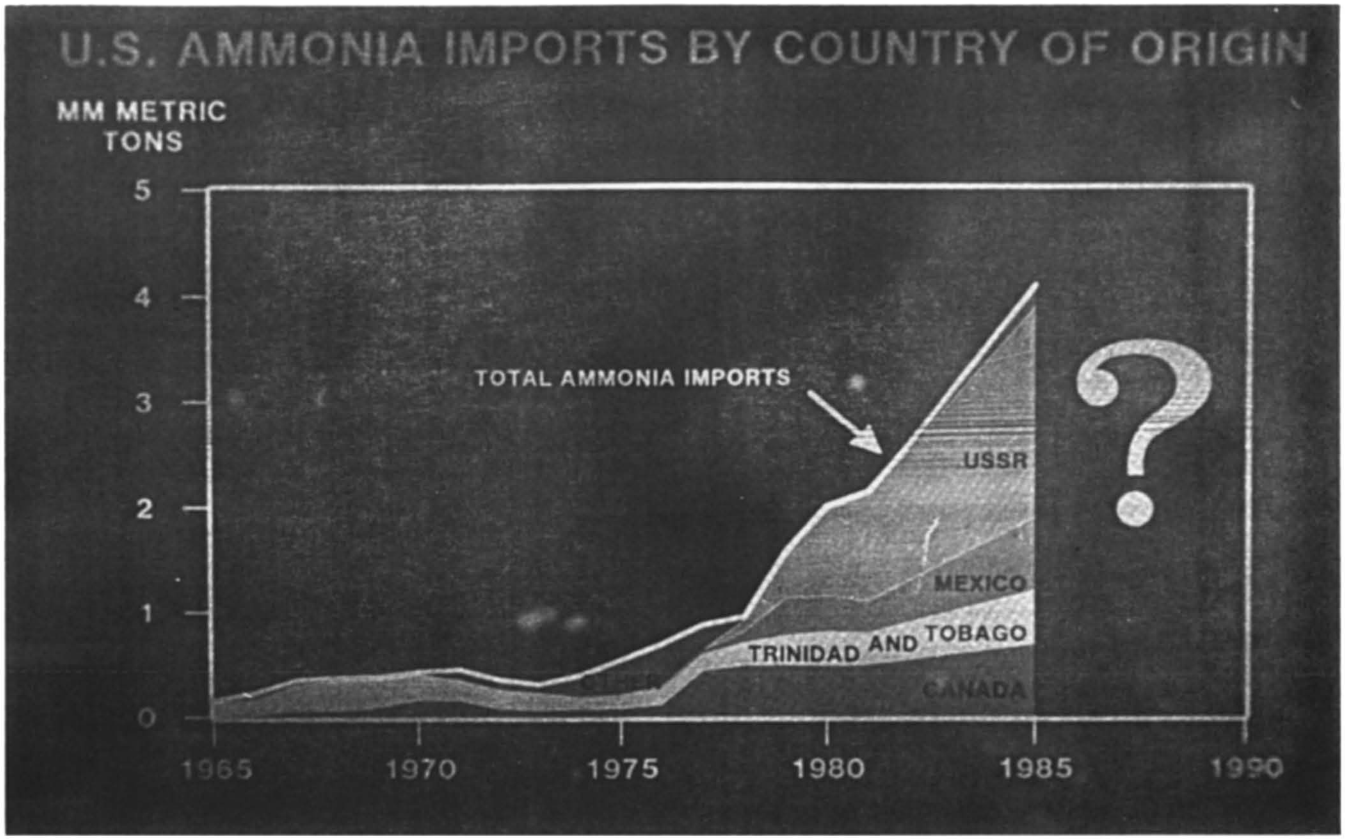
Slide 10



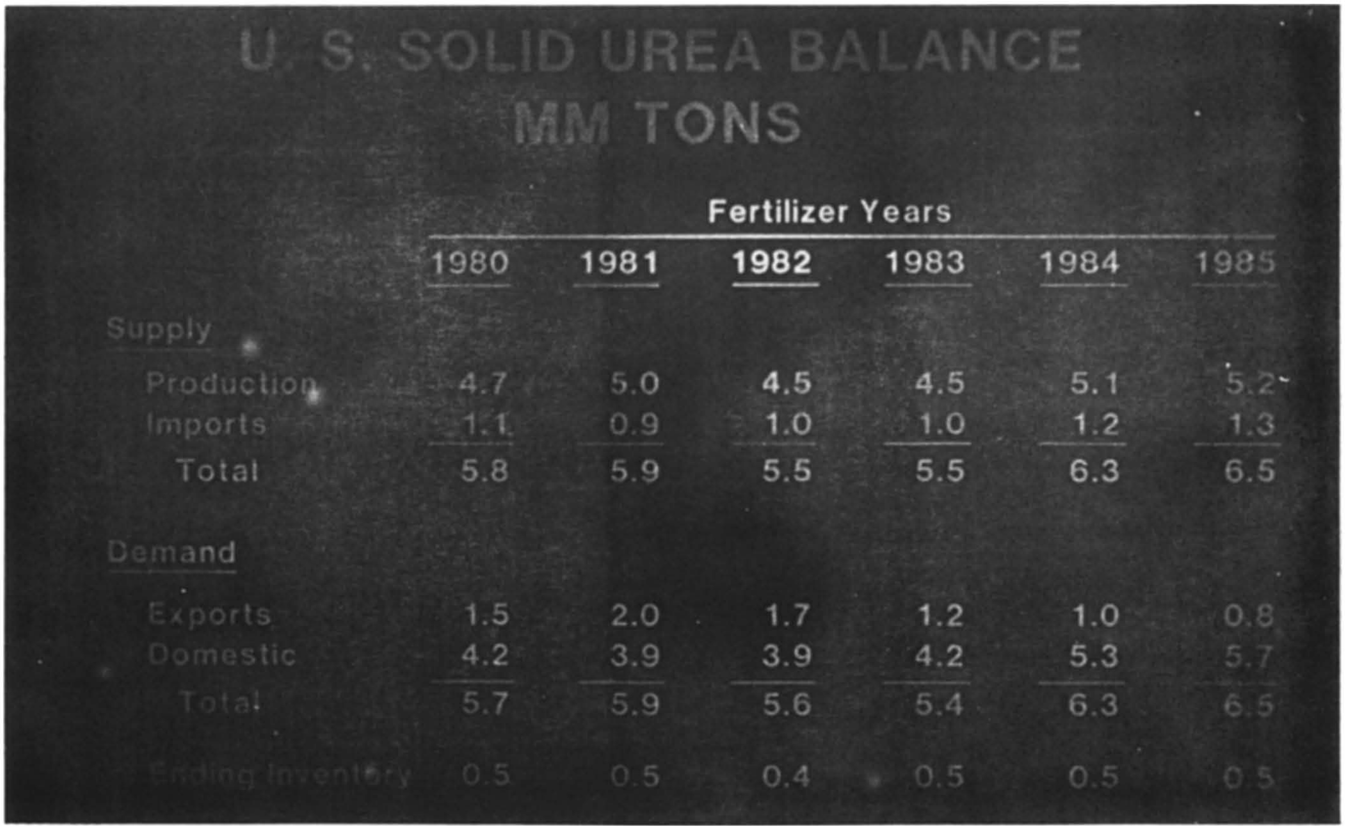
U. S. AMMONIA BALANCE MM TONS

	Fertilizer Years					
	1980	1981	1982	1983	1984	1985
Supply						
Production	19.5	19.5	17.7	18.0	19.0	18.4
Imports	2.2	2.2	2.2	2.5	3.1	4.0
Total	21.7	21.7	19.9	20.5	22.1	22.4
Demand						
Exports	0.8	0.8	0.8	0.7	0.5	0.3
Domestic	20.9	21.0	18.6	19.9	21.6	22.2
Total	21.7	21.8	19.4	20.6	22.1	22.5
Ending Inventory	1.6	1.5	2.0	1.9	1.9	1.8

Slide 11



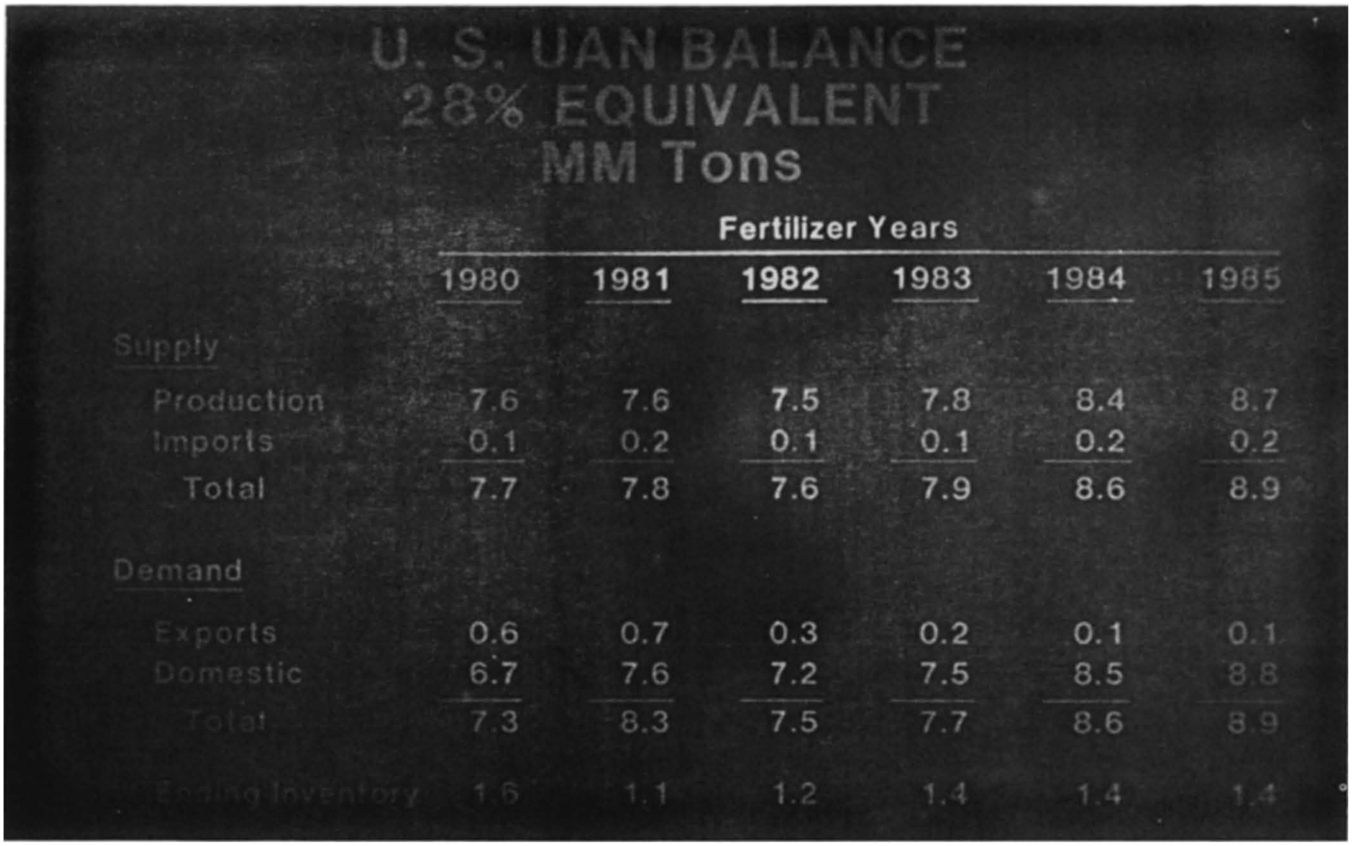
Slide 12



U. S. SOLID UREA BALANCE
MM TONS

	Fertilizer Years					
	1980	1981	1982	1983	1984	1985
Supply						
Production	4.7	5.0	4.5	4.5	5.1	5.2
Imports	1.1	0.9	1.0	1.0	1.2	1.3
Total	5.8	5.9	5.5	5.5	6.3	6.5
Demand						
Exports	1.5	2.0	1.7	1.2	1.0	0.8
Domestic	4.2	3.9	3.9	4.2	5.3	5.7
Total	5.7	5.9	5.6	5.4	6.3	6.5
Ending Inventory	0.5	0.5	0.4	0.5	0.5	0.5

Slide 13



U. S. UAN BALANCE
28% EQUIVALENT
MM Tons

	Fertilizer Years					
	1980	1981	1982	1983	1984	1985
Supply						
Production	7.6	7.6	7.5	7.8	8.4	8.7
Imports	0.1	0.2	0.1	0.1	0.2	0.2
Total	7.7	7.8	7.6	7.9	8.6	8.9
Demand						
Exports	0.6	0.7	0.3	0.2	0.1	0.1
Domestic	6.7	7.6	7.2	7.5	8.5	8.8
Total	7.3	8.3	7.5	7.7	8.6	8.9
Ending Inventory	1.6	1.1	1.2	1.4	1.4	1.4

E. B. GRAVES: Thank you Gentlemen for your kind attention. (Applause)

MODERATOR BLENKHORN: We will move on to the "Phosphate Outlook" which will be presented by Mr. Jim Williams of Zellars-Williams, Inc. Mr. Williams is a Bachelor of Science Graduate in Chemical Engineering, from the Georgia Institute of Technology, and obtained a Masters Degree also in Chemical Engineering, from West Virginia University. He has been associated with the Phosphate Industry for the past seventeen years, and his present position is Executive Vice President, Zellar-Williams, Inc., a member company of the Jacob Engineering Group, Inc. Mr. Jim williams, please. (Applause)

Phosphate Outlook Near Term And Through 2000

James M. Williams

Introduction

Commodities which are essential to human life, which are consumed by use, and for which there are no substitutes will always be in demand. But even essential commodities suffer in a severe recession. The problem facing the world's phosphate industry today, as often in the past, consists of level of demand as related to supply costs, and uniformity of consumption. The problem grows more complex as fewer people are responsible for the supply of food via an intricate system to the majority.

Variation in consumption due to crop failures and bumper crops remains a variable in the equation; however, the "beans or beef" variable, which is directly related to the general economic health, has a major impact on demand. The economic ability of consumers to buy fertilizer directly and indirectly is the primary throttle of demand.

The problem of costs are not confined to consumers who may not have the funds to buy the desired quantities of fertilizers or at the end of the chain the type and amount of food needed. Cost of fertilizer production and distribution, at a minimum must be returned to the producer or he will eventually stop production and provided this type impact is broad enough, short supply may result but more correctly demand will be balanced against affordable supply. The simple equation where all fertilizers cost the same to produce and demand responds to price created by cycles of over and under supply does not work. In an economy that is on the "bean diet" track, it is unreasonable to assume that recovery will occur directly to the "beef diet" tract when inventories are depleted and the basic subsistance demand is all that requires supply.

The near-term recovery picture for phosphates is of great importance to producers suffering from low demand and low prices. The longer term projections are essential for planning of new and replacement capacity. This outlook on phosphate demand is based on predictions of the future economy, the level of the economy to support fertilizer demands, studies of phosphate production costs, and study of individual country phosphate demands to sustain normal agricultural and industrial requirements plus expected growth.

Economic Outlook

The near-term U.S. economic outlook was extracted from material provided by Mr. Joe Loftus of Pace Consultants, a division of the Jacobs Engineering Group. The midyear forecast pace prepared last August made no mention of a stock market rally, but it did detect the prevailing trends that spawned the rally. Figure 1 suggests that Pace anticipated the prime interest rates second-half decline and expects additional improvement in late 1983. Any downward movement in interest rates is welcomed, but the message evident in Figure 1 is that interest rates remain far too high. Morgan Guaranty, the first bank to lower its rate to the 12-percent level, recently reminded its customers that after factoring for inflation, the current rate is still much higher than the prime registered during the severe recession of 1974-1975. Until that situation improves, the high cost of borrowing will remain the primary obstacle in recovery.

The unfavorable interest rates expected in 1983 are responsible for the lingering weakness apparent in the gross national product as shown in Figure 2. The pattern that emerges in the predictions of gross mational product are somewhat encouraging, but the meager gains and sluggish pace suggest as weak recovery that will neither support vigorous growth nor withstand a surge in interest rates.

Of the key indicators which measure total output, personal consumption was the sole source of strength in the second quarter (Figure 3). But the midyear surge in consumer spending resulted from the reduced income taxes and expanded social security payments granted July first; however, indications are that near-term growth in the consumer sector will be erratic and will come to a virtual halt if interest rates rebound in the first quarter of 1983. Unemployment levels also signal weakness in this area.

Residential investment will remain intensely sensitive to interest rates and improve only modestly. Despite some growth in the third quarter, housing starts will remain flat in 1982-83.

The outlook for business investment is even worse. The lack of new investment reflects a lack of liquidity, which is not likely to improve while interest rates remain high. With business reluctant or unable to borrow and factories operating at only 70 percent of capacity, business will tend to divert earnings originally earmarked for capital projects into the restructuring of balance sheets, a maneuver that weakens the economy further.

The same high interest rates that discourage car buyers and homebuilders also discourage exports. U.S. interest rates have contributed to the economic problems afflicting our major trading partners in Western Europe, Canada and Japan. Those internal difficulties and the strain imposed by increased value of the dollar continue to restrict export growth (Figure 4).

Unreliable export markets are a major concern to the agricultural sector, which suffers from a variety of serious maladies. Among them is another record harvest that will swell the surplus already in storage. This record harvest comes despite a decline in fertilization last spring. The grain glut means lower crop prices and lower farm incomes at a time when growing costs continue to rise. Faced with huge crop surpluses, falling prices and high interest rates, farmers are predicted to cut costs and risk minimal fertilization despite bargain-basement fertilizer prices.

Phosphate Forecast - Economic Impact

Translating the economic outlook into a phosphate forecast is a difficult task complicated by lags and seasonal effects, but some trends are evident.

- Unfavorable interest rates are likely to persist in 1983 and constrain economic growth, a situation that signals cautious, conservative action, particularly to farmers.
- Similar signals are evident overseas, where our major trading partners suffer internal economic problems linked to high U.S. interest rates. This, plus the strength of the dollar, will continue to discourage U.S. exports.
- Record surpluses and uncertain foreign markets may convince farmers they can survive yet another year of low fertilization.
- The large phosphate rock inventories that prompted producers to curtail production throughout 1982 have not been reduced sufficiently. Sustained curtailments may be necessary, and producers operating mines below capacity will suffer the inevitable cost penalty. By the end of 1982, the world will still be working on an inventory about 30 percent higher than 1980 levels.

These trends suggest the near-term picture is a bleak one. We expect 1983 to be similar to 1982, with only minor improvements apparent by the end of next year. This protracted period of very difficult times, plus the slow and painful recovery, will probably result in significant changes in the phosphate industry. Plans for the future expansions that seemed imminent only months ago are, for the most part, "on the shelf", and the timing of such projects remains uncertain in the face of weak demand, low capacity utilization, high interest rates, and high capital costs.

By 1984, the U.S. economy should begin to gain some momentum and foreign economies should be more favorable. In the agricultural area, the long period of low fertilization should reduce crop production, indicating the need for normal or near-normal application rates by the spring of 1984. Phosphate prices may still tend to be too weak to support new production, and replacement capacity will undergo careful scrutiny, but by '85 we should see stabilization and return to expected long-term growth rates. We must keep in mind, however, that this recession has set the industry back at least the equivalent of one year.

Phosphate Costs

In dealing with costs, reference will be made to constant 1981 dollar cash and whole costs. Cash costs refer to the "out of pocket" cost of production. Whole costs include depreciation, depletion (i.e., fair or real cost of reserves, sales expenses, and a 25 percent interest charge on net book value after depreciation to provide a reasonable return on investment. Thus, cash costs represent the basic return needed to sustain the producers cash flow, while whole costs indicate the dollar amount necessary to return a reasonable profit to the investor.

The attainable world rock capacity, excluding China, today is approximately 151 million tonnes. This is our estimate of what could be produced, not the name plate capacity. This exceeds the peak world production of 131 million tonnes achieved in 1980 by about 20 million tons or 15 percent. During the adjustment period of '82 to '83, cost of production at below capacity operation will be high. This complicates the industry's recovery.

In constant dollars, the cost of new and replacement production must increase, even for good mines, due to the cost of new capital. New technology and large mine size do not totally offset this effect. Large increments of new production are difficult for the market to absorb. New production is also vulnerable to demand and price cycles since the margin is smaller. This problem is illustrated in Figure 5 which is a representation of world production within specified whole cost ranges.

Supply is composed of layers of production which satisfy demand at increasing cost increments. Large, mature mines with rich ore generally occupy the lower cost brackets. As these mines are depleted, production is replaced from more expensive sources, which usually fall in the upper layers of the chart. The competitive position for new mines is difficult until a number of other new mines fall in above their position. This graphic depicts FOB rock cost only and does not reflect problems with transportation and conversion costs of new rock sources. Figure 6 is the same type presentation as Figure 5, but shows cash costs.

The distribution of whole cost components summarized in Figure 7 compares three large, new mines and a mature Central Florida mine of approximately the same size to pooled Central Florida costs as a base. The relative cash and whole cost values are also compared to the base mine. This demonstrates the impact of capital costs on new mines.

Capital requirements by five year periods for new, replacement, and expansion capacity on a world basis (excluding China) are shown in Figure 8. The world demand for rock capital will be $1.7 billion until '85, about $8.5 billion in the '86 to '90 period, $2 billion in the first half of the 90s and about $1 billion in '96 to the return of the century for a total of 139 million tons of capacity. The ability of countries to obtain this capital will be of great importance, but the actual interest rates charged for use of the monies will be of even greater impact. Actual whole costs will depend on the true interest rates which probably will not be a parity around the world.

The world weighted average cost of production in constant dollars does not increase dramatically until 2000. Average whole costs increase only about 4 to 5 percent and cash costs increase only 8 percent. This is due in part to a predicted easing in growth rate until the end of the century, which reduces the number of new mines needed. Present rock demand estimates indicate an average annual growth rate of about 2.6 to 2.7 percent per year after 1985. The growth in 1984 may range between 6 and 11 percent setting the level for future demand. The stabilized '85 demand level is uncertain at this time; however, it is expected to be at the higher level of about 154 million tonnes.

The distribution of world production tonnage by whole costs increments based on predicted country production rates and costs for 1981, 1990, and 2000 are shown in Figure 9. The value of this graphic is to illustrate the major tonnage cost-level concentrations into the future. The relatively large peak at the high end of the scale represents mainly USSR production, which will be primarily used internally with the exports being high-grade Kola concentrates which command higher prices. The miscellaneous high-cost tonnage is usually from smaller mines and/or mines suited to serve local markets where other advantages such as low transportation or fertilizer production costs justify high rock costs. On the very low end of the cost scale is the small tonnage from Christmas Island and Naura. In this graphic, the U.S. includes western phosphates but excludes Tennessee. Figure 10 is the distribution of tonnage by cash cost increments.

Removing the USSR from the picture shows that through the year 2000, 70 to 75 percent of the remaining world supply will come from the U.S., Morocco, and Jordan at relatively the same level of cash and whole cost; with Tunisia and other established African producers supplying 10 to 12 percent more production which will be more expensive but near the cost range of the leaders. The basic increases in costs with time is not great over the study period. It is predicted, therefore, that the competitive situation based on rock alone for most of the real market will not change percipitiously. It must be added, however, that the percentage contribution to world production by the U.S. is expected to decrease slowly from more than 40 percent in 1981 to about 30 percent by the turn of the century. Rock production, however, is expected to continue to grow, but there are indications that production may start to decline near the turn of the century. Growth in the U.S. could range between 5 and 25 percent above the 1980 high of about 54 million tonnes mainly as a function of total demand but also heavily dependent on the U.S. future competitive stance.

Looking in more detail at the competitive market situation and considering transportation, conversion and distribution costs are necessary to insure that the relative balance of market share of the major producers has a sound basis. This has been done based on end-product delivered costs for a variety of cases. In general, the results indicate that the major producers will maintain a reasonable competitive balance through 2000, but the competitive balance can best be maintained through production of fertilizer chemicals. The U.S. is expected to maintain a strong position of competitive leadership in the fertilizer chemicals market. The future will be very complex and require the very best of the producers.

Since decreases in demand and prices such as presently being suffered affect all producers no matter what their competitive position, there is ample reason to question whether confidence will return and if there is a basis for that confidence. The hard reality of present conditions and the protracted length of the recession will most likely result in some less competitive producers dropping out or selling out, which establishes a more competitive future economic base. These adjustments will affect the future; however, new mines and chemical plants will not be built without adequate product prices. This means higher prices.

The pertinent question is, however, will the future market support sufficient prices. We believe that it will. The relative stability of the majority of the world production cost indicates that average prices of products will not increase dramatically and percipitate market resistance. Once the basic price requirements for profitable operation have been established in '84-'85, moderate price growth sufficient to support expansion should be possible as new mines are needed. This scenario does indicate some blending of old production costs with new production costs to allow expansion without jumps in prices. This can be done very well by established central management producers such as Morocco and Jordan, but will be more difficult for new, single-mine U.S. producers.

Demand

Estimates of P_2O_5 demand were prepared through the turn of the century after a country-by-country study of agricultural and industrial practices plus consideration of a variety of variables derived from the involvement of agronomists, economists, market analysts, etc. These P_2O_5 demand ranges were translated to rock production requirements allowing for conversion, handling and other losses. Based on a detailed study of world mines and chemical plants considering a broad range of production influences and costs, assignments of production of rock and chemicals were made by producer to balance the high and low points of the demand range. It was, of course, necessary to work through the maze of trade inventories and competitive situations to arrive at a reasonable balance.

Since this discussion deals primarily with phosphate supply, the total demand ranges for phosphate rock are shown on Figure 11, with a breakdown of rock supply by major world regions. The growth rate for phosphoric acid is predicted to be in the range of 5.6 to 2.7 percent per year.

Conclusion Summary

- The short term view for phosphates is very poor until the first quarter of 1984. Fertilizer chemicals will tend to fair slightly better than rock as inventory of rock is worked down, but total demand is expected to be weak. Total U.S. rock production is not expected to exceed 35 million tonnes or about 65 percent of the record production in 1980.
- 1984 is predicted to be the recovery year rather than 1983. The general world economic recovery necessary to restore export trade should begin by late 1983, and the domestic market should recover after two years of under-fertilization.
- The remainder of the century should experience a rock demand growth rate of approximately 2.7 percent per year as the system gets back on tract. On a world basis, the level of the growth tract may range high to low by as much as 9 percent of the total production.

In this climate of uncertainty, the timing of startup of new or replacement mines will be of extreme importance since sufficiently strong prices to justify building may not materialize on schedule. This can result in heavy losses during early years of operation. However, waiting too long will be a lost opportunity to obtain economics in construction costs. The impact of capital costs on the competitiveness of new mines is so large that innovation in design plus incorporation of new technology to reduce costs are essential. That is, we must design to a competitive cost rather than designing and accepting whatever cost results. The same principles must be applied to existing operations.

Acknowledgements

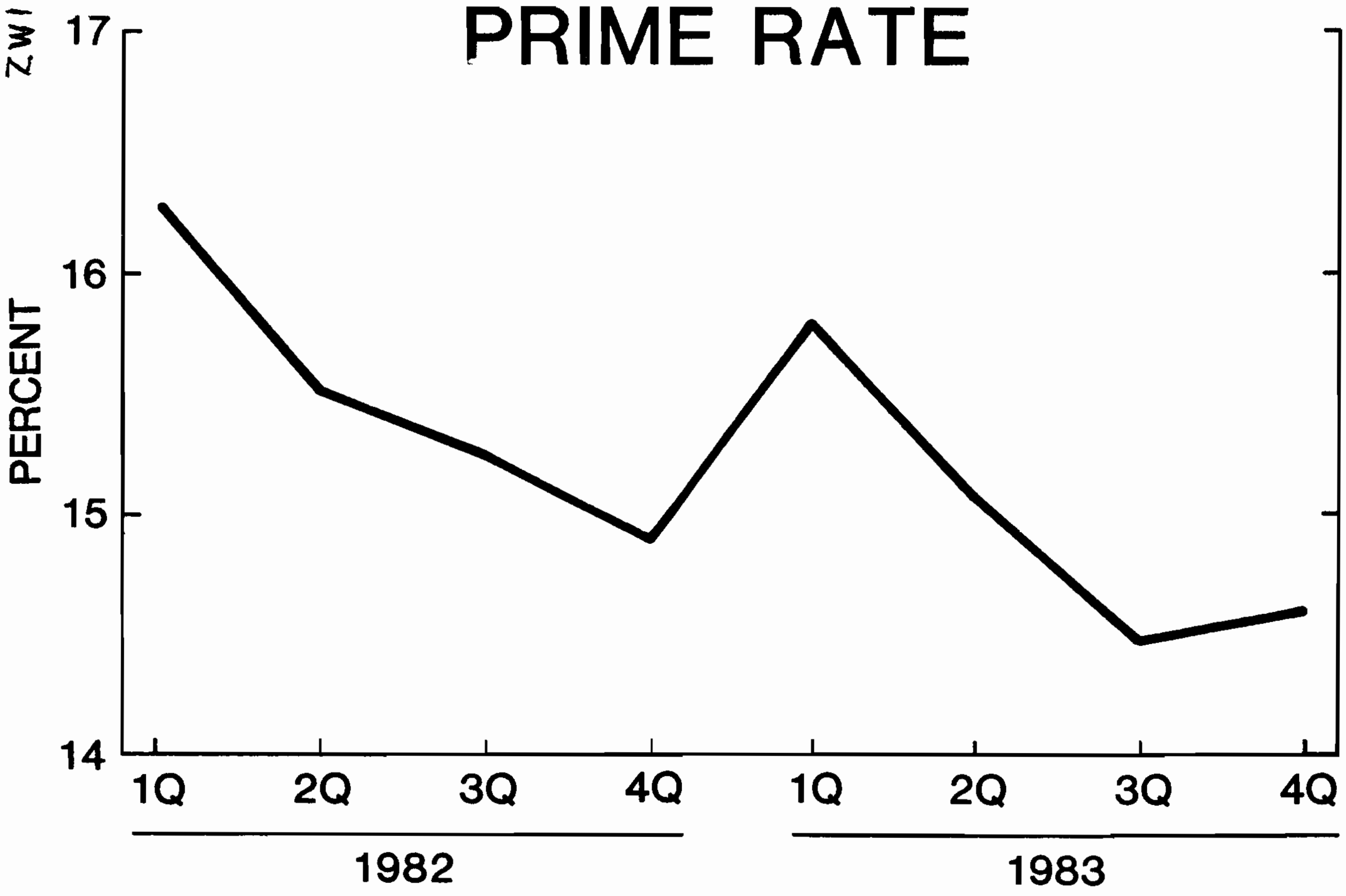
The contributions of the Pace consultants in the economic projections was greatly appreciated. The work and assistance of SRI International, FERTECON, and the Zellars-Williams staff on the basic data for the

multi-client "World Phosphate Study" which provided much of the basis for this paper is gratefully acknowledged.

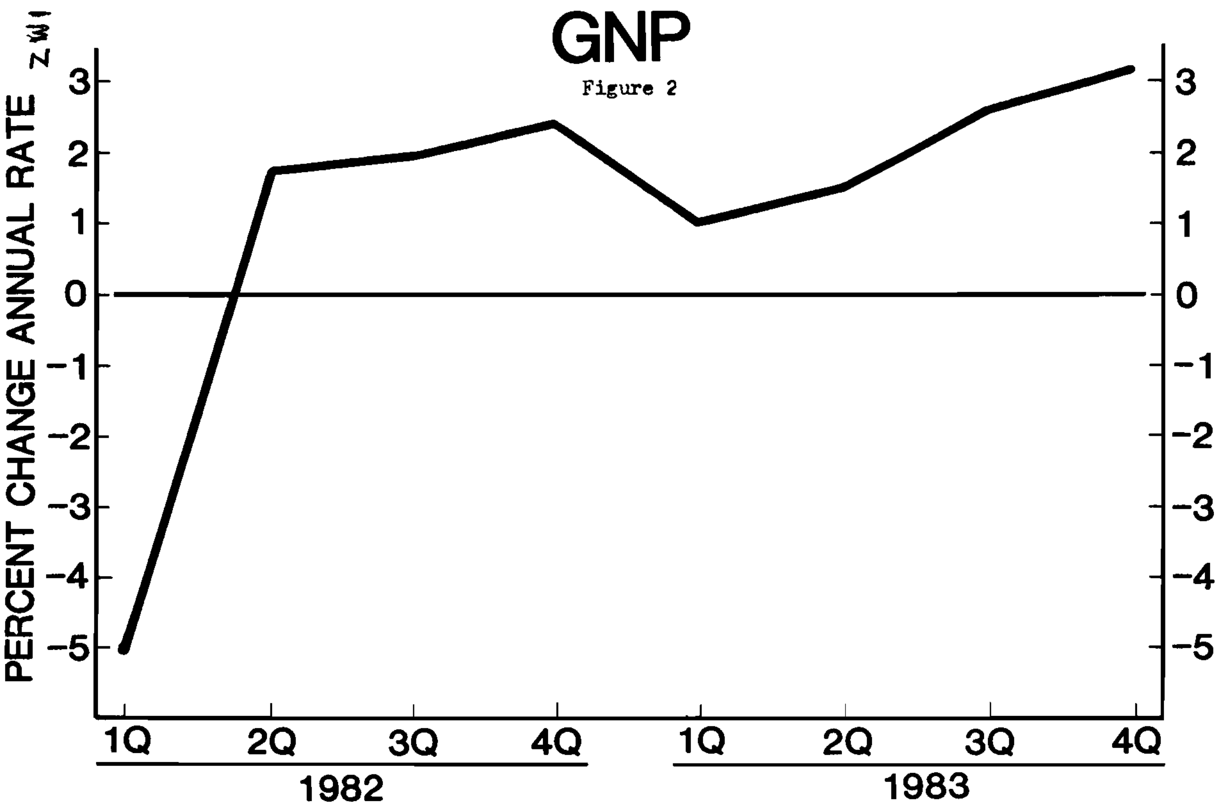
References

- Pace Economic Report, August 1981, plus updates.
- J. M. Williams, International Fertilizer Industry Association, Vancouver, Canada, September 1982, "Trends in the Technology for the Beneficiation and Processing of Phosphate Rock and Their Possible Influence on the Economics for Future Production".
- SRI, ZWI, FERTECON, "World Phosphate Multi-client Study", unpublished.

MODERATOR BLENKHORN: Thank you Mike Williams for an excellent review of the Phosphate Outlook. (Applause)



Source: PACE CONSULTANTS



GNP

Figure 2

Source: PACE CONSULTANTS

ZWI

NATIONAL INCOME ACCOUNTS
(1982:1 to 1982:2)

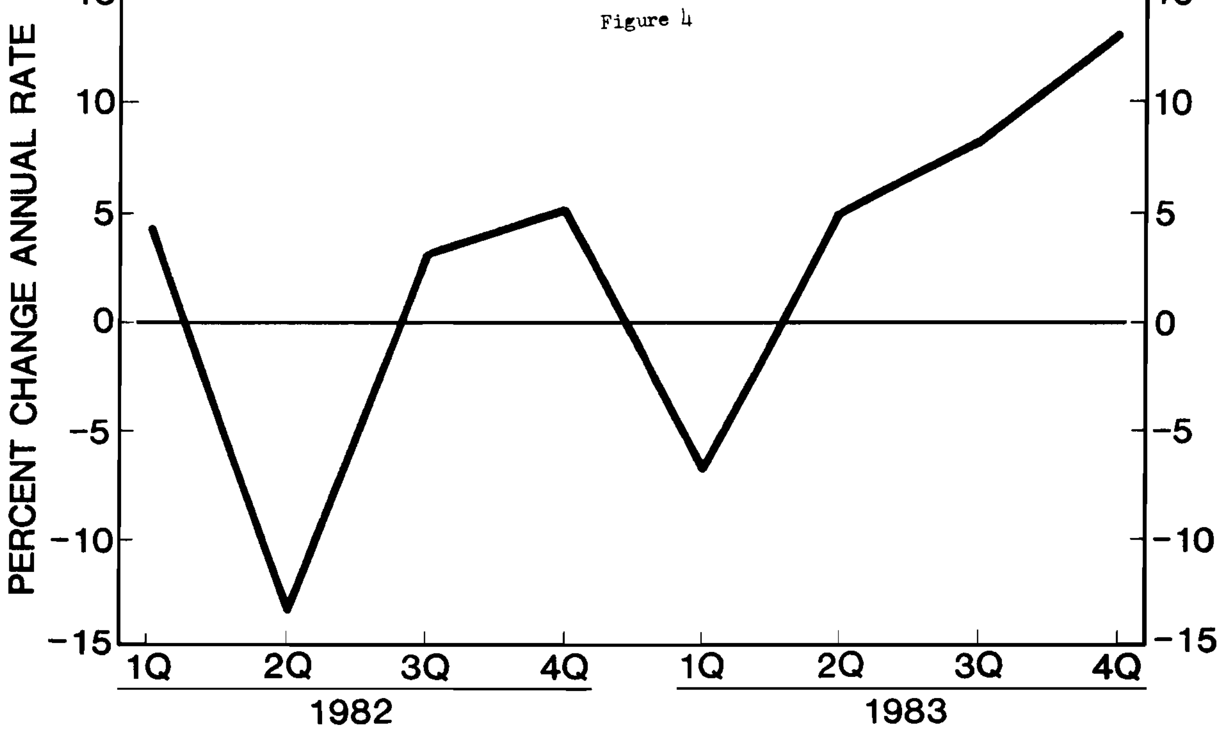
Figure 3

	CHANGE (Billion 1972 $)
PERSONAL CONSUMPTION	7.2
RESIDENTIAL INVESTMENT	0.3
BUSINESS FIXED INVESTMENT	(3.8)
NET EXPORTS	(1.3)
GOVERNMENT PURCHASES	(4.7)
FINAL SALES	(2.3)
INVENTORY CHANGE	8.4
GROSS NATIONAL PRODUCT	6.1

Source : PACE CONSULTANTS

NET EXPORTS

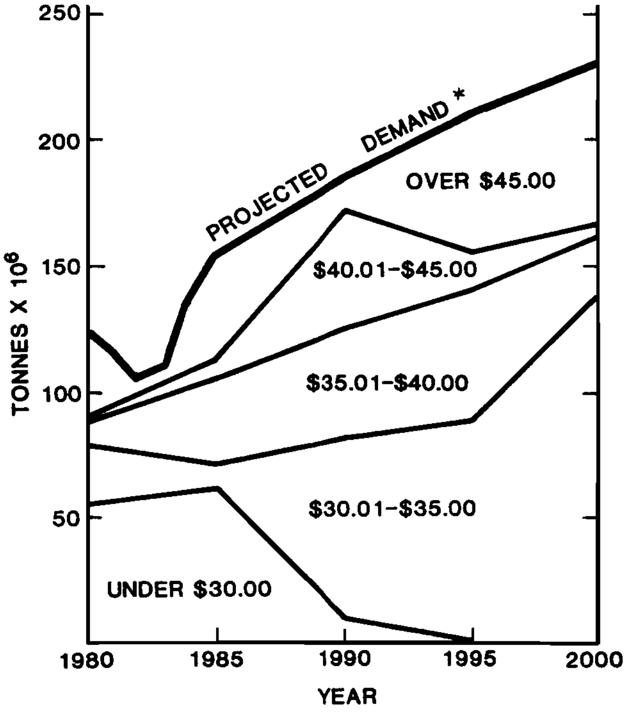
Figure 4



Source: PACE CONSULTANTS

ROCK AVAILABILITY AT SELECTED WHOLE COSTS

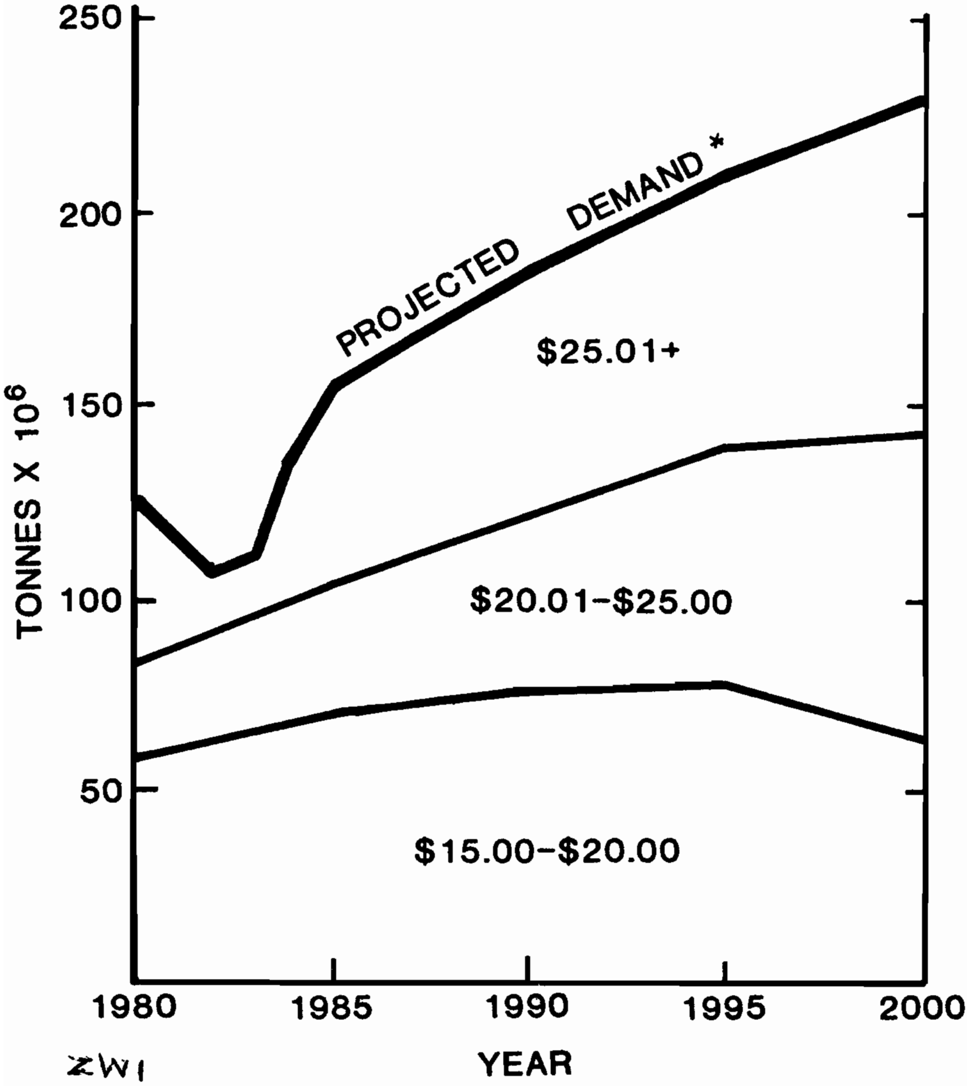
Figure 5



* EX. CHINA

ROCK AVAILABILITY
AT
SELECTED CASH COSTS

Figure 6



* EX. CHINA

Figure 7
Whole Dry Cost Comparison
(Basis: Percent of Cost/Ton)
Constant '81 $

	Pooled Central Florida '81 Costs (Base)	Typical Central Florida Mature (4 MMTPY)	Typical Future South Florida (3MMTPY)*	Future South America (3 MMTPY)*	Future North Africa (5 MMTPY)*
Power & Fuel	12%	15%	11%	11%	8%
Maintenance Parts & Supplies	9	7	4	7	7
Supervision & Labor	12	9	7	7	8
Other Costs	40	43	28	22	20
Subtotal Cash Costs	73	74	50	47	43
Other Costs	13	14	10	13	12
Capital Related Items	14	12	40	40	45
Whole Cost	100%	100%	100%	100%	100%
Cash Cost, $/Tonne	19.19	18.35	21.49	20.45	19.51
Whole Costs, $/Tonne	26.25	24.71	42.49	42.72	45.24
Relative Cash Cost	100%	96%	112%	107%	102%
Relative Whole Cost	100%	94%	162%	163%	172%

*Start up year at design capacity

Figure 8
New Capital Investments - World
(Excluding China)

	$ Million	Annual Capacity (MT x 10^6)
1981 Existing	4,815	151
1981-85	1,721	27
1986-90	3,061	52
1991-95	2,126	41
1996-00	1,131	19

New capital includes replacement and additional capacity.

Average investment cost of existing capacity is $32 per tonne; new capacity investment cost averages $59 per tonne. Constant 1981 dollars.

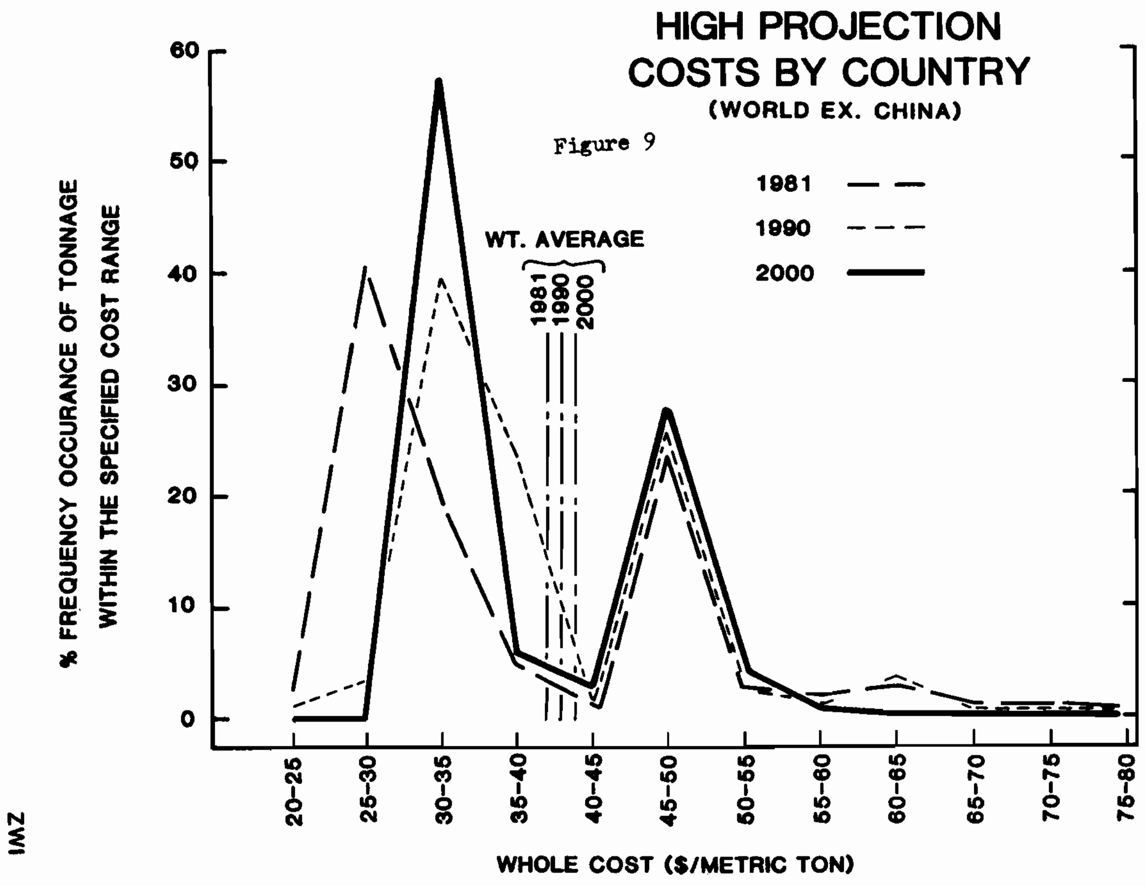
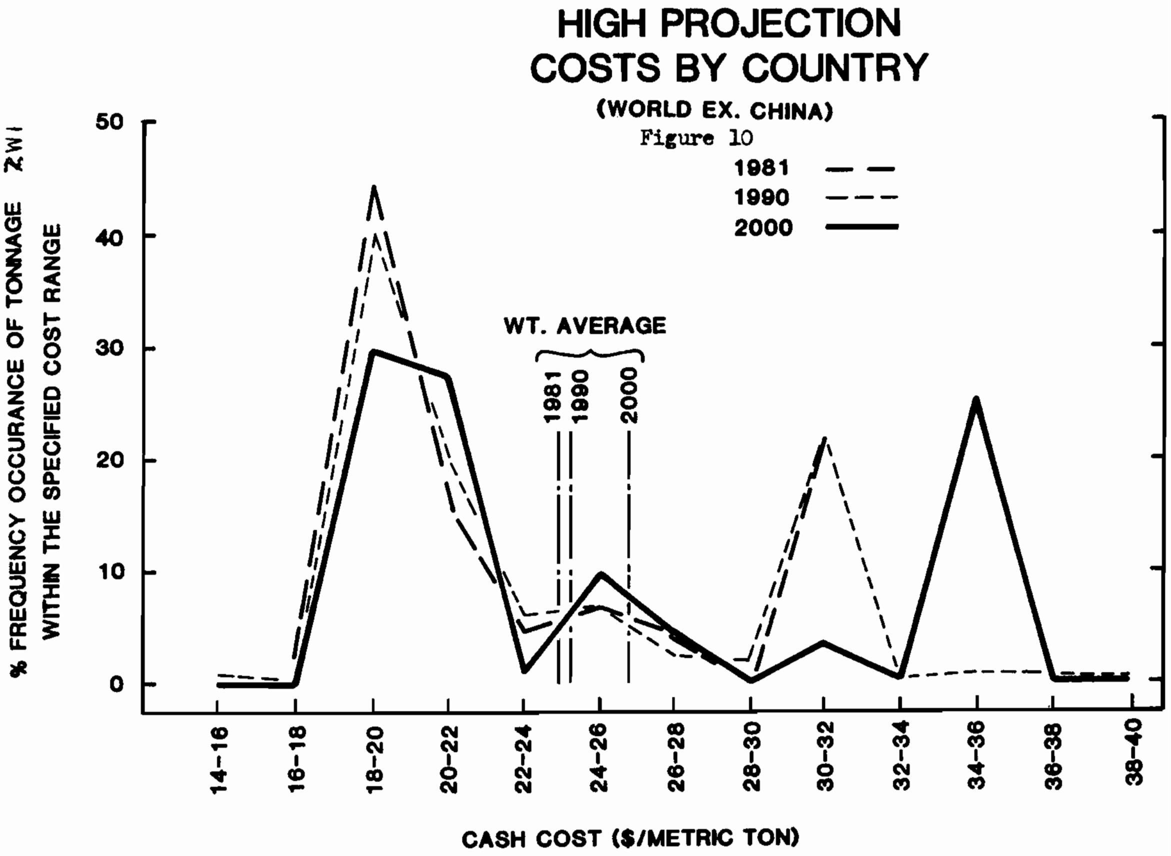


Figure 9



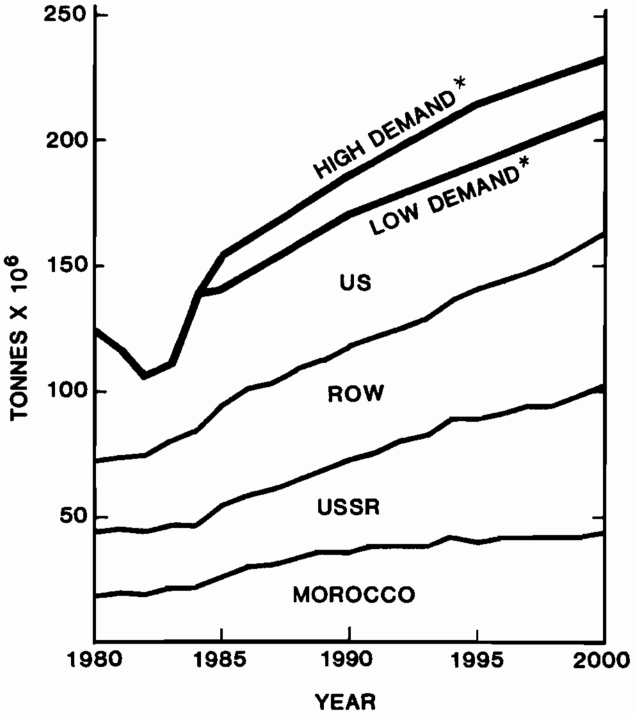
HIGH PROJECTION COSTS BY COUNTRY

(WORLD EX. CHINA)

Figure 10

PROJECTED DEMAND

Figure 11



ZWI

* EX. CHINA

MODERATOR BLENKHORN: The Potash Situation will be presented by Deneb Teleki of the International Minerals and Chemical Corporation. Deneb came to this country from his native Rumania in 1947. He graduated from Rutgers University in 1954, and joined I.M.C. in 1959. His present position is Director, Agricultural Market Planning. (Applause)

The Outlook For Potash

Deneb Teleki

It's no secret that potash and agriculture rise and fall together. . . . our fortunes are interlinked with the farmer, no matter if he grows corn in Iowa, wheat in France or rice in India.

And there is no need to elaborate on the farm problem here and around the world. You read about it in the daily newspapers . . . radio and TV offer a steady stream of bad news impacting on agriculture and the industries that serve it worldwide.

Potash is one of the three primary fertilizer nutrients and North American potash producers saw their shipments fall by 20 percent in the year ending last June.

What caused this large setback and what's next in store for this industry?

Perhaps a brief historical note is in order to put the situation in perspective.

Mineral-based commercial fertilizers were introduced in the early 1850's. Their acceptance by farmers showed only modest growth until demand accelerated in the 1940's after World War II. Further acceleration came with the adoption of hybird corn, and then with the development of higher yielding wheat and rice varieties during the so-called green revolution, an era of increased fertilizer application rates in the developing nations.

It has not been uncommon in recent years for annual incremental increases in fertilizer usage to exceed the total of four million nutrient tons consumed annually in the early 1920's.

But country-by-country, year-by-year progress has never been as smooth in the fertilizer business as our summarized long-term chart indicates. It remains a highly-cyclical business.

We now are going through another difficult period in our industry. Demand has been depressed as several of the important factors influencing our business, including grain prices, continue to be negative and, in some ways, beyond our control.

For instance, the cash price of corn in Omaha was still at a favorable level well over $3.00 per bushel up to July, 1981, but it fell by 25% as the harvest brought record yields. This year, the prospect of another record breaking crop has further depressed prices and net farm income.

However, domestic corn demand is form and exports are likely to recover from their recent slump. But the supply is simply far too large, and acreages for corn and other important fertilizer consuming crops will be down next spring.

These factors have caused U.S. fertilizer nutrient consumption to fall by an estimated 7% in 1981/82. We expect a further decline of three percent in 1982/83 and recovery to the 1980/81 high may take until 1984/85, by which time grain acreages and prices also will have recovered.

Low general economic activity, a cost/price squeeze on farmers and foreign exchange shortages have weakened fertilizer demand in several overseas markets as well. Worldwide, this is the second time in 20 years that demand has dipped below IMC's long-term forecasts. This time, it may take a little longer to catch up from stagnation to trendline growth of 3-4 percent per year that after the decline in 1975. But such abberrations do eventually balance out as general and agricultural economies return to normal and growing populations can again afford to improve their diets.

Now let's return to potash. First, the North American industry.

Total deliveries of North American producers have grown irregularly but substantially during the last twenty years, reaching a record 10.4 million short tons of K_2O in 1981. During the ten years ending in 1981, this growth averaged 5% per year, deliveries to the U.S. and Canada rising 4% per year while offshore sales increased by over 8% per year, on the average.

But some of the delivered product accumulated in the wholesale buyers' hands in North America and overseas. Then, last fertilizer year, wholesale demand declined sharply and total deliveries fell by 20%, with demestic shipments down 14% and offshore sales down 34%. These large declines had a common cause in world economic stagnation, a continuing cost/price squeeze on farmers in most western nations and stock liquidation in the distribution system abetted by high interest rates and foreign exchange shortages.

It is especially risky to make demand forecasts after the fertilizer year we've had — and the expected growth rates would seem high or low depending on whether they are based on 1982 or 1981.

We believe that total shipments of North American producers will start recovering during the current fertilizer year but that it may take until 1985 to regain the record of 1981. Then, by 1987, total shipments should reach 11.7 million tons, growing at a trendline value of 3% per year.

Domestic deliveries are expected to be up a little this fertilizer year, despite farmer hesitation, since they no longer suffer of dealer stock liquidation, as they did last year. They should catch up to the trendline growth of 2-3% per year in farm level consumption and this means accelerated growth in the mid-1980's, when we expect crop prices and acreages to recover to their normal levels.

Offshore sales have been especially hard hit by the previously mentioned factors. In addition, overseas competition is fierce, especially from East Germany and Russia, which often insist on shoehorning undiminished tonnages into resisting markets, regardless of price. Nevertheless, the worst seems to be over and overseas shipments of North American producers should recover to a trendline with an annual growth rate of about 4%. This means double digit export increases during at least a couple of the next five years.

The growth in deliveries of the North American potash producers has been, fueled entirely by the Canadian industry, ever since production started there twenty years ago.

U.S. production and deliveries have declined slowly as ore grades declined and some reserves have been exhausted during the last fifteen years.

Growing from zero output in 1962, the Canadian industry surpassed the U.S. in 1979 and now, is about four times its size. Canadian deliveries, especially offshore sales, tend to fluctuate more than deliveries from the U.S. But with no new mines in the U.S., sales from Canada should grow about one percentage point per year faster than the 3% per year trendline growth for total North American sales.

The U.S. and Canada are greatly inter-dependent on potash. The U.S. now fills over 60% of its potash requirements from Canada which ships about two thirds of its potash production to the U.S.

Before potash production started in Canada, 90% of the U.S. market was supplied by U.S. producers, and overseas producers had a 10% market share, mostly on the east coast.

Large previously-announced imports from Russia have not materialized but increased tonnages are coming in from Israel, and the offshore producers' share has doubled from three to six percent in five years. We expect this trend to be stopped when potash becomes available on the east coast from mines now under construction in New Brunswick, Canada.

Wholesale potash demand in North America used to be quite seasonal ten and twenty years ago, paralleling to a fair degree the even more seasonal nature of the farm level application of the product.

For instance, as late as the 1971-78 period, wholesale deliveries during the July/August summer low amounted to only 12% of the year's volume, while the March/April spring peak garnered 25% of the year's total business.

Then, during recent years, the business was largely deseasonalized through reliable price and cost incentives offered by producers and railroads encouraging summer delivery. For instance by the 1978-81 period, July/August deliveries had grown to 18% of the year's volume, while the March/April peak had shrunk to 19%.

But just now factors are emerging that tend to reseasonalize the business. Farmers are delaying the use of potash and other fertilizers to spring, whenever feasible, to reduce high borrowing costs and to accommodate possible changes in planting intentions in these uncertain times. Dealers and blenders feel that they cannot rely as much as they used to on seasonal price incentives in the current period of unstable prices. And there is less need to stockpile ahead of the application season now that general shortage is less likely to occur, the freight car supply is more than ample and plentiful supplies are available for truck delivery on short notice from proliferating producers' filled warehouses.

The proportions of North American muriate of potash shipments by grade have slowly shifted from the finer grades toward the coarser particle size grades over the years.

Twenty years ago, the "standard" grade made up the majority of the business and was the preferred raw material for the ammoniated mixed fertilizers then most prevalent in North America. "Special standard", of even finer particle size, was developed in the 1960's to serve offshore mixed fertilizer manufacturers.

But in the 1960's and 1970's, the larger particle size "coarse" and "granular" grades rose to dominance in the domestic market with the development of dry blending, bulk distribution to farms and broadcast application to the soil.

As late as 1972, "standard" and "special standard" still made up 40% of total shipments, while "coarse" and "granular" had just risen to a 50% share. But by 1982 the two finer grades' share had shrunk to 30% while the two coarser grades rose to a 60% share. Bulk blending is increasingly penetrating even the southeast, where ammoniated granulated fertilizers have held on to their popularity the longest. And overseas, large dry blending plants are displacing ammoniated product in established markets such as Japan and are spreading to developing nations. Therefore, we believe that the trend toward larger particle size will continue.

Since regular mining and flotation techniques result in the production of a lower proportion of the coarser grades than required in the market place, producers have installed compaction units to supplement them.

No producer in North America or overseas can afford to have an insufficient proportion of the coarser grades in its line. Some are capable of compacting most or all of their finer product while others have installed heavy media flotation systems to increase the proportion of the coarser grades.

It is important to realize the published data we see on potash capacity may not accurately illustrate the pracitical capability of the industry.

Most deal with *nameplate* or theoretical capacity rather than *ability* to produce or production potential.

. . . .Most ignore the fact that a new one or two million ton mine gets to that level gradually over a year to two . . . sometimes even three. It does not reach full potential overnight.

. . . . Most ignore mining and refining problems likely to be encountered with new and often more complex ore bodies . . . or the effect of declining ore grades at old mines.

. . . . Therefore, we think most published capacity data exaggerate the immediate supply impact of new mines and are late in reducing the capability of old mines. We try to take these factors into account in our supply estimates and report capacity according to both of these definitions.

Fifteen producers operate 19 mines in the U.S. and Canada, with a theotetical capacity of 12 million short tons a year of K_2O. The industry shipped a little over 8 million short tons of K_2O last year.

The last big expansion in North American capacity took place when the Canadian deposits were developed between 1962 and 1972 when capacity was more than quadrupled.

When prices slumped badly in the late 1960's, some new Canadian potash mines did not install all the equipment needed to reach design capacity. Others deferred maintenance during that period with the same effect.

However, as shipments increased during the 1970's, the Canadian potash industry steadily expanded its ability to produce without significantly increasing theoretical capacity. Our research indicates that between 1970 and 1980 Canadian potash production potential increased about 34 percent while theoretical capacity increased by only 13 percent.

In the United States, declining ore grades preclude production at original design capacities of existing mines. Ore hoisting and processing capability has actually increased, but finished potash production potential has gone through a period of slow decline.

There is an, as yet almost unexplored deposit in Montana, but its depth of more than 7,000 feet means that solution mining would be the only practical way to exploit it.

The Potash Corporation of Saskatchewan (PCS), a provincially owned entity, is the largest single producer in Canada. A government change last spring and market conditions have slowed an ambitious expansion program, announced in 1979, to double capacity by 1990. However, several incremental expansions were completed during the last two years and, after a postponement by a year, the new refinery at Lanigan should be finished by late 1984. That will add about 1.2 million short tons per year K_2O to PCS capacity.

IMC is sinking a fifth shaft at the Carlsbad, New Mexico mine to sustain future operations there.

However, IMC's two Canadian potash expansion projects are on temporary hold. Permits are in hand for a 790,000 ton K_2O ton expansion of Esterhazy, Saskatchewan operations. Negotiations for a new potash mine in Manitoba are not expected to resume until there is significant improvement in markets.

Potash Company of America, a division of Ideal Basic Industries (or PCA) is incrementally expanding its Saskatchewan mine, and is well along on refinery construction for its New Brunswick venture, which it expects to come onstream next spring.

Also in New Brunswick, Denison Mines has sunk a shaft and is now conducting feasibility studies, having delineated sufficient reserves for a 600,00 K_2O tons-per-year mine.

Last year, U.S. capacity fell by 11 percent as AMAX expanded but Kerr-McGee reduced capacity at Trona and Freeport-Macmoran shut down its national potash operation.

If the capacity expansion plans in Russia do materialize as estimated by TVA, world potash capacity will expand by 23 percent between now and 1985. The estimated 29 percent expansion of Russian capacity in three years seems optimistic, but it will be achieved eventually.

Remember, too, that these figures are based on design or theoretical capacities and do not reflect actual production potential.

Overseas, potash has been discovered or has been known to exist for some time in Australia, Brazil, Mexico, Peru, Thailand, and the Dead Sea.

None of these deposits are nearly as large or as important as the Canadian or Russian deposits

However, let's review some of the more significant developments.

The Arab Potash Company just started production to recover 1.3 million tons of product from the brines of the Dead Sea, adding to the growing tonnages Israel is already producing from the same source.

The carnallitic ore in Brazil will be difficult to process, but Petrobras has sunk a shaft for a 500,000-ton mine that should come onstream in two to three years.

The Australian, Mexican and Peruvian deposits are lake brines, which could support at the most a production of a few hundred thousand tons a year each.

It usually takes from four to six years to bring a new potash deposit into actual production. So actual supplies during the next three years must come from capacity in place or currently under construction.

It may be appropriate at this time to review recent historical trends to get a better view of future potash supply/demand conditions.

Following a period of good supply-demand balance and growth, the North American potash industry experienced excess capacity and low operating rates from 1969 to 1973. In 1970 the government of Saskatchewan instituted a potash conservation program, including production controls and minimum price levels.

Demand surged in 1974, prompting the Saskatchewan government to remove production controls and terminate the floor price system.

Shipments declined sharply from 1974 to 1976 as buyers, especially overseas, sold off excess stocks. But in 1977 and 1978, wholesale buying returned to a more normal level. Supplies had become tight by 1979 to 1981, aided by a Russian production failure and good worldwide demand.

Then came the 20 percent decline in wholesale demand during fiscal '82. Shipments sank to an equivalent of 77% of production potential from a practically sold out position the year before.

By last March, producers' stocks rose to a record 2.7 million short tons of K_2O, nearly double the year earlier level.

Since then, production has been cut by almost 40 percent, and stocks have declined five months in a row, by a total of 35 percent. Still, they are too high, related either to year-ago stocks or current sales volume.

Offshore sales were higher in the September quarter, and deliveries to U.S. and Canadian markets also should be up for the full fiscal year. However, production will have to be restrained all year if stocks are to return to normal.

Longer term, the supply/demand relationship for North American potash should gradually improve. But first, the tonnage of fiscal 1982 must be regained and market share has to be maintained in growing markets thereafter.

Meanwhile, the market outlook resulted in the postponement or cancellation of capacity additions that would have added 54 percent to existing North American capacity. Nevertheless, projects under construction, unless delayed, will add 25 percent to North American potash capacity during the next three years. And, as these projects come gradually into full production capability, production potential is likely to grow during every one of the next five years, reaching 13.2 million K_2O tons by 1987.

As a result, we see the likelihood of a continuing but slow recovery in the operating rate of the North American potash producers, with total shipments expected to reach 88% of production potential by 1987.

Overall, there should be ample product to supply worldwide demand during the next five years. However, project delays, a recurrence of the Russian production setback of 1979 or another world food crisis could tighten up supplies sooner than our present calculations indicate.

Its difficult to pinpoint exactly how fast or how soon the recovery will take place in potash. The reason is that tough and complex pressures continue to squeeze the world economy, the fertilizer industry and the farmer alike.

But, fertilizers remain the key to world food output . . . the most logical means to reduce per-bushel cost while maximizing per-acre yields for top profits in good times and bad.

Fertilizers are critical to solving farmer's problems today . . . but they will play an even greater role in tomorrow's agriculture.

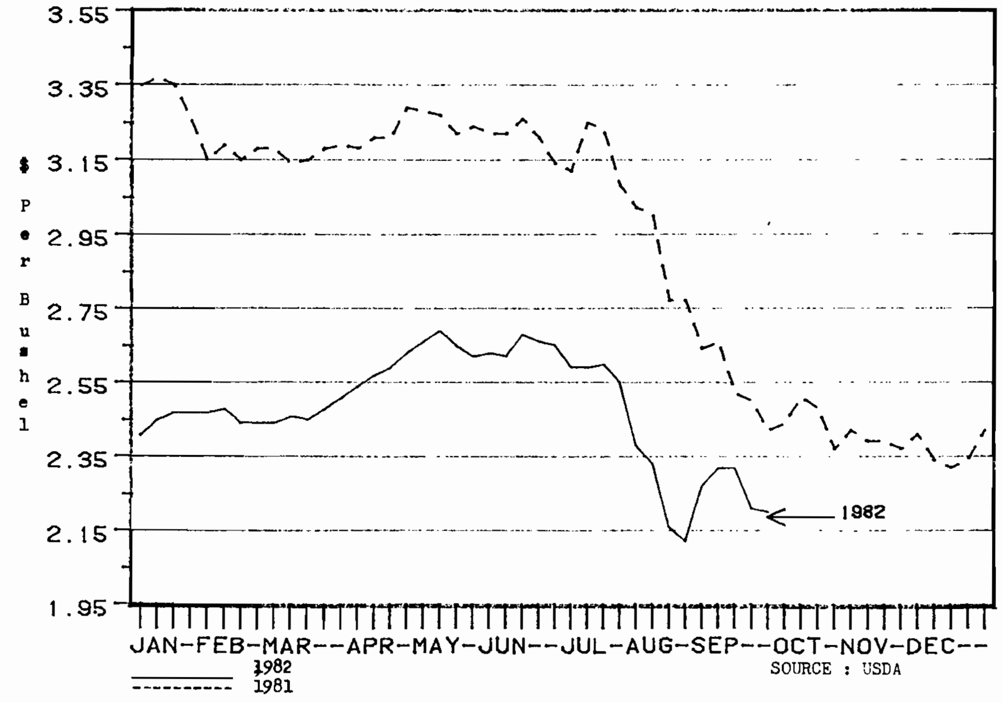
Experts say the world will require at least a 50 percent increase in annual grain output between 1980 and the year 2000 . . . . and growing that grain will require a doubling of fertilizer production over the same period.

The fertilizer industry must not lose sight of that future opportunity.

Meanwhile, it is making difficult decisions to weather current troubles and prepare to meet the challenges of a return to normalcy in the world marketplace. (Applause)

CASH CORN PRICES

(Weekly average for #2 yellow, Omaha)



SOURCE : USDA

U.S. FERTILIZER CONSUMPTION

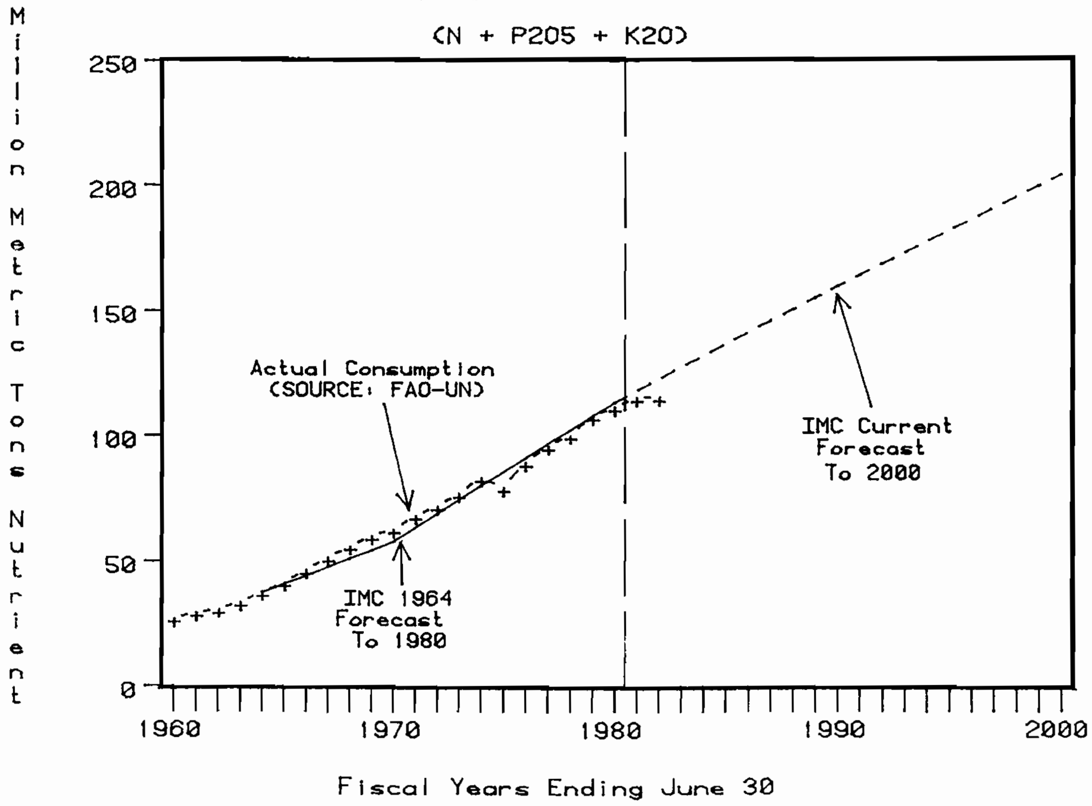
	MILLION SHORT TONS OF NUTRIENT				ANNUAL PERCENTAGE CHANGE		
	79/80 1/	80/81 1/	81/82 2/	82/83 2/	79/80 To 80/81	80/81 To 81/82	81/82 To 82/83
NITROGEN (N)	11.4	11.8	11.3	10.9	+3.3%	- 4%	- 3%
PHOSPHATE (P_2O_5)	5.4	5.4	4.7	4.6	-0.1%	-13%	- 3%
POTASH (K_2O)	6.3	6.3	5.8	5.6	NC	- 8%	- 3%
TOTAL	23.1	23.5	21.8	21.1	+1.6%	- 7%	- 3%

1/ USDA'S COMMERCIAL FERTILIZERS
2/ IMC ESTIMATE

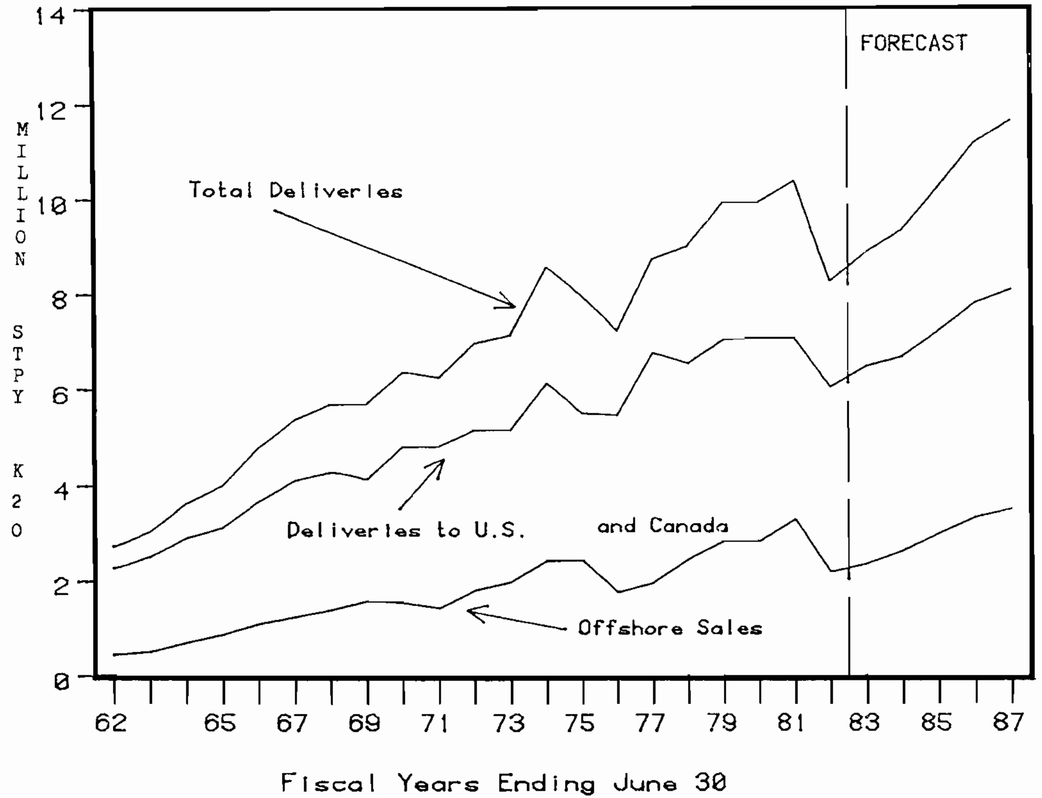
1/USDA's Commercial Fertilizers.
2/IMC estimate.

WORLD FERTILIZER CONSUMPTION AND IMC FORECASTS

(N + P2O5 + K2O)

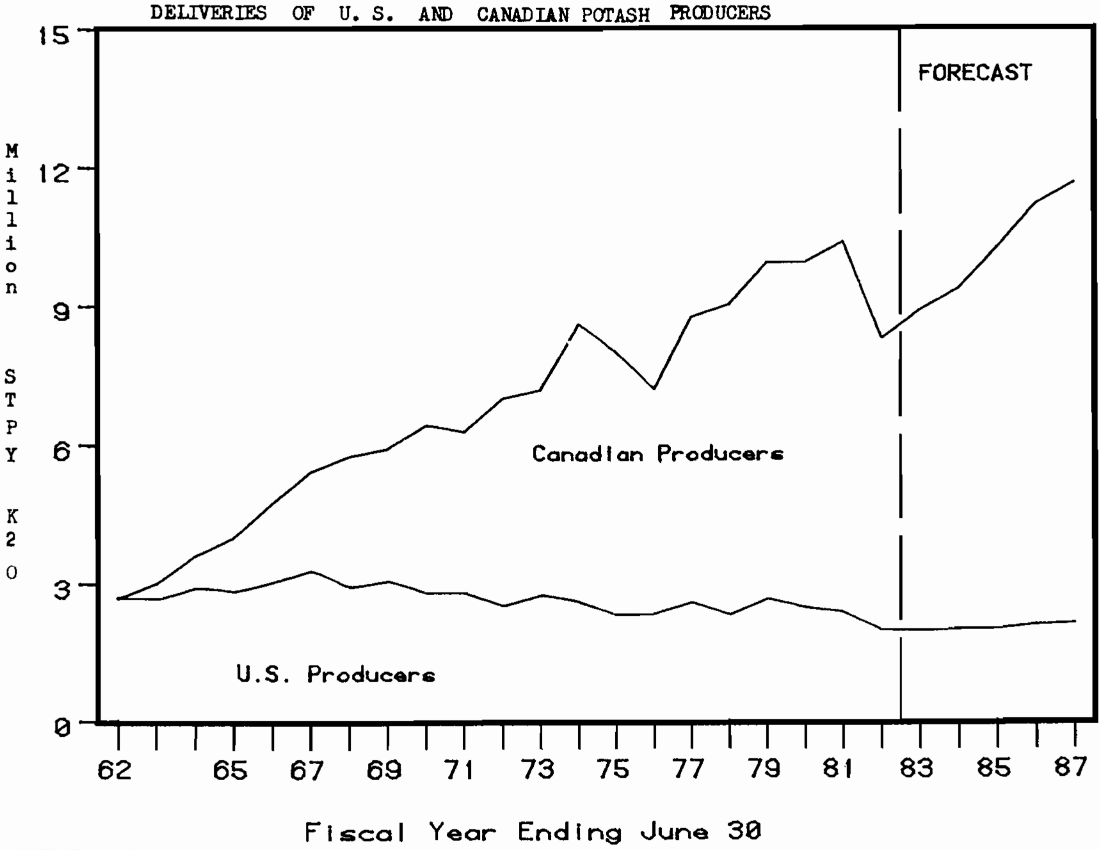


DELIVERIES OF NORTH AMERICAN POTASH PRODUCERS BY MARKET



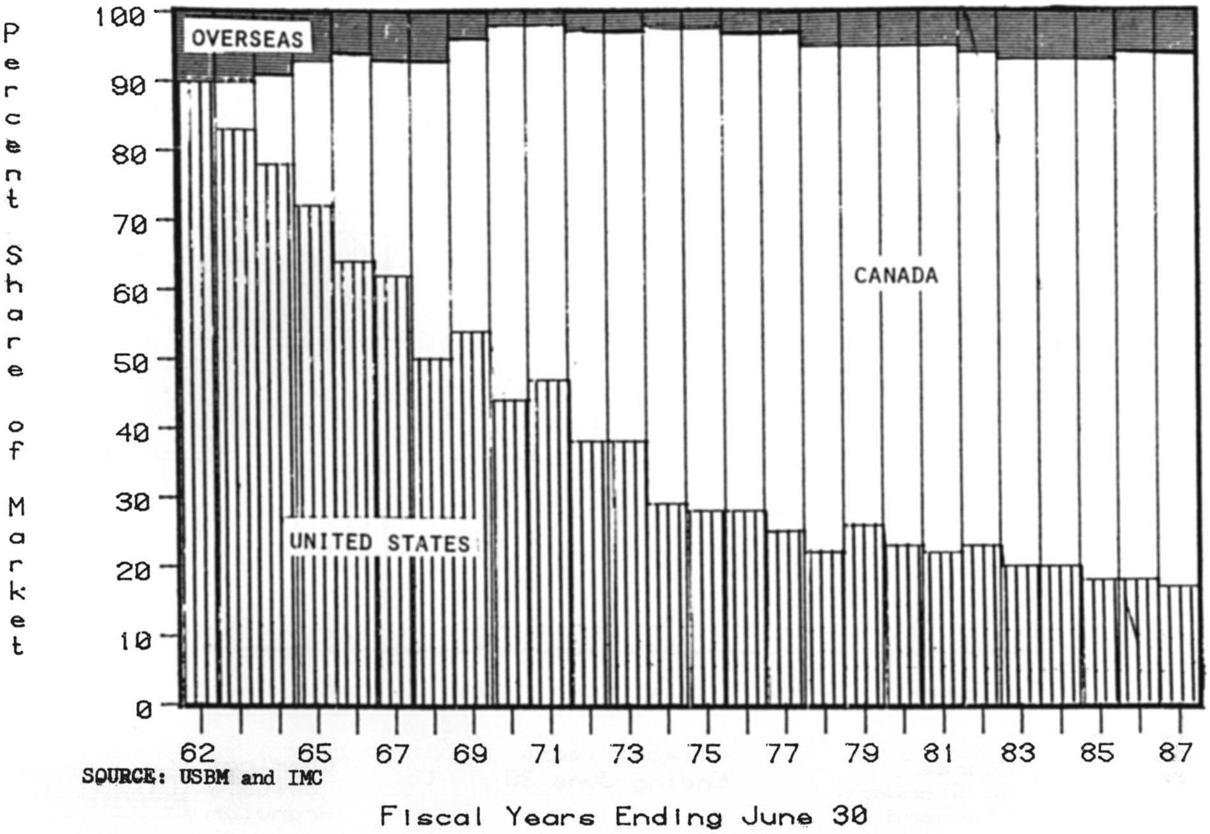
Source: USBM. P/PI and IMC Forecasts

DELIVERIES OF U. S. AND CANADIAN POTASH PRODUCERS



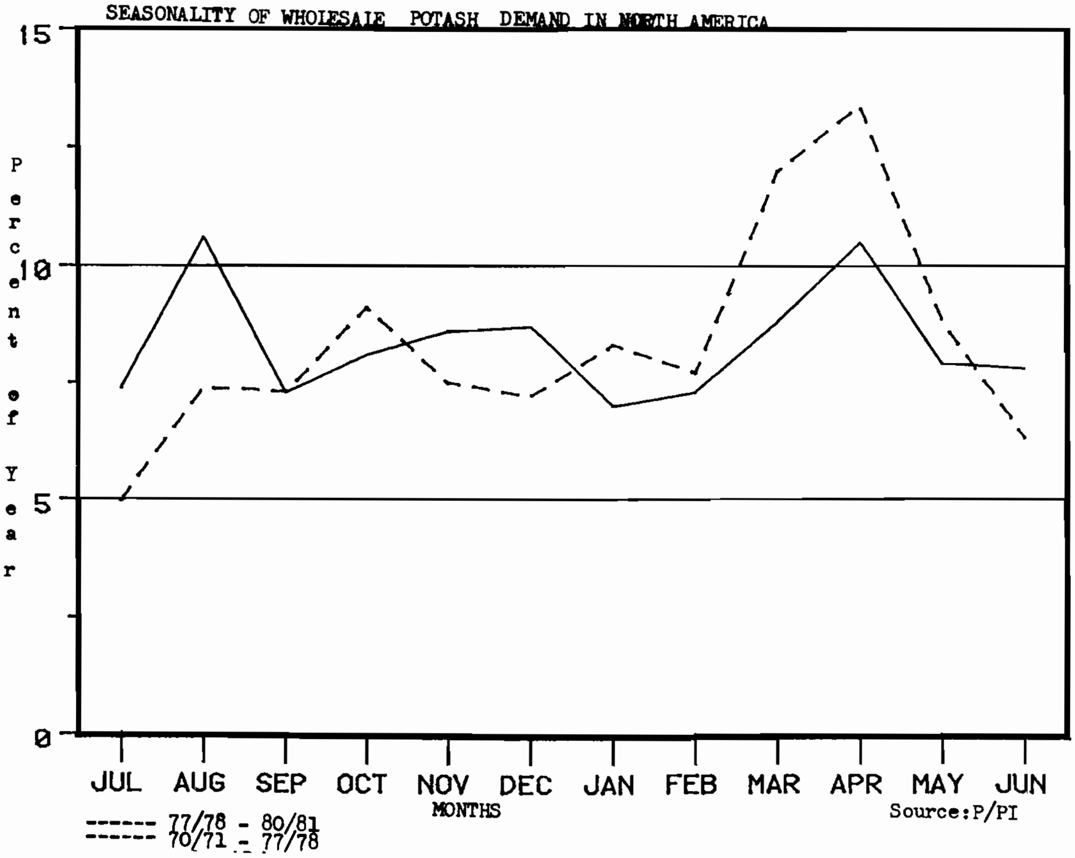
SOURCE: USBM and IMC

POTASH DELIVERIES TO THE U.S. BY SOURCE



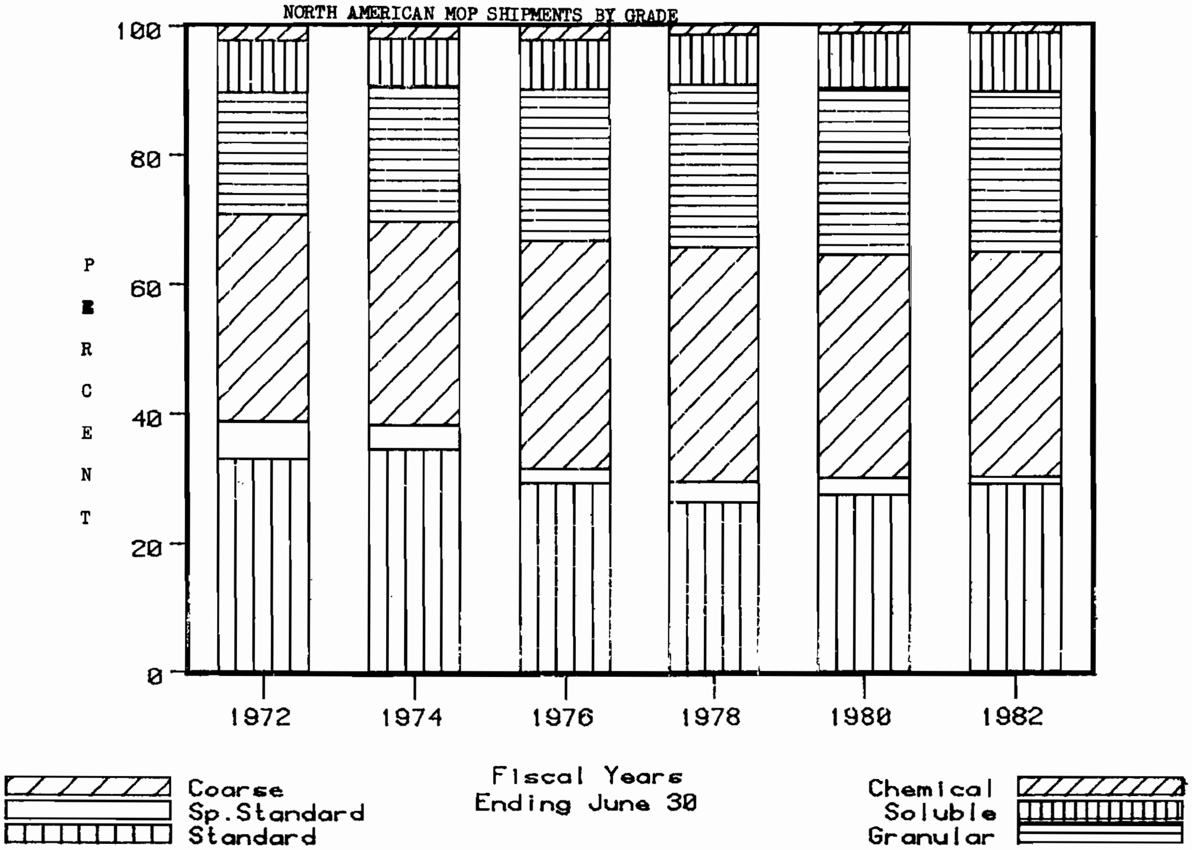
SOURCE: USBM and IMC

SEASONALITY OF WHOLESALE POTASH DEMAND IN NORTH AMERICA

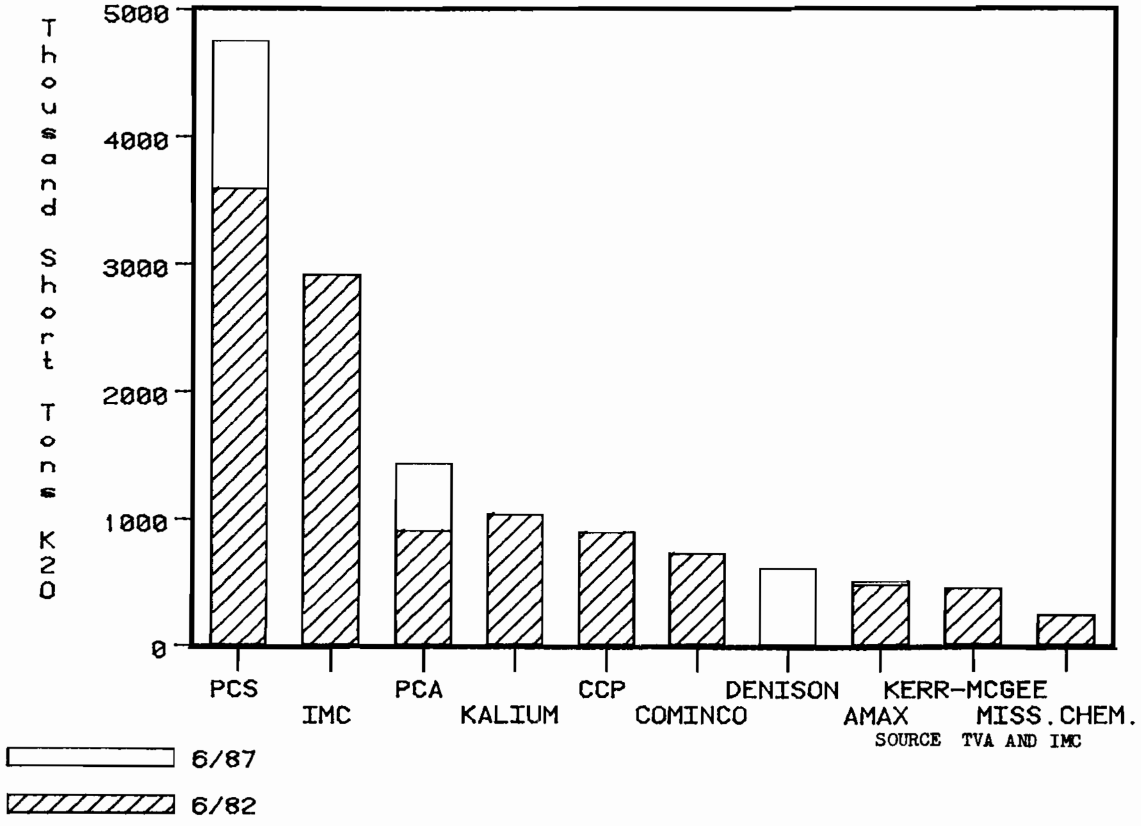


Source: P/PI

NORTH AMERICAN MOP SHIPMENTS BY GRADE

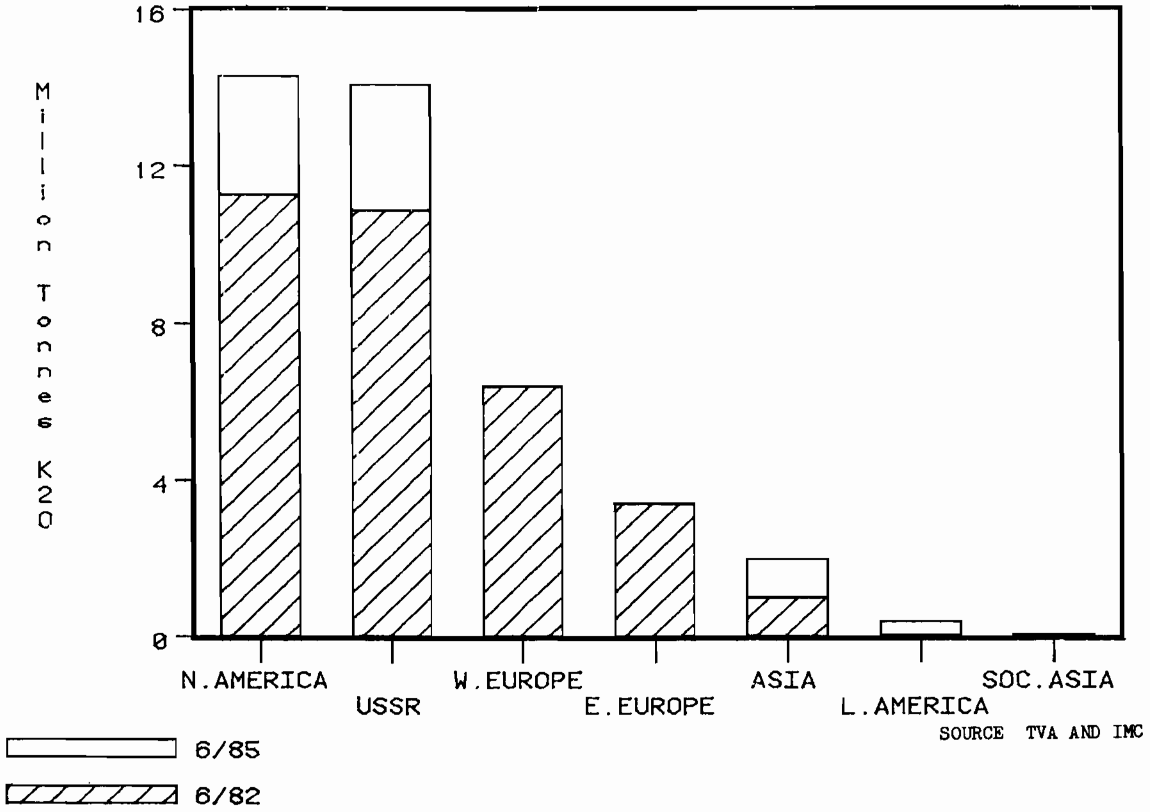


CAPACITY OF MAJOR NORTH AMERICAN POTASH PRODUCERS



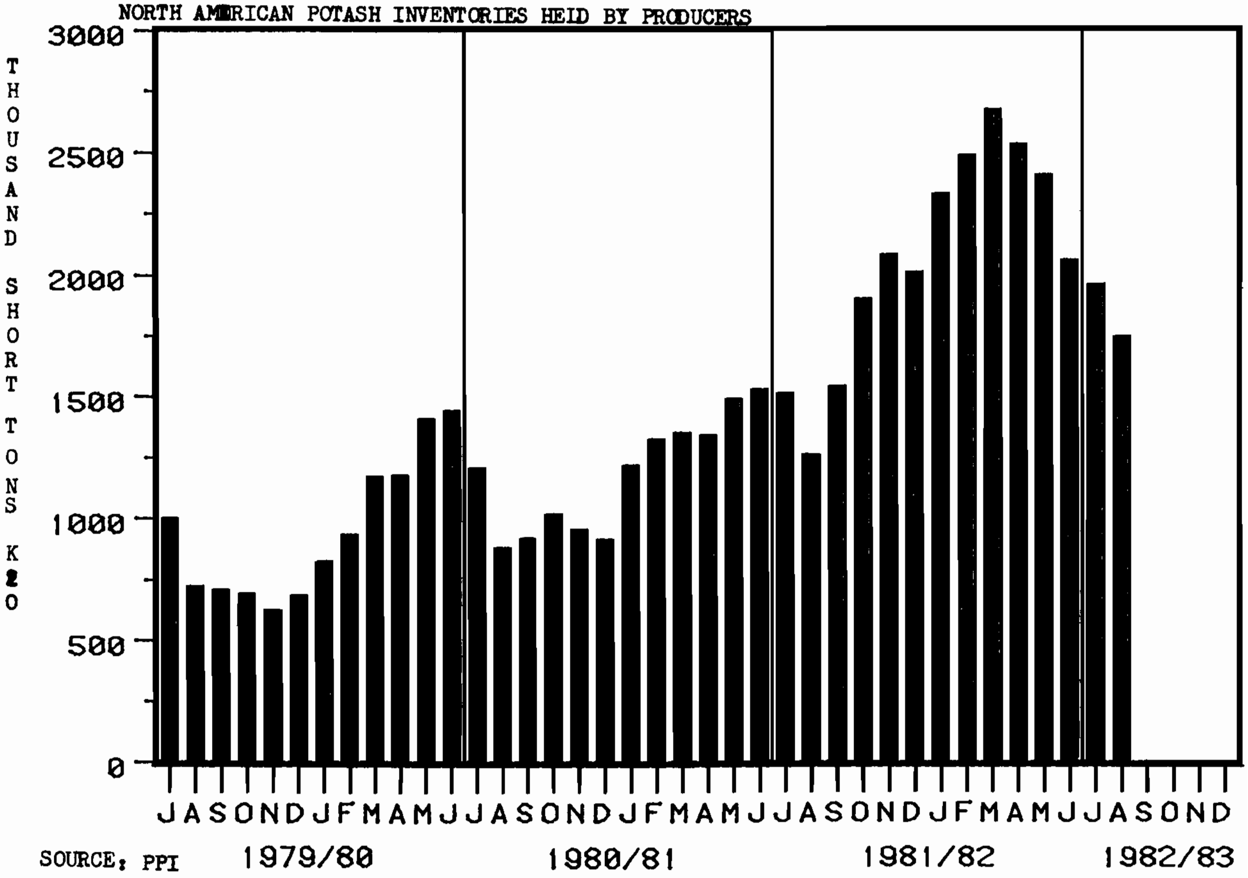
SOURCE TVA AND IMC

WORLD POTASH CAPACITY BY REGION

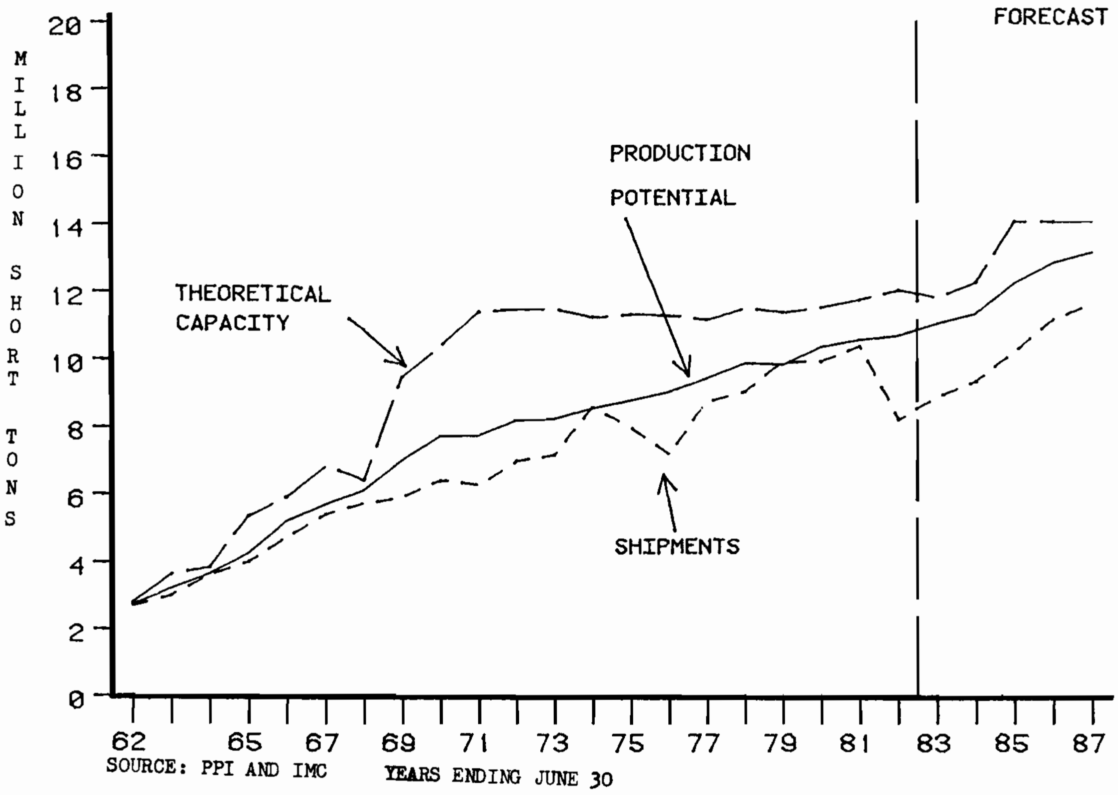


SOURCE TVA AND IMC

NORTH AMERICAN POTASH INVENTORIES HELD BY PRODUCERS



SOURCE: PPI



NORTH AMERICAN POTASH SUPPLY/DEMAND FORECAST - 1986/87

SOURCE: PPI AND IMC

MODERATOR BLENKHORN: Thank you Deneb, for a fine presentation.

We will now proceed to another key chemical in The Fertilizer Industry. Barry Clarke of "Cansulex Limited", located in Vancouver British Columbia, will speak on the subject of "Sulphur". Barry is a native of England. He received a Bachelor of Technology Degree in Industrial Chemistry from Brunel University and following graduation joined the British Sulphur Corporation. Barry moved to Canada in 1970 and was employed by Polysar Corporation and the British Columbia Council prior to joining Consulex Limited in 1977. His present position is "Director, Market Research and Development". Barry please. (Applause)

Sulphur Outlook

B J. Clarke

Introduction

Sulphur is a vital raw material in the production of a vast number of industrial products, however it is the fertilizer sector, particularly phosphate fertilizer that accounts for over 60% of sulphur consumption. While 60% is a fair estimate for sulphur in all-forms, the proportion of elemental sulphur (brimstone) consumed by the fertilizer industry is somewhat greater, as most phosphoric acid capacity is based on sulphuric acid plants utilizing brimstone.

The importance of sulphur to the phosphate fertilizer industry can be seen if we analyze total P_2O_5 consumption by production method: (Slide 1)

— 85% of P_2O_5 consumption utilizes sulphur -65% for the production of phosphoric acid and 20% for single superphosphate,

— 10% is produced by the nitrophosphate route using nitric acid,

— 5% is consumed without chemical treatment, largely direct application of ground phosphate rock.

From this degree of involvement it is apparent that the phosphate industry is the largest single determining factor of sulphur consumption and it is the reduced demand from this sector that has largely affected sulphur consumption in recent years.

I will now review sulphur consumption on a regional basis.

West Europe (Slide 2)

From a peak consumption level of 7.3 million tonnes in 1979 the European consumption of sulphur has steadily declined and is expected to reach a new low level in 1982 - almost 2 million tonnes below the 1979 level.

A large part of this decrease may be attributed to a fundamental change in the structure of the European fertilizer industry, combined with reduced consumption from the industrial sector. The trend in the European phosphate industry to import intermediate or finished P_2O_5 fertilizers is now well established, and even with a change in economic conditions it is not expected that the European fertilizer industry would regain the losses of 1980 and 1981. Sulphur consumption in Europe is therefore unlikely to regain ground lost in these years and even after a moderate recovery predicted for 1984, the level of sulphur consumption in the mid-eighties will be 1 million tonnes lower than 1979.

Africa (Slide 3)

Three countries - Morocco, Tunisia and South Africa account for the most significant portion of African consumption. All three countries support large export oriented phosphate industries based on indigenous phosphate rock. This region has not experienced reduced sulphur consumption in the past 3 years despite a substantial drop in the world demand for P_2O_5. The stability of sulphur consumption in this region is largely the result of compensating factors. The phosphate industry in South Africa has experienced a sharp downturn in consumption as their largest market, Brazil tightened restrictions on the importation of phosphoric acid. The loss of demand in South Africa has been compensated for by a marginal increase in consumption in the North African countries of Morocco and Tunisia. Both countries have maintained production of phosphoric acid and finished phosphates and have increased market penetration in Europe, the Middle East and Asia.

Significant development of the South African industry is unlikely due to the declining potential of Brazil as a market for phosphoric acid. The North African industries on the otherhand are expected to grow significantly during the 80's. Increased phosphoric acid capacity, both in the planning stages and currently under construction, indicates a potential for increased growth in this region.

Asia (Slide 4)

In Asia the largest consumers are India, Japan, Korea and Taiwan. To some degree the reduced consumption in these established markets has been somewhat offset by increased consumption in the newly developing phosphate industries in Israel and Jordan.

Oceania (Slide 5)

Australia and New Sealand constitute virtually all sulphur consumption in this region. A large portion is used in the production of single superphosphate - preferred because of sulphur deficient soils. This region is very sensitive to world economic conditions that affect demand for agricultural products.

More recently Australian fertilizer applications have been affected by a severe drought and recovery in the agricultural sector is expected to be very slow with potential for significant growth in the future very limited.

South America (Slide 6)

Brazil and Mexico are the main consumers in this region. Both have suffered set-backs in 1982 that have effectively reduced sulphur consumption. Future prospects for the region are excellent as both countries strive to develop domestic phosphate industries.

North America (Slide 7)

The severity of the current economic downtown has caused a marked reduction of sulphur consumption in the U.S.A. The Florida phosphate industry, the world's largest concentration of sulphur consumers has moved from being an expanding 6 million tonne market to a diminishing 4 million tonne market. In all, sulphur consumption in the U.S.A. is expected to fall 20% in calender year 1982 compared with 1981. Initially recovery is expected to come in late 1983 and 1984, but thereafter growth will be relatively slow and recovery to the 1980 consumption level is not expected until 1986.

Centrally Planned Economies (Slide 8)

The Centrally Planned Economies (Comecon, [including U.S.S.R.], and Socialist Asia) are the one bright spot in the current sulphur demand picture. The two largest consumers U.S.S.R., and China are both expected to increase sulphur consumption in 1982 and continue a moderate growth rate thereafter.

World (Slide 9)

Worldwide consumption of sulphur peaked in 1980 at 37.0 million tonnes, then declined 2 million tonnes in 1981 to 35 million tonnes, and is expected to fall a further 3 million tonnes or 8% in 1982 down to 32 million tonnes. The forecast shown here, prepared earlier this year indicates a fairly optimistic view of recovery in demand for 1983 and 1984. This recovery will depend largely on a turnaround in the phosphate industry. From another point of view the forecast could be considered conservative as it call for sulphur consumption in 1984 to be at the same level as that achieved in 1980.

Production (Slide 10)

The production of elemental sulphur is also adversely affected during an economic downturn. Involuntary or recovered sulphur is most seriously affected as the demand for energy - oil/gas - reduces the volume of hycrocarbon processed into consumer and industrial products. During the review period there has also been a significant reduction in voluntary sulphur production. Iraq, for example, produced over 700,000 tonnes of sulphur in 1980 but this was drastically reduced to less than 100,000 in 1981 as the Iraq/Iran war escalated.

Central America

In Central and South America, Mexico is the largest producer and supplier. The Mexican-Frasch industry is capable of sustaining a production level of approximately 2 million tonnes per year, and Pemex, the state petroleum company contributes up to 300,000 tonnes of recovered sulphur.

West Europe

In Western Europe the two largest producers are France and West Germany. Production in Germany is stable at 1.1 million tonnes per year whilst French production from the Lacq field is declining.

Asia - Including Middle East

Up until 1980 Iraq and Iran were the largest producers and exporters in this region. As mentioned previously Frasch production in Iraq has been seriously curtailed, and there has been no recovered sulphur production in Iran. The loss of production capacity in the Middle East has been replaced to some degree by Saudi Arabia. Sour gas associated with oil production is now being processed at three plants with a total capacity of 1.2 million tonnes of sulphur per year. However due to reduced off-take of oil, the Saudi Arabia sulphur industry has performed well below capacity - at around 750,000 tonnes. Movement of Saudi Arabia material has also been limited by export logistics.

Centrally Planned Economies (C.P.E.)

In the Centrally Planned Economies, Poland and the U.S.S.R. are the major producers. The Polish industry has reached a production plateau, and is not expected to increase production until 1987. In the interim period (1984-85) production and exports to the west could be reduced.

The U.S.S.R. is making considerable effort to increase domestic sulphur production and lessen dependance on imports. One major project not included in this forecast is the Astrakhan gas plant with a rated capacity of 2 million tonnes per year. This project is now under construction but is not expected to come onstream during this review period. When completed, however it will be one of the largest natural gas gathering systems in the World and a major sulphur producer.

North America

North America (Slide 11) is by far the most important contributor to the World supply of brimstone. Historically, North America has provided between 45 and 50% of the World's sulphur requirement.

The U.S.A. is the World's largest producer of elemental sulphur with a 1981 production of 10.6 million tonnes. Frasch production was 6.3 million tonnes and 4.3 million tonnes were recovered from oil and gas processing. Recovered sulphur production is expected to grow from the 4.3 million tonne level to 6.5 million tonnes by 1985. Frasch production will fluctuate during this period according to market conditions, but it is unlikely to exceed the 6.0 million tonne level. It is interesting to note that Frasch production was over 50% of total production in 1981 but by 1990 Frasch production is projected to be only 30% of total production.

A significant portion of the increase in recovered sulphur will originate from sour gas operations in the Overthrust region of the Western U.S.A. It is along the Canadian section of the Overthrust, in Alberta, that most of Canada's sulphur is produced. As with the Canadian sector, gas found associated with highly folded and faulted formations tends to contain high levels of H_2S.

Activity in the U.S. Overthrust is centered around the Wyoming/Utah border. Extensive exploration and development in this region has revealed large quantities of sour natural gas. Two major U.S. corporations, Chevron and Amoco have built plants in the area to process the sour gas and produce sulphur. Total capacity of 700,000 tpa is due on stream this year but until gas pipeline infrastructure is completed early in 1983, and markets are found for the natural gas, sulphur production will be relatively small.

Canada (Slide 12)

The sulphur industry in Western Canada is based on sour natural gas processing which has experienced large scale growth in production since modest beginnings in the late '50's. With natural gas being the primary product, sulphur production volumes usually exceeded sales and large stockpiles were accummulated. Sulphur production in Canada peaked in 1973 and reservoirs producing sour natural gas have been declining ever since. Inventories grew until 1978 when they exceeded 20 million tonnes.

With growing export markets in the U.S.A. and offshore the industry invested heavily in re-melting capacity and additional forming, loading, transportation and terminal facilities in the late 1970's in order to supplement production with sulphur from inventory. Remelt of block inventories reached a peak of 2.4 million tonnes in 1981 and accounted for 30% of total sales from Western Canada. (Slide 13) Inventories at year end 1981 stood at 16 million tonnes, down considerably from their peak in 1978.

The trend of declining production established over the past 10 years will continue at an accelerated rate during the 1980's. (Slide 14) However there are some factors that could affect the decline:

— Development of new conventional sour gas reserves.

Construction of additional tar sands or heavy oil plants.

Development of high H_2S reserves.

Exploration has shown that the bulk of new gas reserves discovered in Western Canada are sweet and do not contain sulphur. Only one new gas plant is scheduled on stream before 1990. Other sour gas will be directed to existing plants and will help stem the decline at these plants.

Development of very sour gas (90% H_2S and over) will depend on the outcome of research to overcome technological production problems, stable long term sulphur pricing will be necessary before these plants are built as they will produce only sulphur, and not natural gas.

It is expected that Canadian inventories will be required throughout the 80's to supplement world production of sulphur. The rate at which these inventories will be depleated will depend on the demand for sulphur and the rate of export shipments from the Port of Vancouver. Given the current rate of shipments of about 5.0 million tonnes per year, the inventory could be depleted by 1990. (Slide 15)

Conclusion

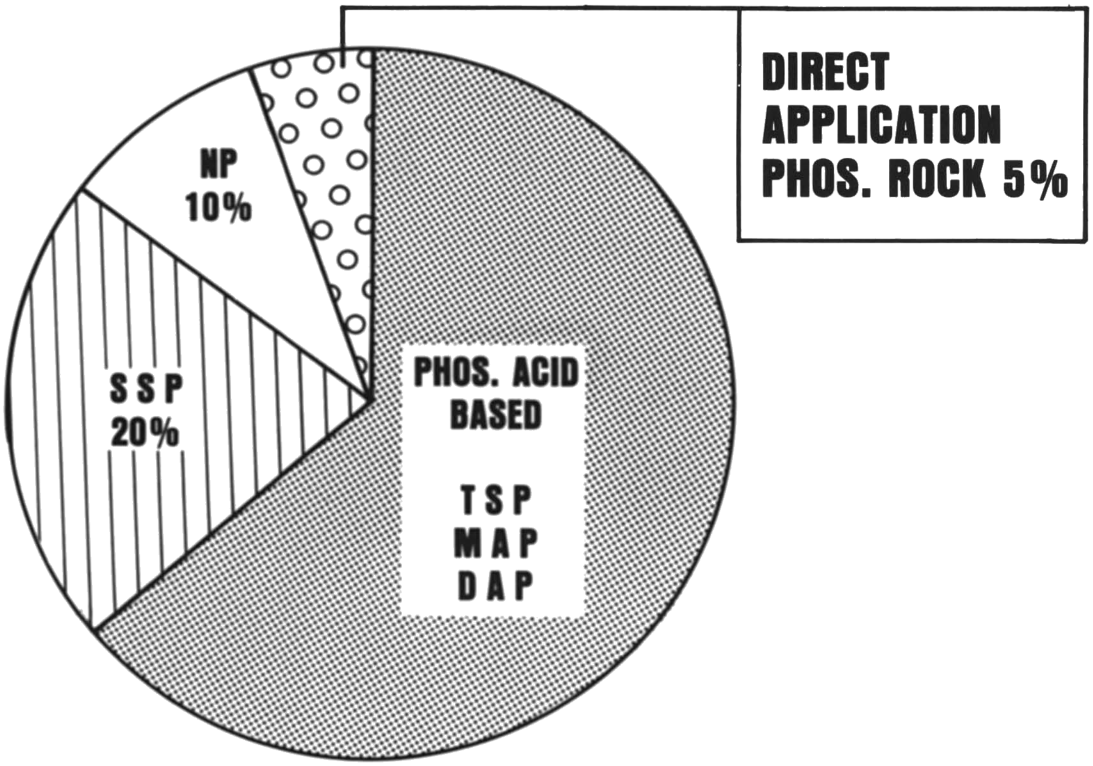
Turning now to the world supply/demand balance. (Slide 16) In 1982 consumption (demand) is expected to be down 8%. Production down 6%. Requirement for removal of material from inventory is negligible. In previous years, demand exceeded production and in 1980 and 1981 1.9 million and 1.4 million tonnes respectively were removed from inventories in the U.S.A. and Canada in order to balance the market. In 1982 and 1983 the market does not require a supplement from inventory as production and demand are virtually in balance. Assuming that there is a turnaround in the current recession, then sulphur consumption is forecast to increase moderately in 1983, followed by a marked improvement in 1984. Production is also expected to increase as the economic climate improves.

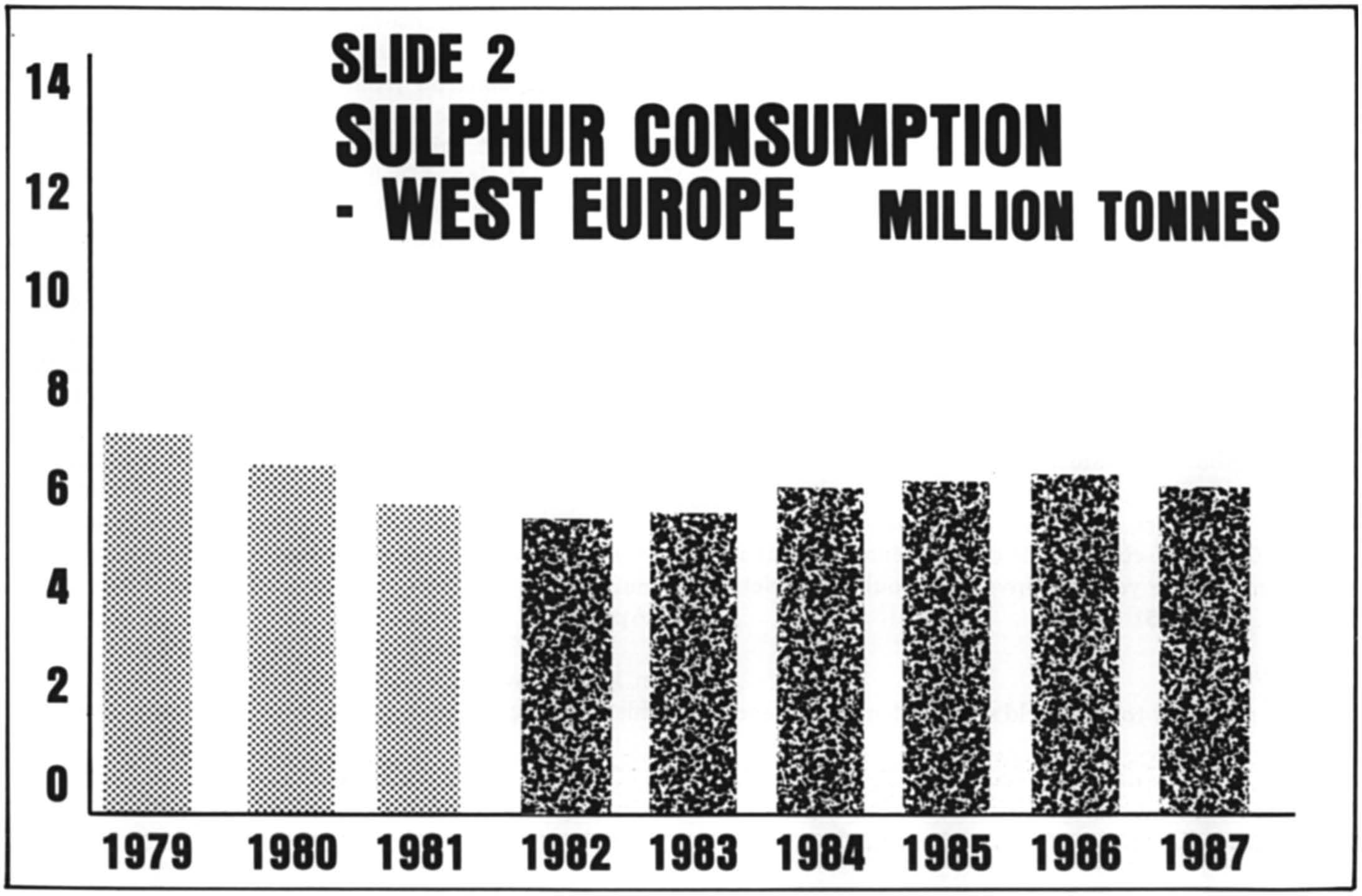
After 1984 it is assumed that demand will increase according to historical trends at about 4.5% per annum. If this is the case, then from 1984 onward sulphur from inventories will again be required to provide a balanced market. I appreciate your kind attention. Thank you. (Applause)

MODERATOR BLENKHORN: Thank you, Barry. In keeping with the "Outlook Paper," we have heard this morning, yours was also excellent. (Applause)

PHOS. FERTILIZER CONSUMPTION

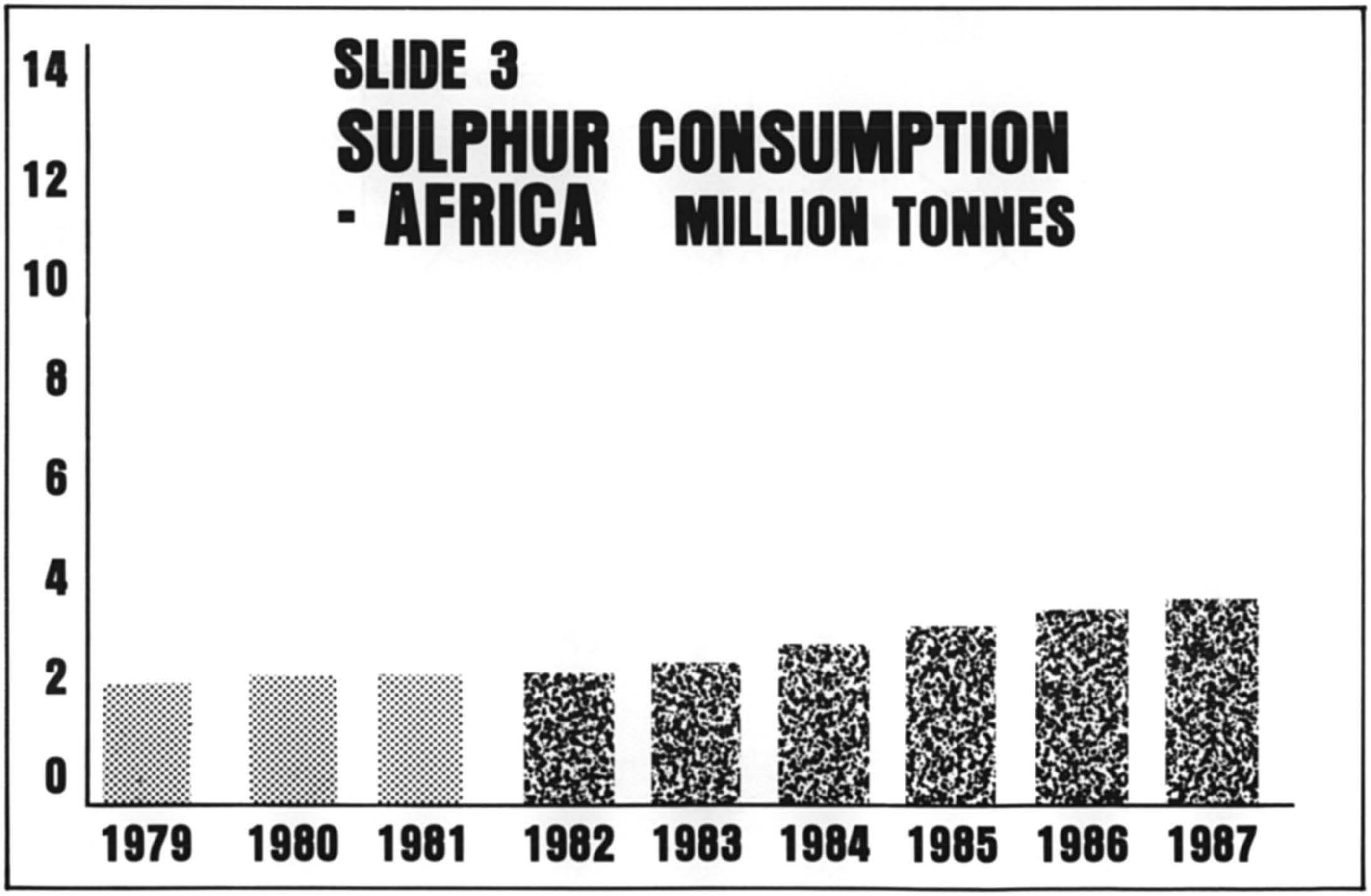
SLIDE 1





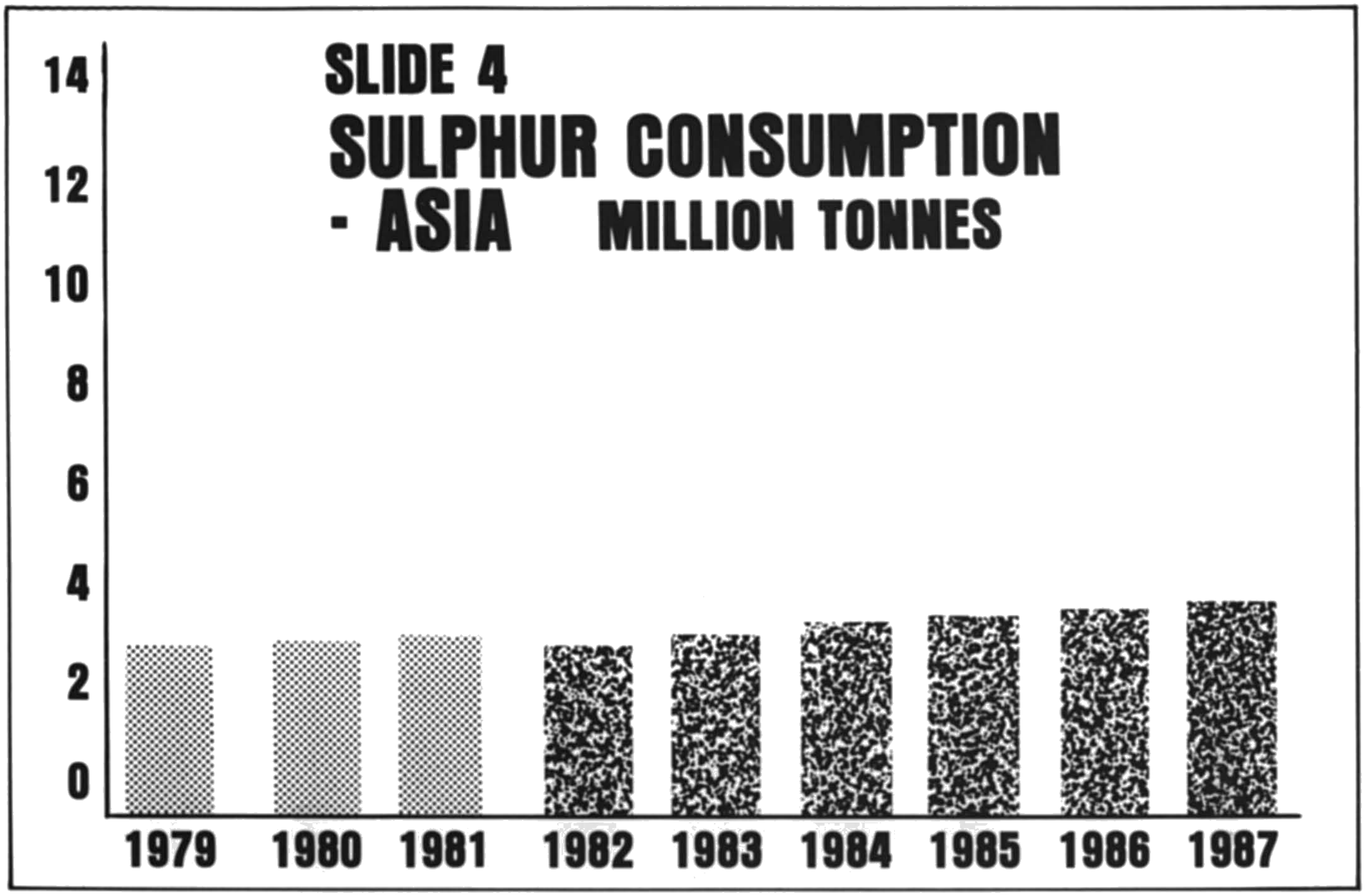
SLIDE 2

SULPHUR CONSUMPTION - WEST EUROPE MILLION TONNES



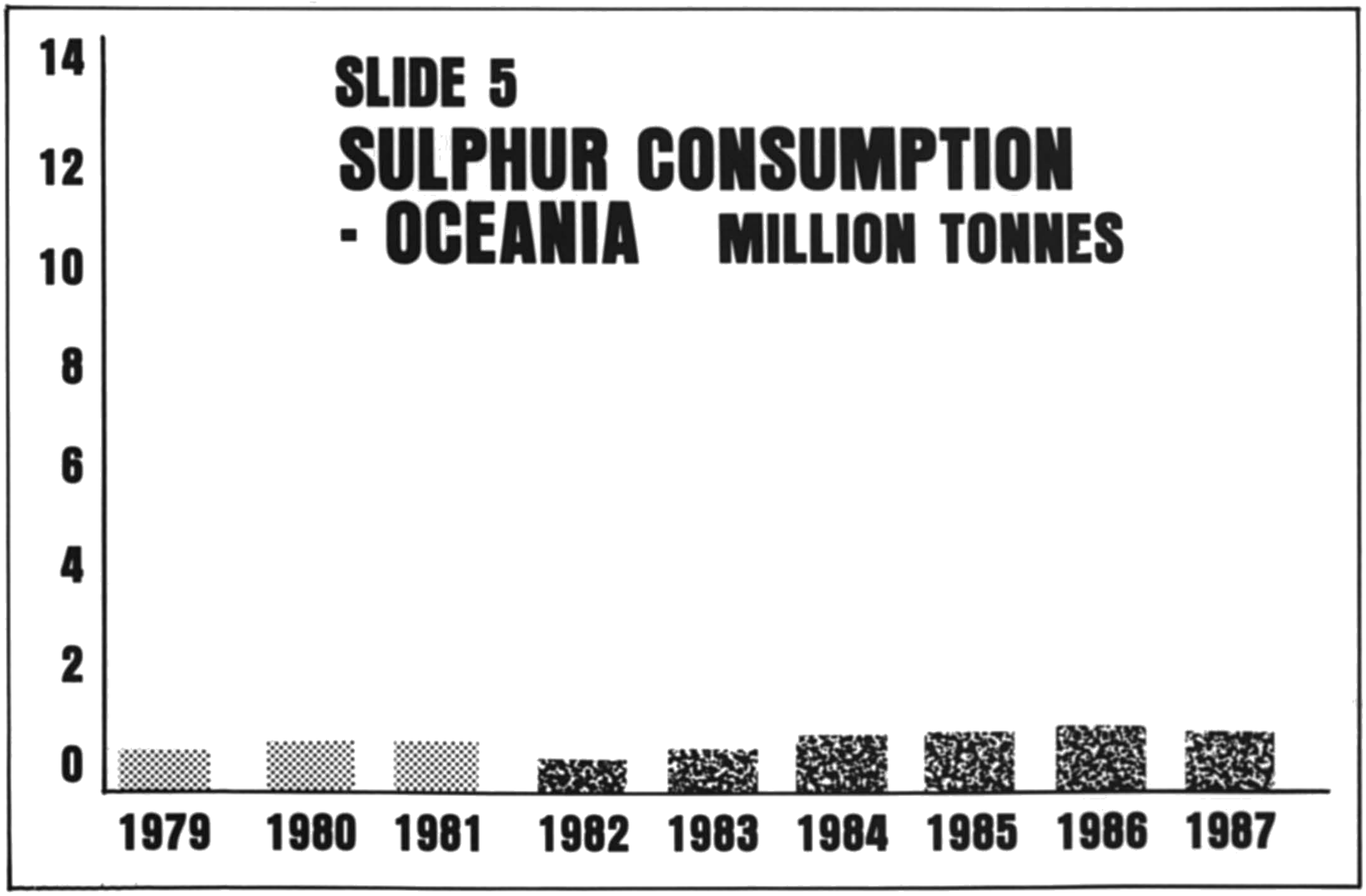
SLIDE 3

SULPHUR CONSUMPTION - AFRICA MILLION TONNES



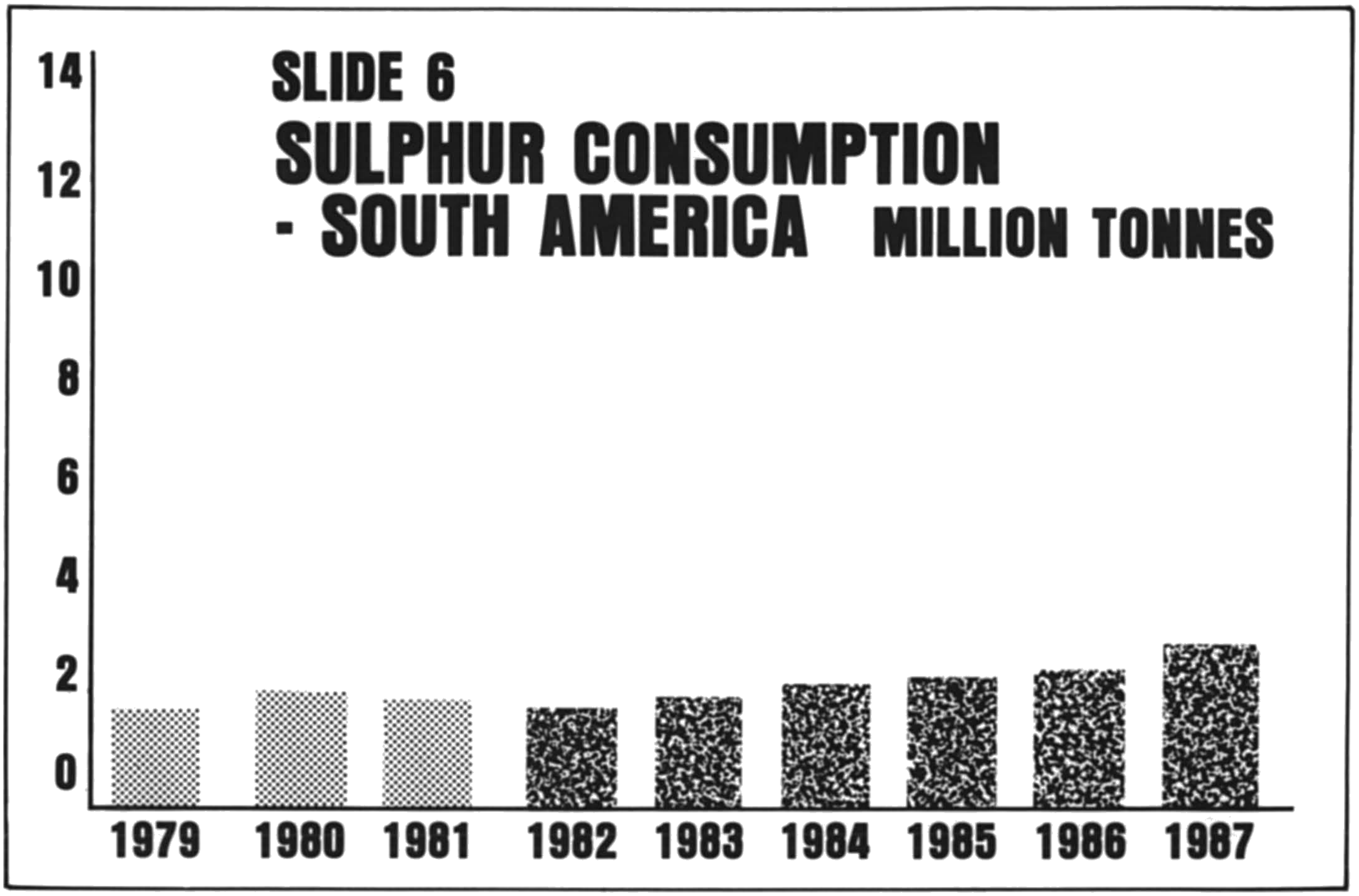
SLIDE 4

SULPHUR CONSUMPTION - ASIA MILLION TONNES



SLIDE 5

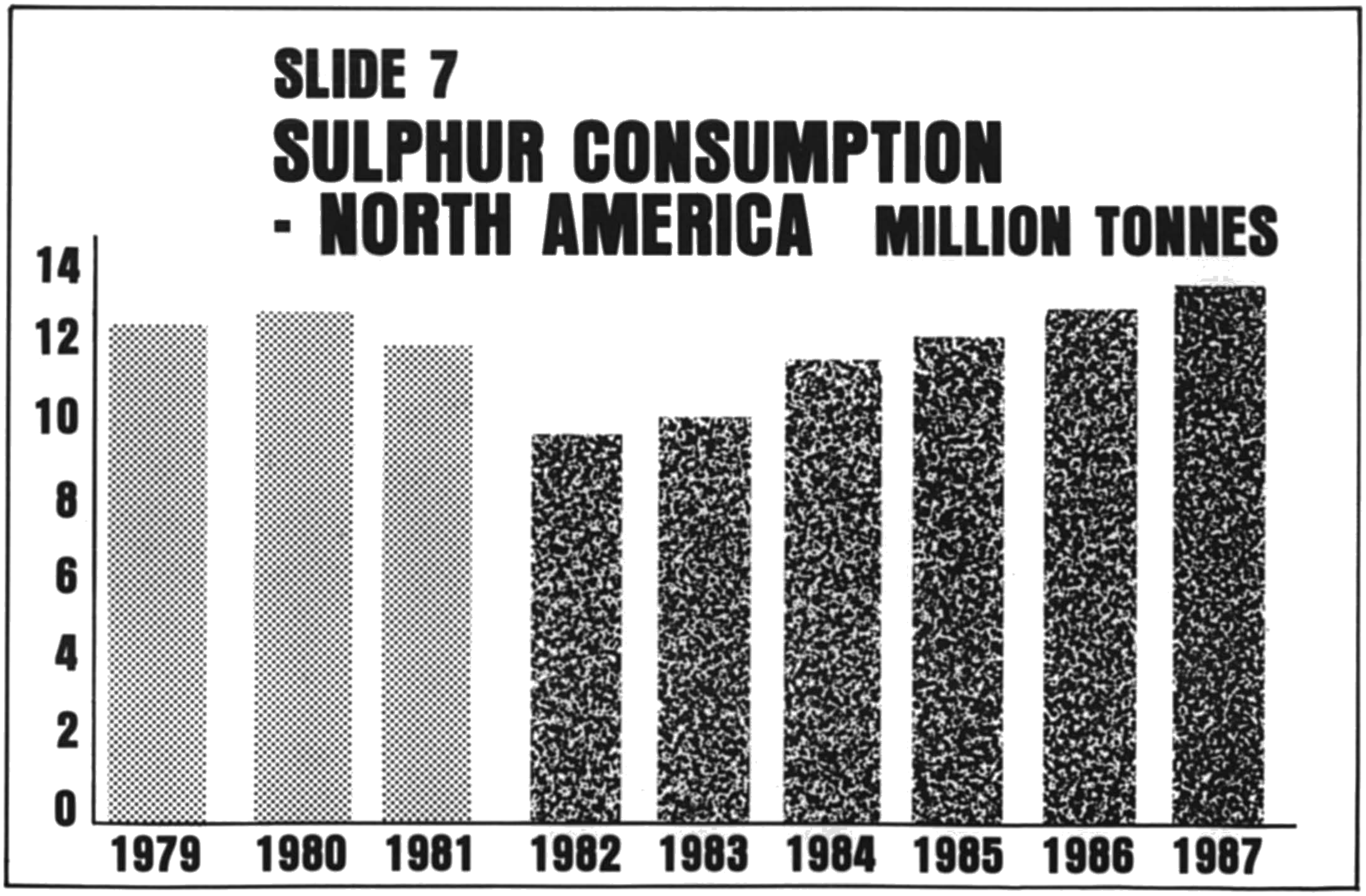
SULPHUR CONSUMPTION - OCEANIA MILLION TONNES



SLIDE 6

SULPHUR CONSUMPTION - SOUTH AMERICA

MILLION TONNES



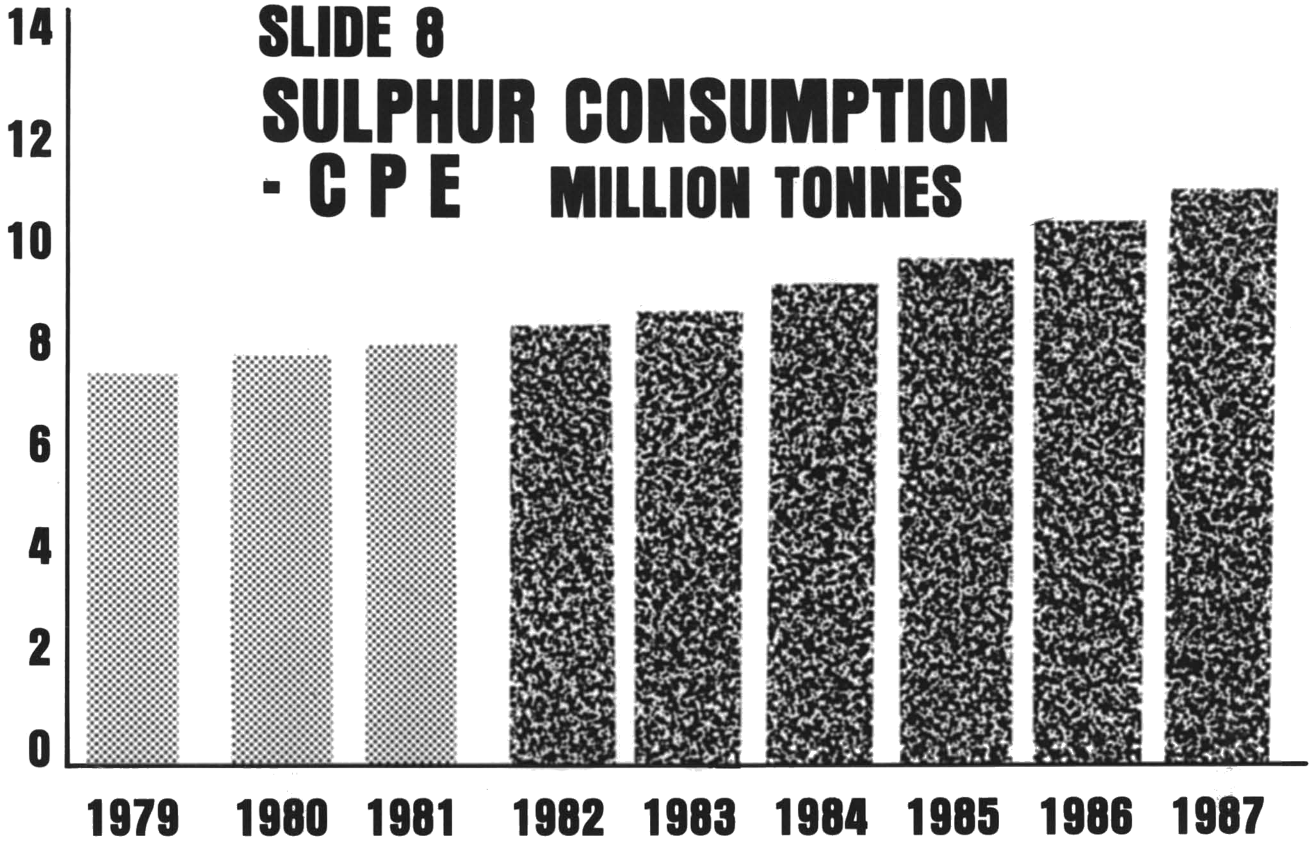
SLIDE 7

SULPHUR CONSUMPTION - NORTH AMERICA

MILLION TONNES

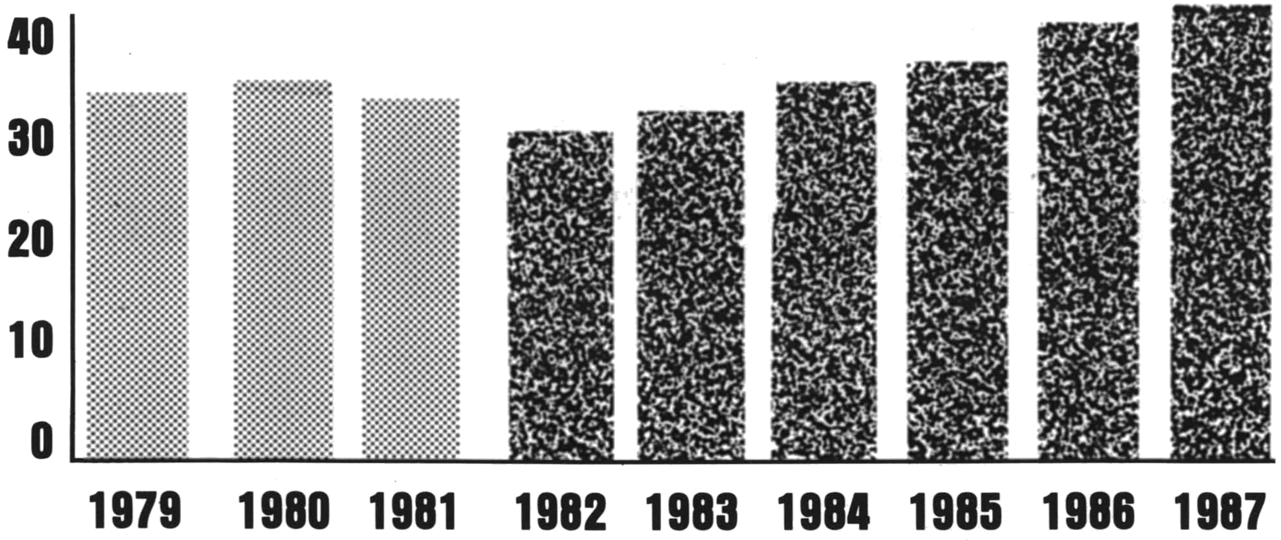
SLIDE 8

SULPHUR CONSUMPTION - C P E MILLION TONNES



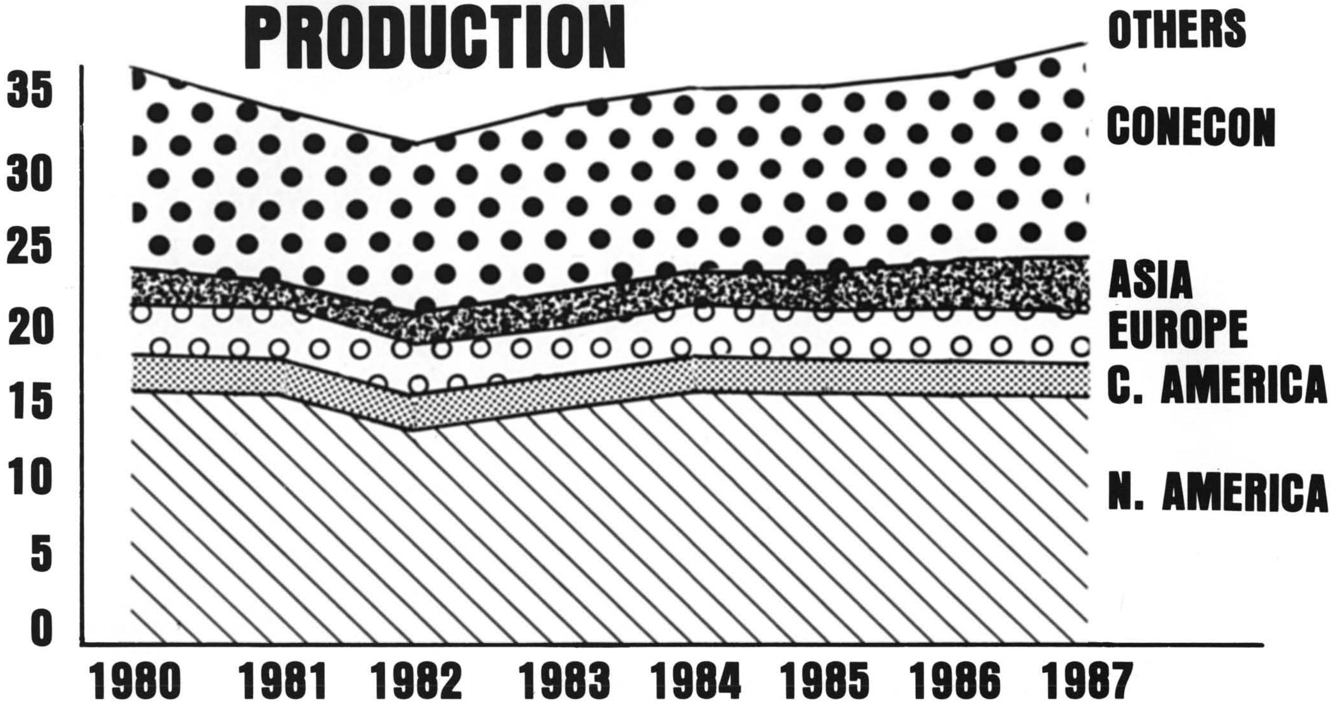
SLIDE 9

SULPHUR CONSUMPTION - TOTAL WORLD MILLION TONNES



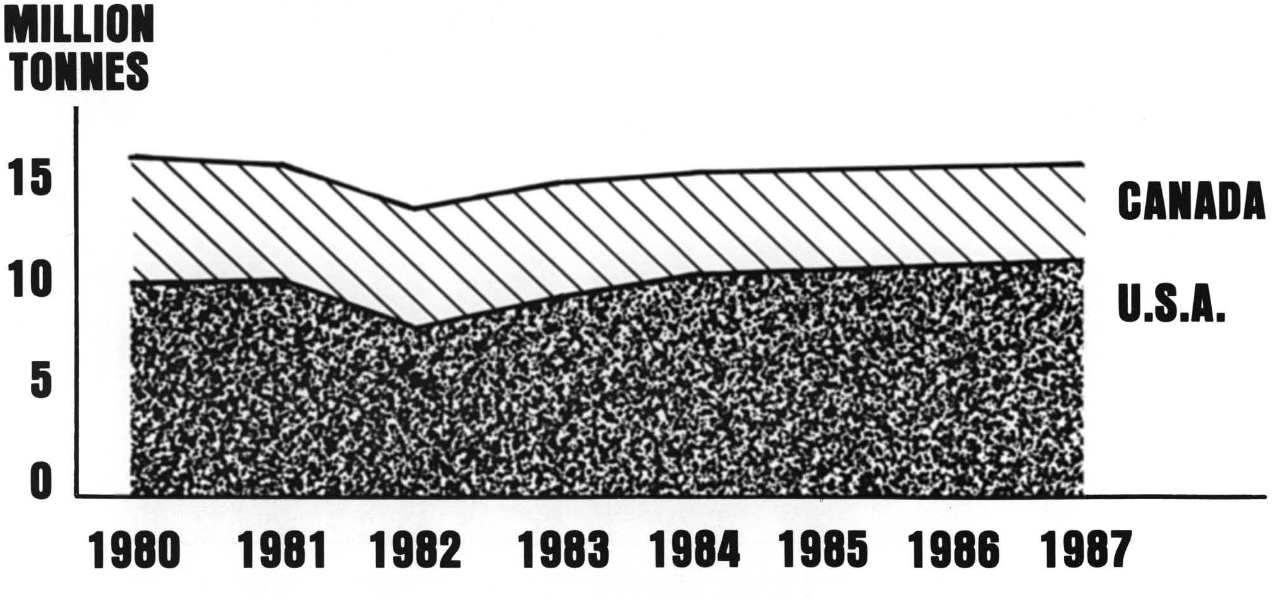
SLIDE 10

WORLD BRIMSTONE PRODUCTION



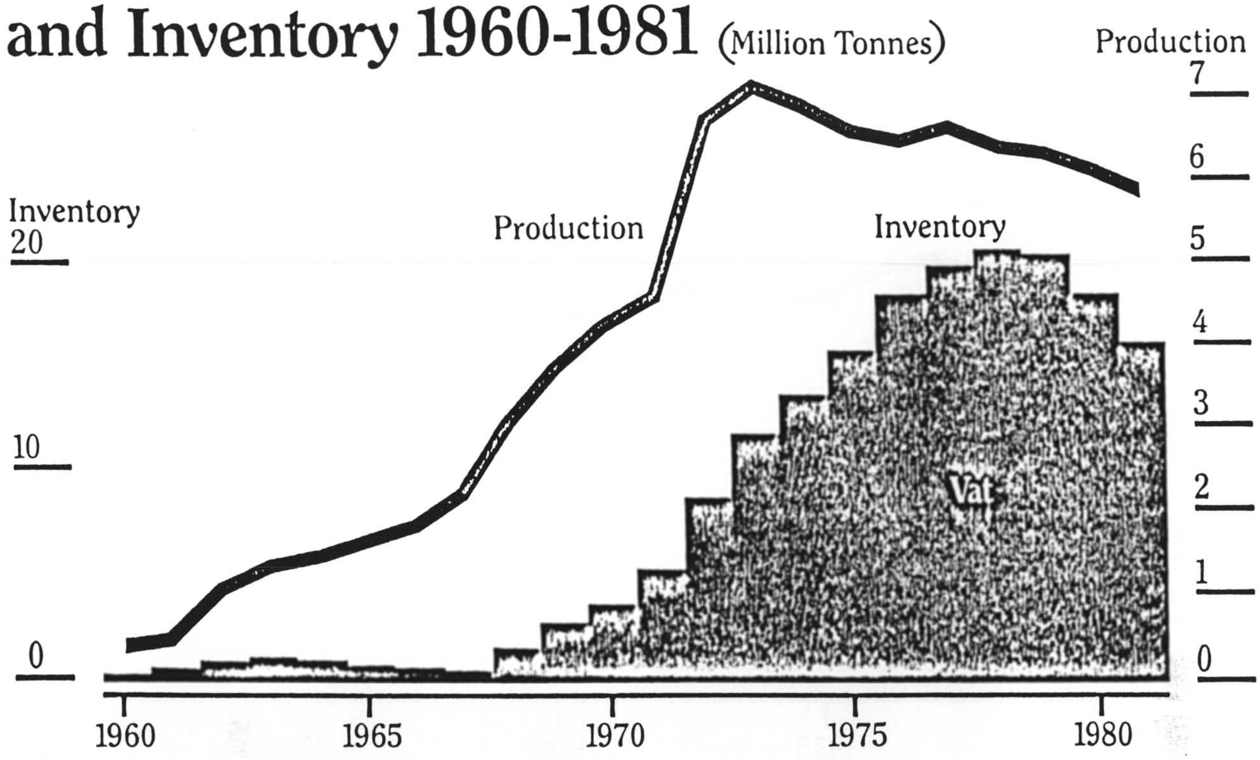
SLIDE 11

BRIMSTONE PRODUCTION - NORTH AMERICA



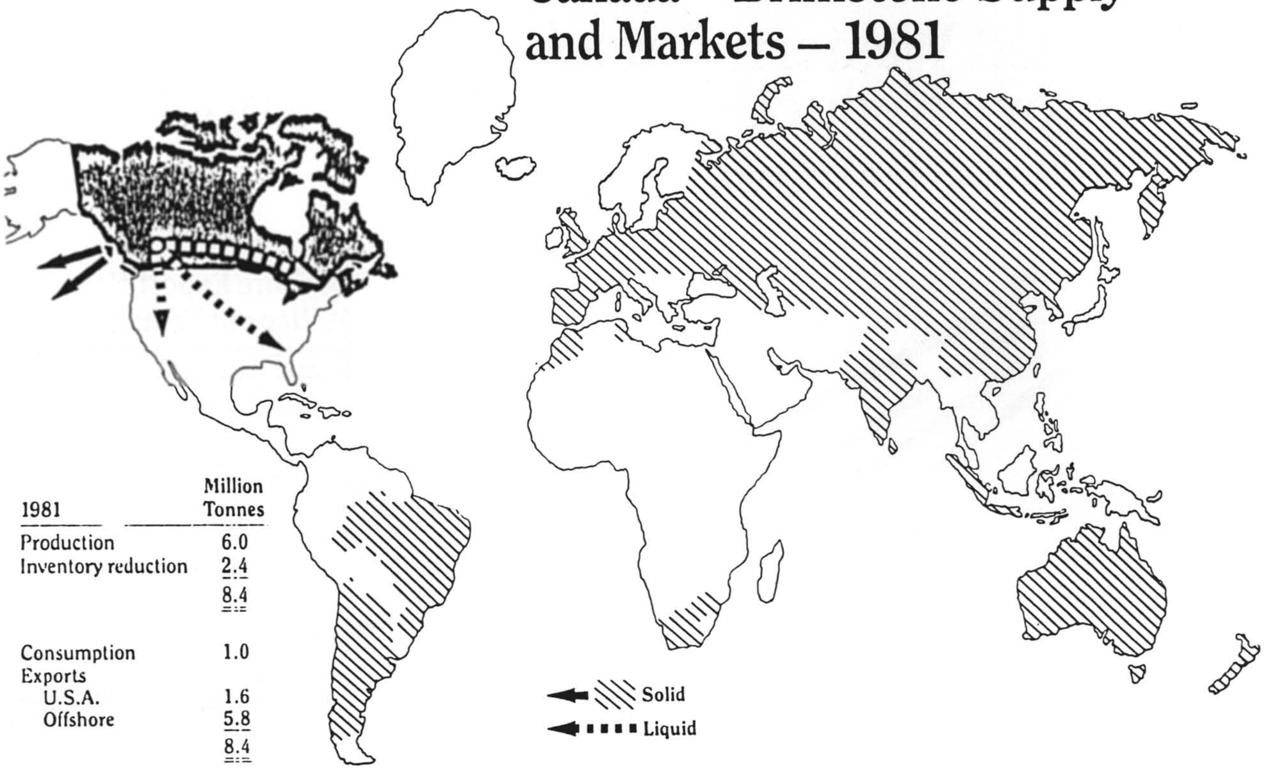
SLIDE 12

Western Canadian Sulphur Production and Inventory 1960-1981 (Million Tonnes)



SLIDE 13

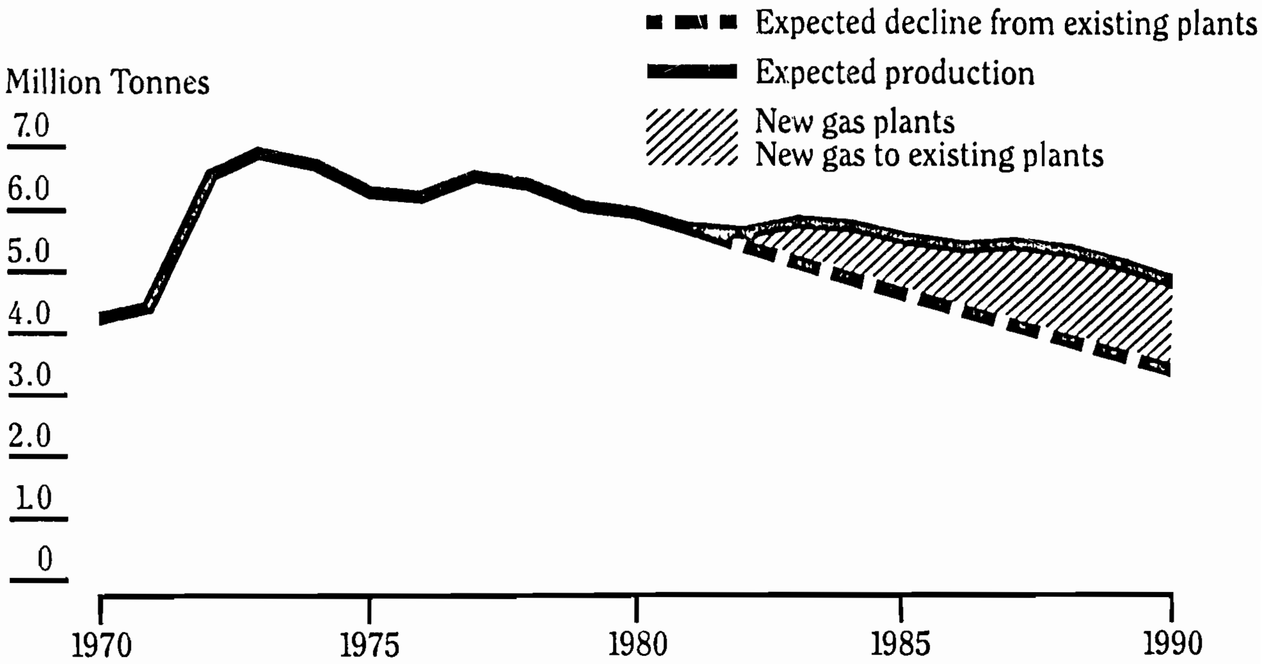
Canada – Brimstone Supply and Markets – 1981



1981	Million Tonnes
Production	6.0
Inventory reduction	2.4
	8.4
Consumption	1.0
Exports	
U.S.A.	1.6
Offshore	5.8
	8.4

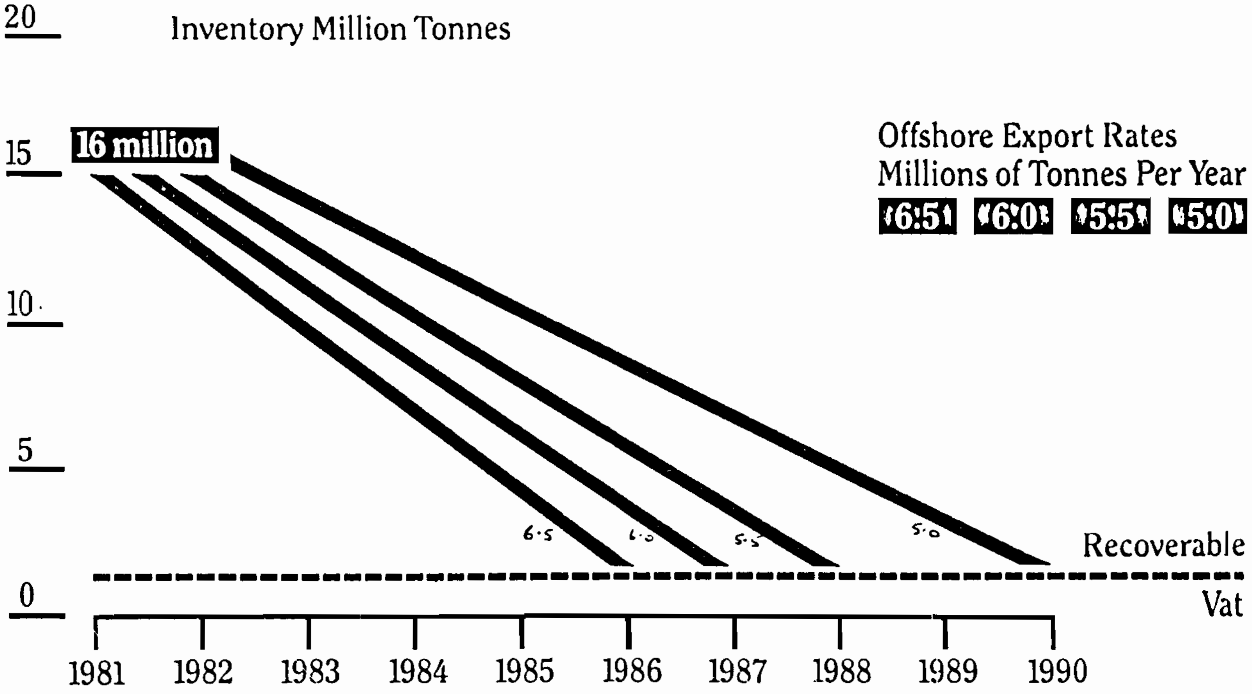
SLIDE 14

Alberta Sulphur Production to 1990. Existing Plants and Additional Production

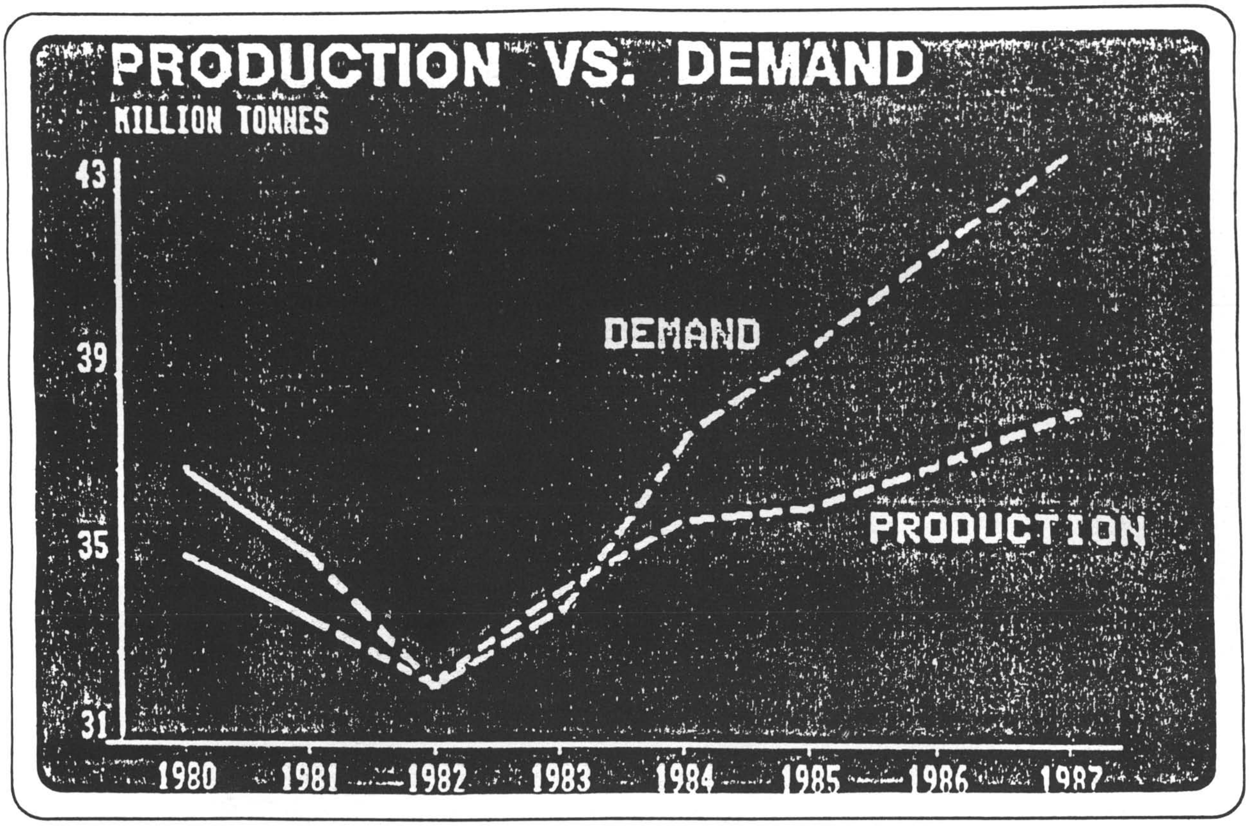


SLIDE 15

Projected Western Canadian Inventory Reduction At Various Export Rates



SLIDE 16



MODERATOR BLENKHORN: In considering supplies of materials we tend to forget that these materials, whether finished goods or intermediates, have to be transported to markets or points of usage. We have with us another highly qualified representative of International Minerals to discuss the topic of transportation. Our next speaker, Tom Regan, is a native of Pennsylvania. Tom graduated magna cum laude in Chemical Engineering from the University of Pittsburgh. He tells me that he spent 19 years in the coal industry, during which time he designed and brought into operation the first coal slurry pipeline in the U.S.A., which explains the connection between engineering and transportation. Tom joined I.M.C. in 1967. His present position is Corporate Vice-President, Traffic and Distribution. (Applause)

Status of Logistics of Transportation, Storage, Handling and Distribution of Basic NPK Commodities

Tom Regan

Good morning, ladies and gentlemen! I certainly hope all of you were as impressed by the title of my little discussion this morning as I was. However, I hope none of you expect a long technical dissertation because that is not my intention.

The key word here is, LOGISTICS. Of course logistics is just another fancy word for having the right product - in the right place - at the right time - in the right amount to satisfy the desires of your customers and at the optional cost to you. What makes it so extremely important to the economic makeup of our country is that the dollars associated with logistics represent over 20% of our gross national product. Now let's look at the important factors that make up logistics.

Naturally, one element is the transportation cost. That is, the cost for the movement of raw material in and product out of your place of production. Then we have the warehousing and inventory costs - of which we are all too familiar. Then there is the cost associated with order processing and customer communications. Finally, as with every other system in our corporate makeup — we have administrative costs. From the standpoint of dollar commitment, working capital, or whatever term you choose to use, the largest category is transportation. However, in the past it received the least attention when marketing and sales strategies were being formulated. The reason being if you were a bulk shipper, which the fertilizer industry is a prime example, you are highly dependent on the railroads for the movement of your products and they were a regulated, utility-like industry. If you wanted to know the costs you called up somebody in the traffic department, they looked it up in a published tariff and reported the associated rate which was known to the Good Lord and all your competitors. Well, that has all changed - yes, we are in a new ball game today with respond to transportation. It is this new transportation atmosphere and its long-range effect on our industry that will be the subject of my discussion this morning.

As a corollary I would like to put into the proper perspective the tremendous amount of talk you have heard recently about the deregulation of the transport industry.

Essentially, there are three modes of transportation in this country with regard to the movement of fertilizer and fertilizer commodities. They are namely, water, truck and rail. Now I know somebody in the back is going to say, "Hey, that doesn't add up to 100% - it only adds up to 97%. He is quite right. There is a fourth mode namely pipeline which accounts for a rather miniscual 3%. If you want to be pristine about it - there is a fifth mode, namely air - but I don't know of many tons of fertilizer or fertilizer materials that move by air -so I think it is safe to eliminate it from our analysis.

With regard to water, the recent legislation has had essentially no effect. Water has been, and still is, about 95% non-regulated. The other two modes saw two major pieces of legislation passed in 1980 which drastically effected their way of conducting business. These were the Motor Carrier Act of 1980 and the Stagger's Rail Act. In the motor carrier activity the most significatnt change was the ease with which authority could be obtained. This is the so-called "free entry" policy. However, the motor carrier must still be fit, willing and able - must have authority even though he encounters no obstacles in obtaining it - must carry the proper insurance and adhere to the DOT safety standards for his equipment. However, there is a situation that is developing - and I might add, accelerating - complete deregulation by some states of all intra-state truck movements.

At last count, the states of Florida, Arizona and Wisconsin have completely exempt all intra-state movements. What this means in the economic area is that the carrier is free to charge whatever he chooses for his services. Now in the area of safety - driver's loss and hours of driving, each state will set its own standards.

It is in the rail industry that the legislation has had the greatest effect and brought about the most significant changes. As a matter of fact, the rail industry is free at the present time to make any level of rate it so chooses as long as it can be shown that transportation competition exists for the associated movement. Where no competition exists, where the railroad has market dominance, the rates must be just and reasonable and subject to the jurisdiction of the Interstate Commerce Commission.

Some may say, "That's wonderful - we finally got the government out of the railroad industry." However, the definition of market dominance has become a very formidable stumbling block for the regulatory enactment law. In fact, the original definition of market dominance was associated with the Four R Act passed in 1976. It was challenged by the railroads and the ensuing argument resulted in the Four-R Act being superceded by the Stagger's Act passed in 1980. Congress recognized the plight of the captive shipper in mandating that market dominance be a fctor to be considered in both the Four-R Act and the Stagger's Act. Unfortunately, the definition was left up to the Interstate Commerce Commission. Incidently, the Commission's original definition along with other stipulations of the Stagger's Rail Act would leave only about 15% of the existing rail rates under commission jurisdiction. I could spend the rest of the day discussing the ramifications of this item but I will leave it since it is still being argued in the courts. So often two laws have been passed by Congress we still do not have a definition of Market Dominance. It suffices to say that the Stagger's Act has afforded the railroads complete freedom to make any level of rates they choose where it can be shown that effective transportation competition exists. Again, I can hear someone in the back saying, "Well, that's all well and good, but how is it going to affect me and my business?"

Alright, let's discuss the two items that are of greatest interest to you. That is, service and the price of service. With regard to service, the present situation reminds me of a story of the sweet little thing that went to her sweetheart and said, "Honey, I've got some good news and some bad news." He said, "Well Sweetie, what's the good news?" She promptly replied with a smile, "You're not sterile."

Let's look at water transportation first since the regulatory changes have the least effect on this mode. Water is still the cheapest transportation mode available to the bulk shipper. Unfortunately, the Good Lord didn't make the inland water system available to all of the geographic areas of the country. However, those of you who can use it—please do. With the present overcapacity of the barge industry, the quantity and the quality of service available is excellent.

With the trucking industry, a very interesting situation is developing. Due to the ease of entry resulting from the passage of the Motor Carrier Act, there has been a significant increase in the number of carriers. What does all this mean? - very low rates, new truckers appearing on the scene, relaxed regulations - it seems the trucking industry is heading into the same situation from which the railroads are emerging. That is an era where excess capacity results in bankruptcies. In fact, recently, several of the largest trucking concerns have filed for bankruptcy. Be assured, the survivors of this alley fight will be tough and hard businessmen.

With regard to the railroad industry - the combination of mergers and branch line abandonments leave no doubt that the quantity of service available will be drastically reduced in the future.

The Stagger's Act has greatly enhanced the ability of the railroads to accomplish abandonments. As a matter of statistics, in 1981 the Commission received 162 applications for rail abandonments - acted on 140 and granted the abandonment in 139 of those 140 active cases. Further to the point, comparing the miles of railroad today with that which existed in 1979 - we see an overall reduction of approximately 10%. More significantly, some of the states such as Iowa, Michigan, and Oklahoma show a 30% reduction. What does all this mean? - It means the railroads are going to concentrate their activity on mainline, high-density corridor movements. These are the movements that are compatible with trainloads and produce the highest profit for the railroads. Also, the railroads have added significantly to their railcar fleets. This is especially true of covered hoppers which are utilized by the fertilizer industry. They have also increased the number and size of their power units. What does it all add up to? There is going to be less service available - however, the quality of service that is available will be much better. But remember, to obtain this high quality service from the railroads you will have to be on a high-density line where there is plenty of movement.

While on the subject of rail service, the Stagger's Act has presented the opportunity for the shipper to avail himself of good service through the use of contract rates. Frankly, I feel that in order to get the attention of a railroad, with regard to a contract, you must have a competitive system whereby the tonnage can be removed from the rails. After all, why should a railroad listen to a shipper and bind himself to a lower rate, more stringent operating conditions, or both, if they are not threatened by a loss of revenue through the removal of tonnage. Well, so much for the quantity and quality of service - what about the price? - or the more common term, freight rates?

In the area of water the rates are extremely low at the present, due primarily, to the existance of an excess of barge capacity. Now this excess capacity will not disappear with bankruptcies. The bankruptcies will only make barge bottoms available at bargain prices for the survivors. However, there is a sword of this sort of Damoclese hanging over the barge companies - the user fee problem. The effect of user fees is anybody's guess at the moment - from minimal to catistrophic. Personally, I feel when it comes, the effect will be on the minimal side. Likewise, the trucking industry is going through a period of turbulance - low rates due to extremely active competition as a result of the increased number of trucklines. However, with railroad abandonments and mergers, I see a greater dependency on the trucking industry to provide the flexibility required for accomplishing the final delivery of good and materials. Therefore, the rates should go through a period of stabilization then begin to rise as the strength of the survivors of this present cut-throat atmosphere is felt.

Finally, with the freedoms afforded, the rail industry in the area of freight rate making by the Stagger's Act there is no doubt that railroad rates are going to increase. The two major areas of rate freedom are:

1) The rates may be increased quarterly to cover the cost of inflation as indicated by an index to be calculated by the Interstate Commerce Comission. Incidentally, there are public hearings being held at the present time to determine the method of calculating this index.
2) A so-called zone of flexibility equal to 6% of the prevailing rate. Now this is over and above the inflationary effect and is used solely at the discretion of the railroads.

It must be understood that in both these areas, the shipper cannot challenge the action of the railroad regarding the rate increase.

There you have it - an atmosphere of dynamic and unprecedented change - an atmosphere where water and trucks are lowering rates - rails increasing rates while reporting record earnings. This is exactly the atmosphere that exists in the transportation industry today.

On the other hand - this is an aura of comparative peace and contentment for the bulk shipper. In the water and trucking areas he has the availability of low rates - with the rail industry his every desire for car supply meets with immediate satisfaction. How long is this going to last? - if someone can tell me when our economy is truly going to turn around, I might be able to give them their answer and we can all join hands and skip down the yellow trick road to the land of Oz together.

Now that we have talked about the present situation, the next question to ask ourselves is, "Where are we going?" - both from the carriers' viewpoint and the shipper's viewpoint. You know, I like to predict the future, in fact, it runs in my family. I had an uncle once who not only predicted the day he would die but also predicted the exact hour - that's because a judge told him!

Well let's look at the carriers first. On the rail side what I see emerging is a strong system consisting of five or six large carriers concentrating on trans-continental moves in high-density corridor areas. This is in contrast to today's present 30 or more Class A rail carriers. I see a tendency for greater dependence on the trucking industry for the final delivery of goods and materials. And finally, I see a closer coordination between all transportation modes to ensure the most efficient use of each. This is evidenced by one of the largest rail carriers in the country offering to handle on a single bill-of-lading, the truck movement from a shipper's plant the transfer from truck to rail - the long haul by rail - and finally the truck delivery to destination.

Moving on the shipper's side I see a more business oriented attitude being used in making the transportation decisions. But first, a word of caution - the worst thing that we as shippers and businessmen can do is to be complacent and ignore the present fast-moving stream of proposed changes in the regulatory laws. As an example, the railroads are regulatory laws. As an example, the railroads are seeking to establish by regulatory law, a Standard Revenue Adequacy for their industry that very few, if any, of the Fortune 500 Corporations could obtain. The reason this revenue adequacy standard is so important is the fact that as long as the railroads are considered to be revenue inadequate, they can prevail in their requests for rate increases. In addition, they are attempting to broden the definition of market dominance so that no shipper will be considered captive to the railroads. In essence, this will remove all rail rates from ICC's jurisdiction and abolish the concept that the rates must be just and reasonable. The effect would be to drastically increase the rates on such items as fertilizer ingredients, coal, and grain - raw materials that make up the foundation for the economic welfare of the country. The detrimental inflationary effect of these rate increases would be magnified as they coursed through the higher levels of the economy of the country.

There will be a greater use of the contract mechanism to obtain rates and service commitments. This will of course, produce an erosion of the common carrier obligation. How beneficial this trend will be is hard to say. Only time itself will give us the answer.

I see transportation decisions being more business oriented rather than the pre-Stagger's reliance on ICC regulation. Therefore, a much closer coordination of transportation with the other corporate disciplines such as, production, sales, marketing is required. Gone are the days when the vice president of marketing and sales tells his president in a budget meeting that he has the transportation costs covered in his numbers by saying casually, "I added $20/ton and two weeks to cover that item." Transportation will have to become an intregal part in formulating corporate business strategies. In turn, transportation officers will have to formulate long-range plans that dove-tail with the other disciplines of the corporation.

In spite of all the sound and fury that surrounds transportation, the opportunity exists for the mutual enhancement of both carrier and shipper. This is going to require the virtual elimination of adversity and the development of an attitude of mutual trust between both parties. To some it may sound like an unsurmountable task. I do not think so - at least I sincerely hope that both the shippers and carriers will use their new found freedoms wisely to strengthen both our domestic economy and our competative position in the world markets.

It is quite obvious that any country which has a land mass of almost 4 million square miles and 95% of its over 200 million population lives on only 5% of that land mass, a financially strong and efficient transportation system is vital to its well-being. I think this is what congress had in mind when they passed the Motor Carrier Act of 1980 and the Stagger's Rail Act. It is unfortunate that the regulatory interpretation of these laws has percipitated such strong and lengthy arguments. But this too will pass. Nevertheless, let's hope that the stabilization and efficient use of the transportation facilities in the country becomes a reality as quickly as possible.

One final thought - let's also hope that these transportation facilities remain in the free enterprise system because it is the free enterprise system that is the backbone and strength of what America is all about.

Thank you. (Applause)

CHAIRMAN ACHORN: I certainly want to thank you Tom..

We have had a full program this morning and are running short of time, so we will not have a question period. If any of you have specific questions on the various subjects covered this morning, I suggest you contact the speaker directly and I am sure he will answer them.

We will meet in this room at 1:30 to start the afternoon program. I encourage all of you to come because this is the part of the program where we start to get into the nuts and bolts of fertilizer manufacture. We will be discussing processes and how to control them, new processes and energy conservation measures, all of which are important to fertilizer production people.

Again, I want to thank all of the speakers. Let's give them a good hand. (Applause)

Tuesday, October 26, 1982

Afternoon Session
Moderators

Frank P. Achorn
David W. Brochstein

CHAIRMAN ACHORN: We have an excellent afternoon planned for you. Your moderator is David Brochstein. David has been very active in work with the Fertilizer Industry Round Table. He is a member of the Round Table Board of Directors and has contributed greatly to the success of this organization. He is Manager of Field Operations for USS Agri-Chemicals, Incorporated, a division of U.S. Steel Corporation, and is located here in Atlanta. David. (Applause)

MODERATOR BROCHSTEIN: Thank you Frank. Welcome to this Tuesday afternoon session of The Fertilizer Industry Round Table. It is my pleasure and privilege to act as your moderator for this program. We have some most interesting subjects that will cover granulation, emission control, ammoniated TSP, insulation, and lower energy ammonia. Let us please reserve our questions until all speakers have completed their talks.

Our first speaker will be Doug Myers. He will present "Practical Processes for Determining Losses from Granulation Plants." Doug is a chemical engineering graduate of Oklahoma State University. He has been with TVA since 1953 in various assignments. Since 1966, he has been a Chemical Engineer with TVA's Division of Chemical Development, investigating air and water pollution problems associated with plant operations, to study and produce new and improved fertilizer materials. Doug, may we please have your presentation. (Applause)

Practical Processes For Determining Losses From Granulating Plants

Edwin D. Myers

Pollution abatement and control are major concerns in TVA's development of new and improved fertilizer processes. Various equipment configurations, combinations of formulations, and operating conditions are tested to ensure that losses of process materials to the environment are minimized. Such tests are gegun with small-scale studies and are continued through all phases of process development. When new processes are initially adopted, either commercially or in TVA demonstration production units, tests may be made to measure losses of process materials and to evaluate methods of pollution control and plant modifications needed to comply with government regulations on plant emissions. Also, periodic measurements of emissions from full-scale production facilities are made to ensure that the installed pollution control equipment continues to perform satisfactorily.

TVA's experience in pollution abatement and control has led to the development of some equipment and procedural innovations tailored to the needs of the fertilizer industry. These innovations, some of which are discussed in this paper, include equipment that can be easily fabricated or assembled. Also, the equipment is well suited for use in fertilizer plants because it is portable, rugged, corrosion resistant, relatively inexpensive, and sufficiently accurate for obtaining data for new process design.

Standard Gas-Sampling Train

Figure 1 shows a sampling train that is used to sample stack gases isokinetically at sample flow rates from about 0.4 to 1.0 standard cubic foot per minute. Chief features of the sampling train that make it especially useful for the fertilizer industry are the filtering system in the sampling probe; the compact arrangement of the impinger assembly; the leakproof, diaphragm-type vacuum pump which is coated internally with Teflon; and the metering arrangement. Because of the use of filters, a ceramic-thimble-type filter in the cartridge on the probe and a backup fiberglass filter at the hose end of the probe, the sampling train may be used where there is heavy dust loading of the airstream being sampled, such as in airstreams from granulators, dryers, and coolers. If the relative humidity of the gas stream is below the critical relative humidity of the fertilizer dust, the dust is dry and the filter system can filter up to 10 grams of dust without excessive restriction of the gas flow through the sampling train. Other TVA studies of the critical relative humidities of fertilizer salts at elevated temperature[2] have shown that a relative humidity of 50% or less normally will not exceed the critical relative humidity of most fertilizer materials. If the relative humidity of the gas inside the stack does exceed the critical relative humidity of the fertilizer materials being produced, the filters usually are omitted, and the weight of fertilizer dust is determined by calculations based on chemical analysis of the impinger catch.

The sampling probe is not heated; this is to prevent decomposition of ammonium salts and possible weight loss of the sample. The compact arrangement of the impingers (standard Greenburg-Smith types) allows the impinger assembly to be packed with ice in a 3-gallon bucket. The ice helps to decrease moisture content of the gas and helps to protect the impingers against breakage. The first two impingers contain 150 milliliters of 1*N* acetic acid solution to absorb ammonia and trap the other materials. The third impinger is empty, and the fourth contains silica gel as a drying agent. The impingers are weighed before and after sampling to determine the amount of moisture in the sample so that total gas flow can be determined.

Any fertilizer dust that adheres to the inside of the sampling probe is dissolved and washed into the impingers with acetic acid before the sample is anlayzed. The sample then is analyzed chemically for free ammonia and excess suffates, chlorides, and fluorides, and the weight of the fertilizer dust in the washing is calculated and added to the weight of the dust trapped by the filter.

The meters (Fig. 2) are arranged so that the dry-gas meter operates at near atmospheric pressure, which decreases chances of leaks and consequent metering error. As shown, the meters and orifice and the depulsing chamber for the pump are all mounted in a compact aluminum box for protection and portability.

Results obtained with this sampling train have been very satisfactory, and it can be hand carried to the sampling site without too much difficulty or danger of breakage. Total cost of the sampling train is about $1000.

Midget Sampling Train

Figure 3 shows a small, relatively inexpensive sampling train that is used to sample stack gases where flow rates required for isokinetic sampling range from about 0.01 to 0.4 standard cubic foot per minute. It has been used successfully to sample for particulate at pickup points in a miscellaneous dust-handling system where gas flow rates were relatively high (0.3-0.4 std ft^3/min). It has also been used to sample for formaldehyde vapor in air where a very low (600 mL/min) and accurate gas flow rate was required.

Chief differences in this midget sampling train and the sampling train previously described are the lower range of flow rates and smaller size. The small size is made possible chiefly by the use of the miniature dry gas meter and also by the use of midget impingers.

Hand-Pumped Sampler

The hand pump and midget impinger sampling apparatus shown in Figure 4 has been a very useful innovation for testing for ammonia concentrations. The pump, which has a capacity of 0.1 liter per stroke, is used both to draw the sample through the midget impinger and to measure the total volume of the sample. The midget impinger contains 10 milliliters of 1/100*N* sulfuric acid solution containing a titration endpoint indicator. Since 1.7 milligrams of ammonia is required to neutralize this amount of sulfuric acid, the ammonia concentration in the sample is 1.7 milligrams divided by the total volume (no. pump strodes x 0.1 mL/stroke) of the gas required to neutralize the aicd. Thus, if 10 pump strokes were required to cause the indicator to change color, the ammonia concentration in the sample would be

$$\frac{1.7\ \text{mg NH3}}{\frac{0.1\text{L}}{\text{stroke}} \times 10\ \text{strokes}} = \frac{1.7\ \text{mg NH3}}{1\text{L}} \quad \text{or about 2445 ppm NH3}$$

If the gas flow rate in the stack being sampled is known, the rate (lb/h) of ammonia loss also can be calculated. Accuracy of this apparatus is about plus or minus 10%.

Dew Point Monitoring

In a TVA granulation pilot plant equipped with a baghouse dust collector on the miscellaneous dust pickup system, very satisfactory continuous measurements of the humidity of the baghouse gas stream have been made with the dew-point hygrometers installation shown in Figure 5. The purpose of this installation was to provide the pilot-plant operator with information to indicate when application of heat to the baghouse was required to prevent wetting of the fertilizer dust and blinding of the bag filters. Other TVA studies of the critical relative humidities of fertilizer salts at elevated temperature[1] showed that if the relative humidity of the baghouse gas stream were maintained at 50% or lower, there would be little chance of exceeding the critical relative humidity of most fertilizer materials. Also, those studies showed that absolute safe operating temperature for a baghouse to avoid wetting of fertilizer dust (and thus blinding of the bags) was 40°F above the dew point.

The dew-point hygrometer as installed in the TVA pilot plant displays or records both dew-point and dry-bulb temperatures of the gas in the baghouse. The gas sample for dew-point determination is drawn from the cleaner, downstream side of the baghouse becuase the absolute humidity, and hence dew point, do not change in passage of the gas through the system. A portion of the baghouse exhaust air (about 1.25 ft^3/h) is filtered and passed across a sensor mirror in the instrument and then is returned to the exhaust stream. The temperature of the mirror surface is continuously and automatically

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[1] Hoffmeister, George, and Cecil P. Harrison, 1982.

controlled very accurately by the instrument to the temperature (dew point) at which minute condensation occurs on the surface of the mirror. The dry-bulb temperature of the airstream is measured with a thermocouple.

Wet-Bulb / Dry-Bulb Apparatus

Wet-bulb readings inside a duct are commonly made with a wetted wick on the mercury bulb of a thermometer inserted into the gas stream in the duct. However, fertilizer dust impinging on the wetted wick may result in a false wet-bulb reading. To solve this problem, a wet-bulb/dry-bulb apparatus (Fig. 6) was fabricated from a 6-inch length of glass tubing with an inside diameter of about 1/2 inch. About 1 cubic foot per minute of gas is withdrawn from the duct through the apparatus using a vacuum pump. Particulate in the gas stream is removed by a glass wool filter. The air flows by the dry bulb then by the wet bulb at a velocity of 800 to 900 feet per minute. The wick on the wet bulb is wetted with water from a small well in the glass tubing. After the start of gas flwow, temperatures stabilize in 1 to 2 minutes. Results obtained using this apparatus have been reliable, and when repeated tests have been needed, the apparatus has proved to be a time saver.

Simplified Pitot Tube

Figure 7 shows a pitot tube that can be made easily from various size tubing from 1/8- to 1-inch diameter. It consists of two pieces of tubing cut at 45-degree angles and soldered together to form a 90-degree angle at the tip. The pitot calibration factor is about 1.0 for 1/8-inch tubing and about 0.85 for 1/4-inch and larger tubing. Since this pitot tube has a sharp tip, it can be inserted into a smaller hole than can the standard "S" type pitot tube. Also, the sharp-tipped pitot tube is resistant to plugging even where heavy dust loads are encountered.

Calibration of Flow Meters

At the National Fertilizer Development Center (NFDC), each pitot tube is calibrated before use. For this purpose, a wind tunnel (Fig. 8) was made out of 14-inch pipe and powered with a compressed-air blower. The pitot tube to be calibrated and the standard pitot tube are inserted into the airstream simultaneously with tips of the pitot tubes about 1 inch apart. The pitot tubes are connected to a double, inclined-tube manometer, which enables observation of the differential pressure on each tube simultaneously. Airflow through the wind tunnel is controlled between zero and 4000 feet per minute, and the constant ratio between the pitot tubes is observed and recorded. The use of the double, inclined-tube manometer, with both pitot tubes in the airstream, has greatly simplified the calibration procedure and improved accuracy.

Figure 9 shows the method used for calibrating orifices and dry meters as a unit before field use. The calibration train consists of a regulated air supply, a set of impingers to saturate the air, and a wet test meter. Note that the dry-gas meter is at the end of the train so that the meter is operated at about atmospheric pressure, which reduces chances of metering errors due to leaks in the dry-gas meter.

Figure 10 is a typical calibration curve for a dry-gas meter. After a gas sample has been collected, the average gas flow rate is used to read the gas meter error from the curve, and this correction factor is applied to the gas volume of the sample.

Figure 11 shows a typical calibration curve for an orifice. If the orifice has been properly constructed, the calibration curve is a straight line, and the orifice constant is the 1-cubic-foot-per-minute flow rate at pressure differential across the orifice of 1 inch of water column (in. W.C.). This pressure differential is equivalent to 0.58 cubic foot per minute. Therefore, the formula for volume of dry air at 70°F. and 1 atmosphere is

$$V(\mathrm{ft}^3/\mathrm{min}) = 0.58 \sqrt{\Delta H(\mathrm{in.\ W.C.})}$$

The dry-gas meter, orifice, and magnehelic gage are calibrated as a unit.

Microsieve Analysis of Dust Samples for Particle Size

A rapid and inexpensive method of determining particle size distribution of dust collected from a duct or stack is by microsieve analysis. In the method, as little as 1 gram of dry dust is dispersed in about 100 milliliters of 1:1:1 trichloroethane (a commercial degreasing solvent) as soon as possible after sampling to avoid agglomeration of the particles. The solution and dispersed particulate are then poured through the microsieve assembly with shaking; additional solution is used as required to wash small particles through the sieves with openings larger than the particle size.

The microsieves are about 3 inches in diameter and weigh about 70 grams. Sieve openings below the standard Tyler series (44 *u*m) are 30, 20, 10, and 5 micrometers. Sieves with openings down to about 20 micrometers work well with a reasonable amount of shaking by hand. The 10-and 5-micrometer sieves may require shaking in a laboratory model ultrasonic shaker.

Figure 12 shows a data sheet for determination of particle size by microsieve analysis. The data shown in this figure are for a fertilizer dust sample that was obtained from a bag-filter hopper. About 17% of the dust is smaller than 45 micrometers. Figure 13 shows a plot of the sieve retention weights on log probability paper

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[1] Gas flow velocity through the sampling train controlled to match the gas velocity in the stack being sampled.

[2] Hoffmeister, George, and Cecil P. Harrison, "Critical Humidity-Temperature Relationships for Several Fertilizers," paper presented at the 184th National Meeting of the American Chemical Society, Kansas City, Missouri, September 1982.

which forms a straight line. The geometric mean particle diameter by weight in this test was 76.8 micrometers. Thanks for your kind attention. (Applause)

MODERATOR BROCHSTEIN: Thank you, Edwin Myers, for your most interesting and valuable discussion — "Practical Process For Determining Losses From Granulation Plants". (Applause)

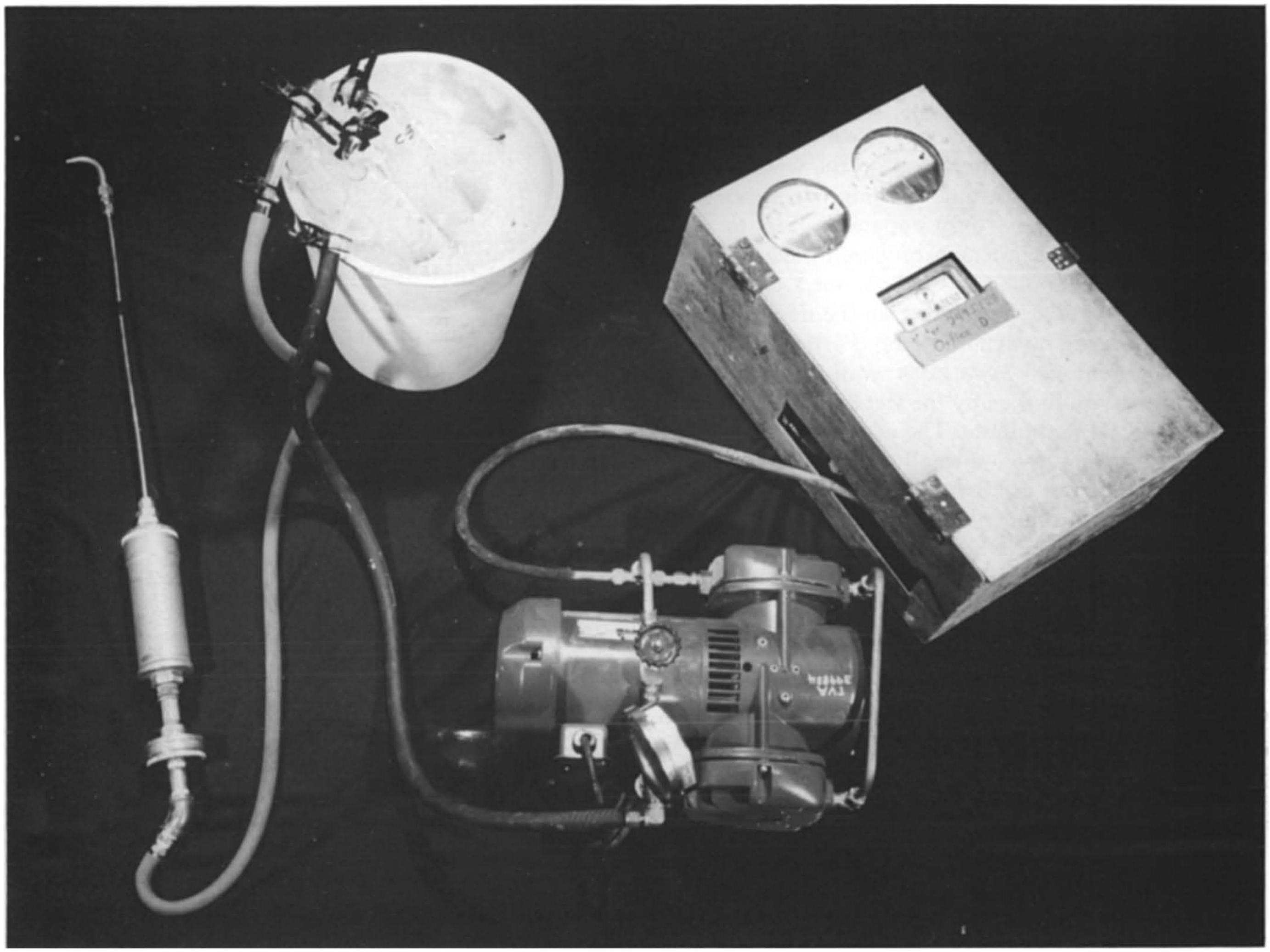


FIGURE 1 — Gas and Particulate Sampling Train

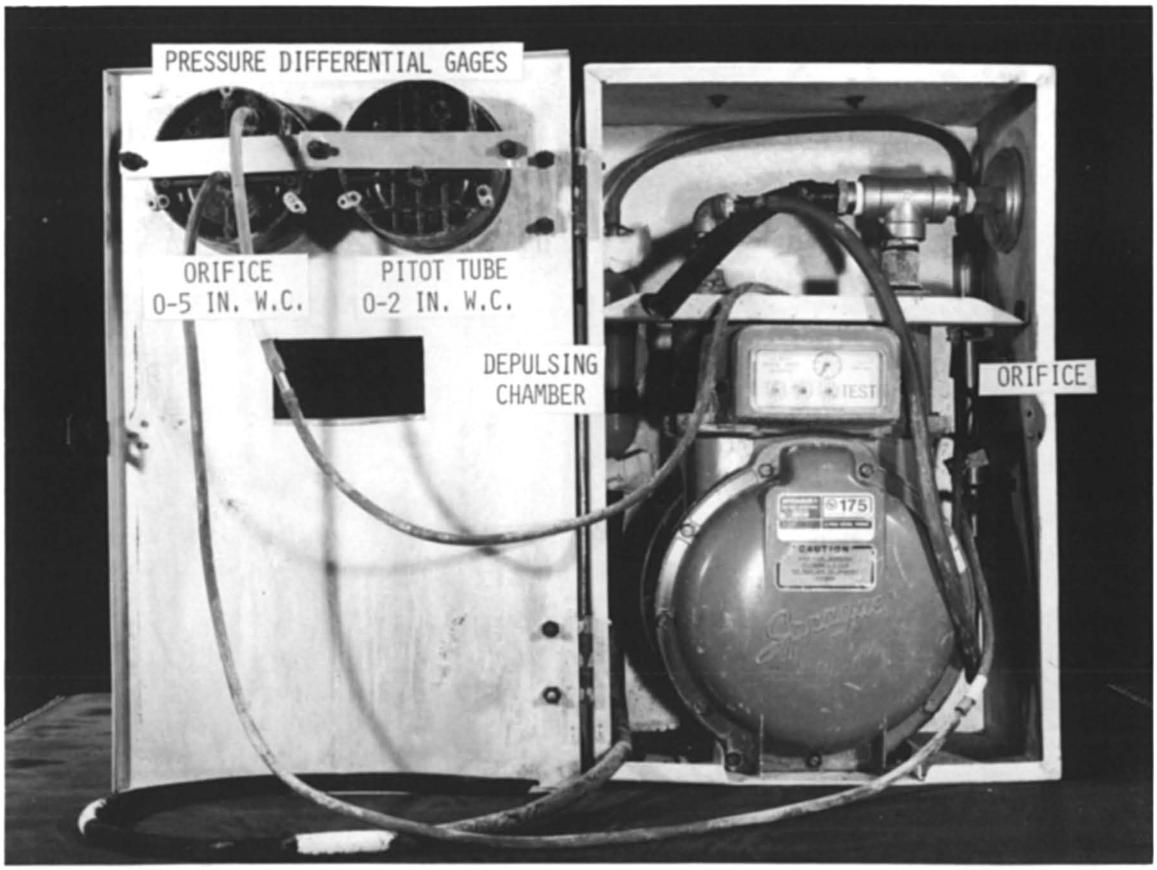


FIGURE 2 — Gas-Flow Metering Box—Internal Arrangement

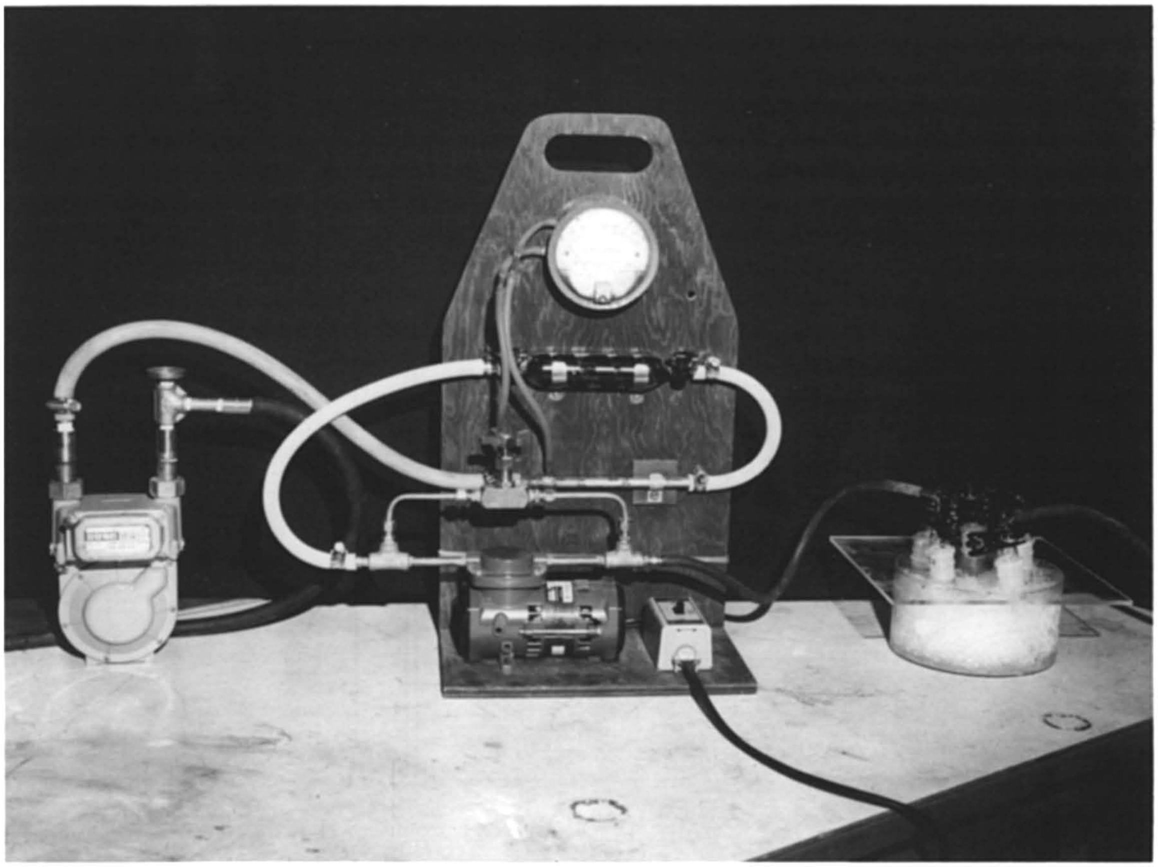


FIGURE 3 — Midget Sampling Train

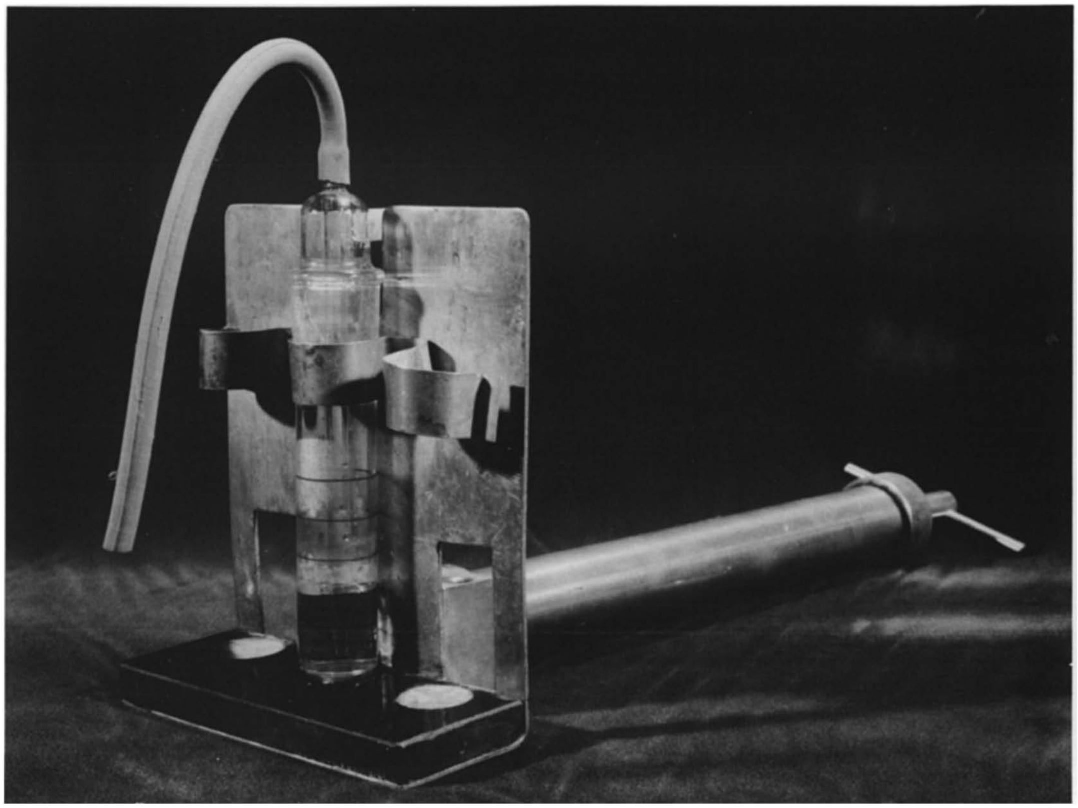


FIGURE 4 — *Hand Pump and Midget Impinger for Measuring Ammonia Concentrations*

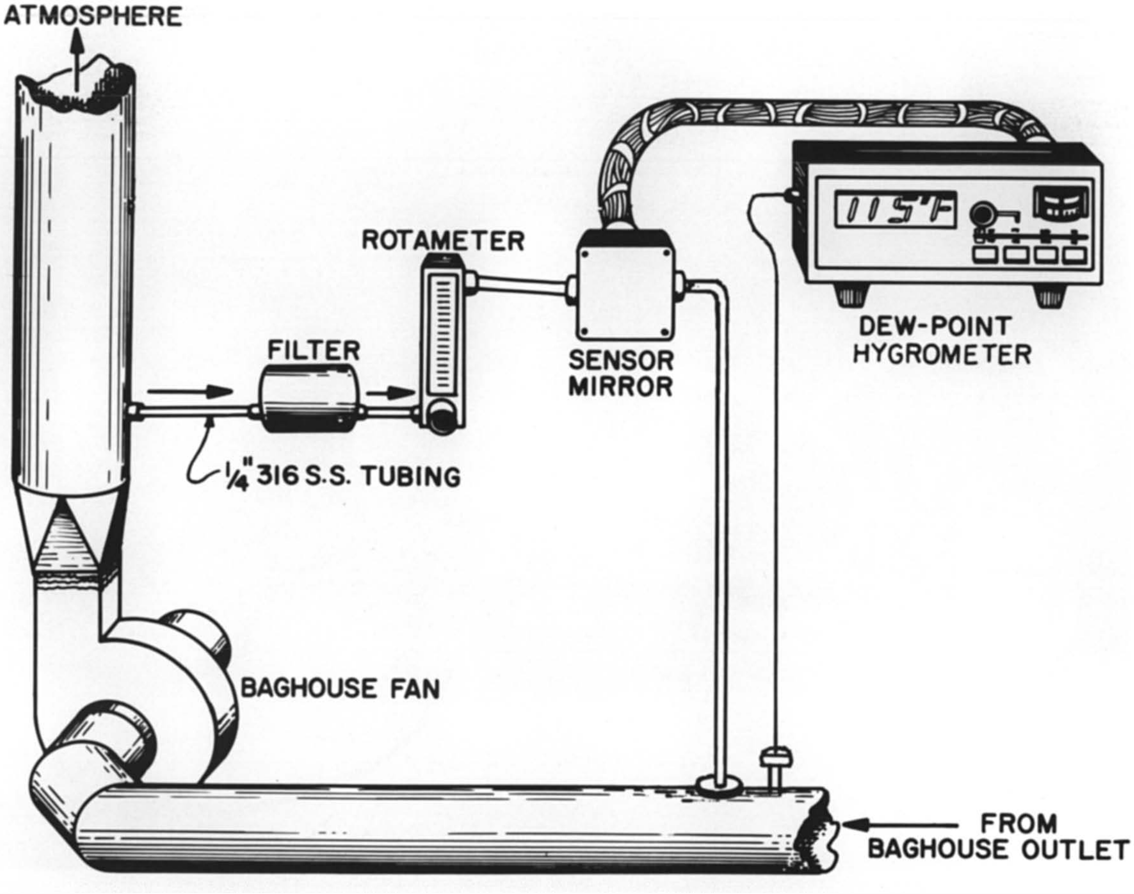


FIGURE 5 — *Dew-Point Hygrometer Installation on Baghouse*

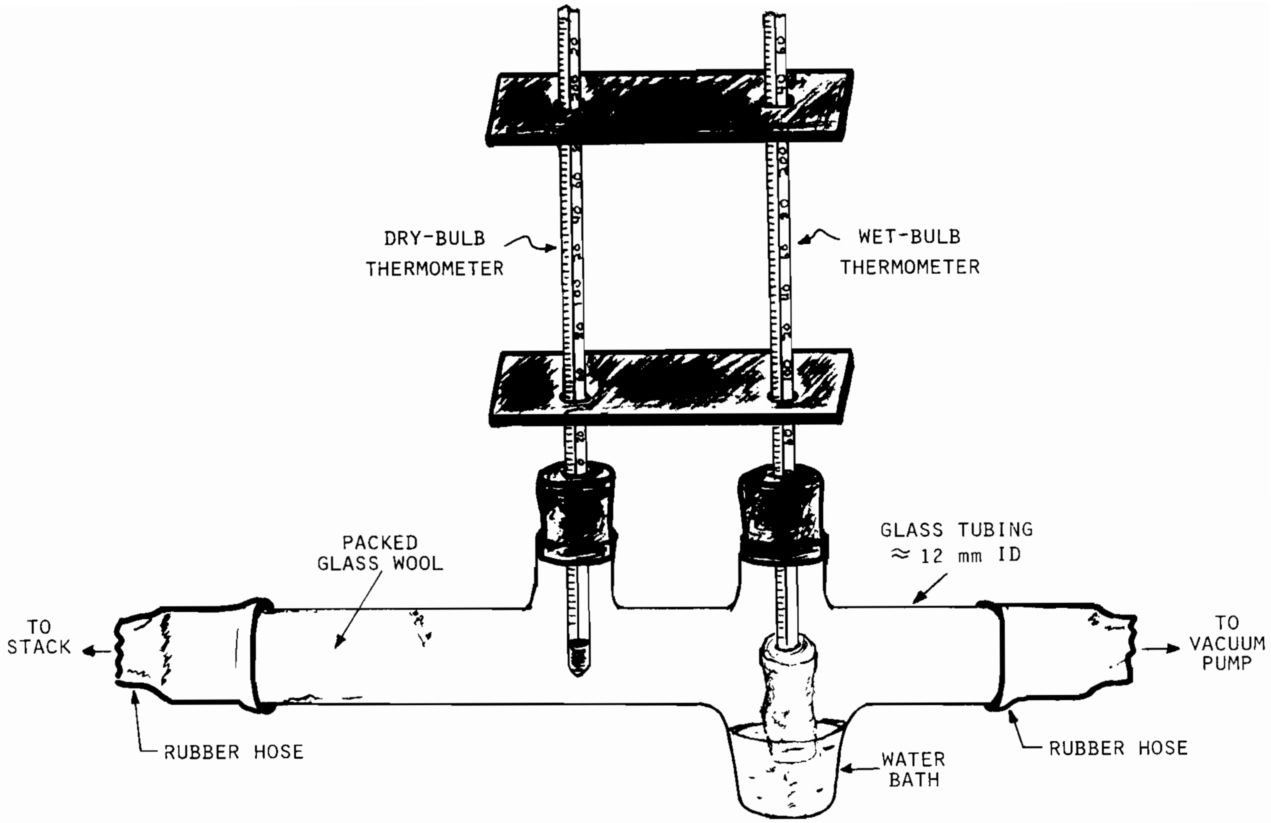


FIGURE 6 — Wet-Bulb/Dry-Bulb Apparatus

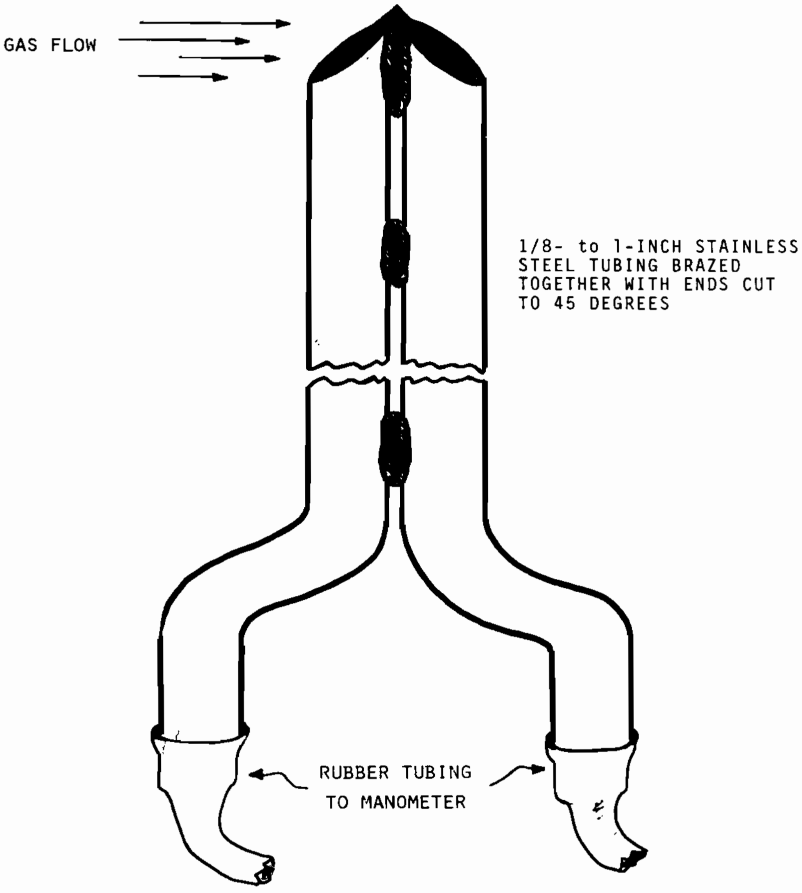


FIGURE 7 — Pitot Tube—90-Degree Angle Tip

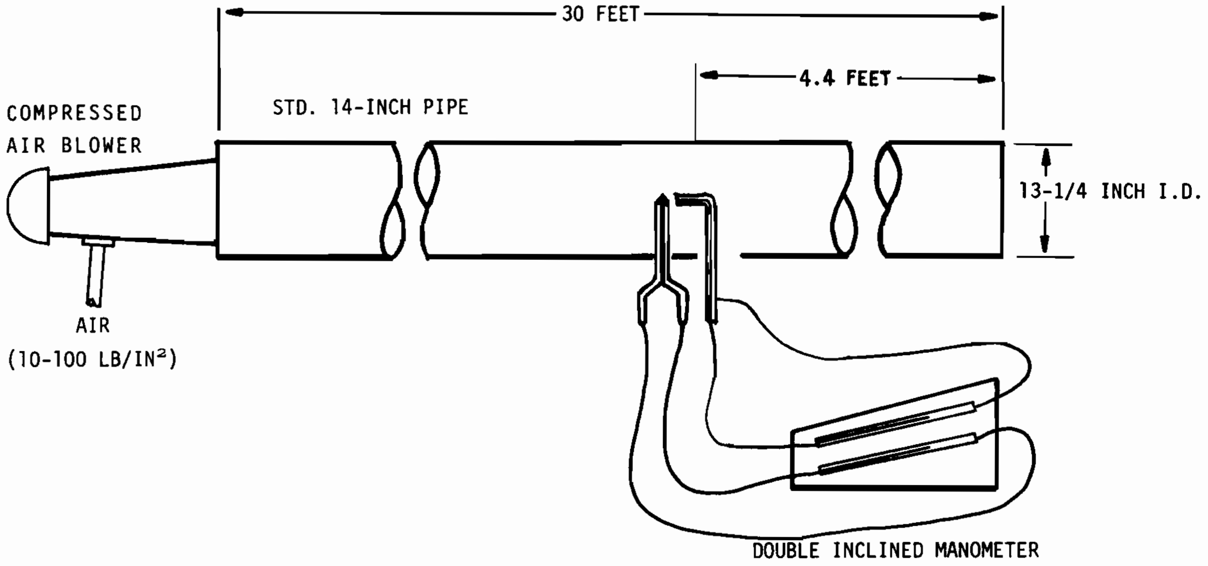


FIGURE 8 — Wind Tunnel for Calibration of Flow Meters

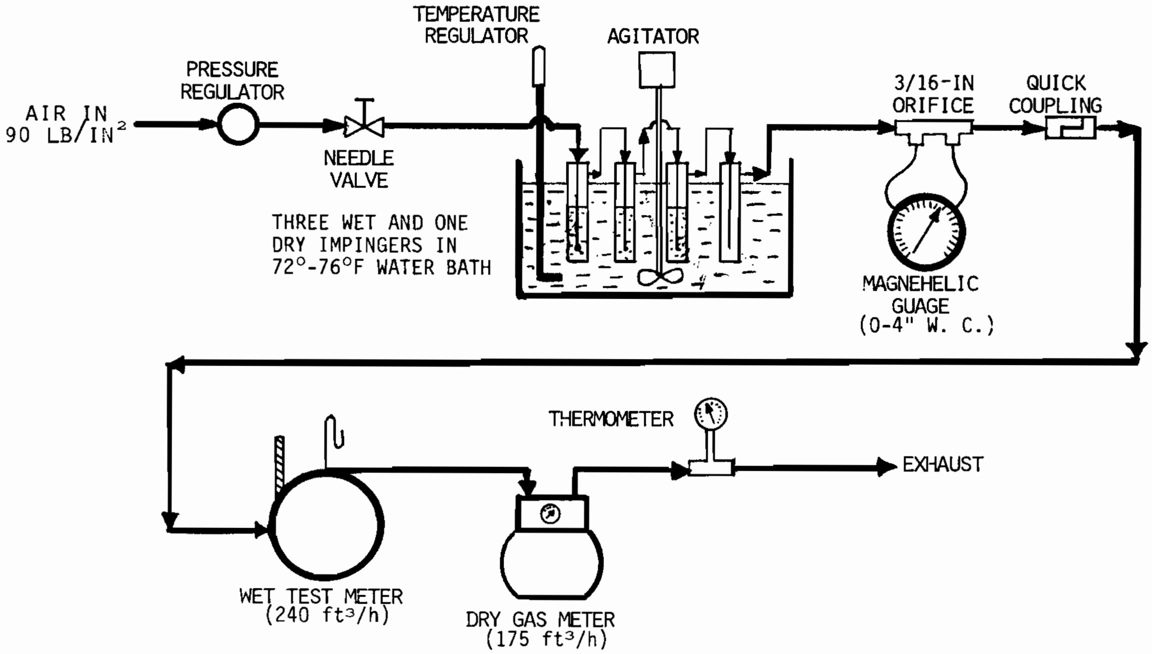


FIGURE 9 — Train for Calibrating Gas Meters

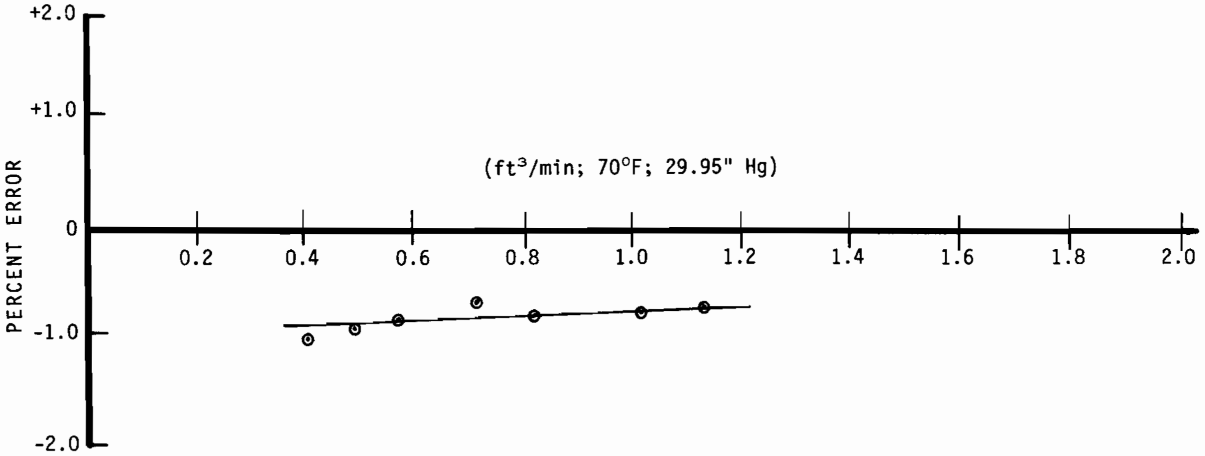


FIGURE 10 — Typical Calibration Curve for Dry-Gas Meter

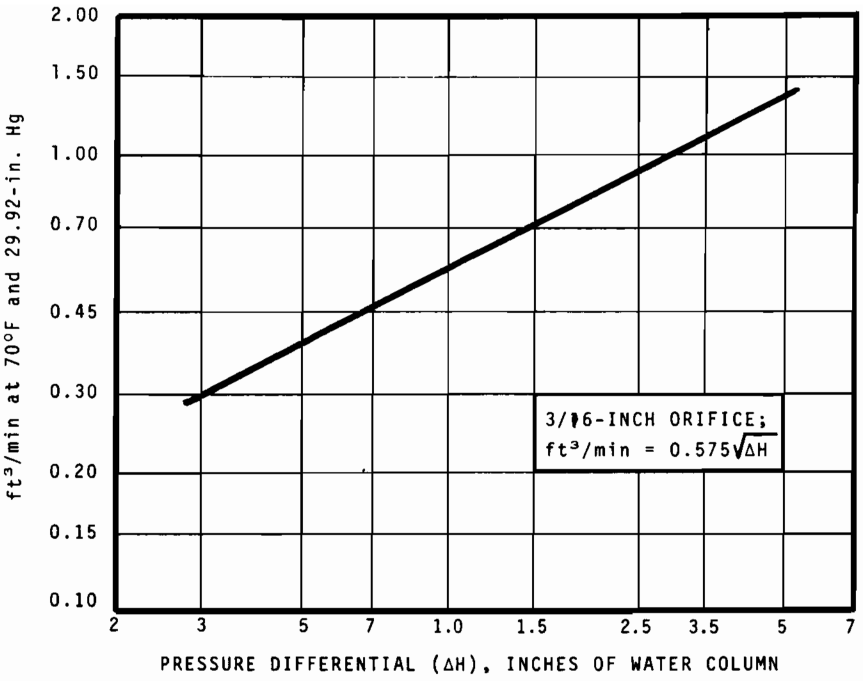
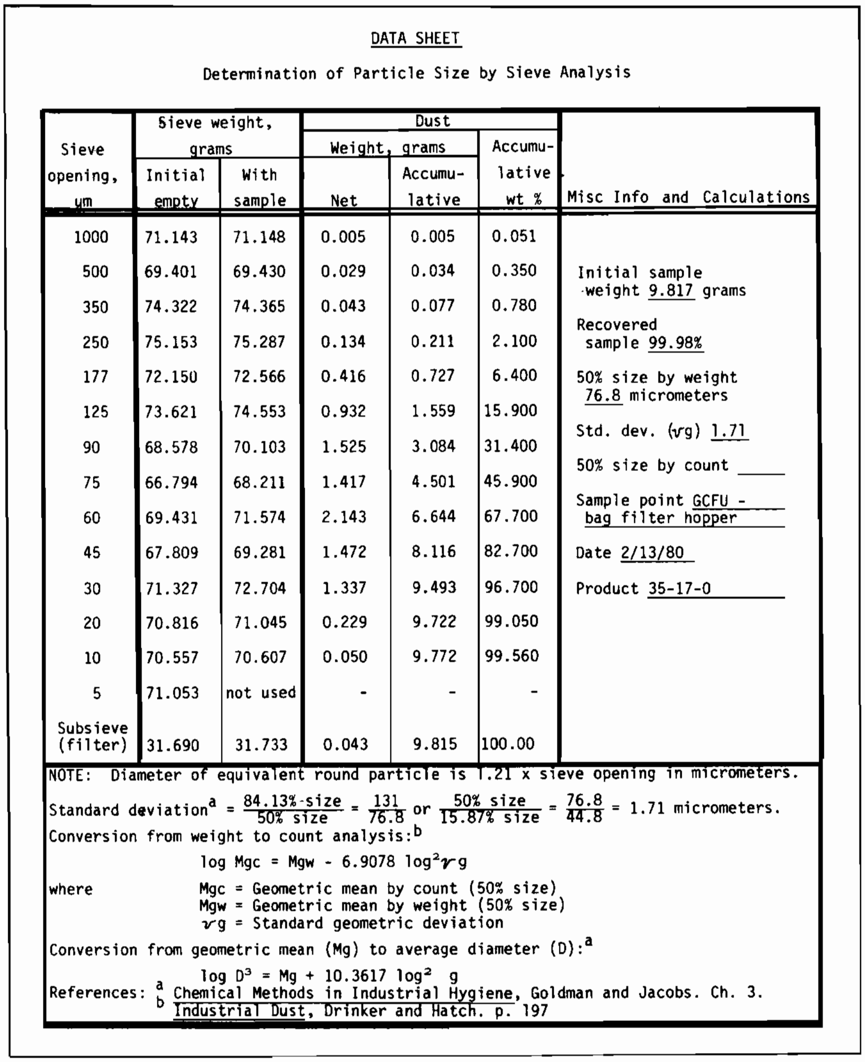


FIGURE 11 — Typical Calibration Curve for 3/16-Inch Orifice



DATA SHEET

Determination of Particle Size by Sieve Analysis

Sieve opening, µm	Sieve weight, grams		Dust			Misc Info and Calculations
			Weight, grams		Accumulative wt %	
	Initial empty	With sample	Net	Accumulative		
1000	71.143	71.148	0.005	0.005	0.051	
500	69.401	69.430	0.029	0.034	0.350	Initial sample weight 9.817 grams
350	74.322	74.365	0.043	0.077	0.780	
250	75.153	75.287	0.134	0.211	2.100	Recovered sample 99.98%
177	72.150	72.566	0.416	0.727	6.400	50% size by weight 76.8 micrometers
125	73.621	74.553	0.932	1.559	15.900	
90	68.578	70.103	1.525	3.084	31.400	Std. dev. (νg) 1.71
75	66.794	68.211	1.417	4.501	45.900	50% size by count ____
60	69.431	71.574	2.143	6.644	67.700	Sample point GCFU - bag filter hopper
45	67.809	69.281	1.472	8.116	82.700	Date 2/13/80
30	71.327	72.704	1.337	9.493	96.700	Product 35-17-0
20	70.816	71.045	0.229	9.722	99.050	
10	70.557	70.607	0.050	9.772	99.560	
5	71.053	not used	-	-	-	
Subsieve (filter)	31.690	31.733	0.043	9.815	100.00	

NOTE: Diameter of equivalent round particle is 1.21 x sieve opening in micrometers.

Standard deviation[a] $= \frac{84.13\%\text{-size}}{50\%\text{ size}} = \frac{131}{76.8}$ or $\frac{50\%\text{ size}}{15.87\%\text{ size}} = \frac{76.8}{44.8} = 1.71$ micrometers.

Conversion from weight to count analysis:[b]

$$\log Mgc = Mgw - 6.9078 \log^2 \nu g$$

where
Mgc = Geometric mean by count (50% size)
Mgw = Geometric mean by weight (50% size)
νg = Standard geometric deviation

Conversion from geometric mean (Mg) to average diameter (D):[a]

$$\log D^3 = Mg + 10.3617 \log^2 g$$

References: [a] Chemical Methods in Industrial Hygiene, Goldman and Jacobs. Ch. 3.
[b] Industrial Dust, Drinker and Hatch. p. 197

FIGURE 12 — Typical Data Sheet for Microsieve Analysis

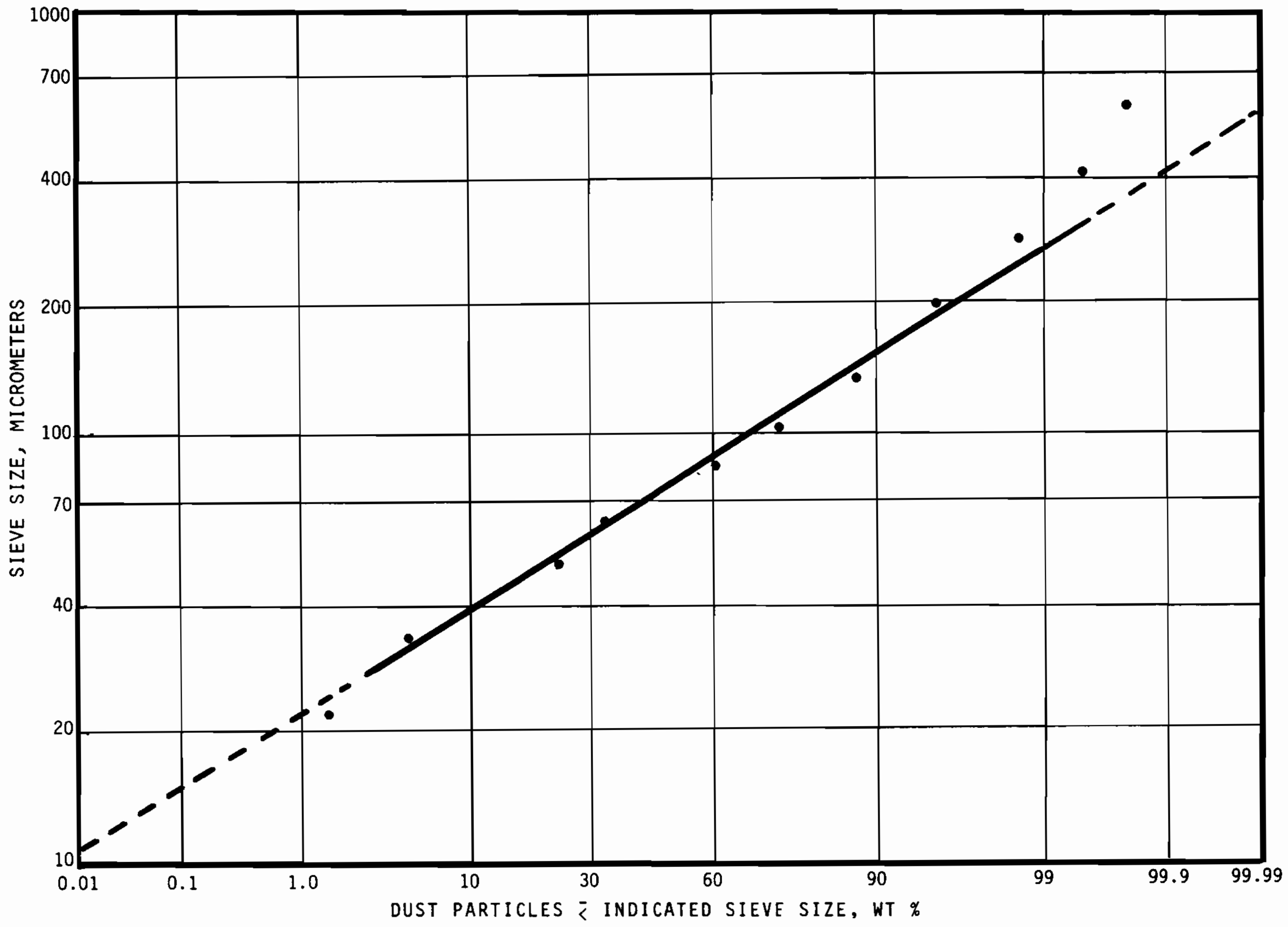


FIGURE 13 — Typical Plot of Sieve Analysis of Fertilizer Dust

MODERATOR BROCHSTEIN: Thank you, Edwin Myers, for your most interesting and valuable discussion. (Applause)

MODERATOR BROCHSTEIN: Our next speaker is Byron Parker. Byron is currently Senior Project Leader in the Development Branch of the Division of Chemical Development, TVA. His background includes both a bachelors and masters degree in chemical engineering from Auburn University. He is a Registered Professional Engineer in the State of Alabama. He is the author of eight papers on fertilizer granultion technology and also holds a patent on a pipe-cross reactor process. Byron is certainly well-equipped to discuss pipe-cross reactors and the production of granular polyphosphate fertilizers. His paper is entitled "Pilot-Plant Studies of the Pipe- and Pipe-Cross Reactors in Production of Granular Polyphosphate Fertilizers." Byron. (Applause).

Pilot - Plant Studies of the Pipe and Pipe Cross Reactors in Production of Granular Polyphosphate Fertilizers

Byron R. Parker
Melvin M. Norton
T. Ralph Stumpe

Presented by Byron R. Parker

A considerable tonnage of granular phosphate fertilizer now is used as an intermediate for the production of suspension fertilizers. The most popular product for this use is monoammonium phosphate (MAP) because of its high P_2O_5 content, the ease with which it can be converted to suspension fertilizer by simple ammoniation and addition of suspending clay, and its ready availability. Granular diammonium phosphate (DAP) also is used for this purpose to some degree, but its use normally requires addition of phosphoric acid to adjust the N:P_2O_5 ratio to the range of maximum solubility and to furnish heat for dissolution. The solid ammonium phosphates are used, instead of phosphoric acid, to supply P_2O_5 for suspension chiefly because delivered costs per unit of P_2O_5 are lower. The lower cost is due to (1) significantly lower shipping rates for solids versus liquids and (2) the use of less pure, and thus cheaper, acids in production of solids.

Granular MAP and DAP, as commercially produced, are ortho-phosphates and normally do not contain significant amounts of polyphosphate. The suspensions made from these solids, therefore, are orthophosphate suspensions and generally are inferior in some respects to suspensions that contain significant levels of polyphosphate. Studies at TVA have shown that both grade and quality of suspensions can be improved significantly by making the suspensions from solid ammonium phosphates that contain part of their phosphate in polyphosphate form. Advantages realized include the following:

1. Increased solubility
2. Sequestration of metallic impurities
3. Increased fluidity
4. Lower solidification temperature
5. More rapid disintegration and dissolution

The first three of these advantages allow production of higher satisfactory grades than those possible using MAP or DAP and thus lower the costs of shipping, storage, and distribution of the polyphosphate suspensions. Also, the sequestration of metallic impurities prevents formation of troublesome gels during storage and increases fluidity of the product. The fourth advantage allows winter storage of some polyphosphate suspensions in colder regions of the country, and the fifth results in shorter suspension preparation times. In the TVA studies, evaluations were made of suspensions containing various levels of polyphosphate produced from solid ammonium phosphates made from central Florida merchant-grade acids. These tests indicated that a polyphosphate content of 10% or more of the total P_2O_5 in the suspension is required to obtain the desired benefits. Since 1 to 2 percentage points of polyphosphate normally is lost in conversion of solids to suspensions, the indication is that the solid phosphate used to make suspensions should contain at least 12% of its P_2O_5 in polyphosphate form to obtain the desired benefits. Data in Figure 1 show that with 10% of the suspension P_2O_5 in polyphosphate form, a suspension of about 11-34-0 grade can be made with a solidification temperature meeting the minus 5__ TVA specification. In comparison, orthophosphate suspension made from MAP normally is limited to 10-30-0 maximum grade and solidification temperature is 0°F. or higher.

Other reasons for inclusion of polyphosphate in granular fertilizers have been claimed. These include improvements in both physical and agronomic properties. Although there may be some validity to such claims, we now consider the major potential advantage to be in connection with use of the solids in suspension fertilizers.

Current TVA Production of Ammonium Polyphosphate

Largely because of the advantages of polyphosphate solids for suspension fertilizers, TVA has, since 1974, produced demonstration quantities of a granular polyphosphate (APP) of 11-55-0 grade from merchant-grade wet-process acid. Although referred to as APP this product is actually an MAP in which about 20% of the phosphate has been converted to polyposphate form. About 200,000 tons of this material has been produced and distributed chiefly for use in suspension fertilizers. About 98% has been used in suspensions; however, it has proved highly satisfactory also for direct application and bulk blending. Handling and storage properties are excellent, and numerous laboratory and field tests have shown the APP product to be superior to MAP in production of suspension. This superiority to MAP is indicated in the tabulation below which briefly summarizes properties of suspensions made from both the APP product and a typical commercial granular MAP.

	APP[a]	**MAP**[b]
Solidification temp, °F	—10	0
Time required for dissolution, min	12	15
Highest satisfactory product grade	12-37-0	10-30-0
Viscosity, cP[c]		
At 80°F.	600	400
At 0°F.	1800	3000

The production process for TVA's 11-55-0 grade APP has been described before in detail[1,2,3,4,5,6,7]. A flowsheet is given in Figure 2. Merchant-grade (53-54% P_2O_5) wet-process acid is normally preheated to 100° to 120°F. and metered to a Hastelloy G spray reactor where it is recirculated and reacted with excess ammonia from the pipe reactor and vapor disengager. The recirculating acid is maintained at 265° to 275°F. and is

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[a] Product obtained from TVA demonstration-scale plant containing 20% of P_2O_5 as polyphosphate.

[b] Typical data from MAP commercial products.

[c] As measured by Brookfield LVT viscometer.

partially neutralized to an NH_3:H_3PO_4 mole ratio of about 0.4 by controlling the pH in the range of 1.6 to 2.0. A side stream of this recirculating partially neutralized acid is metered to one branch of a 6-inch-diameter pipe reactor that has a reaction tube 10 feet long made of Schedule 40, Type 316L stainless steel pipe. Gaseous ammonia is metered to the other branch of the pipe pipe reactor tee so that sufficient ammonia is evolved from the pipe reactor and vapor disengager to maintain the desired spray reactor operating conditions. The temperature of the pipe reactor is maintained at 415° to 440°F., and a melt containing 18 to 22% of its phosphate as polyphosphate is obtained when the pipe reactor is operated at its design production capacity of 12 tons per hour. The pipe reactor has been operated at rates up to 20 tons per hour without any noticeable decrease in melt polyphosphate content. However, when the pipe reactor has been operated at a rate of only 4 tons of melt per hour, melt polyphosphate contents of 30 to 35% of total P_2O_5 were obtained. The APP melt produced in the vertically configured pipe reactor enters the vapor disengager tangentially as shown in Figure 3. The helical rotary blades of the vapor disengager spread the melt along the cylindrical sides to facilitate removal of water vapor (steam) and free ammonia and thus compact and defoam the melt. The melt flows by gravity down a short, heated chute from the disengager to a double-shaft pug mill where it discharges onto a bed of recycle material. Granulation is accomplished by the vigorous working action of the pug-mill blades, and the granular material discharged from the pug mill is cooled and screened. Product-size material is sent to storage. Oversize material is crushed and recycled to the pug mill along with the undersize material.

Sampling has thus far shown that no significant polyphosphate losses occur within this process. When melt and product samples were analyzed during both pilot- and demonstration-scale operations, the polyphosphate contents were identical for all practical purposes.

The thorough vapor disengagement of the melt and the vigorous working action of the melt by the pug mill helps crystallization of the polyphosphate, and these are thought to be the chief reasons for the minimal hydrolysis of the polyphosphate within the process. However, slow hydrolysis of the granular product does occur in storage. The rate of hydrolysis of the polyphosphate increases both with increased storage temperature and with increased free moisture content of the product. Typically, about 1 percentage point of polyphosphate is lost per month during the first 3 months of storage. Therefore, if the product is stored long periods, its suitability for the desired usage must be evaluated.

The process as described above is used by TVA also to produce demonstration quantities of granular urea-ammonium polyphosphate (UAPP) products of 28-28-0 and 35-17-0 grade. In production of those grades, the chief modification is introduction of urea into the pug mill.

Ammonium Polyphosphate Production with a Pipe Reactor and Drum Granulator

In recent years, a number of granular phosphate producers have adopted pipe or pipe-cross reactors in conjunction with TVA-type drum granulators[5,6,7,8,9,10,11,12,13,14,15,16]. Chief reasons for doing this have been to eliminate troublesome preneutralizers, to use large quantities of sulfuric acid, and to conserve chemical heat to reduce or even eliminate the need for a dryer. In some cases, lower cost sludge or spent acids have been used to obtain additional process cost savings. In these numerous commercial installations, production of polyphosphate has not been an objective. The energy savings, convenience, and improved product quality have been the major objectives. TVA has, however, recognized that these plants do have the potential for production of granular phosphates containing useful levels of polyphosphate. With the high temperatures that can be developed in these pipe reactors, it should be possible to produce significant amounts of polyphosphate. Therefore, both bench-scale and pilot-plant studies are being carried out at TVA to identify special operating conditions or processing equipment modifications that could be used in pipe reactor/drum granulator or pipe-cross reactor/drum-granulator plants to develop usable levels of polyphosphate. In these studies, gaseous ammonia and merchant-grade, wet-process phosphoric acid have been fed to the reactors. When the pipe-cross reactor has been used, sulfuric acid of a nominal 92% H_sSO_4 concentration has been fed also.

Granulation Pilot-Plant Studies

In 1975, granulation pilot-plant testing was begun using the pipe-cross reactor/drum-granulator process as shown in Figure 4. These early tests were made to gain design data on the process and to assist in making recommendations to those commercial producers who already had pipe-cross reactors in operation. In addition, many grades of products were tested to determine how they could best be produced with this new process. The commercial plants were operating with an orthophosphate system in which no polyphosphate was produced, so most of the early pilot-plant testing also was done with this orthophosphate system. There was no emphasis placed on obtaining polyphosphate in the product. Later, the pipe-cross reactor was replaced with a pipe reactor. With the pipe reactor, no sulfuric acid was fed to the system. Tests indicated that APP and UAPP products similar to those made with the pipe reactor/vapor disengager/pug process now used at TVA could be produced also with this pipe-reactor and drum-granulation system. However, it was observed that polyphosphate contents were significantly lower. Only about 2 to 7% of the P_2O_5 was obtained as polyphosphate in a granular 11-55-0 grade versus about 20% in the present 11-33-0 grade demonstration product produced at TVA. Two problem areas were identified. First, low-polyphosphate-content melts were being produced with the drum-granulator system. Even when phosphoric acid preheats up to 200°F. were used, polyphosphate contents of the melt and product were less than 15 and 7% of the total P_2O_5, respectively. In addition, polyphosphate losses were occurring in the granulation portion of the process. A series of granulation pilot-plant tests was conducted to determine the significance of these losses. The feed phosphoric acid was preheated to about 200°F. in these tests. The average product polyphosphate content was 6% of the total P_2O_5, and less than 40% of the polyphosphate present in the melt was present in the onsize product. Of the polyphosphate losses observed between the melt and the product, an average of about 70% occurred in the granulator, and 30% occurred in the rest of the process. Since the average polyphosphate content of the melt from the pipe reactor was bout 15% of P_2O_5 during these tests, it was clear that if the polyphosphate losses could be decreased, it should be possible to obtain product with the desired polyphosphate content. Although a product containing 20% of P_2O_5 as polyphosphate, as is made in the present TVA demonstration-scale plant, would not be produced, a product polyphosphate of the required minimum 12% of P_2O_5 or above might be produced. Suspension testing had already indicated that suspensions suitable for cold-weather storage could be produced from granular products containing 12% polyphosphate or above.

Studies to Decrease Process Polyphosphate Losses

A second series of granulation pilot-plant tests was made to evaluate ways in which polyphosphate losses could be decreased in the process. Other studies had indicated that these losses might be decreased by

1. Increasing the ph of the melt and granular product
2. Cooling the melt and granulator product more quickly
3. Improving disengagement of the free water (steam) from the melt

TVA work with fluid fertilizers had indicated that polyphosphate losses by hydrolysis increase as the pH is lowered, and that it is desirable to maintain the pH at 6 or above to decrease these polyphosphate losses. However, this is in a range of high solubility and is detrimental to the granulation system. The reactant $NH_3:H_3PO_4$ mole ratio was, however, increased from 1.00 to between 1.05 and 1.10 for these and future tests. This incresed the pH of the melt and granulator products somewhat, but did not increase the solubility of the products so much that granulation problems were encountered. It is expected that higher mole ratios will be tested later to determine the maximum that can be tolerated with this granulation system. In one test, the melt from the pipe reactor was sprayed onto an inert recycle; sand was used in this particular case. However, this did not decrease the polyphosphate losses, which indicated that observed polyphosphate losses were not due to any reaction between the APP melt and the recycle in the bed of the granulator.

Various other process modifications were tested. Melt from the pipe reactor was sprayed horizontally onto an inclined, flat plate to improve steam disengagement from the melt, but melt distribution to the granulator bed was too poor to obtain sustained operation. The melt distributor was also modified to increase the spraying distance to the granulator bed from about 7 to 8 inches to about 12 to 14 inches in an attempt to improve steam disengagement from the melt. Airflow through the barrel of the drum of the granulator was increased in an effort to disengage steam from the melt more effectively and to cool the melt and granulator product more quickly. Also, the retaining ring inside the drum granulator was lowered from 9 to 5 inches to reduce the retention time in the drum and to cool the granulator product more quickly. However, none of the above modifications was effective in decreasing polyphosphate losses.

Sampling procedures were studied also during this series of tests. In the procedure used before this time, the melt from the pipe reactor was caught directly in a sampling pan and allowed to solidify and air cool to ambient temperatures in the sampling pan. In the modified procedure tested, a layer of dry ice was placed on the bottom of the sampling pan. The melt sample was spread upon the dry ice, and then an additional layer of dry ice was placed on top of the sample to quickly cool the sample. Comparison of the analyses of melt samples from these tests showed an average decrease of almost 3 percentage points in the polyphosphate contents when the samples were quenched with dry ice. This indicated that with the old procedure, polyphosphate formation had been continuing in the sample. The sample therefore was not representative of the melt spraying from the pipe reactor and some of the indicated losses were the result of sampling procedure. However, even with results from the new sampling procedure, only about 50% of the polyphosphate contained in the melt was retained in the onsize granular product. The modified sampling procedure in which the melt is quenched with dry ice was adopted for routine use in all future tests.

Studies to Increase Reactor Melt Polyphosphate

Since the series of pilot-plant tests discussed above was not successful in significantly decreasing the polyphosphate losses occuring in the process, the emphasis in further tests was placed on increasing the polyphosphate content of the pipe-reactor melt. Methods considered were as follows:

1. Increasing heat input to the pipe reactor by
    a. Increasing preheat of the acid fed to the pipe reactor
    b. Introducing sulfuric acid as a feed to the pipe reactor to furnish additional chemical heat
    c. Increasing feed NH_3:H_3PO_4 mole ratio
2. Using heat input to the pipe reactor more effectively by
    a. Insulating the reaction system
    b. Decreasing granulator airflow
    c. Improving the pipe-reactor configuration
    d. Using a steam-jacketed reaction tube.
3. Reducing water input to the pipe reactor by
    a. Increasing scrubber temperature
    b. Using acid of lower water content

The heat input to the pipe reactor was increased in the next series of granulation pilot-plant tests by preheating the phosphoric acid fed to the reactor. The results from this series of tests are summarized in Figure 5. As shown in the figure, the melt polyphosphate content increased with increasing acid temperature. The figure shows, however, that an acid preheat of about 245°F. would be required to produce a product containing 12% of the P_2O_5 as polyphosphate. To produce a product containing 20% polyphosphate, an acid preheat of over 300°F. would be required. At these temperatures, the acid would be very corrosive and a relatively expensive material of construction would be required for a heat exchanger. Polyphosphate losses in the granulation system continued to occur in the process as indicated by the vertical distance between the melt and product curves in Figure 5.

In another series, heat input to the reactor was increased by substituting a pipe-cross reactor for a pipe reactor and feeding sulfuric acid to the reactor in addition to the ammonia and phosphoric acid. The results are shown in Figure 6. This figure shows that an increase in polyphosphate content was obtained. To obtain a product containing 12% of the P_2O_5 as polyphosphate, approximately 230 pounds of 92% sulfuric acid must be added per ton of product and the product grade is no longer 11-55-0 but rather is approximately 12-48-0 containing about 4% sulfur. When sulfuric acid is used, a suitable material of construction should be used for the pipe-cross reactor. Normally, in commercial installations, Hastelloy C-276 is used; however, these reactors usually are operated at temperatures of 300°F. or lower because no polyphosphate formation is desired. With the process as operated on the pilot-scale reactor, temperatures of 400°F. or higher are obtained, and the long-term corrosion effects on Hastelloy C-276 are not yet known. More data on this and other materials are needed.

No problems would be encountered if a granular ammonium polyphosphate sulfate (APPS) fertilizer were to be used in a bulk blend or for direct application, but for producing suspension fertilizers, the effect of the added sulfate on the suspension must be considered carefully. Although sulfate in suspension decreases the solidification temperature, which is an advantage for storage in cold climates, the added sulfate also increases the viscosity and the time required for ammoniation and dissolution of the granules. Suspension testing has been done at TVA to determine in more detail the effects of sulfate on suspensions made from granular APPS products. The overall results indicate that, in general, the time required for ammoniation and dissolution of the granules increased and the highest satisfactory grade decreased with an increase in sulfate content of the granular material. The results further indicate that the solidification temperature and viscosity depend on the proportions of sulfate. The sulfate content of a granular APPS product to be used in a suspension should probably be limited to about 10% SO_4 (3.3% S) if a satisfactory suspension containing at least 32% of P_2O_5 is desired.

The heat input to the pipe reactor can also be increased by increasing the feed NH_3:H_3PO_4 mole ratio to the pipe reactor above the 1.05 used to most tests. However, as it was stated earlier, there are limitations on the maximum mole ratio that can be maintained before granulation problems are encountered. One test has been made with a higher mole ratio as shown in Table I (test 10 vs 8). In test 8, a 1.25 feed mole ratio was maintained, which resulted in an increase in product polyphosphate content of only 0.6 percentage points. Additional tests are planned to study further the effect of the mole ratio on polyphosphate content and to determine the range of mole ratios that can be used with the granulation system.

In another test, a jacketed pipe reactor was used and steam was introduced into the jacket to heat the reactor. The results from these tests were inconclusive although the temperature of the melt was increased about 15°F. and an increase in polyphosphate would be expected. Chemical analysis of the melt, however, indicated no significant difference to polyphosphate contents. Because this modification resulted in a more complicated reactor and used external steam heating, no more work has been done in this area.

More effective use of the chemical heat available in the process was stressed in a recent granulation pilot-plant study program. The major modification to obtain this goal was insulation of the reaction system. This included insulation of the pipe reactor, drum granulator, the hood of the drum granulator, the ductwork to and from the scrubber, the scrubber, the acid lines to and from the scrubber, and the boot tank at the bottom of the scrubber. Although information available is not sufficient to determine exactly how much heat savings were realized, losses in the acid process lines to and from the scrubber were decreased by 65%. This reduction alone was equivalent to approximately 9% of the chemical heat input to the pipe reactor. Test results after the insulation work was done are shown in Table I. While using the horizontal pipe reactor of 1½-inch diameter and 6-foot length, the polyphosphate in the product was increased from about 4 to 6% of P_2O_5 when the insulation was added (test 2 vs 1). Preheating the acid feed to the pipe reactor slightly to simulate elimination of heat loss in the acid feedline increased the polyphosphate content of the product 0.6 percentage points (from 5.6 to 6.2% of P_2O_5; test 3 vs 2). Decreasing the airflow through the barrel of the 3-foot-diameter granulator to the minimum airflow that would not produce "puffing" of dust from the feed end of the granulator, but still remove evaporated water from the granulator, increased the polyphosphate content of the product 0.5 percentage point (from 6.2 to 6.7% of P_2O_5; test 4 vs 3). The airflow through the barrel of the granulator was reduced from 350 cubic feet per minute (at 1 atm and 70°F.) to 230 cubic feet per minute in these and following tests, and this allowed the scrubber to operate at a higher temperature, so more water vapor was removed in the scrubber exhaust airflow.

The effect of pipe-reactor configuration also was studied in granulation pilot-plant tests. The effect of the pipe-reactor configuration is shown in Table II where data for both horizontal configurations and vertical configurations are shown. It can be seen that for comparable tests using the same diameter pipe reactor, polyphosphate was increased 2.1 percentage points (from 6.7 to 8.8% P_2O_5; test 7 vs 4) when the vertical configuration was used. Since the vertical configuration (Fig. 7) was shown to give higher polyphosphate contents, a series of tests was run using the same configuration, but with different pipe sizes to give an indication of the effect of throughput on polyphosphate content. It can be seen that for the conditions shown the 2½-inch-diameter pipe reactor gave the highest product polyphosphate content (tests 8 and 10). The throughput through this pipe was equivalent to 79 pounds of $P_2O_5/h \bullet in^2$. This indicates that there is probably an optimum throughput that should be used for any pipe reactor and that increasing the throughput above this point will decrease the polyphosphate content of the product. Additional work is needed in this area to better predict the effect of throughput on polyphosphate content.

No tests have yet been made to test specifically the effect of decreasing the water input to the reactor. The modifications made to use more effectively the heat generated in the process did, however, indirectly accomplish this purpose by increasing the scrubber operation temperature so that more water was removed from the recirculating acid and exhausted to the atmosphere. An acid of lower water content was fed to the pipe reactor than otherwise would have been without this modification, and higher product polyphosphates were obtained as previously described. Small-scale pipe reactor studies have also shown that for a given acid concentration (% P_2O_5) polyphosphate content of the melt increases significantly with decreasing free water content of the acid.

Pipe-Reactor Basic Studies

Concurrently with the granulation pilot-plant studies, smaller scale testing was begun to supplement the larger scale data. This program was initiated to study the effect of operating variables on the polyphosphate contents of melts produced by pipe reactors. The reactants fed to the pipe were gaseous ammonia and wet-process phosphate acid. The initial tests have been directed toward determining effects on melt polyphosphate contents of changes in (1) heat input to the reactor (acid feed temperature, ammonia feed temperature, and reactant $NH_3:H_3PO_4$ feed mole ratio), (2) phosphoric acid concentration (P_2O_5 and water contents), (3) production rates, and (4) pipe-reactor configuration (vertically or horizontally mounted pipe reactor). Testing and correlation of the data from these pipe-reactor stdies still are underway; however, the following trends are evident:

1. Melt polyphosphate increases with an
   a. Increase in phosphoric acid feed temperature
   b. Increase in phosphoric acid feed temperature
   c. Increase in reactant $NH_3:H_3PO_4$ feed mole ratio
   d. Increase in P_2O_5 content of feed acid
   e. Decrease in water content of feed acid
2. Melt polyphosphate generally varies indirectly with production rate
3. Melt polyphosphate generally is higher when a vertical pipe-reactor configuration is used

Summary and Discussion

Improvements have been made in the pipe-reactor or pipe-cross reactor / drum-granulator process to increase the polyphosphate content of the granular product. The goal of producing a granular APP product containing 20% of P_2O_5 as polyphosphate without adding external heat or sulfuric acid to the process has not yet been realized; however, products containing slightly more than 10% of the P_2O_5 as polyphosphate have been made without the need for external heat. Test results indicate that additions of small amounts of sulfuric acid, use of reactant $NH_3:H_3PO_4$ feed mole ratios greater than 1.05, or use of some acid preheat may be required to consistently obtain 12% of the P_2O_5 as polyphosphate as is desired for use of the product in preparation of suspension fertilizers. However, continued testing is being done to determine how high a mole ratio may be used successfully and to determine the effect of sulfate addition on use of the granular products for producing suspension fertilizers. Although scale buildup in the reactor is not a major problem, more buildup is encountered than when products without significant polyphosphate are made. Some reduction in buildup has been made by feeding small quantities (100-200 lb/ton)of sulfuric acid to the reactor. Polyphosphate losses continue to occur in the granulation portion of the process. Some specific modifications have been made in recent tests to reduce these losses; also, the changes made in increasing heat input to the pipe reactor have resulted in reducing the significance of these losses so that now, in the most recent granulation pilot-plant tests, the products contain an average of about 70% of the polyphosphate present in the reactor melts. The effort to obtain higher polyphosphate levels from the pipe-reactor and drum and the pipe-cross reactor and drum systems is being continued.

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MODERATOR BROCHSTEIN: Thank you, Byron. (Applause)

TABLE I

Granulation Pilot-Plant Pipe-Reactor and Drum-Granulator Process

Test no.	Nominal pipe size, in	Configuration	Length, ft	Method of operation[a]	Pipe-reactor throughput Lb/h•in^2	Pipe-reactor throughput Lb P_2O_5/h•in^2	Product polyphosphate, % of total P_2O_5
1	1-1/2	Horizontal	6		536	284	3.7
2	1-1/2	Horizontal	6	1	329	184	5.6
3	1-1/2	Horizontal	6	1, 2	338	190	6.2
4	1-1/2	Horizontal	6	1, 2, 3,	353	198	6.7
5	1-1/2	Horizontal	6	1, 2, 3, 4	340	175	9.9
6	1	Vertical	10[b]	1, 2, 3	889	439	8.1
7	1-1/2	Vertical	10[b]	1, 2, 3	331	185	8.8
8	2-1/2	Vertical	10[b]	1, 2, 3	144	79	10.3
9	4	Vertical	10[b]	1, 2, 3	54	30	8.7
10	2-1/2	Vertical	10[b]	1, 2, 3, 5	160	83	10.9

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[a] Methods of operation defined were as follows:

1. Insulated reaction system (pipe reactor, granulator, granulator exhaust duct, scrubber and its acid inlet and drain lines).
2. Preheat (approx 20°F) to feed acid to simulate elimination of heat loss in acid feedline to pipe reactor.
3. Minimum granulator airflow.
4. Sulfuric acid (93%) added to process at rate of 200 pounds per ton of product.
5. 1.25 feed NH_3:H_3PO_4 mole ratio.

[b] Vertical section is a 4-ft length of nominal pipe size shown. The remainder of the total length is two horizontal sections perpendicular to each other to distribute melt into granulator. Horizontal sections are made of 1-in pipe for the 1-in reactor and 1-1/2-in pipe for the other size reactors.

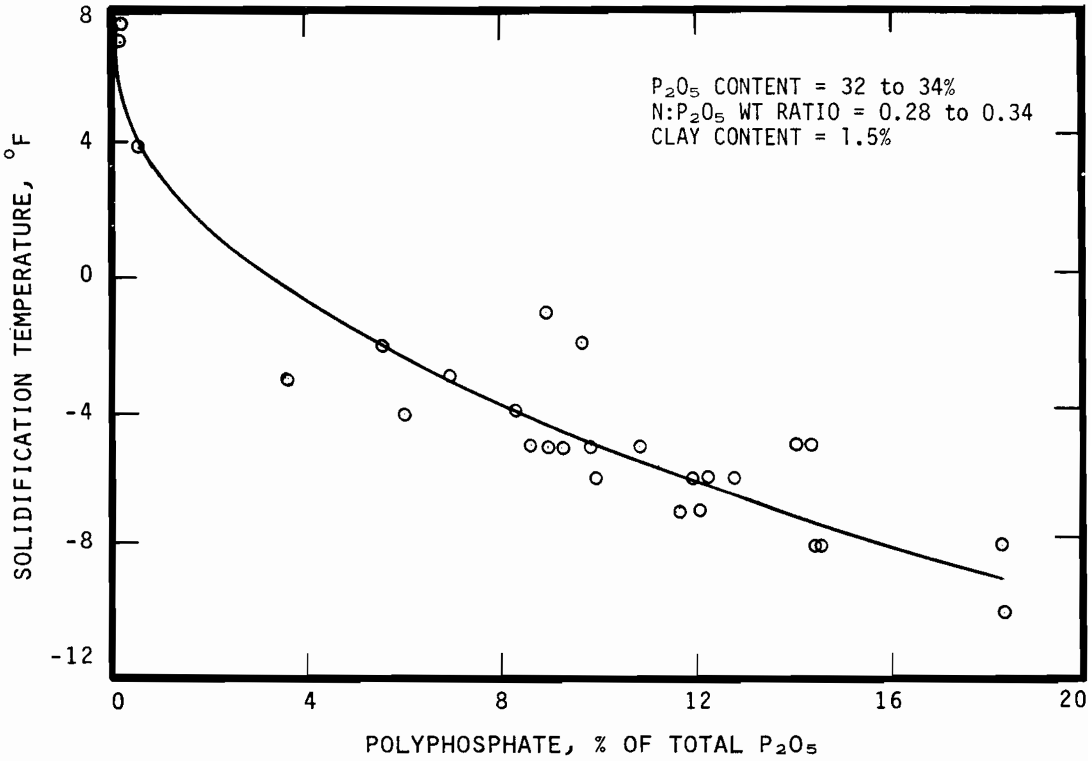

FIGURE 1

Effect of Polyphosphate Content on Solidification Temperatures

of NP Base Suspension Made from Solid Ammonium Phosphate

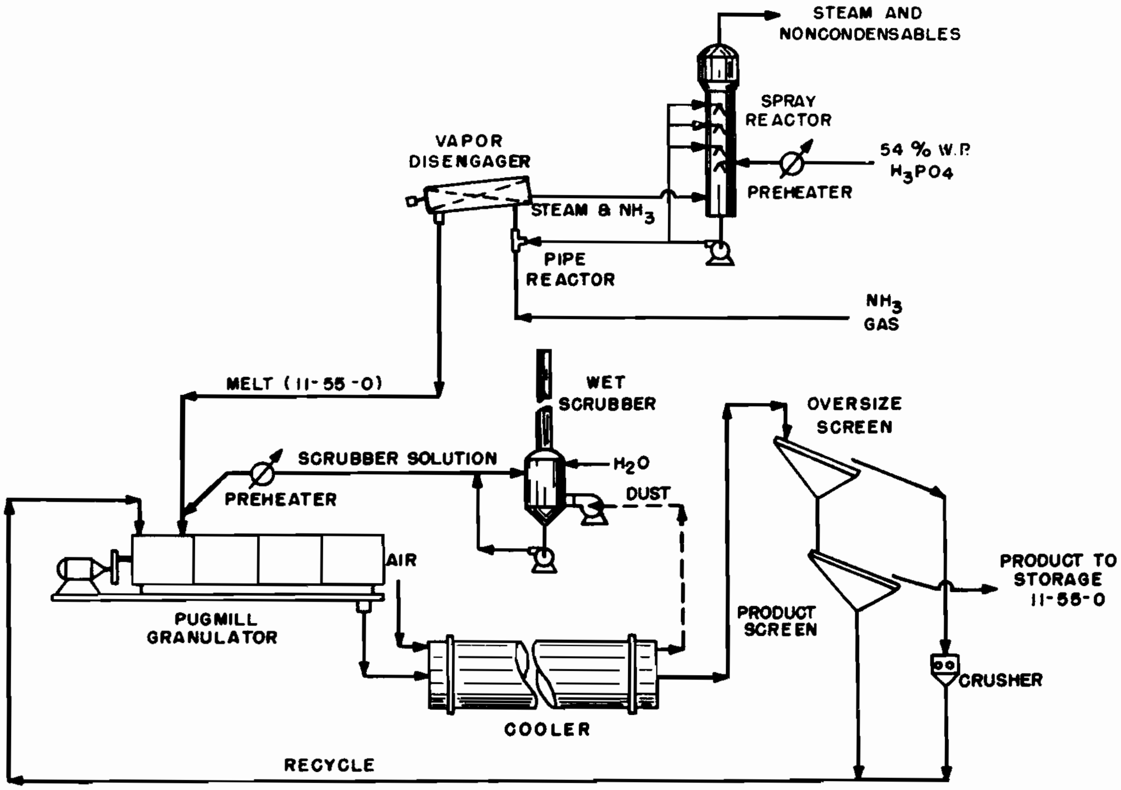

FIGURE 2

Pipe-Reactor/Vapor Disengager/Pug-Mill Process

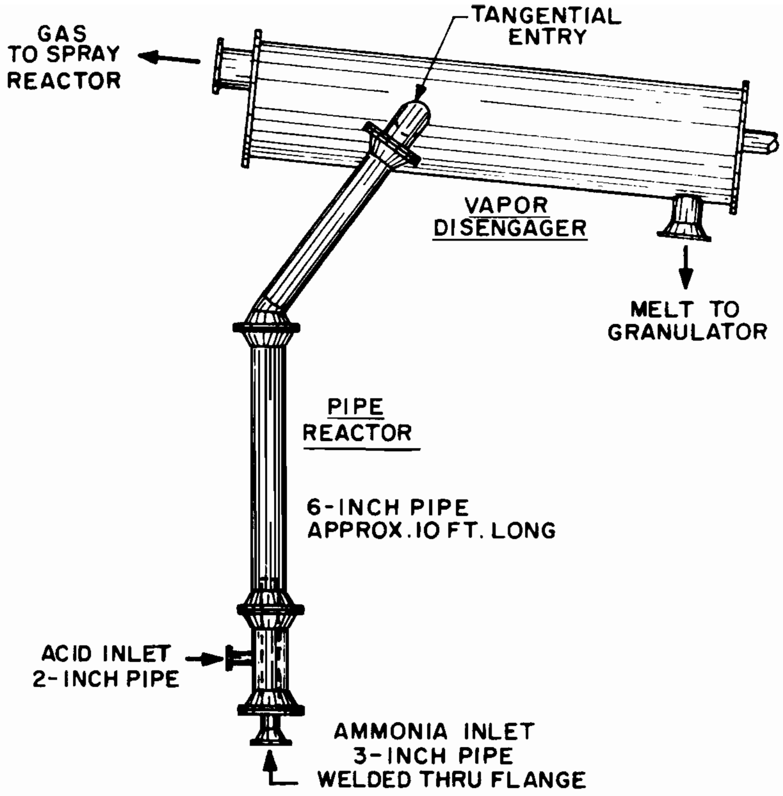

FIGURE 3

Pipe-Reactor/Vapor-Disengager System Used in TVA's Demonstration Plant for Production of 11-55-0 Ammonium Polyphosphate

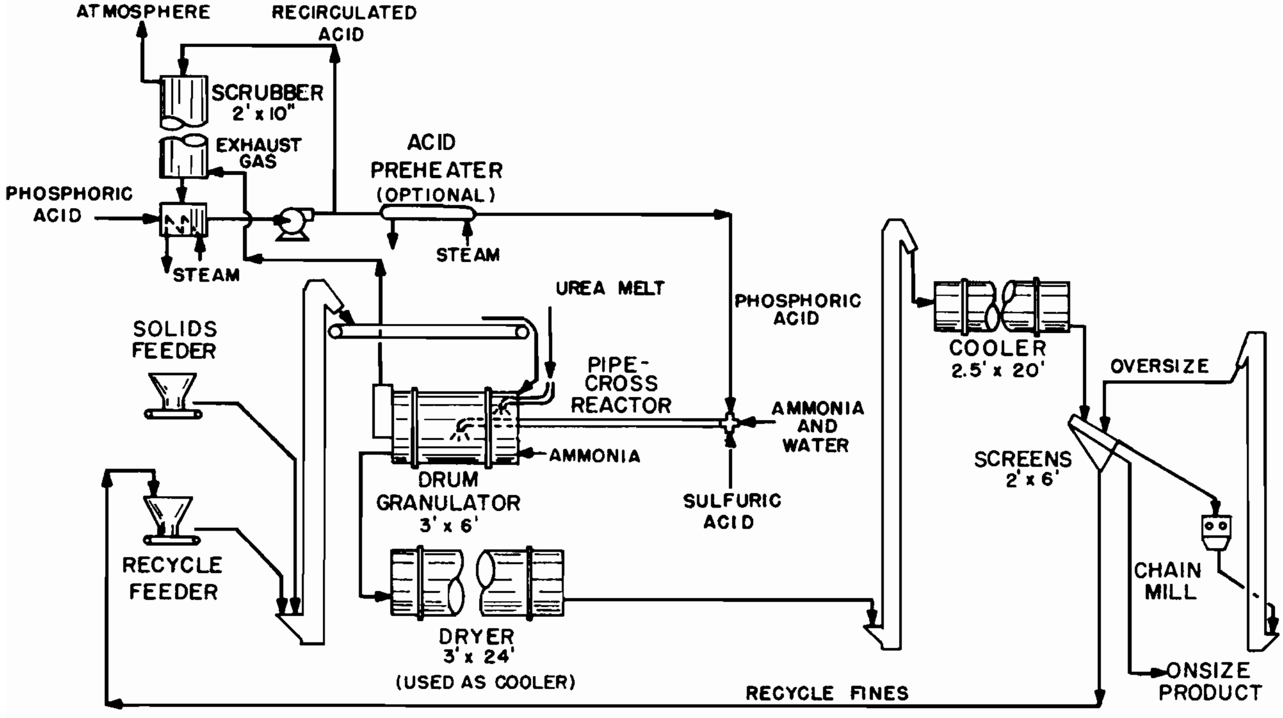

FIGURE 4

Flow Diagram of TVA Granulation Pilot Plant for Production of Granular Fertilizer Using Pipe-Cross Reactor

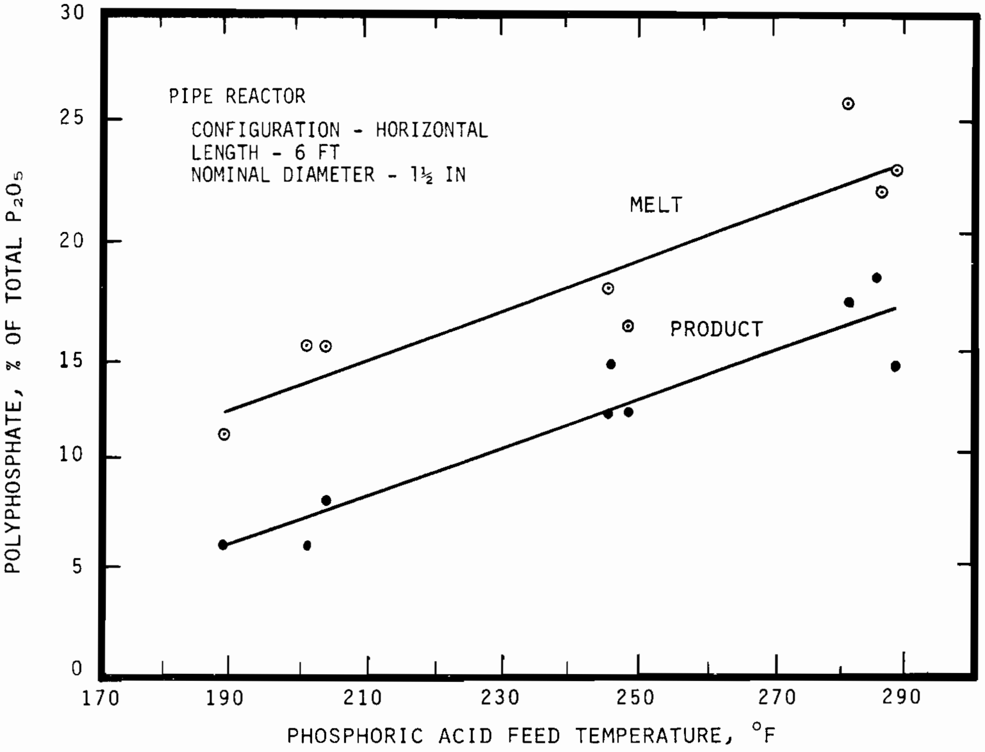

FIGURE 5

Effect of Feed Acid Temperature on Polyphosphate Contents of Pipe-Reactor Melt and Granular Product

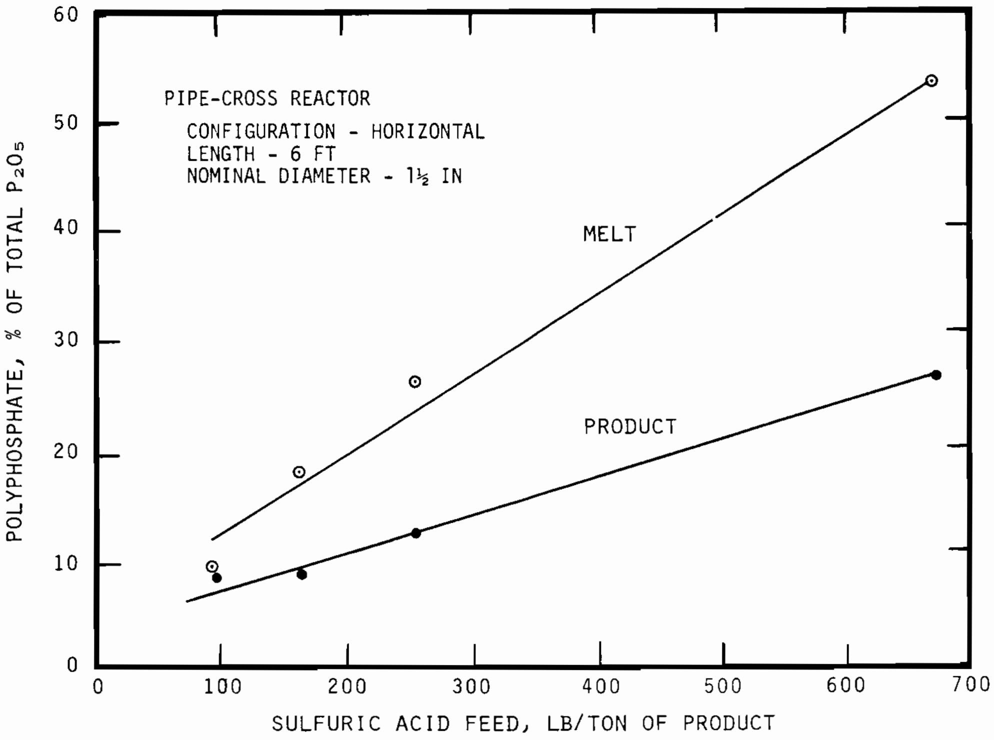

FIGURE 6

Effect of Addition of Sulfuric Acid on Polyphosphate Contents of Pipe-Cross Reactor Melt and Granular Product

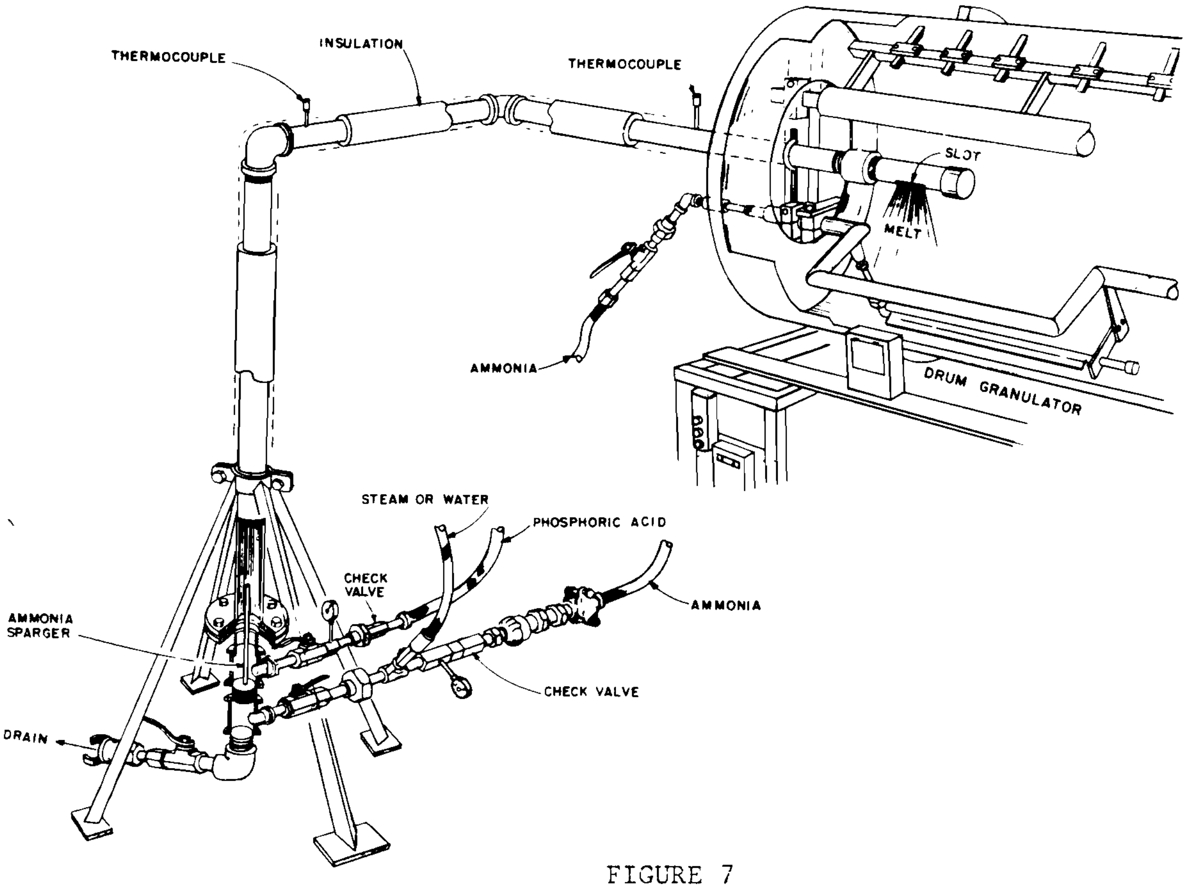

FIGURE 7

Vertical Configuration of Granulation Pilot-Plant Pipe Reactor

MODERATOR BROCHSTEIN: Thank you, Byron. (Applause)

MODERATOR BROCHSTEIN: Our next paper this afternoon is entitled "Ammoniated Granular TSP for Developing Countries" and will be presented by Jorge R. Polo with the International Fertilizer Development Center in Muscle Shoals, Alabama. Jorge has a degree in chemical engineering from both the University of Michigan and the University of Los Andes in Bogota, Columbia. Jorge has approximately ten years of plant engineering and management experience in petroleum, polyethylene and other petrochemical plants. He has been associated with the IFDC for the past six years and is currently Deputy Engineering Coordinator. Jorge, may we please have your presentation. (Applause)

Ammoniated Granular TSP For Developing Countries

James J. Schultz - Jorge R. Polo

Presented by - Jorge R. Polo

Introduction

Urea is the major source of nitrogen fertilizer in the developing countries. The total urea production capacity in the world is sufficient to produce about 80 million mt of urea, containing about 37 million mt of nitrogen. This amount of nitrogen is equivalent to about 60% of the 1980/81 world nitrogen consumption which amounted to about 60 million mt.[1]

Urea or other straight nitrogen fertilizers do not always completely satisfy crop nutrient needs. For example, in field tests conducted by FAO in 1977/78, straight nitrogen was found to be the "best treatment" in only 2 out of 41 tests carried out in 13 countries. The best treatment in the FAO tests referred to the highest ratio of the value of increased yield to the cost of the fertilizer.

Furthermore, in many cases the inclusion of certain common phosphate, potassium, and magnesium in urea-based compound fertilizers adversely affects the manufacturing process and the physical characteristics of the products. Mixtures of urea and superphosphate are especially prone to form an adduct accompanied by the release of water which causes severe caking and deterioration if the blended materials are stored for an appreciable length of time.

Diammonium phosphate is the most compatible and frequently used source of phosphate for preparing compound fertilizers containing urea. In order to provide an improved or alternative phosphate material for

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[1] FAO consumption data compiled by the Tennessee Valley Authority (TVA).

the urea-based NPK blender, a process for producing a partially ammoniated granular triple superphosphate (GTSP) fertilizer (5-44-0) by the direct slurry process was studied by IFDC. The phosphate content (44% P_2O_5) of the modified fertilizer refers to total P_2O_5 rather than available P_2O_5 commonly used to describe nutrient value. The product, including phosphate availability, may better fit the requirements of the farmer in the tropics where acidic soils (pH of 4-5) and long growing seasons predominate. The modified phosphate production process was also designed so that only a relatively simple retrofit to existing facilities would be required for commercial production of the new product.

Ammoniation of single and triple superphosphate has been studied for many years. TVA conducted an extensive study using run-of-pile raw materials in development of an ammoniator, with and without simultaneous granulation, in the early fifties.[2] The products had relatively high P_2O_5 availability when produced, but the availability was significantly affected (reduced) by increased storage time, temperature, and product moisture. Ammoniation of the run-of-pile material, without granulation, yielded a relatively dry product with good physical properties. Ammoniation and granulation of superphosphate along with other materials are now practiced in many compound (NPK) fertilizer plants around the world.

IFDC is not aware of an ammoniated GTSP product being produced commercially by the direct slurry process for direct application or bulk blending. There is a trend toward GTSP production by the single-step process not involving pile curing. IFDC felt that the merits of this product and process should be evaluated in reference to developing countries as discussed in this paper.

Description of Process

The plant equipment and process used for the pilot plant-scale prodution of the partially ammoniated GTSP was a variation of the slurry-type GTSP processes originally developed by the former Dorr-Oliver, Inc., and Davy Powergas, Inc., companies. The most notable variations from the commercial GTSP processes included (1) the use of a single-tank digester for the phosphate concentrate/phosphoric acid reaction, and (2) simultaneous ammoniation and granulation of the partially digested phosphate slurry in a conventional drum granulator. Most of the tests were performed at a production rate of about 250 kg/hour, while the unit was operated at a throughput rate of 1,100-3,500 kg/hour, depending upon test conditions. During the course of the pilot plant-scale process development, many equipment and process variations were evaluated. A description of the most nearly optimum process configuration tested (Figure 1) follows.

Phosphate concentrate, usually 90% minus 100-mesh (Tyler), 0.15-mm openings, was fed continuously to an agitated premix tank with a variable-speed screw conveyor. The premix tank was 32 cm (12.5 in) in diameter and 46 cm (18 in) deep. It was equipped with a fixed overflow and had a working capacity of about 20 liters (0.71 ft^3) which was equivalanet to about 8 minutes retention time when operating at a production rate of 250 kg/hour. Phosphoric acid (usually 54% P_2O_5), water, and an antifoam agent were also fed to the premix tank. Magnetic-type flowmeters were used to measure the phosphoric acid and water feeds, and a peristaltic pump was used to feed an aqueous solution of the antifoam agent.

The thoroughly wetted mixture of phosphate concentrate and phosphoric acid overflowed into the digester. The digester was 61 cm (24 in) in diameter and 207 cm (82 in) deep, including a cone bottom 9 cm high. It was equipped with a variable-speed agitator fitted with three axial-flow, downward-thrust turbines. The normal depth of slurry in the digester was 75 cm (29.5 in) above the cone, which was equivalent to a retention time of about 90 minutes when operating at a production rate of 250 kg/hour. At this level, only two of the turbines were submerged. An exhaust fan and spray-type wet scrubber were used to ventilate the digester and treat the gases before exhausting them to the atmosphere. The exhaust fan and scrubber system were constructed of fluorine-resistant reinforced polyester. The system was operated at an airflow rate of 450 m^3/hour. A drawing of the premix tank and the digester is shown in Figure 2.

Slurry was transferred to the drum granulator by using a progressive cavity pump fed from a constant level overflow on the digester. Since foaming in the digester was controlled by the addition of an anti-foam agent, operation of the constant-level overflow system was very reliable and a steady feed of slurry to the drum granulator was maintained.

A drilled pipe with an air atomizer was used to distribute the partially digested slurry onto the rolling bed of recycle material in the drum granulator.

The drum granulator was 92 cm (3 ft) in diameter and 1.8 m (6 ft) long. A 15-cm (6-in) high retaining dam was located 61 cm (2 ft) from the discharge end of the granulator. The granulator was normally operated at rotational speed of 18 rpm which was equivalent to 41% of the critical speed. An air exhaust system, consisting of a reinforced polyester venturi scrubber and a type 316L stainless steel fan, was used to treat the dust- and fume-laden air from the granulator and surrounding work area before it was exhausted to the atmosphere. Ammonia gas was fed to the granulator through a drilled pipe distributor (sparger) submerged beneath the rolling bed of material. An orifice-type flowmeter was

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[2] Yates, L. D., F. T. Nielsson, and G. C. Hicks. 1954. "TVA Continuous Ammoniator for Superphosphates and Fertilizer Mixtures," Part I. *Farm Chemicals,* 117:38, 41, 43, 45, 47-48 (July 1954), Part II, Ibid., 117:34, 36-38, 40-41 (August 1954).

used to measure the flow of ammonia and control was done manually or automatically depending upon the test objectives. A diagram of the drum granulator is shown in Figure 3.

The moist, plastic material from the drum granulator discharged by gravity into a rotary dryer 92 cm (3 ft) in diameter and 7.3 m (24 ft) long. The dryer was operated with a cocurrent flow of air that was heated in a propane-fired combustion chamber located at the inlet (material feed end) of the dryer. The operating temperature of the dryer was indirectly controlled by the temperature of the air in the discharge breeching. A cyclone-type dust collector was located in the process air duct between the dryer discharge and the exhaust stack. The flow of air through the dryer was measured and controlled by use of an orifice-type flowmeter and damper in the exhaust stack. The dryer was usually operated at a rotational speed of 7 rpm, an airflow rate of 4,000-5,000 m^3/hour (2,300-3,000 cfm) (outlet conditions), and an air temperature at the dryer outlet of 115°C (240°F). Under these conditions, the superficial velocity of the air through the dryer was about 2 m/second.

A centrifugal discharge-type bucket elevator was used to transfer the material from the dryer to a double-deck, mechanically-vibrated (unbalanced flywheel) screen. The screen was fitted with a 6-mesh (Tyler), 3.35-mm opening, Ty-Rod oversize screen, and a 10-mesh (Tyler), 1.70-mm opening, Ty-Rod undersize screen to yield a product in the 1.70-3.35 mm size range. Oversize material from the screen was routed to a single-shaft chain mill. The material discharged from the chain mill was returned to the screen. Normally, the quantity of oversize material was small (about 15% of the total dryer discharge) and the amount of crushed oversize in the product was usually less than 20%.

The undersize material together with a fraction of the product was returned to the granulator as recycle. The material handling equipment for the recycle system consisted of a horizontal drag-type conveyor, a 0.39 mt (860 lb.) capacity live-bottom surge bin fitted with a variable-speed screw conveyor, a positive discharge-type bucket elevator, and an inclined drag-type flight conveyor. The quantity of recycle fed to the granulator could be controlled or allowed to "float," depending upon the particular test objectives. Under normal operating conditions the quantity of recycle fed to the granulator was maintained at a relatively constant rate by regulating the fraction of product diverted to recycle.

Tests were also made to identify the feasibility of retrofitting the ammoniated GTSP process to a standard NPK granulation plant where the screens are located downstream from the cooler. When this mode of operation was duplicated, the material discharged from the dryer was fed to a rotary cooler 92 cm (3 ft) in diameter and 7.3 m (24 ft) long. The flow of air through the cooler (about 3,900 m^3/hour at outlet conditions) was countercurrent to the flow of material. The cooler, like the dryer, was equipped with a cyclone-type dust collector and airflow measuring and control equipment. A double-deck, horizontal, gyratory-type screen was used to remove the oversize and undersize fractions. The screen was fitted with square mesh screen cloth. The oversize screen was 6-mesh (Tyler), 3.35-mm opening and the undersize screen was 10-mesh (Tyler), 1.70-mm opening. The oversize material was crushed and returned to the screen and the undersize, together with some of the product, was routed to the recycle system previously described. The temperature of the recycle material returned to the granulator was significantly lower when a cooler was used and its effect on the process was determined.

In all tests, the product discharged from the system was sampled to determine its chemical, physical, and storage properties. L:ikewise, all scrubber liquor streams and process air exhaust stacks were monitored to determine the magnitude and distribution of fluorine evolution and other material losses. Although meaningful electric power consumption data could not be obtained to the pilot plant-scale equipment, fuel consumption for drying under the various process conditions was closely monitored.

Process Development

Forty-seven tests wee made over a period of 6 months. The length of continuous operation in each test varied from 6 to 12 hours. Actual granulation time totaled 316 hours. Many problems were identified and most were solved during the course of the test program. Problems of a strictly chemical process nature were few. Most of the problems centered around the traditional difficulties of handling slurries. Furthermore, the problems attributed to handling slurries and moist or plastic solids are usually more difficult to cope with in pilot plant-scale equipment because the flow rates, pipelines, chutes, and other material handling equipment are disproportionately small while the material characteristics, including granule size, lumps, and buildups, are more typical of commercial-scale operation. A discussion of the major problems encountered and their solution follows.

Digestion and Slurry Transport

From a chemical point of view, digestion of the phosphate concentrate (apatite) with phosphoric acid occurred as expected and without any unusual incidents. The level of free phosphoric acid in the slurry fed to the granulator indicated that approximately 45%-50% of the phosphoric acid-apatite reaction occured in the single tank digester. The retention time of the slurry in the digester was maintained close to 100 minutes in all tests.

The most troublesome problem identified was unexplainable changes in the physical properties (viscosity, fluidity, color, specific gravity, and pumping characteristics) of the partially digested slurry. In most of the initial tests the desired quality (pumpability) of the slurry deteriorated with time. After about 6 hours of continuous operation, the slurry usually began to thicken and became difficult to pump to the granulator. Frequent plugging of the 1.3-cm diameter (½-in) Schedule 40 slurry pipeline at valves, elbows, and other restrictions usually signaled the onset of the phenomenon. The entire slurry piping system was either steam jacketed or steam traced.

In trying to solve this high viscosity problem, the following actions were tested unsuccessfully:

1. Changing impeller design and speed on digester agitator.
2. Varying the steam pressure (temperature) on the tracing and jacketing of lines.
3. Changing the concentration of the feed acid to the digester. In all cases the total water added, including the water and steam added directly to the digester, had the net effect of diluting the phosphoric acid to about 42% P_2O_5.

Two changes were made in the slurry digestion and transport equipment configuration that effectively solved the problem. First, a cone-type premixer was replaced with a small mixing tank. The phosphate concentrate, phosphoric acid (54% P_2O_5), water, and antifoam agent were fed to the tank which was vigorously stirred with an air-motor type of agitator. The premixed slurry overflowed into the digester as previously described. Second, use of a centrifugal pump and slurry recirculation system required for operation of the cone-type mixer was discontinued.

With the new system, slurry was withdrawn from a fixed overflow point on the side of the digester. The overflowing slurry was fed by gravity into the suction of a progressive cavity pump that fed the granulator. An open-ended, half-moon vertical baffle was installed in the digester to isolate the overflow nozzle from the main body of slurry to a minimize short-circuiting of slurry before it has sufficient time to react. This system eliminated the need for level control in the digester and, more importantly, it eliminated the centrifugal recirculation pump that was assumed to be the cause for the excessive shear of the slurry (crystal errosion and breakage).

These changes made it very easy to operate the digester and produce a slurry with predictable and acceptable handling (pumping) properties. Photo-micrographs of the slurry solids before and after the modifications of the digester and slurry transport systems are shown in Figure 4.

With the initial premix and slurry transport system, petrographic examination of the slurry fed to the drum granulator indicated a change in the size of the mono- and dicalcium phosphate crystals with the passage of time — the longer the plant was operated, the smaller the crystals became. Although these observations were not always definite and repeatable, a clear correlation between operating time and the crystal size, color, viscosity, and pumpability of the slurry began to emerge.

The small and eroded nature of the crystals indicated that excessive mechanical shear was occurring, presumably because of the centrifugal pump used to recirculate slurry to the cone-type premixer. Furthermore, the gradual decline in the size of the crystals as a function of operating time was possibly aided by inadvertent crystal classification caused by the bleed stream piping configuration used to divert a fraction (about 15%) of the slurry from the recirculation system to the drum granulator. The increased concentration of small crystals favored the entrainment of air in the slurry and this resulted in variable and unpredictable slurry properties, making it impossible to operate the unit. A possible third factor that may have contributed to the adverse changes in the slurry properties probably was short circuiting of unreacted apatite directly to the suction of the recirculation pump at the bottom of the digester. Apatite, continuing to react in the recirculation pump and transport system, could have contributed further to the entrainment of reaction gases in the slurry.

Slurry Distribution in Drum Granulator

Uniform distribution of slurry was essential to obtain the desired rate of ammonition, and to minimize problems associated with overgranulation and buildup of material on the interior walls of the granulator, ammonia sparger, and other support structures. The most practical and trouble-free distribution system was found to be a drilled pipe fitted with an air atomizer. The air atmoizer was simply another drilled pipe arranged in parallel with the slurry pipe. Mild velocity jets of air broke and gently spread the streams of slurry causing uniform wetting of the recycle material. The assembly was placed above the bed of material.

Ammonia Distribution in Drum Granulator

A simple drilled pipe ammonia sparger that is 1.3 cm in diameter (½-in Schedule 40 pipe) and 91 cm (3 ft) long containing a single row of 10 holes (3 mm [1/8 in] in diameter) was used to feed gaseous ammonia below the bed of material in the granulator. During the initial period of operation, a hard buildup of material on the ammonia sparger usually caused severe upsets in granulation and excessive losses of ammonia. However, as soon as the slurry distribution problem was solved, the problems of buildup on the ammonia sparger largely disappeared.

Granulation

The 122-cm (4-ft) long ammoniation section of the drum granulator was originally fitted with 3-mm

(1/8-in) thick neoprene rubber panels. In previous granulation studies using other fertilizer materials, the panels were very effective in minimizing the accumulation of solid buildup on the walls of the granulator, thus eliminating the need for a more elaborate mechanical scraping system. However, in these tests, the rubber panels were not effective in preventing buildup of material on the granulator walls. For these reasons they were removed and a reciprocating mechanical scraper originally supplied with the granulator was installed. This modification eliminated the problem and made it possible to position the ammonia sparger slightly deeper in the bed to achieve improved ammoniation, good rolling bed characteristics, and optimum granulation.

Drum Granulator Scrubber

The dust- and fume-laden air from the drum granulator and surrounding operating area was treated in a venturi-type scrubber using a closed-loop recirculated stream of water (scrubber liquor). Severe foaming of the relatively clean scrubber liquor frequently occurred. Petrographic and chemical analysis of the foam and suspended solids in the recirculated liquor indicated a high concentration of finely divided silica that presumably retarded the escape of air from the liquor and caused the foam. The problem of foaming was eliminated by filtering a side stream of the liquor through a Dynel cloth bag. The filtered liquor was returned to the recirculation tank. The filter bag was cleaned between tests.

Drying

Operation of the rotary dryer was routine for most tests. On a few occasions a buildup of material accumulated on the walls and lifting flights near the inlet and mid-section of the dryer. This occurred during the early stages of process development when the level of free acidity or the degree of ammoniation caused the material to become unusually sticky. Once the proper operating parameters had been defined for GTSP and ammoniated GTSP, the problem of excessive stickiness and buildup in the dryer disappeared.

Screening and Crushing

The performance of the screening and crushing equipment was similar to that of the dryer. When the process parameters were first explored and defined, some sticky product was made that contained a large amount of oversize. This material was difficult to screen and crush. In addition to being sticky because of excessive free acidity or solubility when ammonia was added, the crushed oversize was also very moist. This material, after passing through the chainmill-type crusher, was recirculated to the screens and caused them to blind. Buildup of material in the chutes leading to and from the crusher also occurred during this period, but the chainmill itself never had to be cleaned. As in the drying operation, once the proper operating parameters had been established, the material fed to the screen and crusher was dry and crisp, and the problems of blinding of the screens and plugging of chutes were eliminated.

Process and Product Characteristics

Many of the tests were of a short duration—usually about 6 hours to accommodate the normal workday. Most of these short tests were of an exploratory nature designed to evaluate a specific portion of the process or equipment configuration. During this time, many of the operating problems already discussed were identified and solved. After completion of the exploratory tests, several tests of longer duration were made (Table 1). A discussion of data pertaining to the raw materials, plant operation, and product characteristics follows.

Raw Materials

All raw materials used were purchased from domestic (U.S.) sources.

Phosphate Concentrate—Most of the tests were made using phosphate concentrate obtained from north Florida (Occidental Chemical Company, White Springs, Florida). However, some tests were made using concentrate obtained from central Florida (International Minerals and Chemical Corporation, Mulberry, Florida). Both materials were received, ground to a nominal 90% minus 100-mesh (Tyler), 0.15-mm openings.

Phosphoric Acid—Wet-process phosphate acid for all tests was obtained from TVA. This acid was produced by several companies who supply TVA on a contract basis. Because TVA may obtain acid from more than one supplier at the same time, it was not possible to identify the specific supplier.

Ammonia—Ammonia required for the tests was produced by TVA. A 2-mt capacity trailer-type tank was used to transport liquid ammonia from TVA to the IFDC pilot plant. Ammonia gas was fed to the process. No tests were made to evaluate the use of liquid ammonia because of the difficulty in metering and uniformly distributing the small quantity of liquid (about 15-20 kg/hour).

Antifoam Agent—An antifoam agent was added to the digester. The agent was a solution containing 20% by weight of a sodium salt of sulfonated oleic acid (OA-5 manufactured by Cities Service Company) dissolved in water. Other antifoam agents were not evaluated.

Operating Data

Two basic processes were evaluated in the pilot plant. In the first, GTSP was produced to develop a basis for comparison and evaluation of the ammoniated variation. The process is very similar to most commercial processes with the exception that only one digester was used. However, the retention time (approximately 90 to 100 minutes) of the slurry during digestion was similar to that maintained in multiple digester plants.

The modification of the basic GTSP process to produce ammoniated GTSP was simple—involving only the addition of a drilled pipe ammonia sparger beneath the bed of material in the drum granulator and appropriate ammonia measuring and control equipment. Both products (GTSP and ammoniated GTSP) were normally produced using the hot-screening equipment configuration. However, tests were also made to evaluate the ammoniated GTSP process assuming it was retrofitted to a typical NPK granulation plant in which the screening is done after cooling. A discussion of the operating data follows.

Granular Triple Superphosphate—The objective of the GTSP tests was to develop a data base for comparison with that of the ammoniated product. Close duplication of commercial production practices was equally important. However, the use of 68 BPL (31% P_2O_5) phosphate concentrate and the single tank digestion system made it difficult to obtain the commercially accepted grade of 46% available P_2O_5.

In order to maintain steady plant operation, the following indicators were closely observed (1) digester operation and slurry handling characteristics; (2) product characteristics and handling problems during granulation, drying, screening, and crushing; and (3) recycle-to-product ratio required to obtain optimum granulation.

The only significant process chemistry variable evaluated was the P_2O_5:CaO weight ratio of the materials fed to the digester. In addition to the flows of phosphate concentrate and phosphoric acid to the digester, the free acidity (expressed as % P_2O_5) of the partially digested slurry fed to the granulator, as well as the free acidity of the material discharged from the granulator, and the screened product were closely monitored. The relationship between excess free acidity (above about 4%-8% P_2O_5 at the discharge of the dryer) and sticky product which led to overgranulation, blinding of the screens, plugging of the crusher, and stoppages in the chutes was very similar to that experienced in commercial-scale units.

Weight ratios (P_2O_5:CaO) of approximately 1.80 and 2.00 were evaluated. The conversion of P_2O_5 to the available form (the material ammonium citrate-soluble P_2O_5, including the water-soluble fraction) was erratic at the lower P_2O_5:CaO ratio (64% and 90% conversion) while 94% to 100% conversion was obtained at the higher ratio. The reason for the erratic conversion at the lower ratio is not clear but it may have been related to the physical arrangement of the digestion system initially used and the resulting adverse changes in the slurry composition and characteristics already described. Data during operation at a P_2O_5:CaO weight ratio of 2.00 were obtained after the digestion and slurry transport systems had been modified and the slurry recirculation and cone-type premix systems were eliminated.

At a P_2O_5:CaO weight ratio of 2.00 and a retention time of 90 minutes in the digester, the free acidity of the slurry fed to the granulator was equivalent to approximately 15% P_2O_5. Steam, and sometimes water, was added the the digester to maintain the temperature and specific gravity of the slurry at approximately 93°C (200°F.), and 1.70, respectively. Under these conditions the viscosity of the slurry was about 30-40 cP and the slurry had a watery appearance and was easy to transport (pump) and distribute in the drum granulator.

During the GTSP tests a recycle-to-product ratio of 10 was normally required to obtain optimum granulation and to minimize the production of an excessive amount of oversize that is difficult to dry and crush. The temperature and moisture of the granulated material fed to the dryer was typically 60°-70°C (140°-160°F) and 4% respectively. The values are similar to those obtained in commercial-scale units with the exception of the recycle-to-product ratio of 10. Most commercial-scale units operate at a lower ratio (about 7) presumably because the temperature of the recycle is higher in larger equipment. The temperature of the recycle in the pilot plant was approximately 70°C (158°F.) compared with about 85°C (185°F.) in commercial plants.

The dryer was operated with a cocurrent airflow rate of 4,930 m^3/hour (outlet conditions). This airflow rate was equivalent to a superficial air velocity through the dryer of approximately 2 m/second. The temperature of the air at the dryer outlet was controlled at approximately 110°C (230°F.) to give a product temperature at the dryer discharge of about 105°C (221°F.) to approximate commercial operation. At this temperature, the moisture in the product was usually less than 1.0%. Under these conditions, and while the unit was being operated at a production rate of 250 kg/hour, approximately 8.9 m^3 of propane gas was required per hour for drying. This quality of fuel was equivalent to about 0.8 million kg-cal/mt (3.2 million Btu/mt) of product. Heat losses in pilot plant-scale equipment are relatively large (30%-40%); therefore, fuel consumption estimates cannot be directly extrapolated to commercial scale. No tests were made to isolate the effect of drying temperature on available P_2O_5 in the product.

No problems were encountered in screening and crushing as long as the free acidity of the material fed to the screen remained in the order of 8% P_2O_5 or less and granulation was controlled to minimize the production of oversize. An oversize fraction equivalent to about 25% of the total feed to the screen was acceptable and operation of the screen and crusher was relatively easy to maintain.

The product size fraction not needed for recycle was routed to storage. The temperature of the product was about 70°C, and no further cooling was required.

In a commercial-scale unit this temperature would be higher, and additional cooling may be required, depending upon free acidity, moisture, and subsequent handling, packaging, and processing requirements.

Ammoniated Granular Triple Superphosphate—The objective of the ammoniated GTSP pilot-plant studies was to determine the operating parameters for the production of a partially ammoniated product that has an optimum combination of the desired physical, chemical, and agronomic properties. The ratio of nitrogen to phosphate was not predetermined, but for practical commercial purposes, a nitrogen content intermediate between GTSP and DAP was established as a goal while maintaining a maximum level of P_2O_5. A 5-44-0 grade was found to be the most practical to produce.

The nitrogen content of the ammoniated GTSP product is completely water soluble, but the P_2O_5 (44%) is expressed as total P_2O_5 and not as available. In most cases about 20%-25% of the total P_2O_5 is not available when the neutral ammonium citrate method is used for the determination. The distribution of the P_2O_5 according to solubility is discussed later.

For practical purposes, operating parameters for the digester while producing the 5-44-0 grade were identical with those used when producing GTSP. The degree of ammoniation that could be obtained in the granulator was determined by the amount of free phosphoric acid in the partially digested slurry fed to the granulator.

In the granulator, the free phosphoric acid was ammoniated to form monoammonium phosphate (MAP) and essentially no ammoniation of the digested fraction of the slurry (mono- and dicalcium phosphate) appeared to occur. The degree of ammoniation during granulation was also controlled to maintain a pH in the granulator of about 5.0 to minimize the loss of ammonia, thus eliminating the need for an ammonia recovery system on the granulator. When the free phosphoric acid was not ammoniated to a nitrogen level of about 5%, the liquid phase in the granulator increased rapidly and it was impossible to maintain continuous operation.

The net effect of the ammoniation of the free phosphoric acid was to halt the typical GTSP reactions between phosphoric acid and unreacted apatite during granulation, drying, and curing. Since the complete conversion of the phosphate to the available form is not needed or desired in many developing countries for agronomic reasons, this was of little concern. When ammoniated GTSP is being produced, the lack of acidulation-type reactions during the drying and curing stages decreases the need for fluorine recovery and disposal systems but does not eliminate them.

On the basis of the pilot-plant tests, the most significant advantage of the ammoniated GTSP process when compared with the standard GTSP process is the potential for increasing the production rate. In the GTSP process operated in the pilot plant, a recycle-to-product ratio of 10 was required for smooth and reliable operation. The ammoniated GTSP process could be operated equally well with a recycle-to-product ratio of 5. Although these values may not be extrapolated directly to commercial-scale units, the differential is significant. A 400-mtpd GTSP plant could probably produce 700 mtpd of the ammoniated GTSP product at the lower recycle ratio after increasing the capacity of the digester and related raw material feed system. The throughput capacity of most of the major equipment items, such as the granulator, dryer, screens, bucket elevators, and conveyors, would be adequate for a significant increase in the production rate.

Fuel consumption for drying the ammoniated GTSP product was about 7% less than that required for GTSP when the product was dried to about 1% moisture. When the product moisture was maintained between 3.5%-4% the ammoniated GTSP was still in good physical condition and the fuel consumption was about 28% less than that required to dry GTSP to about 1% moisture. However, it is not possible to obtain good correlation between pilot-plant and expected commercial-scale fuel consumption values.

Retrofit of Ammoniated GTSP Process to an Existing GTSP or NPK Plant—The modification of an existing GTSP plant already using the slurry process would be relatively simple. Depending upon the reactivity of the phosphate concentrate being used, it may be necessary to add additional digester capacity and upgrade the phosphoric acid, concentrate, and slurry measuring and transport systems to accommodate the higher production rate that could be obtained. The most capital-intensive addition required for the retrofit to a standard GTSP unit would be the ammonia storage facility. The transport, metering, and distributing system for the ammonia required in the drum granulator is simple and relatively inexpensive. A gaseous ammonia feed to the drum granulator is preferred for obtaining optimum distribution and uniform ammoniation. Therefore, depending upon the ammonia supply facilities, a vaporizer may be required to assure a steady flow of ammonia gas to the process.

Most NPK granulation plants could be modified for the production of ammoniated GTSP without a major investment. An NPK plant already equipped with a preneutralizer represents the least costly conversion. The major equipment additions required for such a plant would be the phosphate concentrate storage and feed systems. A typical single tank ammonium phosphate preneutralizer would usually have to be modified to incorporate the following features (1) intensive mixing with a downward-thrust, axial-flow, turbine-type agitator; (2) slurry discharge through a constant level overflow instead of a bottom discharge normally used with ammonium phosphate preneutralizers; and (3) a low-shear, open-face impeller centrifugal pump or a progressive cavity-type pump to transport the slurry to the drum granulator. A small premix tank (about 10% of the capacity of the digester) would also be required to wet the phosphate concentrate to assure uniform distribution and reaction in the digester.

The production rate of ammoniated GTSP that could be obtained in an ammonium phosphate-based NPK plant would be dependent upon the retention time in the digester, reactivity of the phosphate concentrate, product specifications with respect to available P_2O_5, and the throughput capacity of the granulation unit. Many NPK granulation units operate at recycle-to-product ratios in the range of 1 to 5 depending upon the particular formulation. Therefore, it is not likely that an increase in the production rate could be obtained when producing the ammoniated GTSP product.

Most NPK granulation plants pass all the material through a cooler before it is screened. In these plants, the recycle returned to the drum granulator is much cooler than what is typical in a "hot screening" plant. Most modern GTSP and DAP plants utilize hot screening and only cool the product fraction to economize on the size of the cooler, screens, and associated material handling equipment and to take maximum advantage of the sensible heat (energy) of the recycle to aid in the evaporation of water during granulation and drying.

Production of ammoniated GTSP in a typical NPK granulation plant configuration with cold screening was evaluated in the pilot plant. The lower temperature (40°C compared with 60°C with hot screening) of the recycle returned to the granulator with this configuration had no significant effect upon the process.

Fluorine Evolution—Fluorine is a common constituent in phosphate concentrate and phosphoric acid. The concentrate and acid used in the pilot-plant tests typically contained 3.8%, and 1.1%, fluorine, respectively. Acidulation reactions are usually accompanied by the release of some gaseous fluorine compounds (HF and SiF_4). Sufficient silica is usually present in the concentrate and the HF quickly reacts to form SiF_4. Fluorine gases, even in small quantities, are very toxic to plant and animal life. Removal of fluorine from process gas streams before they are exhausted to the atmosphere is essential and is closely monitored by local pollution control authorities, not only in the Unites States but also in most of the world.

Fortunately, the SiF_4 gas has a very strong affinity for water and can be easily removed from exhaust gas streams by using low-energy scrubbers to produce fluosilicic acid (H_2SiF_6) and silica (SiO_2). Fluorine is very corrosive, precluding the use of mild steel, most stainless steel alloys, and concrete that is not protected or otherwise treated to resist attack.

Although the technology for fluorine scrubbing and byproduct fluosilicic acid production is well developed, the feasibility of installing such facilities is dependent upon the quantity of fluorine evolved, local emission standards, demand and price for byproduct fluosilicic acid, and alternative pollution abatement and disposal facilities that may be available. The sources and magnitude of fluorine evolution from the GTSP and ammoniated GTSP processes were determined.

The digester was thought to be a major source of gaseous fluorine emissions. Therefore, it was equipped with a spray-chamber type of wet scrubber. The premixer, digester, and surrounding work area was ventilated at a rate of about 450 m^3/hour. The scrubber was operated at a liquor (water) recirculation rate of 3.4 m^3/hour. The concentration of fluorine compounds in the recirculated liquor was expected to increase from 0% at the start of a test period to about 11% H_2SiF_6 during a prescribed period (usually 6 hours) if most of the fluorine (based on raw material and product analysis) were evolved during digestion. In all tests, essentially no fluorine was found in the scrubber liquor. The lack of fluorine evolution from the digester was further indicated by the absence of a fluorine odor in the gases exhausted from the digester when the scrubber liquor recirculation was intentionally stopped. The fluorine odor observations were made by actually breathing the exhaust gas as it was discharged from the stack to the atmosphere.

It is well known that the conversion of apatite to available forms of P_2O_5 is associated with the release of fluorine from the apatite. Since about 50% of the P_2O_5 in the apatite was converted to an available form in the digester and no gaseous fluorides were evolved, it was assumed that the fluorine released from the apatite immediately reacted and precipitated in the digester as calcium fluoride and remained in the product.

Material balance data based on the fluorine fed to the process and the fluorine found in the finished product indicated that from 10% to 20% of the fluorine fed was evolved. Most of this evolution was assumed to occur in the dryer. Quantitive measurements of fluorine in the dryer exhaust gas were inconclusive. However, qualitative tests made by injecting ammonia into the dryer exhaust stack caused the instantaneous formation of a dense bluish-white plume, presumably ammonium fluoride.

On the basis of the ammoniated GTSP pilot-plant data, in a plant using phosphate concentrate and phosphoric acid feeds containing a total of 2.5% fluorine (F, dry basis), approximately 3,100 kg (25% of total fed to process) of fluorine would be evolved from a 500-mtpd unit if fluorine scrubbing equipment were not used. Such emissions would not be acceptable; thus, appropriate fluorine removal and disposal equipment would have to be provided.

Product Characteristics

The chemical, physical, and agronomic characteristics of the ammoniated GTSP product produced in the pilot plant were compared with those of alternative phosphate products (GTSP and DAP) produced in the pilot plant or obtained from commercial sources.

Chemical Properties and Distribution of P_2O_5—Three major levels of P_2O_5 solubility occur in the ammoniated GTSP product. Water-soluble P_2O_5 amounted to about 55% of the total while the neutral ammonium citrate-soluble fraction (NAC, excluding water-soluble fraction) was about 22% and the insoluble fraction was approximately 23% of the total. For comparison, the distribution of P_2O_5 in GTSP product made in the pilot plant using identical operating parameters (except no ammoniation) was about 80% water soluble, 12% NAC soluble (excluding water-soluble fraction), and about 8% was acid insoluble. When the 2% citric acid method was used to determine the available P_2O_5 in the ammoniated GTSP product instead of the NAC method, the insoluble P_2O_5 fraction was decreased from 23% of the total P_2O_5 to 8%. A summary of these data is shown in Table 2.

The ammoniated GTSP product was also analyzed to determine the degree of reversion that may have occurred as a result of ammoniation. These tests confirmed that no significant reversion of available P_2O_5 to insoluble P_2O_5 occurred as a result of ammoniation. X-ray diffraction techniques were used to further identify and confirm the major constituents in the ammoniated GTSP product. These examinations indicated that MAP was the predominant phase followed by apatite, calcium sulfate hemihydrate, and traces of silica and other undetermined materials. Mono- and dicalcium phosphate, although present, were difficult to distinguish in the presence of the other materials, especially apatite.

Physical Properties—The ammoniated GTSP product had excellent physical properties with respect to granule hardness, resistance to absorption of atmospheric moisture, and to caking. These properties together with comparative data from other P_2O_5 sources (GTSP and DAP) are shown in Table 3.

NP and NPK bulk blends were prepared from urea, ammoniated GTSP, GTSP, DAP, and potash (KCl). The compatibility and storage charactertistics of the blends were determined. These data are shown in Table 4. The blends using ammoniated GTSP as the source of P_2O_5 remained dry and free flowing when stored in sealed jars at room temperature for a period of 1-21 days. The blends using GTSP from three sources (pilot plant and two commercial companies) or DAF became wet, sticky, and agglomerated after only 1 day of storage in the sealed jars when blended to give a 1:1:1 nutrient ratio. When KCl was not used (nutrient ratio of 1:1:0), the blend using DAP stored as well as the ammoniated GTSP blend, but the others were sticky and agglomerated.

Agronomic Performance—A preliminary agronomic evaluation was made to obtain as indication of the relative performance of ammoniated GTSP as a source of phosphorus compared with GTSP and DAP. The tests were performed under controlled conditions in the IFDC greenhouse. The soil used for the tests (Hartsells topsoil) had a pH of 4.9, and its characteristic of many acidic soils in the tropics. Maize (corn, Funks G5757) was used because it is an excellent indicator crop for phosphate response. Nitrogen (urea) was added to each experimental growing pot in variable quantities to obtain a constant and abundant level of nitrogen regardless of the source of P_2O_5. A micronutrient solution containing magnesium, zinc, copper, sodium, sulfur, and boron was also added to each pot to eliminate the possibility of such deficiencies.

Two successive plantings (6-week growth period each) were made to evaluate the initial and residual effect of a single dose of phosphorus. The phosphorus uptake by the maise plants and the plant-available phosphorus content pf the soil were determined after each harvest. A photograph of a sample of the crop just before the first harvest is shown in Figure 5.

A tabulation of the dry matter yield and distribution of phosphorus between the plant matter and soil is shown in Table 5. Those data, although very preliminary, indicate that the performance of ammoniated GTSP is very similar to that of conventional GTSP or DAP under the conditions used for the experiment.

Production Economics

The production economics of ammoniated GTSP compared with that of TSP can only be generalized because of the many site-specific conditions that exist, especially in developing countries. Perhaps the most important influence upon the feasibility of the ammoniated GTSP process is the price the product can be sold for relative to traditional phosphate products. Regardless of the possibly equal or superior agronomic value (under certain tropical conditions) of the less quickly available P_2O_5 in the ammoniated GTSP compared with GTSP or DAP, it is unlikely that it will command the same price as the traditional more soluble products on a total P_2O_5 basis.

On the production side, it is clear that the capacity of a standard GTSP unit could be significantly increased because of the lower recycle rate required for ammoniated GTSP. The higher production rate would be accompanied by obvious efficiencies in labor, energy, and overhead. However, to obtain these efficiencies an investment in ammonia storage, transport, and metering facilities would be required. Also, because the production rate could be significantly increased, the phosphate concentrate and phosphoric acid supply, storage, and transport facilities would undoubtedly have to be enlarged. Furthermore, depending upon the reactivity of the phosphate concentrate and the required P_2O_5 solubility specifications, a larger digester may also be needed. The fluorine removal (scrubbing) systems in an existing GTSP plant should be adequate for the ammoniated GTSP process although additional ventilation of a larger digester may be required.

Most NPK granulation units would not be able to increase the production rate by converting to the ammoniated GTSP process because the recycle-to-product ratio in these plants is usually well below 4 or 5 (expected ratio for ammoniated GTSP). A significant investment would also be required to modify an existing preneutralizer or to install a new digester and facilities for phosphate concentrate storage, assuming ammonia and phosphoric acid facilities are already available. The existing scrubbing system for the dryer may also have to be modified or replaced to handle the additional fluorine load.

Finally, the economic feasibility of producing ammoniated GTSP will be determined by the farmer. The excellent physical properties of ammoniated GTSP, even when blended with urea and potash, together with an apparent agronomic performance similar to GTSP or DAP indicate that it is a potential alternative phosphate source.

Table 2. Solubility of P_2O_5 in Granular TSP and Ammoniated Granular TSP

				Percentage P_2O_5 Soluble in		
Product	Source	N	Total P_2O_5	Water	NAC[a]	2% CA[b]
GTSP	IFDC Pilot Plant Test 7-174	0	47.4	37.9 (80.0)[c]	5.9 (12.4)	9.8 (20.7)
GTSP	Commercial	0	48.1	39.0 (81.1)	8.0 (16.6)	10.8 (22.5)
AGTSP	IFDC Pilot Plant Test 7-172	5.0	45.0	24.8 (55.1)	9.8 (21.8)	16.5 (36.7)

a. Neutral ammonium citrate, does not include water-soluble P_2O_5.
b. 2% citric acid, does not include water-soluble P_2O_5.
c. Indicates percentage of total P_2O_5.

Table 1. Summary of Operating Data for Production of Ammoniated Granular TSP in the IFDC Pilot Plant

Test	7-131	7-132	7-155	7-158	7-170	7-172	7-174
Date	1-18-82	1-20-82	4-5-82	4-20-82	5-20-82	5-27-82	6-3-82
Type of product	GTSP	GTSP	AGTSP	AGTSP	AGTSP	AGTSP	GTSP
Production rate, kg/h (lb/h)	246 (542)	246 (542)	280 (617)	280 (617)	280 (617)	280 (617)	258 (569)
Test duration, h	5.5	7.5	11.5	9.5	11.5	10.5	11.0
Origin of phosphate concentrate used	N. Florida[a]	N. Florida	N. Florida	N. Florida	C. Florida[b]	C. Florida	C. Florida
Digester slurry							
Retention time, min	100	103	115	100	107	92	95
Temperature, °C (°F)	93 (199)	93 (199)	90 (195)	93 (199)	93 (200)	93 (200)	93 (200)
Specific gravity	1.66	1.67	1.67	1.72	1.70	1.72	1.72
Viscosity, cP	NA[c]	NA	40-500	31	36	37	40
Free acid, % P_2O_5	12	13	14	15	14	16	20
Granulator							
Recycle temperature, °C (°F)	70 (158)	67 (153)	50 (122)	56 (133)	59 (138)	39 (102)	67 (153)
Recycle particle size, %[d]							
Plus 6-mesh	0.0	0.1	11.1	5.4	5.7	0.0	21.6
Minus 6- plus 10-mesh	8.7	11.6	74.8	68.5	59.6	62.0	65.6
Minus 10-mesh	91.3	88.3	14.1	26.1	34.7	38.0	12.8
Recycle-to-product ratio, kg/kg (lb/lb)	18 (18)	11 (11)	6 (6)	7 (7)	5 (5)	4 (4)	9 (9)
Discharge temperature, °C (°F)	67 (152)	65 (148)	57 (134)	62 (143)	71 (159)	63 (145)	59 (139)
Dryer							
Air inlet temperature (combustion chamber outlet, °C (°F)	NA	NA	NA	300 (572)	279 (534)	279 (534)	295 (563)
Air outlet temperature, °C (°F)	NA	NA	90 (194)	92 (198)	115 (239)	112 (234)	113 (235)
Air flow at outlet conditions, m^3/h (cfm)	3,940 (2,320)	3,940 (2,320)	4,280 (2,518)	3,500 (2,061)	4,930 (2,900)	4,930 (2,900)	4,930 (2,900)
Material discharge temperature, °C (°F)	103 (217)	103 (217)	83 (181)	87 (189)	108 (226)	109 (228)	107 (225)
Oversize (plus 6-mesh) in discharge, % by weight	1	1	25	9	16	NA	30
Combustion fuel consumed,							
kg-cal/mt product	NA	NA	520,000	498,000	624,000	677,000	784,000
(BTU/short ton)	NA	NA	(1,873,000)	(1,792,000)	(2,249,000)	(2,436,000)	(2,824,000)
Heat accounted for, % of heat fed to dryer	NA	NA	66	60	70	58	70

(Continued)

Table 1. Summary of Operating Data for Production of Ammoniated Granular TSP in the IFDC Pilot Plant (Continued)

Test	7-131	7-132	7-155	7-158	7-170	7-172	7-174
Cooler	Not used	Not used	Not used	Not used	Not used		Not used
Air inlet temperature, °C (°F)	-	-	-	-	-	31 (87)	-
Air outlet temperature, °C (°F)	-	-	-	-	-	54 (129)	-
Air flow at outlet conditions, m^3/h (cfm)	-	-	-	-	-	3,910 (2,300)	-
Material discharge temperature, °C (°F)	-	-	-	-	-	44 (111)	-
Oversize (plus 6-mesh) in discharge, % by weight[d]	-	-	-	-	-	9	-
Product							
Temperature, °C (°F)	57 (134)	68 (154)	60 (140)	63 (146)	68 (154)	37 (99)	75 (167)
Chemical analysis							
N, %	-	-	5.2	5.5	5.2	5.0	-
Total P_2O_5, %	45.8	46.6	44.0	43.4	43.2	45.0	47.4
Available P_2O_5, % of total P_2O_5[e]	90.4	64.2	78.2	78.6	76.2	76.9	92.4
Water-soluble P_2O_5, %	32.9	22.7	26.7	26.6	23.5	24.8	37.9
Neutral ammonium citrate-soluble P_2O_5, %[f]	8.5	7.2	8.1	7.5	9.4	9.8	5.9
Citric acid (2%) soluble P_2O_5, %[f]	NA	NA	NA	NA	NA	16.5	9.8
Neutral ammonium citrate insoluble P_2O_5, %[g]	4.4	16.7	9.6	9.3	10.3	10.4	3.6
CaO, %	24.1	23.3	22.2	21.1	22.0	22.3	21.5
Free acid (as P_2O_5), %	NA	NA	0	0	0	0	8.4
F, %	2.3	2.5	2.2	2.2	2.2	2.1	2.0
Moisture, %	0.3	0.3	3.6	2.0	1.0	0.6	0.7
P_2O_5:CaO weight ratio	1.90	2.00	1.98	2.06	1.96	2.02	2.20

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a. North Florida--Occidental Chemical Company, White Springs, Florida.
b. Central Florida--International Minerals and Chemical Corporation, Mulberry, Florida.
c. Data not available.
d. Mesh numbers refer to Tyler screen series.
e. Water-soluble plus neutral ammonium citrate-soluble fractions.
f. Does not include water-soluble fraction.
g. Obtained by difference.

Table 3. Physical Properties of Ammoniated Granular TSP and Conventional Phosphate Fertilizers[a]

	AGTSP (Test 7-172)	GTSP (Test 7-174)	DAP (Commercial)
Bulk density, g/cm^3 (lb/ft^3)	1.06 (66.2)	1.10 (68.7)	0.98 (61.2)
Angle of repose, degrees	36	36	35
Crushing strength, kg/granule (lb/granule)	4.2 (9.3)	4.7 (10.3)	4.9 (10.8)
Critical relative humidity, %	80-85	70-75	70-75
Hygroscopicity:[b]			
Moisture absorption, mg/cm^2 exposed surface	72	180	185
Moisture penetration, cm	0.0	1.7	1.4
Moisture holding capacity, mg/cm^3	-[c]	105.6	132.1
Moisture holding capacity, % by weight	-[c]	9.6	14.2
Caking tendencies during bagged storage:[d]			
Condition before handling bags	loose, dry	loose, dry	light, dry
½-in lumps after handling, % by volume	0	0	0

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a. Performed in accordance with TVA Bulletin Y-147, "Physical Properties of Fertilizers and Methods for Measuring Them."

b. Measured after 72 hours of exposure at 30°C and 80% relative humidity.

c. Critical relative humidity of this sample was higher than that of the test conditions. Therefore, moisture holding capacity could not be determined.

d. Measured after 3 months of bagged storage under simulated bottom-of-pile condition (20-bag stack of 50-lb bags), except for DAP which was measured after 1 month.

Table 4. Compatibility of Bulk Blends Prepared From Ammoniated Granular TSP and Conventional Phosphate Fertilizers[a]

	1:1:1 Ratio Blend Using Urea, KCl, and				1:1:0 Ratio Blend Using Urea and			
	GTSP[b]	GTSP[c]	AGTSP[d]	DAP[e]	GTSP[b]	GTSP[c]	AGTSP[d]	DAP[e]
Hygroscopicity:[f]								
Moisture absorption, mg/cm^2 exposed surface	507	504	493	467	429	539	450	381
Moisture penetration, cm	5.5	5.1	20.0	20.0	4.5	6.0	11.3	14.0
Caking tendencies:[g]								
Condition before handling bags	HS[h]	HS	HS	HS	HS	HS	HS	HS
½" lumps after handling, vol. %	0	0	3.3	0.5	2.8	0	2.8	0.5
Hardness of lumps	-	-	light	light	light	-	light	light
Compatibility:[i]								
After 1 day	WA[j]	WA	dry	SA[k]	SA	SA	dry	DLS[l]
After 21 days	WA	WA	dry	DLS	SA	SA	DLS	DLS

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a. Performed in accordance with TVA Bulletin Y-147, "Physical Properties of Fertilizers and Methods for Measuring Them."

b. Commercial GTSP.

c. From IFDC test 7-174.

d. From IFDC test 7-172.

e. Commercial DAP.

f. Measured after 72 hours of exposure at 30°C and 80% relative humidity.

g. Measured after 3 months of bagged storage under simulated bottom-of-pile conditions (20-bag stack of 50-lb bags), except the DAP blends which were measured at 1 month.

h. Hard bag set.

i. Blends were sealed in 16-oz. glass jars, stored and observed at room temperature.

j. Wet and agglomerated.

k. Sticky and agglomerated.

l. Dry and lightly set.

Table 5. Agronomic Performance Data on Fertilizers Produced--Dry Matter Yield, Phosphorus Uptake and Plant-Available Phosphorus Content of Hartsells Topsoil After Each Harvest[a]

Source of Phosphorus	Dry Matter Yield, g/pot		Phosphorus Uptake, mg P/pot		Plant-Available Phosphorus Content of Soil, ppm	
	First Harvest	Second Harvest	First Harvest	Second Harvest	After 1st Harvest	After 2nd Harvest
Control (No fertilizer added)	2.7	2.4	2.4	2.2	5.1	6.8
AGTSP (Test 7-154)	21.3	32.1	38.3	38.5	52.3	37.1
GTSP (Test 7-112)	22.1	35.2	35.3	49.3	51.6	39.1
DAP (Commercial)	24.2	31.9	50.8	51.0	52.8	38.3

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a. Crop grown was maize (corn, Funks G5757), grown in greenhouse pots, on Hartsells topsoil, pH 4.9.

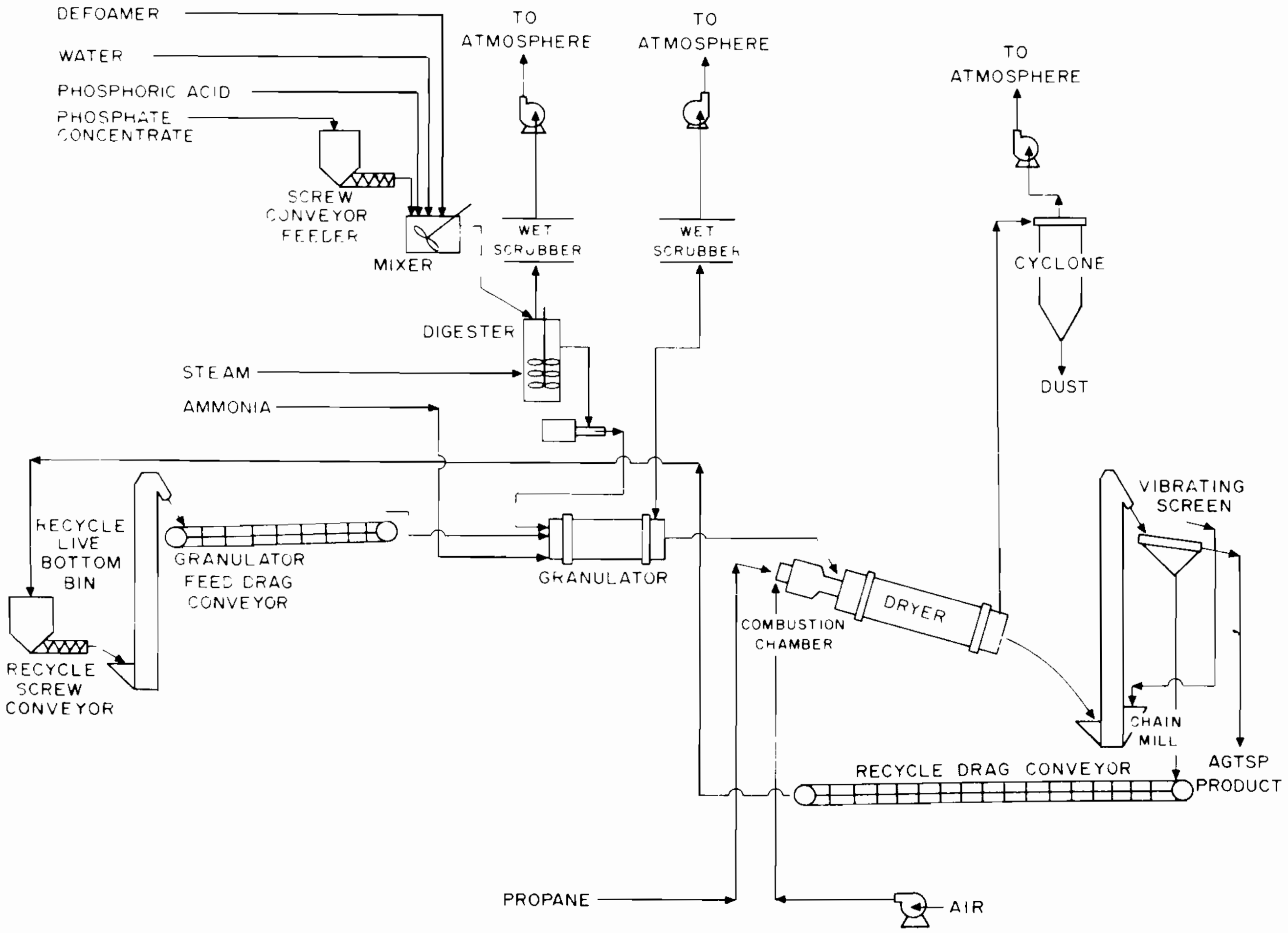


Figure 1. Flow Diagram of Ammoniated Granular TSP Process.

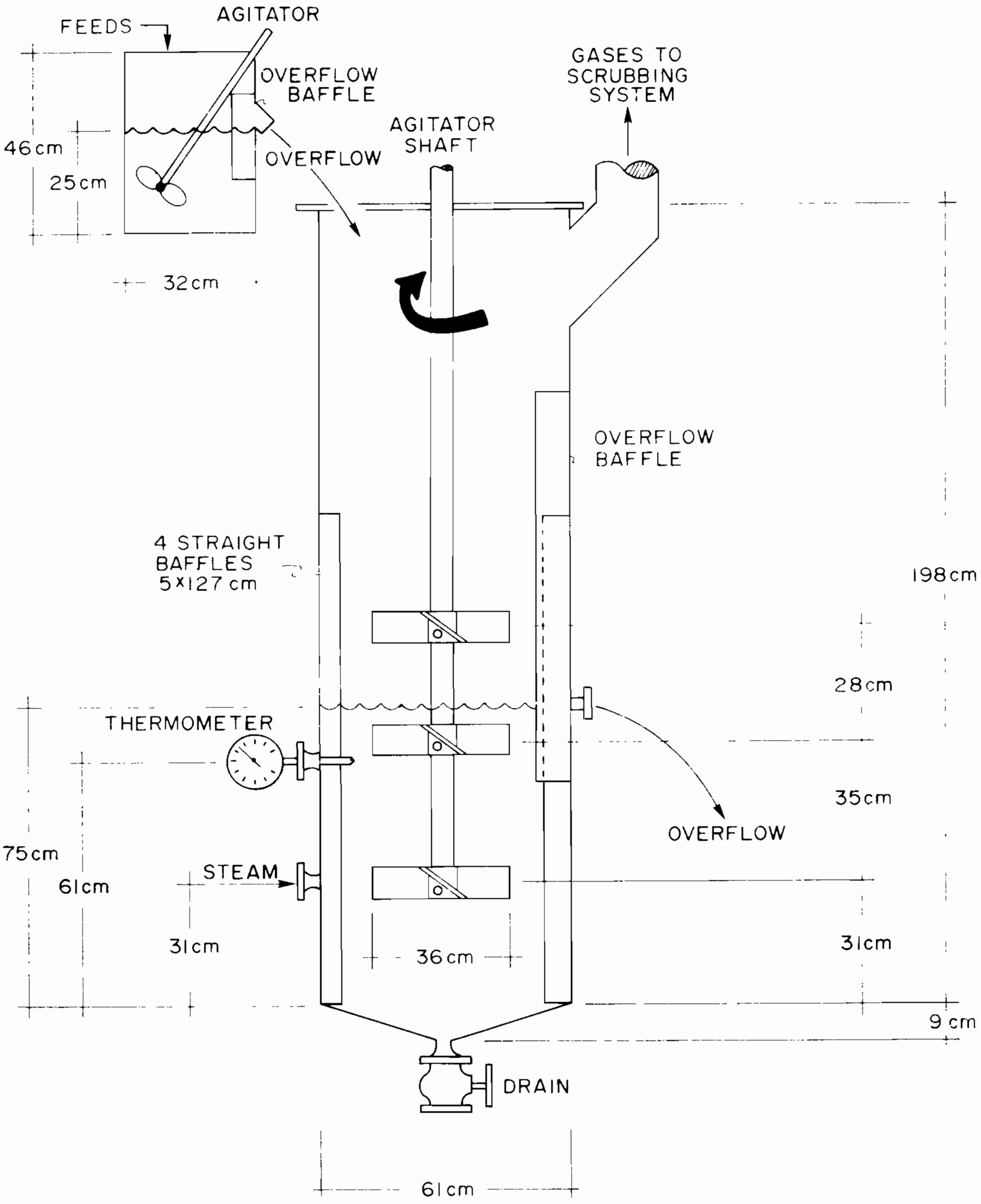


Figure 2. Diagram of Digester and Three-Turbine Agitator.

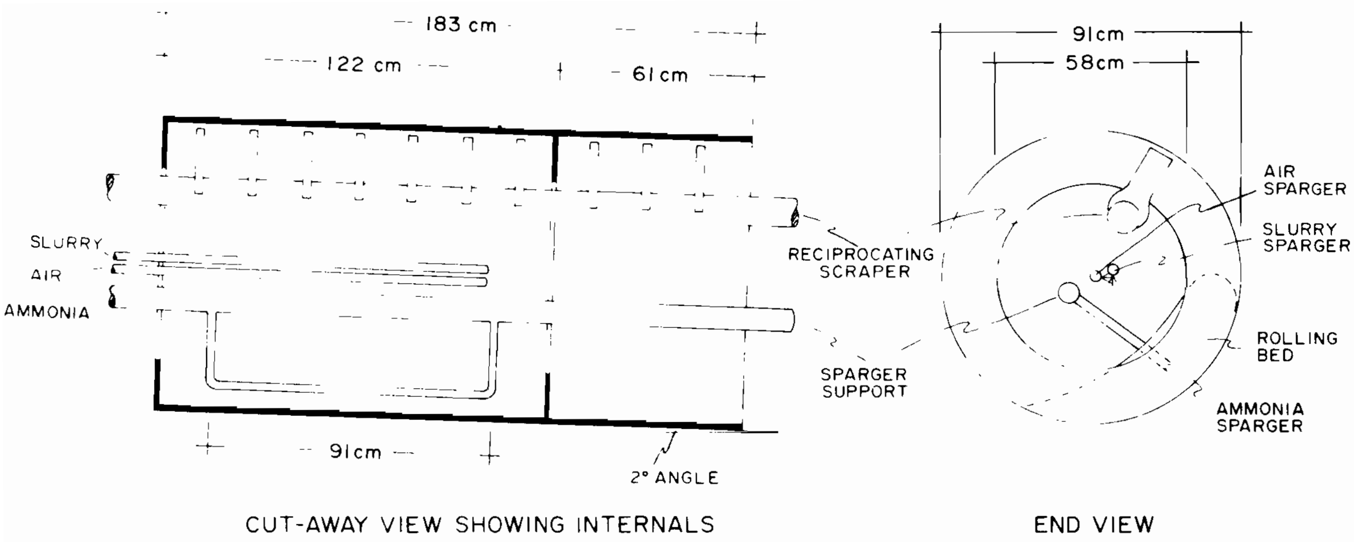
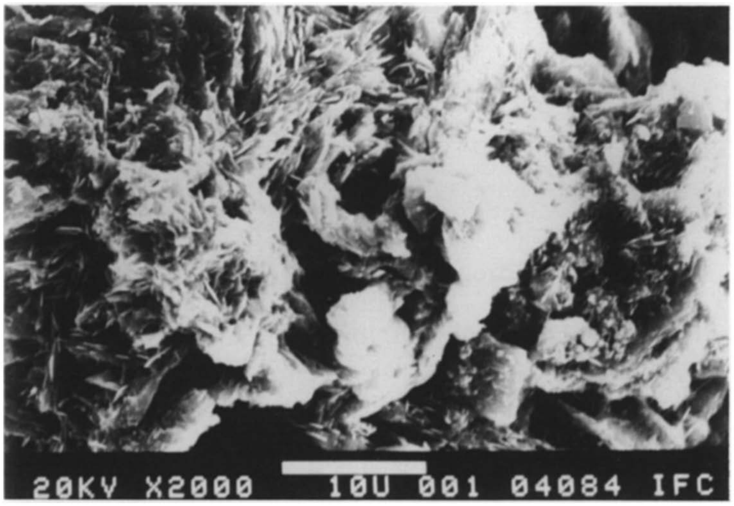
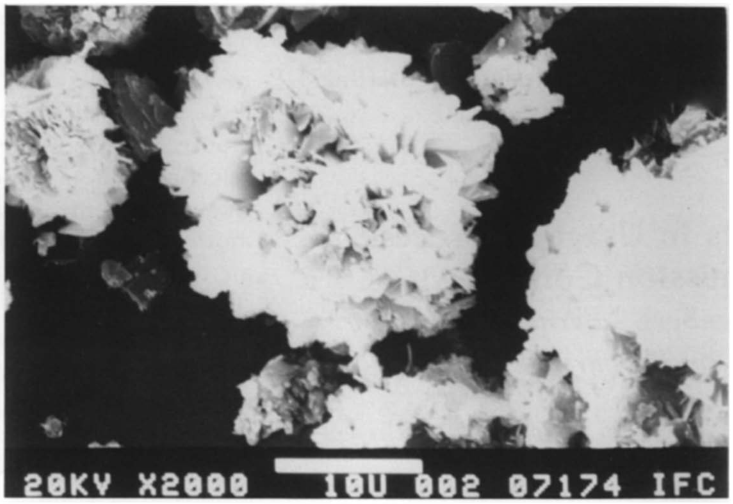


Figure 3. Diagram of Drum Granulator.



Crystals of small size from early runs, using a high-velocity centri-fugal pump to recirculate digester slurry.



Crystals of larger size from runs with no recirculation of digester slurry.

Figure 4. Photomicrographs of Slurry Solids.

Figure 5. Photograph of Maize (Corn) Crop Before First Harvest.

MODERATOR BROCHSTEIN: Thank you, Jorge, for your excellent, interesting discussion. (Applause)

MODERATOR BROCHSTEIN: Our next speaker is Bernard Berry who will present "Refinements in Usage of Process and Emmission Control Air". Bernard is a graduate Engineer with a Bachelors Degree in Engineering Science from the University of Notre Dame. He joined FEECO International in 1971, immediately after graduating. He is currently Technical Manager and is responsible for project management, corporate engineering, as well as engineering design and drafting. Bernard please. (Applause)

Refinements In Usage of Process and Emmission Control Air

Glen H. Wessenberg - Bernard M. Barry

Presented by Bernard M. Barry

Good afternoon Members and Guests of The Fertilizer Industry Round Table.

The subject of our presentation is "Refinements in Usage of Process and Emmission Control Air". We will present two areas of refinement in air usage.

First in the area of Refinement in Usage of Process Air in Drying and Cooling. We will present a typical Dryer application and then show the effect of varying temperature for various products. We will show, for a typical Dryer application, the affect of varying air speed on equipment sizing and efficiency of emission control. We will then review benefits obtainable from a "Closed Loop System" by recycling process air in Drying and Cooling Systems.

Second is the area of Refinement in usage of (Air Transfer) Equipment Arrangements and Design (both new and existing facilities) for Air in Drying and Cooling. We will show several typical Cyclone/Bag House/Fan/ Scrubber Arrangements and the reason for selecting one as opposed to another, as well as how these arrangements can be modified and improved for more efficient air handling. We will explore the area of air transfer between equipment as it relates to proper selection of air speed, optimum clarification of dust particles and the use of multiple duct systems. In both areas of refinement of air usage (in Process and in Equipment) we will indicate the use of computer technology - to comprehensively consider variations in conditions and equipment design and to then optimize these same conditions in new and existing systems (to give maximum production and profitability while using minimum equipment capital investment operation and maintenance cost, and energy cost).

Slide #1 shows the *Material Basics* for a typical dryer application. The material name, temperature of the material entering the dryer, the temperature of the material exiting the dryer and specific heat of the material which should all be specified and inserted into the computer. The percent moisture (wet basis) of the material entering the dryer and the maximum percent moisture desired in the material exiting the dryer should be selected and entered into the computer program as well. *Ambient Conditions,* such as design ambient air temperature, percent humidity in ambient air, and location elevation in feet should also be selected and entered. (The same with which multiple variations in conditions can be checked to aid in dryer selection can be seen. Drying of different materials or variations in entering and exiting temperatures, and/or inlet and outlet moisture contents for the same material can all be easily examined to aid in the best practical selection of a Dryer system or to check performance potentials of an existing system. Likewise, the affect of variations in ambient conditions can also be comprehensively considered to assist in proper selection [and operation] of a Dryer system.)

Slide #2 shows other constants and factors to be entered into the overall dryer selection program. The temperature of the air exit the dryer, the maximum air temperature allowable which is a function of the material being dried, the boiling point, specific heat and heat of vaporization of water are all entered. You will note that, although they are not listed, the melting point, specific heat of ice and BTU's to change water from solid to liquid are automatically accounted for if these conditions prevail. The specific heat of water vapor, the weight of vapor for saturation per pound of dry air and the specific heat of air are some other constants which are accounted for in the computer. Although this group is not as subject to variations as the previous one, (with the exception of the maximum allowable temperature), there is still the ease and flexibility of making alterations to these numbers to reflect specific conditions for particular applications. *The maximum allowable air temperature can vary widely, depending on the material being dried.* We will explore the implications of variations in the maximum temperature allowable later in the presentation.

Slide #3 shows the *Material Balance and Air Balance* to be considered for the Dryer selection. For the *Material Balance,* the amount of material into and out of the dryer, the water content of this material going into and coming out of the dryer and the totals in an out of the dryer are all recorded. For the *Air Balance,* the amount of air in and out of the dryer, the water content of this air going into and coming out of the dryer and the totals in and out of the dryer are all entered. As with the previous slides, all of these conditions can be altered to reflect variations in specific applications.

Slide #4 - the *Heat Requirements* for drying can be categorized into two groups: The *Heat Utilized* in the dryer and *Heat Inputs Not Available* for drying.

Slide #5 is a computer printout showing the *Heat Requirements* for a typical dryer calculation. This slide shows the *Heat Utilized* in the dryer. The essential inputs that go into the heat balance calculation are: the heat required to raise the air to the temperature required for drying - *as dictated by the characteristics of the material being dried* - and the heat required to raise the water vapor in this air to the same temperature, the heat required to raise the water vapor in the air from its inlet temperature to its required exit temperature (since this heat is not available for drying), and finally the heat required to raise the air temperature from its inlet level to its exit level (since this heat is not available for drying). On this slide is a computer printout showing the *Heat Requirement* for the same dryer calculation. This slide shows the *Heat Inputs Not Available* for drying. Shown first is the required to raise the material from its inlet temperature to the required exit temperature and the heat required to raise the residual moisture in this material to that same temperature, and the heat required to evaporate the water removed from the material being dried as well as the heat to raise the temperature of this water from its inlet level (which is the same as the material) to 209°F. and then the water vapor from 209°F. to the exit air temperature.

On this Slide #6 is shown the total BTU's per hour required for this example. By allowing for appropriate radiation and leakage losses from the computer data for predictable variations, an overall heat requirement is obtained. The source for this heat requirement is the air, and to a minor extent the vapor in this air. (In fact, from this point forward we will only be referring to the input air with the understanding that the appropriate - again minor - allowances are automatically being made for the heat available from the water vapor in the air.) From the total heat requirement the cubic feet per minute of air is calculated. From this information the computer program will select the proper dryer diameter based on all of the conditions and factors previously entered as well as the allowable air speed and adequate retention time for air, especially as related to material contact for efficient heat transfer.

We will now examine the *affect of temperature on air flow,* based on the already referred to computer program. Consider three cases - NPK fertilizer, urea or hi-urea grade fertilizer and potash. In each case we will assume: Ambient temperature of 70°F., 20 TPH of material at 180°F. inlet temperature is to be dried from 12% to 1% moisture, the exit temperature of the material is 220°F. and the exit temperature of the air is 230°F.

In the case of the three materials considered - NPK fertilizer, urea or hi-urea grade fertilizer and potash - the heat utilized in the dryer plus those heat inputs not available for drying is approximately the same (10,000,000 BTU/hour) . . . . this assuming the relatively conservative dryer efficiency of 65%. Slide 7.

In the case of the NPK fertilizer we can set a maximum temperature for the inlet air (exit the combustion chamber) of 800°F. Using an average specific heat for air of 0.2450 BTU/lb.°F., the amount of air required will be approximately 54,000 PPH.

In the case of the urea or hi-urea grades we will only set a maximum temperature for the inlet air (exit the combustion chamber) of 400°F. By again applying the appropriate specific heat for air, we can calculate the air required to be approximately 119,000 PPH.

In the case of potash we can set a maximum temperature for the inlet air (exit the combustion chamber) of approximately 2000°F. Once more using the specific heat for air, and solving for the amount of air, we find only 20,000 PPH are required.

In each of the above three cases we can see that, for the same amount of total heat available for drying a significantly variable amount of total air is required depending on the maximum allowable temperature permissible exit the combustion chamber. Therefore, it is important that careful design consideration be given to optimum allowable dryer temperature so that the total air required is minimized . . . and correspondingly the cost of all related air handling equipment is decreased.

Slide #8 shows the potential savings in energy because of the lower kilowatt-hour (horsepower) requirement for the various air volume requirements in the three cases - NPK fertilizer, urea or high urea grades, and potash. In the case of NPK fertilizer, the air requirement was 54,000 pounds per hour. Based on (as all three examples are) a 24 hour per day operation for 300 days per year and using a price of 4 cents per kilowatt hour -we realize a cost per year of about $47,000.00. In the case of urea or high urea grades, the air requirement was 119,000 pounds per hour. The annual cost per year is $112,000.00. In the case of the potash, the air requirement was only 20,000 pounds per hour. The annual cost per year is $17,000.00.

A second important consideration in the Refinement and Usage of Process Air in Drying is the maximum allowable air speed through the dryer. Depending on the inherent heat transfer properties of the material and more specifically the average, maximum and minimum mesh sizes of the particulate, the speed of the air through the dryer can be varied to allow for best separation effect and dust collection efficiency. (An important design consideration is use of the dryer exit air breeching as a type of clarifier to help separate particulate from the air stream and return it to the material bed. By not designing any small diameter passages in the breeching - which will produce vacuum and turbulent effects that will actually increase the amount of particulate in the air stream - but rather enlarging the diameter of the air passages in the breeching - this has the affect of slowing down the air speed, which allows particulate to drop out of the air stream - it is possible to further maximum air speed through the dryer.) In the case above where 54,000 PPH of air was required, it would be determined - at the conventional 500 feet per minute - that a seven foot diameter drum is required. But with a computer type analysis of data it may be possible to increase the allowable air speed to (say) 750 FPM. In this case it would be then adequate to have a 6 foot diameter dryer. Therefore, a significant savings could be realized on this important piece of equipment as well as on the air handling equipment required for the system. Slide #9 shows the affect of the selection of proper (optimum) air speed on the sizing of the diameter of shell for the dryer.

A third area of Refinement of Usage of Process Air in Drying is the implementation of a "Closed Loop Drying and Cooling System". The *Closed Loop Drying and Cooling System* provides the efficiency of using the heated Cooler exit air as inlet air to the Dryer. Thus less BTU's are required to heat this inlet air to the temperature needed for Drying. As you can see on Slide #10, the air is drawn through the Cooler, where the air temperature is increased as it cools the material temperature. This warmed air is then drawn through the Cooler Cyclone - where the fines are dropped out of this air and returned to the system - and the Cooler Fan to the Dryer Combustion Chamber. At this point special Combustion Chamber air feed ring design allows mixing of the (Closed Loop) Cooler air, which makes up the largest portion of the drying and combustion air, with the air from the burner blower. In the combustion chamber special refractory (hi heat castable) and brick lining prevents loss of heat in the air which is now increased considerably in temperature by the burner. (The air temperature in the Dryer is controlled by placement of thermocouples in the Combustion Chamber throat and the Air Discharge Breeching exit the Dryer, and in some cases the material discharging from the dryer. This affords strategic control of air temperature through continuous monitoring and automatic and adjustment as required, to provide optimum material temperature and moisture content exit the Dryer.) Special labyrinth seals and breeching design - enlargement of the breeching relative to the duct diameter with a vertical transition at the pick off point - provide additional clarification of dust from the air being drawn to the Dryer Cyclones. This feature in turn increases the efficiency of these Cyclones. The air is then drawn through the Dryer Cyclone - where again the fines are dropped out of this air and returned to the system. Finally the air passes through the Dryer/Cooler Scrubber - where remaining contaminants are dropped out of the air and returned to the system - and out the stack.

The closed loop system works quite well with the *hot recycle single deck screens* in the system. Again it will be useful to refer to Slide #12. By screening the material exit the Dryer and then returning the fines to the Granulator, there is correspondingly less material (oversize and product size only) to go through the Cooler. This ensures that the Dryer will handle more air than the Cooler - an essential feature for a closed loop system. There will always be additional gases entering the system from the combustion blower and products of combustion. The system also becomes more controllable if there is allowable capacity in the Dryer for a small amount of ambient air to be entered into the system at the Combustion Chamber. Screening out the majority of the hot fines and recycling them back to the granulator system without having them pass through the Cooler is not altogether new and has been used by others for sometime; however, most systems have double deck screens which are hard to maintain at this location. *By only sending oversize and product size through the Cooler, it helps to further dry any larger particles of oversize while going through the cooler.* This decreases buildup tendencies in the oversize chain mill by reducing the wetness of the particles to make them easier to break up. The hot recycled screening also decreases the rate of blinding or plugging of the fines screen of the double deck product screens. The efficiency of the final product screens is significantly increased and they can be smaller in size because they do not have to handle as large of a capacity. Finally, the Cooler and subsequent material handling equipment and air handling system from the Cooler can be of smaller design because of lower material flow rates.

On this Slide we show the potential savings in fuel cost that can be realized by an efficient Closed Loop System. On the one hand, if the air being returned to the system (at the dryer inlet) is only 50°F. warmer than the ambient air available, it is possible to realize a savings in fuel (natural gas) cost of almost $45,000.00 per year. (This is based on an air requirement of 100,000 pounds per hour, which would be about 30 to 40 tons per hour of NPK fertilizer, for a plant operation at 24 hours per day and 300 days per year. Natural gas was figured at 50 cents per therm. Oil was figured at $1.25 per gallon.) The cost for fuel, if oil is used, would be $83,000.00 per year. If the air being returned to the system (at the dryer inlet) is 130°F. warmer than the ambient air available, it is possible to realize a savings in fuel (natural gas) cost of almost $117,000.00 per year. The cost in fuel, if oil is used, would be $216,000.00 per year. Obviously, based on the particular plant output product, capacity, days of operation per year and normal ambient conditions, there would be variations in the fuel savings figures. But regardless of conditions, this concept (closed loop drying) has a significant affect on normal daily plant operation cost and maintenance. This does not include the other factors of cost savings because of reduced equipment requirments and more available space (always at a premium in fertilizer plants) in existing facilities and small space requirements for new facilities.

Second is the area of Refinement in Usage of (Air Transfer) Equipment Arrangements and Design (both new and existing facilities) for Air in Drying and Cooling.

There are several different types of Dust Collecting System arrangements available and the proper choice of equipment for any single particulate collection problem is determined by many variables; primary among these are process considerations and economic factors. We would like to present four. In the first system, the air is drawn from the Dryer outlet through the Dryer Cyclone and then to the fabric filter collector with the collector fan on the air discharge side of the collector. In this system the minimum particulate size is such that a significant amount of dust can be removed from the air stream (usually in the range of 5 microns and larger) at an efficiency which merits the use of a cyclone. A reasonable cyclone collection efficiency would approach 99% with a particle size of approximately 44 microns. The ductwork recommended would be FRP with a Nexes veil, or steel construction, and should be insulated, Depending on the specific operation the fabric filter collector should be designed with adequate air to cloth ratio, steel construction, proper interior and exterior coatings and insulation. Air heaters to control moisture and temperature within the collector and an air monitoring probe in the collector exit duct ahead of the fan to give continuous reading in the control room of total static pressure and total volume of the system are two devices that will enhance the proper operation of the system. The fan should be designed for the higher static pressures and higher temperatures common to a Cooler/Dryer system. A heavy duty louvred outlet damper is also a requirement to accommodate variations in air demand relative to the product being handled as well as to assist in cold starts and other changes in ambient conditions.

The second system has air being drawn from the Dryer outlet through the fabric filter collector directly without passing through the cyclone. In this case the particulate size is small enough that the collection efficiency of a cyclone would not be significant. The fabric filter collector, on the other hand, is a high efficiency collector which handles dust from 0.01 microns with efficiencies usually in excess of 99.9 percent. There are several general types of fabric filters. The most common is the tubular or bag filter, which contains freely suspended fabric tubes usually fastened at both ends. The other is the sleeve or envelope type which depends on the internal wire frame for support. Some of the limitations on the fabric filter are temperature, humidity of the gas and corrosive nature of the gas or dust.

In this case a third system is possible in which air is drawn from the Dryer outlet through the Dryer Cyclone and then to an electrostatic precipitator. The precipitator is, like the fabric filter, characterized by efficiencies approaching 100 percent for particle sizes over the entire dust zone range. In each of these three cases, dry collection of the recoverable products is used.

Dry collection is preferred if at all possible; however, in some cases where wet processing is practical, and fumes are present, wet scrubbing may be required. Slurry recovery adds to system requirements. Once again, a properly designed wet scrubber with an adequately sized pressure drop can achieve very high efficiencies for very small particle sizes.

In the planning of new production facilities it is quite common to talk about design conditions versus normal operating conditions. Although this is applicable to air handling systems, it is important to use a certain amount of caution.

If the design conditions exceed the normal operating conditions by too large of an amount, then the result under normal operating conditions will be that the air speeds through the ductwork are too slow (because the duct diameter has been too greatly oversized.) (Under typical conditions we have found that a minimum air speed of approximately 3000 FPM and a maximum air speed of approximately 4200 FPM to be satisfactory - with 3500 to 4000 FPM recommended). At lower air speeds the particulate is not efficiently carried through the air stream. The result is plugging of the ductwork. This results first in an increase in resistance because of the reduced duct diameter and eventually the complete shutoff of air flow. Continual maintenance is undesirable in normal plant operation.

In some cases, however, it is requested to have a design capacity for the ductwork that is considerably larger than the capacity for normal operating conditions. Without this consideration, it will be discovered that under those maximum design conditions air speeds will be too fast. The result is that too much particulate is drawn into the air stream. This has the affect of greatly reducing the efficiency of the cyclone and also eventually again plugging up the ductwork because of the large dust load in the air stream.

Therefore, it is desirable to size the air handling ductwork system so that the design conditions and the normal operating conditions can both be reasonably satisfied without loss of efficiency and eventual plugging of the ductwork air stream. *There are situations under which it may not be possible to satisfy both design and normal operating conditions with the same ducting network.* In these cases it may be determined that two paralleled separate ductwork systems is a viable solution. Although there is an additional cost in the beginning, this cost will be more than offset during actual operation because of greatly reduced maintenance and downtime cost. A separate run of ductwork can be used under normal operating conditions and then, through a series of tight shutoff dampers and Y-connections, a bypass can be set up to use a separate run of ductwork when operating at maximum design conditions. Thus optimum air speeds and dust collection efficiency can be gotten under both sets of conditions.

Again, well planned breeching design can greatly enhance the transfer of air in the ducting network. The design of the breeching should be such that the space for allowable air flow actually widens out upon entering the breeching (exit the dryer). This has the effect of slowing down the speed of the air stream sufficiently to allow more particulate to drop back down into the material bed. Special attention is also paid to a streamline design of the duct opening at the top of the breeching where the dust is picked off. By affording a "streamlined" (aerodynamic) design which gradually tapers down to the diameter of this duct pick off opening, the "vacuum" type effect is greatly reduced. This prevents the pull off of excessive dust which will decrease cyclone efficiency and greatly increase the chances of plugging in the air stream - all as discussed earlier. It shall be noted that this feature, using the discharge breeching as a type of clarifier, (with good design of the back breeching wall, it can act as a particle impingement surface and assist in particle separation) also allows the opportunity to maximize the speed of the air flow through the dryer - which in turn allows the optimization of dryer sizing mentioned previously.

A production facility that was constructed many years ago may have several inherent design features that are a source of continual energy loss and cost inefficiency. These energy-costs may not have been a viable area of concern when the facility was constructed, but these same costs now inflated to the point that they are a primary concern in the operation of today's facility. Changes in production requirments, ever shifting to meet customer demands, may be far removed now from the original design intentions of the plant. The implementation of the pipe reactor and the wider use of high urea grades are two of several other features which have also developed to greatly alter the actual operation of the facility and its equipment from its original design plan.

A drying setup which does not allow for sizing of air handling equipment based on optimum air temperature may be greatly oversized for the normal operating conditions of the plant. The same problem could exist for drying systems where maximum air speed is not being realized because of changing requirements. If a conventional drying/cooling air loop can be closed, it is possible to attain a significant savings in existing energy coats because it makes use of air for drying that has already been heated in the Cooler. In most conventional facilities, the energy that could be saved is merely passed through the Cooler Cyclone and exhauster and then out the stack. Existing Dust Collecting systems should be reviewed to ensure the optimum arrangement of Collector/Fabric Filter/Scrubber/Precipitator is being employed. And finally, the air transfer between equipment - especially with regards to duct sizing and the possible installation of a separate, parallel dust system to facilitate large differences between design and normal air usage - should be reviewed. Available now is modern computer technology which facilitates to optimum combination of variables to produce the most productive and profitable operation of the drying and cooling systems.

Material Basis *(Slide 1)*

Material Name	Sample
Temperature of Sample Entering (DEG. FAH.)	60/0
Temperature of Sample Exiting (DEG. FAH.)	250.0
Specific Heat of Sample (BTU/LB/DEG. FAH.)	.250
Percent Moisture in Wet Basic Sample OUT	15.00
Percent Moisture in Sample OUT	3.00

CONDITIONS

Design Ambient Air Temperature (DEG. FAH.)	60.00
Percent humidity in ambient air	50.00
PSI at elevation	14.06

Other Constants & Factors *(Slide 2)*

Exit air temperature	260.0
Air max temperature allowable	1000.0
Boiling point of water 14.06 PSI (DEG. FAH.)	209.0
Specific heat of water (BTU/LB/DEG. FAH.)	1.000
BTU'S to change H2O liquid to vapor	980.0
Specific heat of water vapor	.447
Weight of vapor for saturation/lb. of dry air	.011
Specific heat of air (BTU/LB/DEG. FAH)	.245

Material Balance/Hour *(Slide 3)*

	IN	OUT
Sample	85000.0	85000.0
Water in Sample	15000.0	2628.9
Total	100000.0	87628.9

Air Balance Hour

Air	50677.7	50677.7
Water in air	280.0	12651.1
Total	50957.7	63328.8
Total Sample air and water	150957.7	150957.7

Heat Requirements *(Slide 4)*

HEAT UTILIZED

A. Air From Source to max. allowable			
50677.7# air	60 to 1000	11 909259.5
B. Moisture in source air to max. allowable		
280.0# water vap	60 to 1000	124362.0
C. Moisture in source air to dryer exit		
280.0# water vapor	60 to 260	25032.0
D. Air from source to dryer exit		
50677.7#	60 to 260	2483207.3

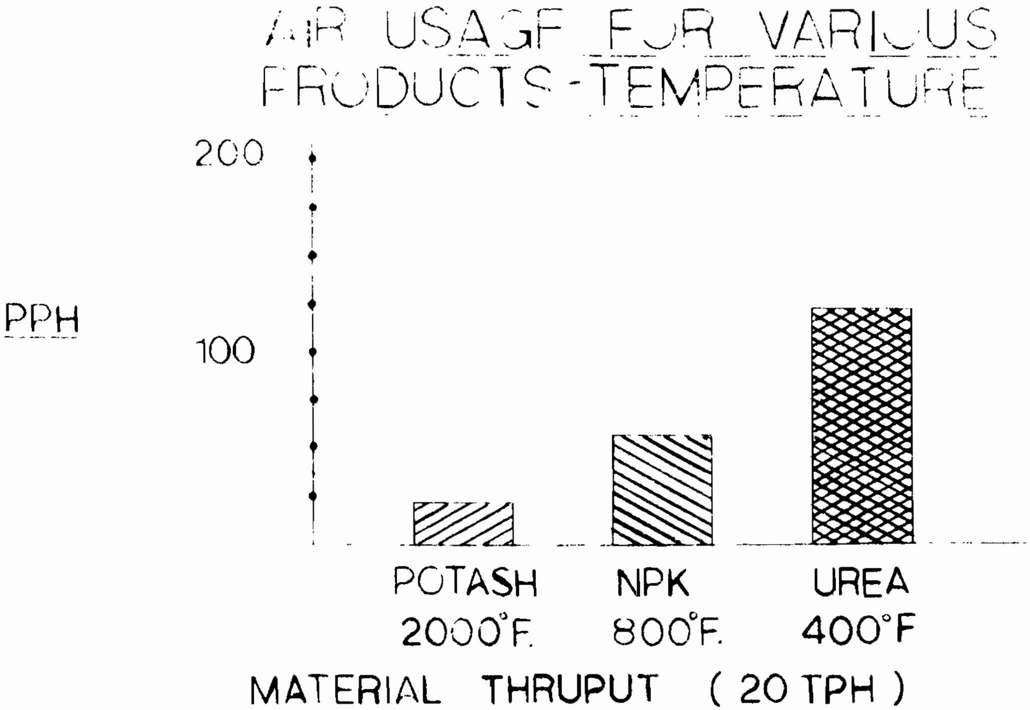
Heat Requirements *(Slide 5)*

HEAT NOT AVAILABLE FOR DRYING

E. Sample (Dry)		
85000.0# sample	60 to 250	4 037500.0
F. Water, from sample: Exiting in sample		
2628.9# Water	60 to 250	499491.0
G. Water, from sample: Exiting in air		
12371.1# water	60 to 209	1 843293.9
12371.1# water liq to vap	209 to 209	12 123678.9
12371.1# water vap	209 to 260	282024.0

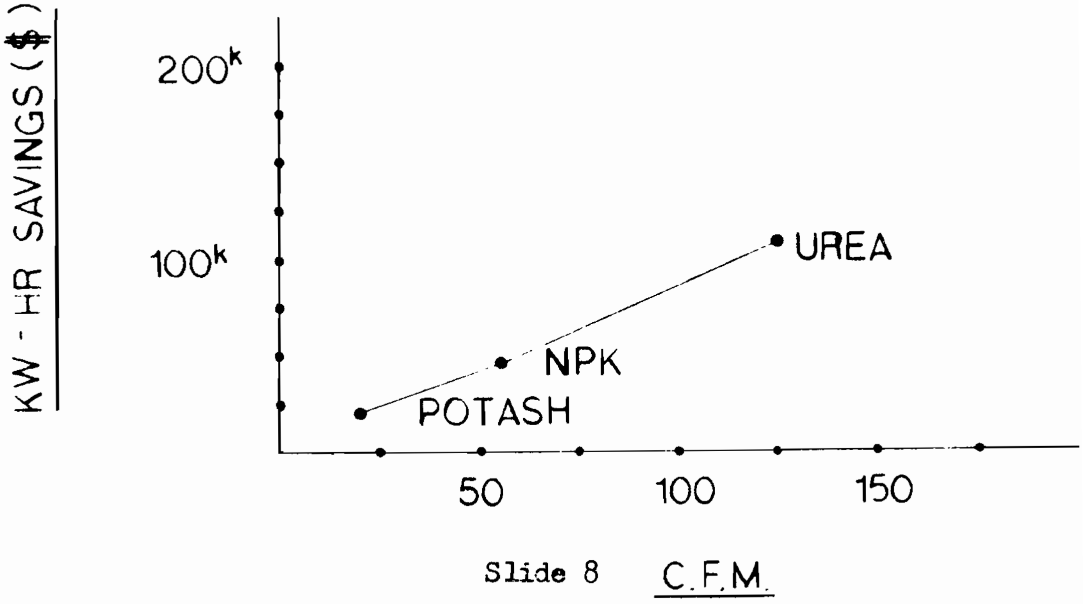
(Slide 6)

Total BTU's	22 358937.5
ACFM	22428.5
Inside dryer diameter	8.2



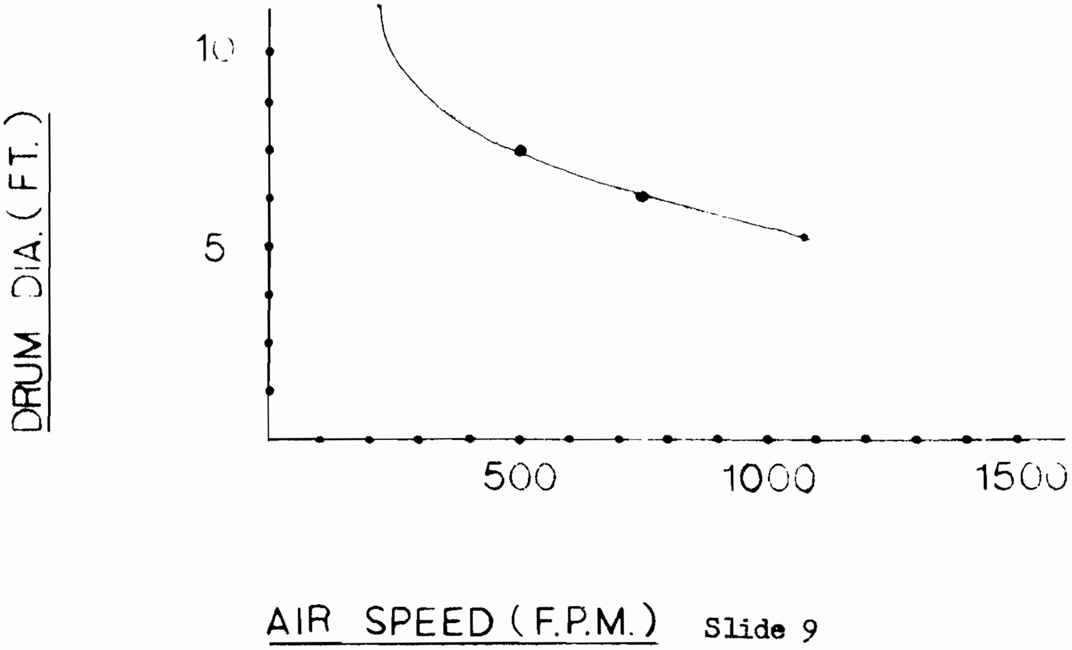
SLIDE 7

ENERGY SAVINGS FOR AIR USAGE



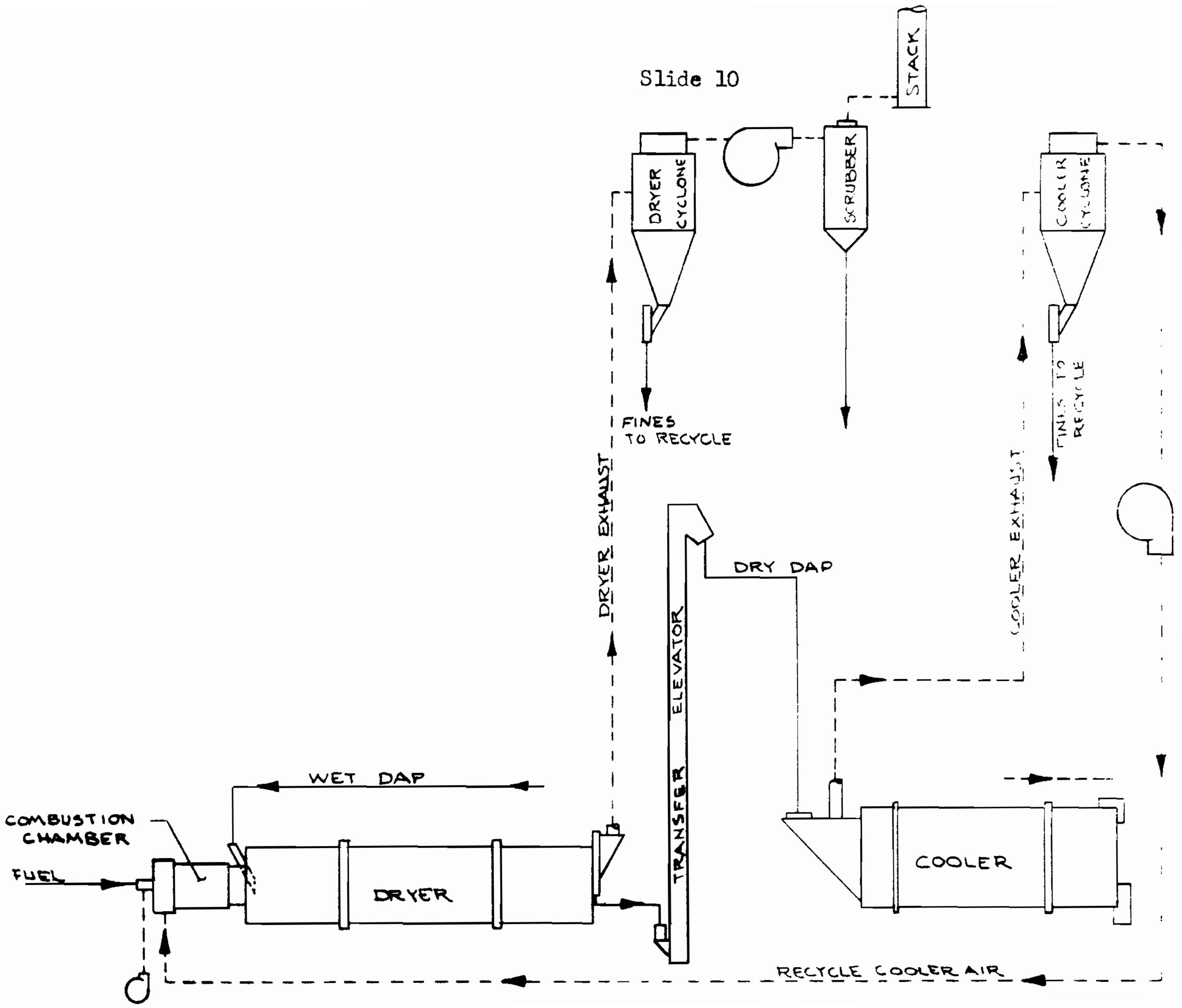
Slide 8

DRUM DIAMETER AT VARIOUS AIR SPEEDS



Slide 9

Slide 10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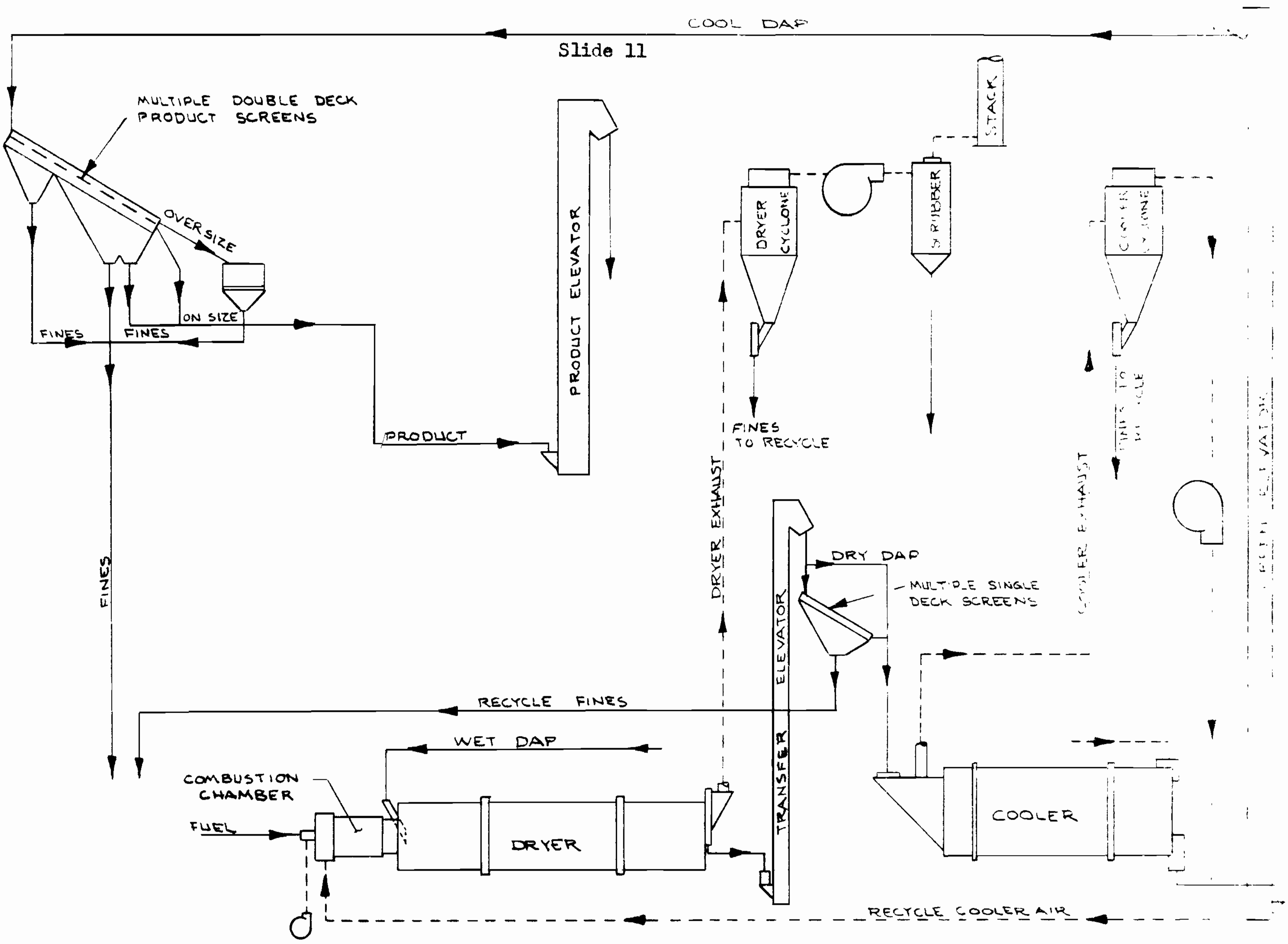
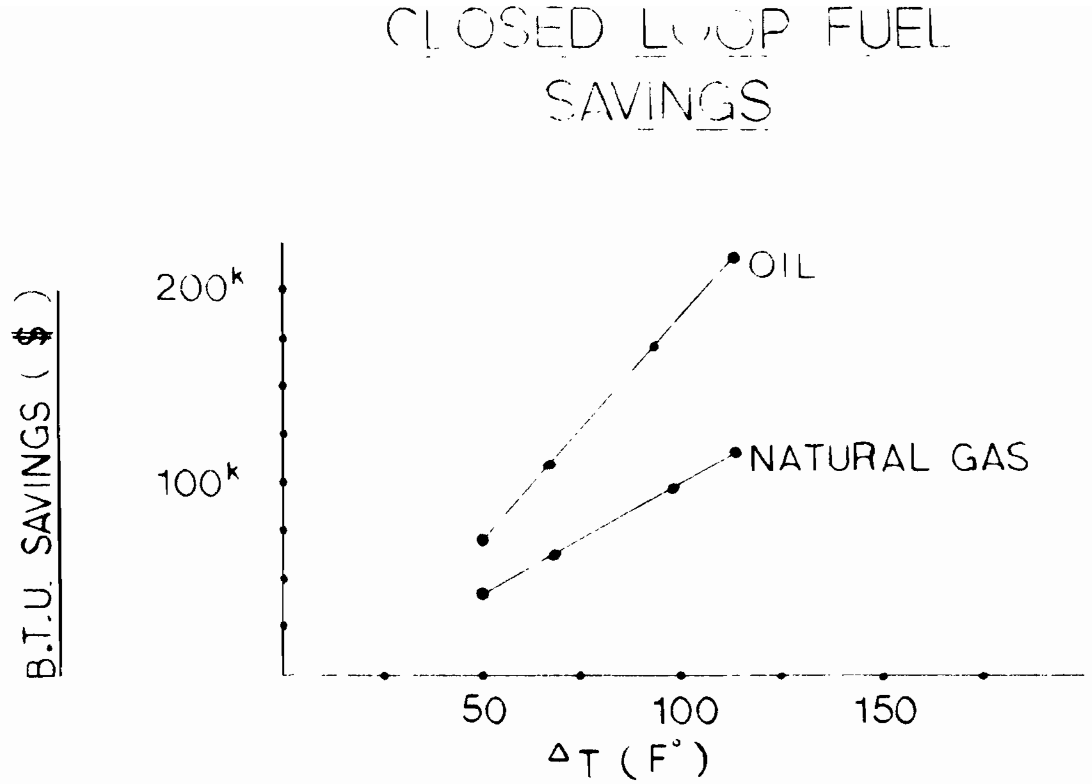
DRYER CYCLONE
SCRUBBER
COOLER CYCLONE
FINES TO RECYCLE
FINES TO RECYCLE
DRYER EXHAUST
COOLER EXHAUST
DRY DAP
TRANSFER ELEVATOR
WET DAP
COMBUSTION CHAMBER
FUEL
DRYER
COOLER
RECYCLE COOLER AIR

Slide 11


COOL DAP
MULTIPLE DOUBLE DECK PRODUCT SCREENS
OVER SIZE
ON SIZE
FINES
FINES
FINES
PRODUCT
PRODUCT ELEVATOR
DRYER CYCLONE
SCRUBBER
STACK
FINES TO RECYCLE
DRYER EXHAUST
COOLER CYCLONE
FINES TO RECYCLE
COOLER EXHAUST
ELEVATOR
DRY DAP
MULTIPLE SINGLE DECK SCREENS
TRANSFER ELEVATOR
RECYCLE FINES
WET DAP
COMBUSTION CHAMBER
FUEL
DRYER
COOLER
RECYCLE COOLER AIR



Slide 12

BERNARD BARRY: Thank you Ladie and Gentlemen for your courtesy and kind attention. We would be glad to answer any questions at this time or later on. (Applause)

MODERATOR BROCHSTEIN: Ray Shirley is our next speaker. Ray is President of Applied Chemical Technology, Inc., located in Muscle Shoals, Alabama. He received his bachelor of chemical engineering from Georgia Institute of Technology in 1962 and later became a technical supervisor with Monsanto in the inorganic division before joining TVA in 1967. AT TVA, he was an engineering specialist and Senior Project Leader in the Development Branch. He resigned in June of 1981 to form Applied Chemical Technology, Inc., a small engineering firm with special emphasis on process development and small plant design. He has authored numerous papers and holds patents in the field of granulation, particle coding and heat transfer. He is also a Registered Professional Engineer. Ray will present "Insulation - Economics of Usage and Materials Selection." Ray. (Applause)

Insulation Economics of Usage and Materials Selection

A. Ray Shirley, Jr.

It is a pleasure to discuss money with you this afternoon; money in the form of saved BTU's. It is estimated in the current issue of *Insulation Outlook* that the U.S. is losing $2.3 billion annually in fuel costs just from inadequately insulated industry steam pipes. In those lost dollars there is surely some potential savings for our respective companies and organizations. I hope our discussion today will help you find some of them or at least prevent a further addition to that amount.

Insulation in the past years was the last item considered in the design of a plant and the last item completed in the plant's construction. As such, insulation too often was poorly specified and even more poorly installed. In fact if a project cost overrun was eminent, very often a major portion of the insulation was left for plant maintenance forces to install later during periods when work was slack. That was all changed in the 1970's when the cost of fuel went from an average of $0.75 per MM BTU's in 1970 to our present estimate of between $5 and $6 per MM BTU's today. Now the pendulum has swung the other direction and we are all energy minded or we should be. A tremendous effort has been expended by those in the insulation industry in cooperation with the U.S. government to develop economic thickness formulas which relate the amount of insulation which should be used to a set of directly involved variables. Economic Thickness of Insulation (ETI) is a concept which originated with L. B. McMillan of the Johns-Manville Corporation in 1926 when he published the basic equations governing it. Because of their complexity the equations were little used until the computer made it feasible. A succession of updated economic thickness manuals have been published beginning in 1960 with a manual developed by West Virginia University and Union Carbide in connection with the Thermal Insulation Manufacturers Association (TIMA). Later in 1976 the York Research Corporation developed a book entitled *Economic Thickness of Industrial Insulation for the Federal Energy Administration.* It is an excellent manual which is available from the U.S. Government Printing Office. The information is given in tabular, graphical and nomographical form to allow economic thickness to be developed without the use of a computer. However, computer programs were developed in connection with that manual. In 1980 the TIMA asked Louisiana Tech University in cooperation with the National Insulation Contractors Association (NICA) to make revisions to the Federal Energy Administration work. The result was too basic programs, ETIH and ETIC, which are available in Fortran IV cards or paper tapes from TIMA at the shown address of 7 Kirby Plaza, Mt. Kisco, New York 10549. Member companies of TIMA will run client data through the programs as a free service. Further, several members have developed their own programs covering both original installation and retrofit programs on piping, flat surface insulation, metal building insulation, and tank insulation. Some programs can be done directly by your design engineer in telephone communication with the computer. Other programs require filling out data sheets and sending them to a representative of TIMA. In most cases you will receive a full printout of the information supplied to the computer plus the results. The computer programs are excellent tools but it must be remembered that they are put out by the TIMA and they are trying to sell insulation. Therefore it is important that your design engineer have knowledge of the variables in the computer, how the program handles them, the weaknesses of the computer program, and the best way to interpret the results. It can all get overpowering to the engineer who works with the specification of insulation only sparingly and subsequently to the manager who is called on to approve the money for the insulation. It is hoped the following discussion will help.

Before we get too involved with the economic thickness of insulation, however, let us look at the three main reasons for the installation of insulation. They are:

- Energy Conservation
- Personnel Protection
- Process Control

Quite often the protection of personnel from hot surfaces or the control of process conditions is more important and may require more or less insulation than that required for the most economic energy conservation. In insulating for personnel protection the temperature and composition of the jacketing materials is very important. Metal jackets transfer heat to the touch at a much more rapid rate than non-metallic surfaces and thus it is generally recommended that insulation be provided to limit the temperature of the jacket to no more than 120°F with metal jackets and no more than about 140° with non-metalalic jacketing when the objective is to provide good personnel protection.

When designing for process control there is usually a critical heat lose rate which cannot be exceeded; for example, holding the temperature in a reaction vessel for a given period of time in the event of a power failure. The insulation thickness is thus specified on hat basis even if the thickness is excessive on an economic basis.

Now let us discuss Energy Conservation by using the Economic Thickness of Insulation concept. First, what is meant by Economic thickness of Insulation? It is best described by the graph shown in Figure 1.

The optimum economic thickness is that which provides the most cost effective solution for insulating and is determined when the total cost, made up of fuel cost and insulation cost, is a minimum. As can be seen in the graph of Figure 1, the return on investment gets more marginal as the minimum value is approached and it is questionable whether money would be well spent getting to the absolute optimum value since in actuality many of the variable inputs from which the optimum is arrived will be questionable themselves.

In the evaluation of an economic insulation thickness, it is important to keep in mind the basics of heat transfer through the insulation barrier. In brief review: We know the basic heat transfer equation shown here

$q = U_O A \Delta t$ q = heat flow rate in BTU/hr

U_O = overall heat transfer coefficient in BTU/hr ft^2 ^{O}F

A = area of heat flow surface in ft^2

Δt = difference in temperature between the inside hot surface and the outside surface of the insulation jacket

By dividing both sides of this equation by the area of heat transfer, A, and substituting $1/R_O$ for the overall best transfer coefficient where R_O is the overall sum of the resistances to heat flow in an insulation system, we get the equation shown here:

$$\frac{q}{A} = \frac{\Delta t}{R_O}$$

Now both sides of the equation are in the terms of BTU/hr-ft^2. If we substitute thermal conductivity terms, k, for the insulation materials and the thickness of the materials used, x, in place of the overall resistance, we get an equation for the flow of heat per unit of area through relatively flat surfaces covered with insulation as shown by the following equation:

$$\frac{q}{A} = \frac{\Delta t}{\frac{x_1}{k_1} + \frac{x_2}{k_2} + \ldots + \frac{1}{h_I}} \cdot \quad h_I$$

in the equation is the total surface heat transfer coefficient.

For pipe this equation will be shown by the following equation:

$$\frac{q}{A} = \frac{\Delta t}{\frac{r_o' \ln \left(\frac{r_{o_1}}{r_{i_1}}\right)}{K_1} + \frac{r_o' \ln \left(\frac{r_{o_2}}{r_{i_2}}\right)}{K_2} + \ldots + \frac{1}{h_I}}$$

where r_o and r_i are the outside and inside radii of a layer of insulation and r_o' is the outside radii of the total insulation system.

Another important equation in heat transfer is that heat passing through one part of the insulation must pass through the total insulation, as shown in this equation: $q_t = q_i = q_j$ where q_t = BTU/hr rate passing through the total system and q_i and q_j equal BTU/hr rates passing through the insulation and the jacket respectively. Heat is lost from the jacket in two ways -by radiation and by convection as shown here: $q_j = q_r + q_{cv}$. The heat transfer by radiation is given by the formula shown here:

$$q_r = 0.1713\,\varepsilon \left[\left(\frac{T_s + 459.6}{100}\right)^4 - \left(\frac{T_a + 459.6}{100}\right)^4 \right]$$

The importance of this equation is the emissivity term, E, and the fourth power effect of the jacket's surface temperature, T_s, and the surrounding air temperature, T_a. This equation explains why polished metal insulation jackets such as aluminum with an E value of 0.12 get hotter for the same BTU/hr flow rate than painted canvas jackets with an E value of 0.9.

The heat transfer by convection is given by this formula:

$$q_{cv} = C \left(\frac{1}{d}\right)^{0.2} \left(\frac{1}{T_{av}}\right)^{0.181} (T_s - T_a)^{1.266}$$

$$(1 + 1.277v)^{0.5}$$

where C is a constant and depends on the shape and orientation of the surface.

T_{av} is the average temperature of the insulation surface and the surrounding air and v is the wind velocity.

With the previous equations heat losses in an insulation system can be predicted. Surface temperature can be specified and insulation thickness calculated for proper personnel protection. Insulation thickness for process control also can be calculated and specified. Further, the variables controlling heat flow rates through insulation can be listed as on this projection and we can predict their effect on the economic thickness of insulation. The variables are:

- Type of insulation and thus its thermal conductivity, k, value
- Pipe size (no effect for flat surfaces)
- Hot surface temperature
- Ambient temperature
- Type of insulation jacket and thus its emissivity, E, value
- Wind speed
- Shape and orientation of the insulation surface

The type of insulation must be picked based on factors which relate to service, thermal conductivity, and economics of insulation. For example, if the insulated surface will be walked on some engineers prefer to use calcium silicate block even to install and have a higher l value than fiberglass. The computer will not select the material for the engineer, he must do this and his selection is extremely important in the calculation of the economic thickness. With small pipe sizes and high surface temperatures the pipe size can have a pronounced effect on the economic thickness. Larger pipes require much thicker insulation.

The temperature of the hot surface can be very important in the amount of insulation needed when considered in terms of ±100°F. but not in terms of +10°F.

Ambient temperature has a large effect on the economic insulation thickness when hot surface temperatures are low such as on large storage tanks, but has very little effect on the insulation required for high temperature steam pipes. The same is true for the three jacket oriented variables, emissivity, wind speed, and shape of the surface. As the hot surface temperature increases the effect of these variables decline.

Economic thicknesses can only be specified through the use of equations which are based on the cost of heat losses thus the cost of energy in combination with the cost of the insulation system as our graph depicted earlier.

Factors affecting the cost of energy are listed on this projection. They are:

- Fuel cost
- Heating value of the fuel
- Efficiency of conversion of fuel to heat
- Expected annual fuel price increases

- Annual hours of operation
- Life of the project or desired payback period
- Capital investment for heat plant
- Cost of money to finance the heat plant
- Amortization period of heat-producing plant
- Tax rate

The effect of fuel cost in connection with the heating value of the fuel and the efficiency of its use can have a pronounced effect on the cost of energy and thus on the economic thickness. A large steam unit using coal would have a much lower BTU cost than a small unit using fuel oil or an electric boiler. A plant using one of the latter would thus certainly justify use of thicker insulation.

Most steam systems can now obtain 80 to 90 percent efficiency in the conversion of the fuel to heat and thus that factor if it remains high is relatively unimportant in its impact on the thickness of the insulation.

In the last decade energy costs have increased at the rate of about 18 percent per year. This definitely can have a major effect on the cost of fuel because for economic evaluation all future fuel costs for the life of the project are estimated and put on a present worth basis.

A change in annual hours of operation for a plant will have a major effect if the plant is seasonal. However a plant shutdown for one month in a year for a turnaround, instead of two weeks, will see almost no effect on any economic thickness calculations.

Life of the project is very important from a desired payback time consideration which is another method of evaluating the proper degree of insulation for a given project. In some of the computer programs putting the life of the project in on a desired payback basis instead of an actual life basis will give a thinner economic thickness solution.

Since it is more costly to retrofit insulation to obtain a thicker insulation later than to install it originally, this is sometimes an improper way to look at the economic thickness.

The three capital investment factors for the heat plant can in most cases be discounted. If the capacity of a heat plant is so marginal that the precise economic thickness of insulation might make a capacity increase necessary, it is probably too marginal and the increased capacity should be put in regardless of the insulation thickness. In retrofit cases, of course, available heat plant capacity would be increased but credit could be taken for the increased capacity only if it was used. There are, of course, special cases where the heat plant factors should be considered.

Tax rates are important especially if you are a little company or have a bad profit picture. If so, your economic insulation thickness will be thicker.

The cost of the installed insulation is extremely critical and the most difficult area to define. The basic factors are:

- Cost of insulation
- Cost of installing the insulation
- Cost of maintaining the insulation
- Cost of money for the project

The first two factors must be considered together in designing the plant in order to obtain a least costly system. Obtaining the proper cost for them is the most difficult to overcome in the determination of economic thickness of insulation. Typically the labor cost for a pipe insulation job runs between 60 and 80 percent. Insulation contractors we have contacted lately say their present rule of thumb is that 70 percent of an insulating job is labor. Material manufacturers are introducing systems which are aimed at reducing the labor requirements per unit length of pipe. They include eliminating two layer application of insulation where possible by producing pipe insulation up to 6 inches thick, performing valve and fitting insulation, and providing pipe in specified lengths already insulated and ready for installation with a special foamed insulation joint system. Most contractors are now basing their quotations when using union labor at $25 per hour. Some plants use their own maintenance force and install insulation for half that amount. Some economic thickness programs have labor productivity values for insulators built into them, others use your own value or ask you to supply a quoted price for two thicknesses of insulation on the surface you will be insulating. This is best as contractors have told us they estimate and bid every job separately.

The cost of maintaining the insulation is usually considered to be small or about 1 percent of the insulation cost per year and thus an insignificant factor.

The cost and availability of money would be considered the most important factor. It is considered on an annualized cost basis by using the capital recovery formula as shown:

$$\mathrm{CRF} = \frac{i\ (1+i)^n}{(1+i)^n - 1}$$

where *i* is the interest cost of money and can be adjusted to reflect your company's return on investment requirements.

Some computer programs take into account capital expenditure tax credits, but most do not. It is possible they could be significant so they should be considered.

Summary

The economic thickness of insulation computer programs are comlicated but they are good and as available as your nearest phone. With some knowledge of where the important variables are and the fact that design and specifications of the insulation system is still up to the company engineer, I hope you can all save some money. The money is there just vanishing into the air.

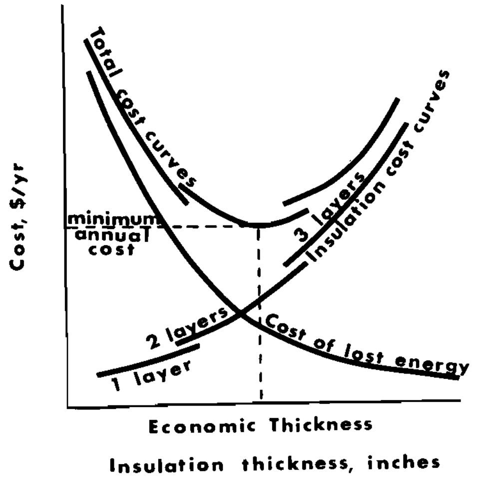


Figure 1

Economic Thickness Graph

MODERATOR BROCHSTEIN: Thank you Ray. (Applause)

MODERATOR BROCHSTEIN: Continuing with our presentations, Vince E. Leon will discuss "Design and Operation of a Modern DAP Granulation Plant." He graduated with a BS degree in chemical engineering from the University of Florida in 1970. Vince had four years of plant engineering experience before joining Davy McKee Corporation in 1974. His various assignments in process and process design engineering, covering all aspects of the phosphate industry, make him well-qualified to cover today's subject. Vince. (Applause)

Design and Operation of A Modern DAP Granulation Plant

M. R. Pearson - J. H. Marten - V. E. Leon

Presented by V. E. Leon

1. *Introduction*

Despite the recent regrettable downtown in domestic and world fertilizer markets, granular diammonium phosphate retains its preeminent position for the American fertilizer producer and farmer. Although development work by TVA and others continues on the application of a pipe-cross reactor to produce DAP, the well tried and proven slurry granulation process is responsible for most of the present DAP producton. The process also has the significant flexibility to be suitable for alternative production of MAP or GTSP or NPK with minor plant modification.

In the mid 1970's the world's largest grassroots phosphate fertilizer complex was brought on stream at New Wales Chemicals Inc. by the International Minerals and Chemicals Corporation (IMC). A 50% expansion of these facilities to 1.5 million tpy P_2O_5 was given the go-ahead in 1979. New grass roots process plants were two sulfuric acid plants, a Prayon phosphoric acid plant and a 140 STPH DAP granulation facility. Associated feed and product storage and handling facilities were also expanded.

With energy costs at the time increasing, particular attention was paid by IMC and Davy McKee to energy conservation measures[1]. In addition strong emphasis was placed on achieving high on-stream time by selecting well-proven, reliable equipment and by laying out the plants to ensure good access for cleaning and maintenance. A spacious layout almost inevitably results in more dollars spent for equipment and bulk materials but it is felt that this can be more than offset by the savings made in construction costs and time. In addition an increased plant operating factor will quickly recover any extra investment cost.

The new phosphoric acid and granulation plants were started up in sequence in November 1981, just over 2 years after project start. This was a creditable performance in view of the facts that initial construction progress was halted for 2 months due to permit delays and a considerable degree of integration with existing facilities was required. The close working relationship between the two parties was undoubtedly a key factor in project implementation.

The subsequent performance of the DAP granulation plant was up to expectations and is considered an improvement in IMC and Davy MdKee previous independent experiences with this type of plant. Unfortunately the plant had to be shut down after a few weeks of operation because of poor market conditions. However, the improvements built into the new plant should be invaluable when the general economy revives. Some of these features have been tried elsewhere but not all on one plant in the initial design. Many of these improvements would be suitable for retrofitting on existing plants.

2. *Plant Description*

2.1 *Rock Grinding*

As part of the expansion more rock grinding capacity was required. This was accomplished by converting an existing dry ball mill to wet grinding and closing the circuit on this and another wet ball mill. All rock grinding at New Wales is now wet.

Advantages of wet rock grinding over dry grinding are[2]:

- Drying of rock is eliminated saving fuel at the typical rate of $1.5 per ton rock (for fuel oil at 60-/gal).
- For a new installation in non-freezing climates rock storage in the open can be used.
- Dust pollution is virtually eliminated. This is an environmental benefit of interest to everyone but perhaps more importantly to accountants when one considers the cost of the typically 2 or 3 percent rock dust losses which occur in dry transportation and storage.
- Wet grinding has proven to have a higher reliability and on-stream factor. There are fewer equipment items in a less severe service.
- Electrical power consumption is reduced by up to 30% for the same capacity.
- Capital investment is less.

The next development of wet rock grinding is likely to be use of neautralized pond water rather than fresh water[3]. This will recover P_2O_5 values in the pond and eliminate liming of excess pond water. Davy MdKee has pioneered the LANG process on a pilot plant with the cooperation of IMC with very encouraging results.

2.2 *Phosphoric Acid*

The thord phosphoric acid train has the same nominal capacity, 912 STPD P_2O_5, as the two existing, but all ancillaries such as pumps, piping, instrumentation plus evaporation capacity were designed for 1600 STPD P_2O_5. The latter capacity was achieved with lower power consumption and an indication of higher P_2O_5 recovery than the original trains[4], [5]. An interesting feature of the new plant is the low level flash cooler concept jointly developed by Prayon and Davy McKee. With its high recirculation rate and low temperature drop while using less power, the degree of scaling in the flash cooler system was significantly less than normal. The attack tank power consumption is considerably reduced by use of a new agitator design.

2.3 *Offsites*

An 8 MW turbogenerator was added to cogenerate power from the high pressure steam from the two new sulfuric acid plants. The unit has since been upgraded to 10.4 MW which is an indication of the attractive economics of cogeneration for either a new or an existing plant.

2.4 *Granulation Unit*

A standard flow diagram for a slurry DAP granulation plant is shown in Fig. 1. The IMC plant design follows this flow scheme except in the finishing section arrangement.

The required capacity of 140 STPH is recognized to be practically beyond the scope of a single train using conventional technology. Normally the accepted design recycle ratio (recycle rate/product rate) in such a plant has been 5:1. Available continuous elevator chain designs for the lift required at the dryer exit restrict plant throughput (recycle rate + product rate) to less than 700 STPH for a single elevator with gravity feed to the screens. This limits maximum production rate to about 115 STPH unless twin elevators or a screen feed drag flight conveyor are used. Use of parallel exit dryer elevators is possible but imposes certain undesirable effects on layout and operational considerations. Although use of a design recycle ratio of say 4:1 would allow a theoretical production rate of 140 STPH, a single stream plant was decided against because it would not have:

- operating flexbility
- the possibility of overcapacity
- relevant equipment operating experience
- simple screen layout with good access for cleaning and maintenance
- common spares with existing granulation plants at the site.

In order to obtain an economic design while incorporating the above desirable features, a novel approach was taken. A dual train mirror image plant was designed with a common cooling and finishing section, all housed in a single building with a common control room. The design recycle ratio was selected by IMC as 4:1 rather than 5:1 in recognition of the experience of the New Wales operators in running an existing DAP plant, and because of the intention to use vapor rather than liquid ammonia to the granulator.

The common finishing section is shown in Fig. 2. Combined product size in excess of recycle requirements from both units passes through a rotary cooler and polishing screens and then to storage. The product-size recycle rate is controlled independently by a vibrating pan feeder on each product recycle stream. Thus recycle rates are kept fairly constant ensuring a stable granulator condition. This method is in contrast to the often used product rate control with recycle overflow. The latter would have resulted in an impractical layout with the twin granulation unit, common finishing section concept.

3. *Design Features*

3.1 *Cooler Bag Collector*

It was decided to pass cooler exit gases through bag collectors rather than venturi scrubbers for removal of entrained dust. IMC already had good experience with bag collectors in shipping sections of their plants, and other fertilizer companies have reported satisfactory experience in some process duties. It was expected that removal of entrained process cooler dust would be a worthwhile application. The advantages are significant:

- The gas pressure drop through a dry bag collector system is less than half that of a conventional cyclone, venturi, tail gas scrubber system. Consequent power savings were of the order of 300 HP.
- Since wet gas flow to the atmosphere is reduced by up to one-third, fluoride emissions are similarly reduced.
- A dry collection system is less likely to cause downtown from scaling and blockages than a venturi system, especially considering the much shorter ducts that are possible.
- Corrosion problems are eliminated, especially for the exhaust fan which can be carbon steel construction.

Two parallel collectors were selected rather than a large single unit for operating flexibility and to avoid total plant shutdown in case of bag breakage. The bags are 10 ft. long, made of Dacron and are designed for quick inspection and removal. Cleaning is by pulsed reverse air jets. Collected dust can be returned to either recycle unit. As a contingency measure each collector includes a small fan and heater for recirculation of hot clean air around the unit to avoid condensation problems when the unit is shutdown and prior to startup.

3.2 *Use of Vapor Ammonia*

The plant was designed to be able to use vapor or liquid ammonia in the reactor and granulator. Many plant operators do not like vapor ammonia spargers, particularly in the granulator, but our experience is that in a correctly designed system the granulation characteristics are equal and the stability of the system, because of elimination of freezing and "bumping" caused by flashing in pipes, gives vapor ammonia an advantage. From a process design approach vapor ammonia gives a reduction in fuel consumption of about 20% over liquid ammonia. Since drying of fertilizer by fuel is rather inefficient, evaporation of ammonia by a heat source such as low pressure steam or hot water generally saves on operating cost. The IMC plant uses low pressure steam to evaporate ammonia in a vaporizer but conversion to a hot water system is under consideration. This improvement is discussed further in Section 5.

For times when liquid ammonia is used as feedstock directly, an ammonia chiller is fitted upsteam of the vaporizer to ensure accurate metering of liquid ammonia. Incoming liquid is cooled indirectly by flashed ammonia in order to condense any ammonia vapor present in the feedstock due to ambient heat ingress to the long feed line.

3.3 *Dryer Insulation*

In our experience not many fertilizer plant dryers are insulated. There seems to be a general assumption that it is not worth the cost and the insulation will deteriorate and eventually fall off anyway. The presence of hammer bands, tyres and girth gear also limit the shell area available for insulation.

Our calculations showed that fuel consumption savings of about 2% could be realized with a payback time of less than 2 years. Insulation selected was 3" thick mineral wood board within a stainless steel jacket. Overall R factor was about 11. Skin temperature data was obtained from operating uninsulated dryers. With only two hammer bands, well over 60% of the total shell length was able to be insulated. It is also worth noting that insulation of the dryer reduces heat input to the building atmosphere thus considerably improving personnel comfort.

3.4 *Plant Layout*

A block model was used extensively in development of the plant layout. This was especially useful considering the added complications of incorporating two mirror image trains in a single building. As well as confirming suitable locations for individual equipment items the model greatly assisted in routing of chutes and ducts and establishing of access for construction, cleaning and maintenance. This was a prime project consideration as realized by the following examples.

Each unit has four double deck process screens which are laid out facing each other. Each screen has a side stairway for access for inspection, cleaning and cloth changing. Likewise all eight oversize mills are located in the same area, on the floor beneath the screens.

Each granulator discharge is easily visible and accessible from the adjacent common control room.

A large equipment maintenance well is located in the center of the building in addition to two smaller ones in the corners close to the screens. This central well also proved invaluable during the construction period.

A monorail is included in the building roof to service all the elevators and a personnel/freight elevator is installed at the end of the building.

A drag flight conveyor is included in each unit. Some companies have strong objections to these but IMC and Davy McKee have found them capable of the job required when properly designed and maintained. In this plant they were particularly useful because of the chute cross-connections between units from the common finishing section.

The combined DAP product from the finishing section is weighed and conveyed directly into the 35000 ton storage building next to the plant. An automatic traveling reclaim scraper was installed as an integral part of the storage building design. These machines are more common in Europe than in the U.S. for granular fertilizer reclaim. Capacity of this machine is 250 STPH. Although expensive, they have a low operating cost and create less noise, dust and product degradation than the several pay-loaders they replace. One extra benefit is that the exposure of operators to uncomfortable working conditions is reduced.

On a large plant such as this the scrubber exhaust fan and duct sizes are such that duct entry to each stack is a significant height above grade. The false bottom of each stack is conveniently used as a liquid storage vessel in order to save valuable ground space. One stack stores water, the other defoamer.

Mention should be made here of our Construction Department effort in implementing the design. A special safety award was presented to Davy McKee in 1981 by the Florida Governor in recognition of over 2 million construction man-hours without a disabiling injury at the New Wales site.

4. *Plant Performance*

4.1 *Capacity*

The East Unit was started first and ran from four weeks with only a scheduled stoppage during the Thanksgiving holiday. Slurry feed rate to the granulation was increased to the design rate (and maintained) only seven hours after initial start-up. The West Unit similarly had a trouble free start-up and both trains ran together for about two weeks. Reactor slurry Sp. G. averaged 1.520 and N:P mole ratio was in the range 1.4 to 1.5 which is in the range of maximum solubility of salts in solution which is shown in Fig. 3. Each slurry feed rate was held at 240 gpm (equivalent to 70-75 STPH DAP product) all the time the plant was running except for a few hours towards the end of the run when the East Unit rate was increased to 300 gpm for a few hours. No processing or equipment problems were evident at this time, so the plant appears to have a reasonable capacity for production at higher than design rate of 70 STPH per unit. The record plant production for one day was 3400 tons.

As with most slurry granulation plants recycle rate is not directly measured in tons per hour, mainly because there is no belt conveyor in the circuit. However, in an attempt to provide operators with a better "feel" for plant operation, recording wattmeters were installed on the recycle drag flight conveyor, recycle elevator, dryer and cooler. These give a continuous measure of plant load and a relative indication of recycle rate.

The lack of recycle bottlenecks at higher than design production rate confirmed our impression that a design recycle ratio of 4:1 was more than adequate for a 100% vapor ammonia feed. Comparison with an existing DAP plant with the same model elevators but operating at higher chain speeds also tended to conform the lower recycle rate for similar production rate.

4.2 *Raw Materials*

The phosphoric acid feed was 54% P_2O_5 plus either 28% P_2O_5 filter acid or 40% P_2O_5 acid. Dry basis P_2O_5 content of each acid averaged

65.5% P_2O_5 dry basis.....	For 54% acid
63.3....................	40% acid
61.0....................	28% acid

As part of the expansion a second belt filter was added for removal of 40% acid sludge[6]. The consequent increase in dry basis P_2O_5 from filter acid is significant.

The average metallic impurity levels in the feed acid were calculated to be as follows. They are presented as the ratio of $Al_2O_3 + Fe_2O_3 + MgO$ to P_2O_5. The ratio in 66 BPL rock feed to the phosphoric acid is also given.

0.080....................	For 54% acid
0.090....................	40% acid
0.095....................	28% acid
0.096....................	Rock

The level of these impurities in the rock is about equal to the maximum (0.095) normally used by IMC and Davy McKee as a criterion for predicting whether DAP grade of 18-46-0 can be made or not[6], [7]. Studies of the chemistry of the impurities in acid has tended to support such general "rules of thumb" quite well.

4.3 *Product*

The average of of all the laboratory shift analyses for product exit plant was

N......................18.0% wt
P_2O_5 (total).............46.6
Free water...............1.5

This is equivalent on a dry basis to 18.2/47.3/0.

Citrate insoluble P_2O_5 content in the product has turned out to be something of a mystery. The reasons for citrate insoluble P_2O_5 in DAP have been studied by various organizations including TVA but no single conclusive cause has been found. It was not normal IMC practice to routinely analyze C.I. P_2O_5 in DAP as produced since levels in the existing plant over the last few years had consistently been 0.2% P_2O_5 or less. Samples from the new DAP pile (sometime after initial plant startup) were taken prior to shipping and showed higher C.I. than normal. An accurate average figure for the whole production is not available but is believed to be more than 0.5% P_2O_5. In trying to understand how this had occurred it was discovered that MgO content in the rock feed to the acid plant during the time of the new DAP plant operation was higher than IMC had ever previously recorded. MgO level in rock for several weeks averaged 0.64% with a maximum daily analysis of 0.86%. Whether this or some other factor was the cause of the problem is currently being investigated by test work.

Sulfuric acid was continuously added to scrubber seal tanks to adjust product P_2O_5 content on a routine basis. Rate was normally between 1 and 2% of the formulation. The product *N* content is in close agreement with that predicted from the raw material metal impurity levels, as discussed in Section 4.2 above.

Product size after the single deck polishing screens averaged 94% between 6 and 14 Tyler Mesh. With more than 1% +6 mesh, some minor adjustment of the process screens oversize cloth mesh is indicated. Product is normally screened again after reclaim from storage before shipping.

4.4 *Utilities*

No. 6 fuel oil consumption over the whole operating period including startup periods averaged less than 2.5 gallons per ton of DAP product. This was within design for the desired product mositure exit plant of 1.5% H_2O maximum. It should be reduced when some burner problems are resolved (see Section 4.6), reactor slurry Sp.G. is increased, and vapor ammonia is used more continuously in the granulator.

4.5 *Emissions*

There was some initial difficulty in obtaining reproducible stack gas flow data probably due to the tangential inlet to the stacks. This was resolved and emissions were well within EPA and State regulations of 0.5 lbs. of particulates and 0.06 lbs. of fluoride, both per ton of P_2O_5 feed. particulate emission from the cooler bag collectors was regulated at 4.5 lbs/hr maximum.

It is interesting to note that high fluoride emissions were recorded for a short period coinciding with bad combustion in the dryer furnace. This phenomenon has been observed by IMC in their other granulation plants at New Wales including those producing GTSP and Animal Feed Ingredients.

The scrubbing medium for the tail gas scrubber was once through pond water thus ensuring a stack gas temperature of about 105°F. E.P.A. fluoride emission regulations are now very difficult to meet on a new plant if only recirculated water is used.

4.6 *Equipment*

Most equipment problems were of a routine nature and were identified and resolved during the extensive mechanical check out procedure prior to start-up. Some problems only identified after startup were as follows.

- Spalling of refractory fire brick in the dryer air heater. Poor combustion and flame impingement was evident and is being corrected by the manufacture by modification of air inlet ports.

- It is standard IMC practice to install panel mounted vibration monitor and bearing temperature indicators for large rotating machinery. These enabled out of balance conditions on two large scrubber fans to be detected quickly and remedied by rebalancing.

- Excessive buildup in the reactors was discovered after plant shutdown. This is expected to be resolved by adjusting the ammonia sparge insertion length. The reactors are not fitted with agitators and the spargers are semi-tangential to compensate by giving a swirling motion to the slurry.

— High pressure in the ammonia vaporizer. This was not a problem as such since all the equipment was capable of operation at the higher pressure. It may be corrected if required by enlarging the granulator sparger holes. These were originally sized as a compromise between liquid and vapor ammonia requirements based on standard TVA recommendations and IMC previous experience. The bias in Calculation was towards the smaller area required for liquid ammonia and this apparently caused too much pressure drop for vapor ammonia.

Although not an operational problem, there was an interesting aspect of the product storage scraper reclaimer design which was not identified until the machine was erected. The machine is German in design and the key components were supplied from West Germany for assembly with the locally made frame. Rather late in the day it was discovered that certain federal/OSHA safety requirements had not been compiled with. These were corrected satisfactorily but it is a point for all designers to watch out for when dealing with standard equipment from overseas.

The main conclusions of the plant performance to date are satisfaction with ease of bringing the plant on-line, and meeting capacity, and emission requirements. There were several other positive aspects of the design proved by operation.

The common finishing section with bag collectors for cooler exhaust air was very successful and resulted in low particle emissions. No tag blinding or breakages occured.

The venturi scrubbers were of all stainless steel rather than being rubber lined carbon steel. They are of the coaxial type design which can be difficult to get at and clean, in addition to being more complicated to rubber line. In fact these scrubbers were very free of buildup after a month's operation in comparison with other types of construction with which we have experience. Using large bore tangential inlets for the liquor venturi throat may also have contributed in this respect since pluggage problems were less than typically experienced on other plants.

Similarly the vertical tail gas scrubbers were completely free of pluggage problems, probably due to the extensive use of pond water sprays in the ducts at the outlet of the venturi scrubber. The packing in the tail gas scrubbers, when necessary in the future, can be quickly dumped via chutes to a concrete bay at grade. Here it can be washed or removed quickly thus saving on downtime. Reinstallation of clean packing is easily done via a top entry vertical core chute in the scrubber. The cross sectional area taken up by the packing feed chute necessitated a slightly larger diameter scrubber so as not to exceed the normal gas design velocity.

5. *Future Improvements*

Despite the success of the IMC design and startup operation, we are continuously evaluating potential improvements in granulation plant design for this and other operating plants as well as for new plants.

5.1 *Bag Collectors*

Use of bag collectors for cooler exhaust has proved very satisfactory not only on the DAP plant already described but also on the powdered MAP plant at New Wales. Their use on general equipment vent air has also been demonstrated successfully, particularly in shipping areas. The logical extension of this experience would be use for in-plant equipment venting. Presently equipment vent air is usually passed through the venturi scrubber system. Although this removes the particulates, on a DAP plant the scrubbing medium is weak phosphoric acid from which fluorine is stripped by the air and then this fluorine has to be scrubbed out. This consumes a lot of power when all that is required is removal of the dust. A bag collector can do this more efficiently than wet scrubbers. The general hesitancy about using bag collectors in the past has been caused by

— concern about moisture in the gas blinding the bags and possibly causing corrosion.

— ammonia escape from hot DAP dust.

— bag failure causing plant shutdown.

These may well still be valid arguments for dryer exhaust gas but are not now considered a hindrance for most equipment venting applications and we expect to see bag collectors used more in this latter duty. In fact there is at least one plant which uses a bag collector for all process gas dust recovery[8]. This may not be advisable except in extreme circumstances but for low ammonia grades, operation is aid to be satisfactory. It is even reported that some free ammonia is absorbed by fine dust particulates as the gas penetrates the filter cake on the bags.

5.2 *Cooler Air Recycle*

Exhaust air from a cooler is typically at 150°F. The heat content of this air can be totally recovered by recycling the air to the dryer furnace after suitable dust removal. The choice between bag collectors or high efficiency cyclones for dust removal is fairly arbitrary. The bag collector gives a much lower outlet dust loading, typically 0.01 grains/ACF compared to probably about 1 grain/ACF for cyclones, but is more expensive and there is always the potential problem of a bag breaking. We know of at least three installations which use cyclones in a cooler air recycle system. Reasonable carryover of dust does not seem to be a problem in furnace operation but excessive carryover from inefficient cyclones on one plant causes excessive downtime for cleaning.

In a typical scheme all the cooler exhaust air would replace atmospheric air used for dilution in the furnace. Atmospheric air would still be used for combustion. The fuel oil savings would amount to approximately 0.3 gal/T product for a typical slurry DAP plant, equivalent to between 10 and 15% of oil consumption. An emission source to atmosphere would also be eliminated for a plant such as IMC's, and the benefits of not scrubbing cooler exhaust would be additional as previously described in Section 3.1.

5.3 *Screening System*

Any slurry granulation plant, particularly DAP, MAP and GTSP, produces more product size material out of the granulator and dryer than can be exported from the plant as product. At some point excess product size is recycled back to the granulator to keep the solids recycle ratio high enough to absorb the excess free water present in the slurry from the neutralizer. Conventionally all the dryer product has been screened on double deck screens. This is an inefficient use of screens because

— all the product size material is being screened out unnecessarily.

— the total screening area is dictated by that required for the product fines screen.

For example this appraoch would result in six large (4 ft x 20 ft) double deck screens for a 100 STPH DAP plant. This complicates the layout and screen feeding arrangements, necessitating twin exit dryer elevators or a screen feed conveyor as mentioned in Section 2.4. Several improved screen arrangements are possible, one of which is shown in Fig. 4. use of single deck screens means better screening eficiency, better control of operation during granulator upsets and better access to cloths for cleaning. We foresee a general acceptance of this type of screening and milling system in the future for large capacity slurry granulation plants.

5.4 *Elimination of Lump Breaker*

Another traditional concept in large granulation plants has been the use of a lump breaker exit the dryer. This is needed for breaking up lumps formed by an over wet granulator and/or from buildup breaking away from the dryer shell. We prefer to use slow speed elevators (120 to 150 FPM) which give longer chain life than higher speed centrifugal elevators. The larger buckets of the slow speed machine will accept larger lumps. A less sophisticated crushing arrangement is thus possible.

One method we have proven on a large plant is to use lifters at the end of the dryer and let the lumps break up as they fall by gravity onto the grizzly bars. Elimination of the lump breaker should reduce downtime and maintenance costs but also enables the height of concrete plinths and overall building to be reduced. The feed end concrete plinth for the IMC dryer is 25 ft above grade. Studies indicate that about 4 to 5 ft of height could be saved for a similar large plant when a lump breaker is not included.

5.5 *Hot Water Vaporizer*

Anhydrous liquid ammonia (99.5% NH_3) boils at 100 to 110°F. at the normal pressures required for operation of a vaporizer in a granulation plant. Low pressure stream (25 to 50 psig) is normally used as the heating medium. If this steam can profitably be used elsewhere in the complex, then a much lower level heat source can be used for ammonia vaporization, such as hot water. Potential sources of hot water are the sulfuric acid plant cooling system and effluent water from the DAP plant scrubbers.

Sulfuric acid plant return cooling water has the advantage of being clean but is generally no hotter than 120°F and so would have a small driving force and need a high flow. However, if say 99.8% NH_3 is the ammonia quality, then the boiling temperature is only 80 to 90°F. and using this source of hot water would be feasible.

The reactor/granulator gases are generally hotter than the dryer gases inlet the tail gas scrubbers. Fresh or pond water if recirculated in the bottom part of this scrubber would provide a source of water at 140 to 150°F. for the vaporizer, thus ensuring a suitable driving force. This approach is safe for the case of variable ammonia quality.

The hot water vaporizer would obviously be larger than an equivalent steam heated unit and would require fecilities for cleaning the tubes. Quotations from vendors indicate capital cost would more than double but valuing LP steam at $3 per 1000 lbs. would give a pay back time of less than 2 months. An allowance for extra water pumping power is included. With a typical LP steam flow of 235 lbs per ton DAP (all ammonia feedstock vaporized) the annual operating cost savings would be about $0.5 million for LP steam of the above value for a 100 STPH DAP plant.

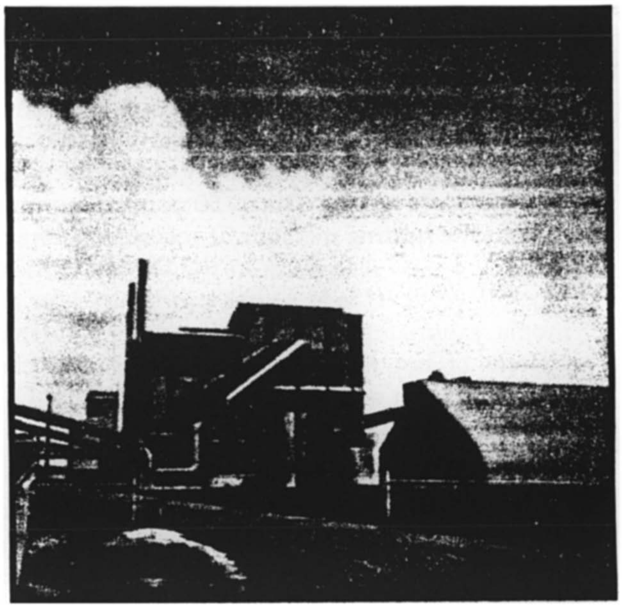
6. *Summary*

The world's largest DAP faculty was brought on-stream with minimum problems.

Improvements to conventional slurry granulation plant design were incorporated successfully.

Further logical improvements are available for new plants or revamps which will further reduce operating cost and downtime.

These will allow slurry granulation technology to remain competive for the foreseeable future.



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DAP/MAP GRANULATION
PROCESS FLOW DIAGRAM

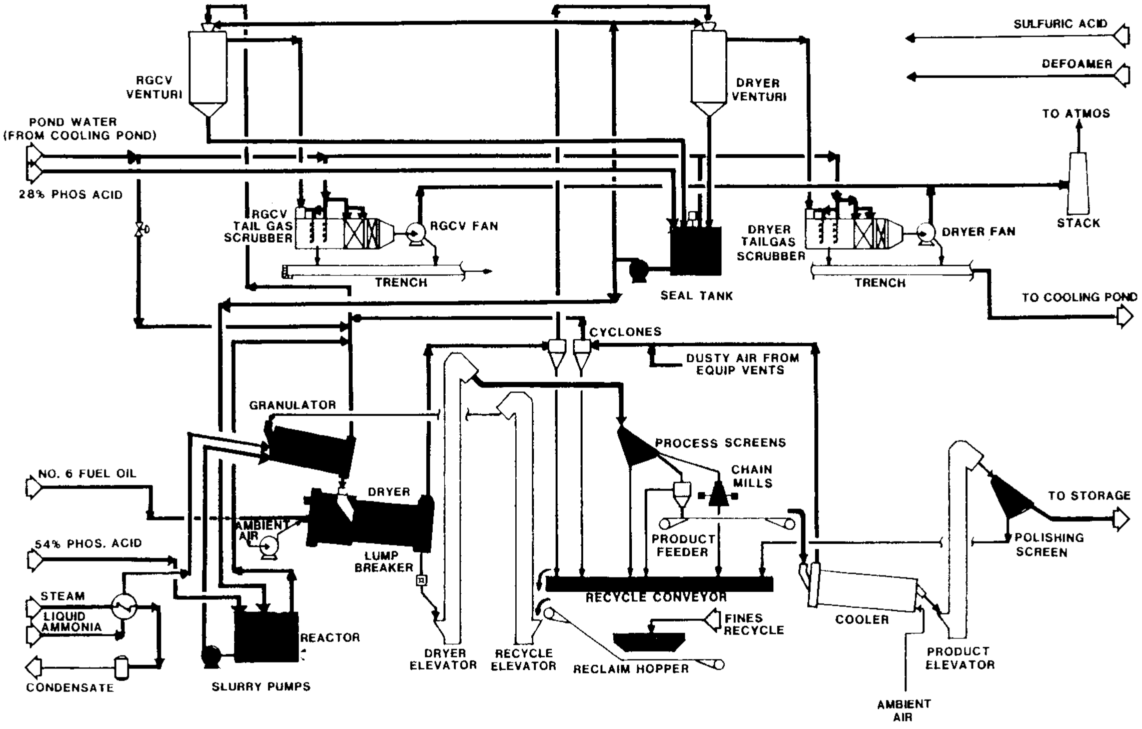
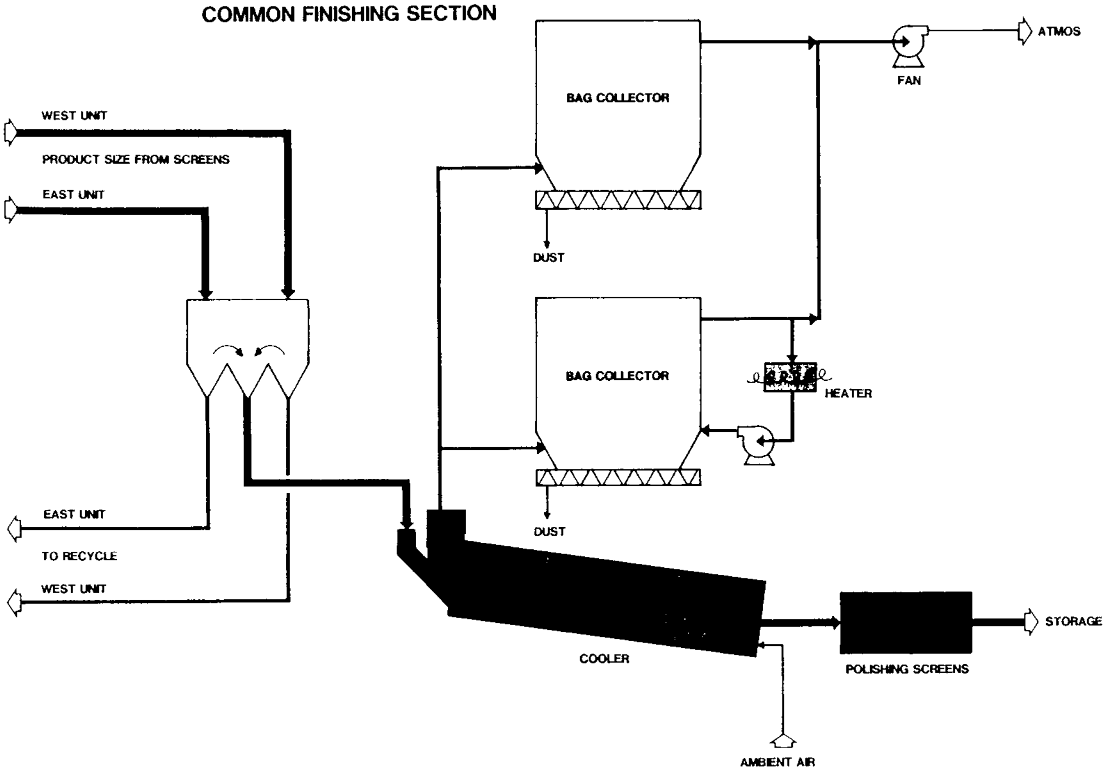


Figure 1

Davy McKee

COMMON FINISHING SECTION



Davy McKee

Figure 2

SOLUBILITY ISOTHERMS IN THE SYSTEM NH_3-H_3PO_4-H_2O

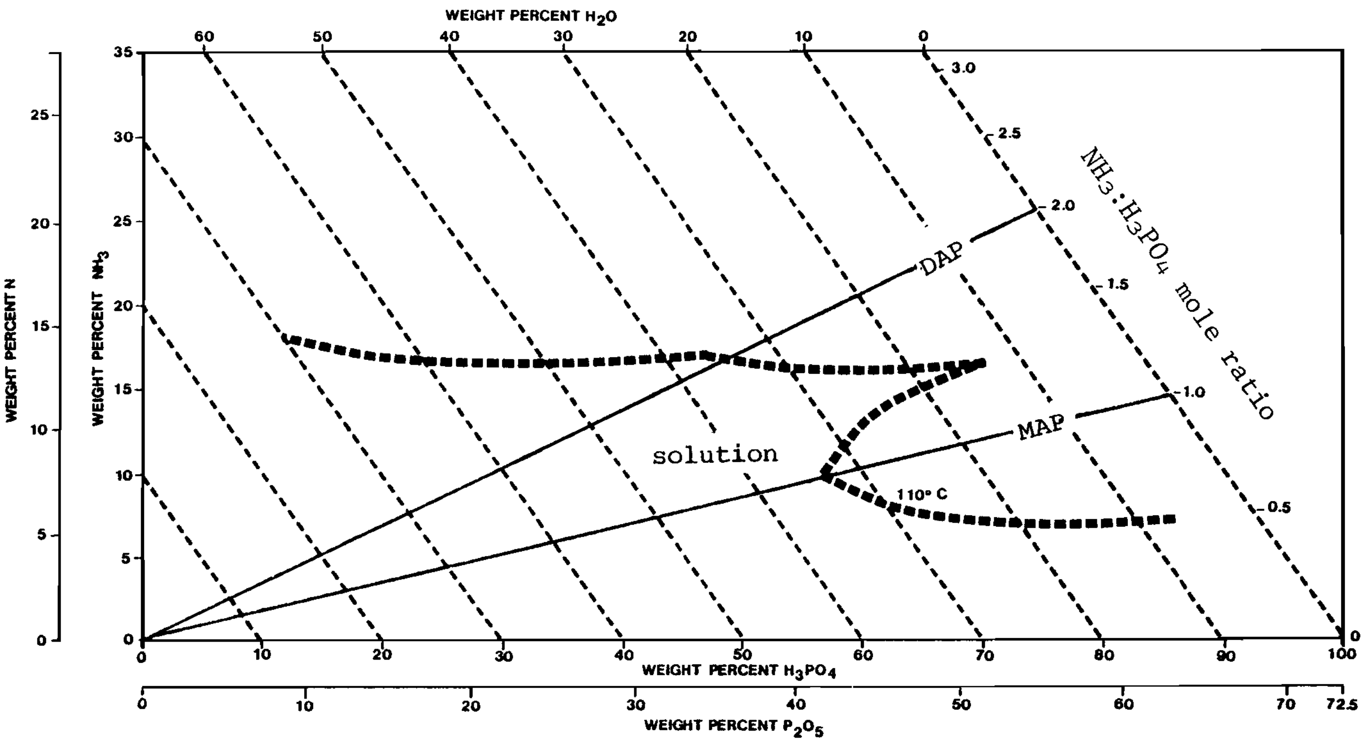


Figure 3

DIAMMONIUM PHOSPHATE PROCESS WITH COOLER AIR RECYCLE AND SINGLE DECK SCREENS

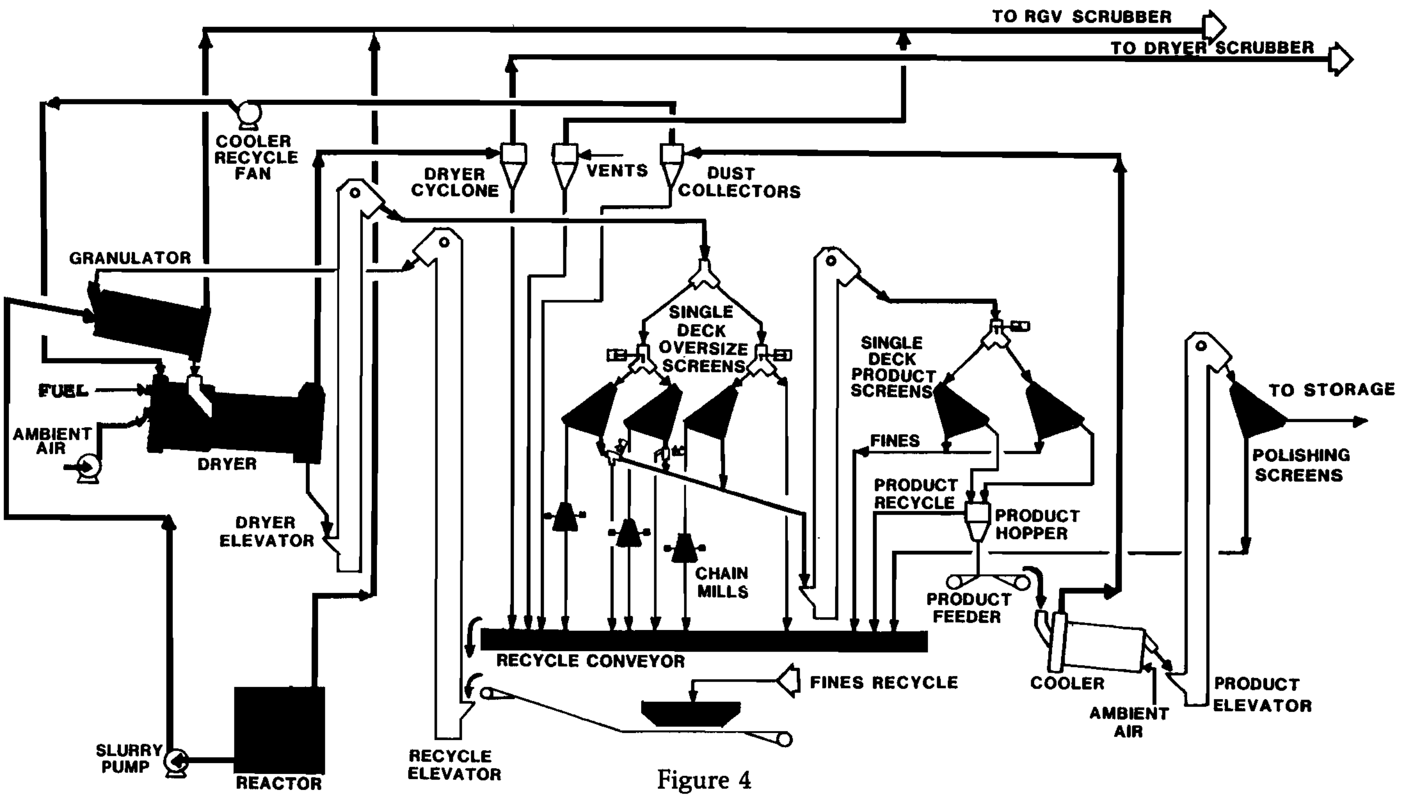


Figure 4

MODERATOR BROCHSTEIN: Thank you Vince. (Applause)

MODERATOR BROCHSTEIN: Our last speaker this afternoon is Leon Buividas. Leon is currently with the M. W. Kellogg Company and has been associated with them since 1951. He holds a BS in chemical engineering, as well as a BS and MS in petroleum engineering. Leon has held numerous positions with M. W. Kellogg and currently is Coordinator, Inorganic Chemical Technology. He has published numerous articles related to ammonia and hydrogen production. Leon will speak on "Lower Energy Ammonia - With Retrofits," Leon. (Applause)

Lower Energy Ammonia Retrofits

L. J. Buividas - J. R. LeBlane

Presented by L. J. Buividas

Introduction

Ammonia - the largest volume industrial chemical worldwide - is applied directly as a fertilizer as well as in the form of nitrates, phosphates (N-P-K), urea and solutions. In addition, ammonia has end uses in many industrial applications such as for plastics, resins, fibers and explosives[1].

The global ammonia production during 1981 was in the order of 90 million metric tons with the potential annual growth projected to be 5-6 percent per year[2].

Energy Savings - Principles[3]

In a typical large ammonia plant (see Figure 1) using centrifugal compressors, the major energy and energy availability losses are in the surface condensers (about 6 MM BTU/ton), the carbon dioxide removal system (about 3.5 MM BTU/ton) and small condensing steam turbine mechanical drives (about 1 MM BTU/ton). In addition, energy availability is degraded by 1300°F temperature difference at the inlet of the primary reformer convection section, 1200°F. at the exit of the secondary reformer and 400°F in the ammonia synthesis converter heat recovery system. Energy availability is also degraded by pressure drops of 100+ psi in the "front end" and 200+ psi in the synthesis loop.

Reducing energy consumption in existing ammonia plants requires concentration in areas where most of the energy or its availability is being lost. Thus, a reduction of total power consumption is required, which means reducing compressor and pumping energy requirements by suing higher efficiency mechanical equipment, higher pressure steam with higher superheat temperatures, reducing frictional losses, etc.

1. Lower total power consumption reduce compression and pumping; use higher efficiency mechanical equipment; use higher pressure steam and higher superheat.
2. Make efficient use of high level energy to maximize power output.
3. Find lower energy consumption carbon dioxide removal system.
4. Make effective use of low temperature level energy.
5. Have high ammonia yield and minimize use of high temperature level energy to separate ammonia from the synthesis loop.
6. Where possible, "bootstrap" low temperature level energy to high levels such as combustion air preheating and boiler feedwater heating.
7. Power recovery.
8. More efficient catalyst utilization.

Constraints

While it is easy to point out what must be done, it is quite another problem to decide in detail how to do it. The constraints in making changes are:

1. Capital Costs? vs. Energy Savings?
2. The need to maintain operational and control stability.

It is *undesirable* to introduce more than the minimum justifiable mechanical complexity, but it is *desirable* to operate at the minimum process severity to reduce maintenance costs.

Any energy savings can only be accomplished by reducing the fuel input to the reformer or auxiliary boiler and/or by reducing feed gas consumption. Thus, reducing energy consumption in some areas, e.g., carbon dioxide removal, does not necessarily result directly in fuel input reduction. To be effective, fuel gas consumption must be reduced. Due to the complexity of an ammonia and its steam balance, energy savings are not necessarily additive.

Capital For Energy Savings

The production of ammonia is not only energy, but also capital intensive. Therefore, any improvements of energy consumption in an existing plant will require capital outlay which may or may not be justified. The tools for energy reduction retrofits can be classified into two categories: — Major and Minor Capital additions.

The major capital additions to be considered are:

1. Combustion air preheater and steam superheat burners.
2. Higher process air temperature.
3. Short-shift LTS guard.
4. Improved CO_2 Removal System.

5. Synthesis gas drying.
6. Additional ammonia synthesis catalyst.
7. Replace the synthesis loop exchangers with a single unitized exchanger.
8. Add-on Purge Gas Converter System.

The minor capital additions are:

1. Purge gas recovery either by a cryogenic unit[4] or by a permeation technique such as the PRISM™ separator[5].
2. Recycle purge gas to primary/secondary reformer.
3. Parallel equipment, such as exchangers, piping, etc.
4. Power recovery via expanders and/or hydraulic turbines.
5. Computer Control.
6. Change small single stage turbines to multi-stage for lower steam consumption, or
7. Convert small single-stage condensing steam turbines to electric motors.

The above major retrofits, through careful and judicious approach, can realize an energy savings of up to 4 million BTUs per short ton. With cautious minor additions, a total savings up to about 6 million BTUs per short ton are realistic and can be achieved.

Utilities

The above indicates areas where energy savings devices are applicable in the process unit. In addition, the utility systems for the ammonia plant are the steam, cooling water, and the make-up water systems, as well as the electric power distribution system and should be examined. Some of the options for energy conservation in these areas are possible, such as:

1. Use of a gas turbine to drive a process compressor, or in locations of high power costs, and/or for a large power consuming complex, to run a power generator. The exhaust from the gas turbine can be used to supply part of the combustion air needed in the primary reformer or can be routed through a waste heat boiler for steam generation.
2. The cooling tower should be monitored and examined for more efficient operation by the installation of fill (packing), etc., to achieve a closer approach to the wet bulb temperature. If cold well water is available as make-up, the plant refrigeration can be reduced by utilizing this water directly in the synthesis loop cooling system prior to sending the make-up water to the cooling tower.
3. During start-ups and partial plant operations, synthesis gas is vented, and natural gas is used in certain catalyst reducing and purging operations. Routing these gas streams to the plant fuel system can result in considerable energy savings.
4. Many ammonia plants operate at over design capacity and therefore the utility systems should be investigated to locate the restraints and where energy consumption can be reduced.

Housekeeping

Close attention should be paid to the plant operations to avoid wasting energy. A series of "housekeeping" checks should be prepared and some of the KEY items to be monitored are listed:

1. Stop leaks (process, steam, etc.).
2. Avoid kickback on centrifugal compressors.
3. Reduce excess combustion air.
4. Clean fouled exchangers.
5. Optimize operation of the catalytic conversion steps (reforming, shift, NH_3 conversion).
6. Change spent catalyst.
7. Properly maintain machinery (turbines, compressors, pumps).
8. Maintain proper ratios (steam to carbon, H_2 to N_2).
9. Maintain proper inerts level in synthesis loop.
10. Maintain proper cooling water distribution.
11. Surface condenser performance.
12. CO_2 Removal System - in balance.
13. Provide adequate insulation.
14. Avoid excessive blowdown.
15. Avoid excessive steam tracing.

Application - Retrofits

Any comprehensive energy reduction study and implementation in an existing plant is a complex undertaking[6]. The costs can be significant, since rating a plant is much more difficult than designing a new energy efficient plant. This is particularly true when the on-stream unit is in a "wide open" operational mode.

Often, additional capacity is desired and a debottlenecking study is needed. Integrative of the utilities with the rest of the complex must be considered.

Careful consideration must be given to dismantling/removal of existing equipment, installation of tieins, down time and attendant loss of production.

Each ammonia plant management team, embarking on a successful energy conservation scheme, should consider the following:

1. Recruit energy analysts or train the plant technical staff in energy balance techniques.
2. Develop a housekeeping checklist for use by the technical staff and plant supervisors.
3. Recommend that the implementation of a "retrofit" project should be performed in phases:

   PHASE I — Bench mark determination of the on-stream plant. A sound understanding of the current operation is extremely important and can be realized by the collection, review, analysis of the plant data, and by the analytical simulation of the existing operation. Screen the energy conservation ideas by addressing each as to the energy cost, savings to be gained, and capital cost to determine if an acceptable payout is achieved. An energy audit of the entire plant (complex) will have a comprehensive influence on how the existing systems are performing and which energy saving devices are to be considered for a particular project.

   PHASE II — Make final selection of the retrofit systems and perform the calculations for the revised plant operation. The final capital cost estimates are generated, along with a down time analysis and project schedule.

   PHASE III —This involves implementation of the engineering, procurement and construction for the retrofit project. Both engineering and construction must address plant turnaround from an early stage. Excessive down time and loss of production might offset any realization in energy savings.

Conclusion

Energy conservation of an existing ammonia plant is an intricate objective which involves detailed planning and studies to achieve desired goals. Significant energy reduction can be attained through a judicious approach to a particular project. Depending upon the existing on-stream plant performance, energy savings equivalent to 3-8 million BTUs per short ton of ammonia product can be realized.

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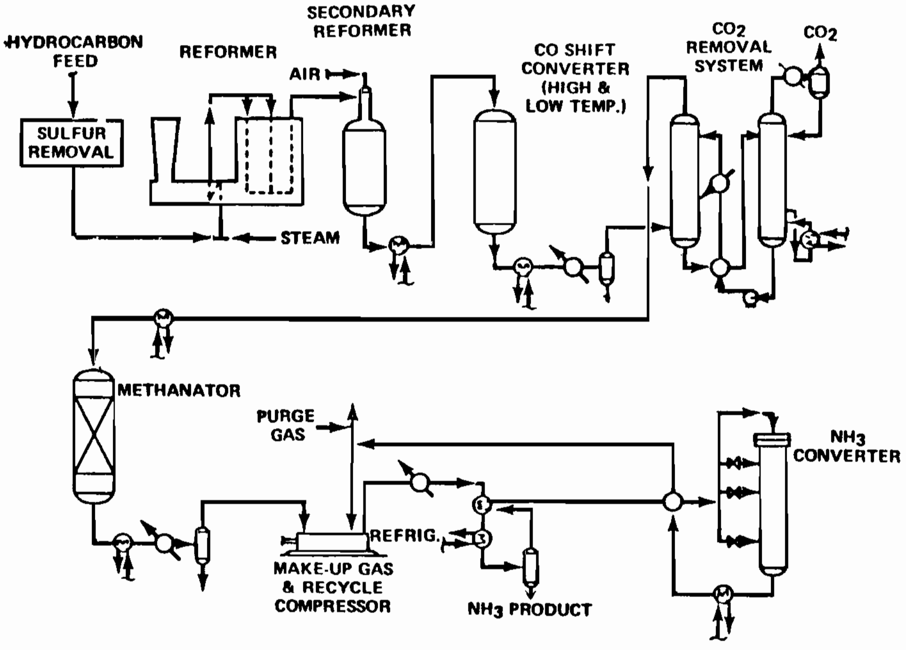

The M.W. Kellogg Company

FIGURE 1 – FLOWSHEET FOR HIGH CAPACITY SINGLE TRAIN AMMONIA PLANT

MODERATOR BROCHSTEIN: Thank you Leon for an excellent discussion on Inorganic Chemical Technology. (Applause)

Let's give a round of applause to seven excellent presentations. (Applause). The Speakers will now entertain any and all questions.

DAVID LEYSHON—Jacob Engineering: I have a question for the author of the paper on ammoniation of TSP. I was interested in looking at the analysis of the product. The author gives the analysis of the product as being 44% total P_2O_5, 25% water soluble P_2O_5 and about 35% APA. It seems to me that if you are producing a slurry process triple, you are using between 70 and 75% of your P_2O_5 from acid; therefore, you should have only between 31 and 33% P_2O_5 in the product as water soluble P_2O_5. This indicates that you may have had some reversion of the water soluble P_2O_5 plus very little conversion of the rock that was added because at 35% available P_2O_5 (APA), that's only slightly over what was added as phosphoric acid. I think we could expect this because, generally speaking, you get perhaps 63% conversion of the P_2O_5 in the slurry state. My question is why wasn't a process which consisted of ammoniation of the product considered rather than a process involving the ammoniation inside the process, around the slurry? Actually, you are taking triple superphosphate and assumedly, by reducing the circulating load, you are increasing the capacity, but you are dropping the APA of the grade from 45 or something down to 35.

ANSWER—JORGE POLA -IFDA: You must remember that we are talking about a product that will be suited for the tropical areas of the world. In these areas, where the acidic soils predominate, we are not really looking for a total availability of P_2O_5. So, when we talk about a material that has some P_2O_5 , has none available, we are not necessarily talking about a product which is of inferior grade. This was checked even through greenhouse testing done under simulated tropical conditions and tropical soils. Why we do not ammoniate the finished product — that's a very good question. In the past, a lot of ammoniation of TSP has been done and in most instances a considerable time after curing. The benefit of this proposed process is to obtain a finished product with the ammonia in with the material and avoid lengthy curing time.

QUESTION—SAMUEL HOUGHTALING - Bearden Potter Corporation: This is directed to Vince Leon of Davy McKee. I would like to know (1) What were the ammonia losses and did the cyclonic action of the ammonia spargers improve the recovery of the ammonia; (2) What type of packing was used in the tail gas scrubber; and (3) What was the height of the dryer elevator?

ANSWER—VINCE E. LEON - Davy McKee: (1) We do not have a lot of ammonia loss data because the plant only operated for about four weeks. At the time it was operating, we were concentrating on plant performance and not optimization. We are anxious, ourselves, to prove the plant could perform and the optimization never did come about. (2) The actual packing in the tail gas scrubber is 3" Intalox saddles in the bottom section and I believe we have 1" Tellerette in the top demister section. (3) The height of the elevator, I believe, is 105' center to center.

QUESTION—LOFTUS BENJAMIN - Belledune Fertilizer (Canada): I have a question for Vince Leon also, Vince, I would like to know whether there is anything new in the design of your cage mills in your DAP plant. Have you succeeded in reducing build-up in that cage mill?

ANSWER—VINCE E. LEON - DAVY McKEE: We buy the equipment which is available and do not design our own cage mills. There has been a little bit of improvement in some of these cage mills and I understand they are now offered with systems that automatically take them apart. But, to answer your question, no, you still have to clean them and you have to clean them every so often.

QUESTION—FROM THE AUDIENCE: What advantages does the use of hot water vaporization of the ammonia have over the use of vaporization of ammonia in the cooler? The other way of vaporizing ammonia would be that instead of using steam, use the air which is normally used in the cooler to vaporize ammonia. Does the use of hot water from the tail gas scrubbers have any advantage over that?

ANSWER:VINCE LEON - Davy McKee: I don't believe you have sufficient Δ T in your product from the cooler to vaporize all of the ammonia required to go to the granulator and the reactor. I don't believe you have enough heat there just by taking the heat away from the product. We probably would vaporize part of your ammonia but I don't think you can vaporize 100 percent of your ammonia going to these units. The ammonia vaporization scheme using the cooler is good, but it lacks vaporization capacity in the wintertime. There's that much Δ T in the wintertime and it's not all that good.

We do not claim the screening innovations as inventions that we have made. I am aware that the Dorr-Oliver plants have had a partial screening approach and so have others.

COMMENT FROM THE AUDIENCE: I would like to add to a point. We have put in an air chilling system going to a cooler, and it doesn't evaporate all the ammonia, even in the summertime, going to the granulator. In fact, it evaporates approximately 60 percent of the ammonia going to the granulator when you chill the air going to the cooler.

QUESTION FORM THE AUDIENCE: What is the temperature from the DAP cooler? Is it much cooler than your regular DAP plant? I understand that you have a baghouse under your cooler. Is there any effect on the temperature exiting the cooler? Is the temperature of your product lower?

ANSWER—VINCE LEON - Davy McKee: No, the baghouse is used to obtain a better job of collecting the dust. What we, in theory, should do with that air is put it back to the dryer instead of shooting it back out to the atmosphere. The temperature of the product coming out of the cooler is 125 to 130, depending on the days that they were measured, obviously depending on the ambient temperature.

CHAIRMAN FRANK ACHORN: I would like to thank all of the speakers for taking the time required to write these papers. I know that it requires (mostly a good secretary!) but it also requires a lot of effort from you. I certainly want to thank all of those this afternoon that gave excellent presentations which will appear in the Proceedings.

We will start in the morning at 9:00 o'clock. I thank you all for staying as long as you did and for being as attentive as you have been. Thank you very much. (Applause)

Wednesday, October 17, 1982

Morning Session

Al. V. Malone, Moderator

CHAIRMAN FRANK P. ACHORN: Our moderator for this morning's session needs no introduction to most of you. Al Malone has participated in the Round Table for a long time — almost from the start. He has been a Board member of the Round Table for several years. Al has held several technical and management positions with Agway and now is Manager, Engineering, Safety and Environmental Protection for the Fertilizer Division. He is located at Agway's main offices in Syracuse, New York. Here is our long-time friend Al Malone. (Applause)

MODERATOR MALONE: Good morning. The Round Table is known for its ingenuity and creativity. For this morning's interesting session we are bringing you speakers who are creative. One of the obstacles to creativity is that there are killer phrases which discourage. I have a list of these killer phrases today, and as I introduce the speakers I want to announce some of those phrases that our creative speakers have conquered.

Our first presentation today is by Carl A. Cole, Jr. Carl is a graduate chemical engineer of Auburn University. He has worked for five years for the Tennessee Valley Authority in research and development, provided technical assistance to the fertilizer industry, and helped start up fertilizer plants. He is a chemical engineer with Frank Achorn's group, the Field Engineering Staff, Division of Agricultural Development, Muscle Shoals, Alabama, and has coauthored several technical papers and articles. Carl has wrestled and pinned these killer phrases:

> *We've never done it that way before.*
>
> *We haven't the manpower.*
>
> *It's not in the budget.*
>
> *We're not ready for it yet.*
>
> *All right in theory, but can you put it into practice?*
>
> *Too academic.*
>
> *What will the customers think?*

He will be discussing "Bulk Blending Mixing Efficiency Tests." We are pleased to introduce Carl to the Round Table. (Applause)

Bulk Blending Mixing Efficiency Tests

Hubert L. Balay
Carl A. Cole
David W. Rutland

Presented by Carl A. Cole

In 1968 Bridger and Bowen reported results from tests of several kinds of mixers used for bulk blending[1]. Among the mixers tested were a 2-ton standard concrete mixer with fixed inclined axis and helical flights and a cyclindrical rotary mixer 78 inches in diameter and 38 inches long. The conclusion was that the cylindrical rotary mixer did a good job of mixing and that the standard concrete mixer did a poor job of mixing.

Logic supports Bridger's conclusion. A concrete, or concrete-type mixer, must be stopped and reversed for discharge. Hoffmeister showed that most segregation in bulk blends is the result of segregation of particles of different sizes when the fertilizer mixture is allowed to form a cone[2]. Since it appears that such a cone will be formed in the bottom of a concrete-type mixer when the mixer is stopped for reversing to empty the mixer, it was assumed that all such mixers would segregate, or unmix, materials which had previously been well mixed. Also large particles tend to empty first from this kind of mixer as a result of the auger action of the flights during discharge.

A distinction must be made between a standard concrete mixer of the kind that Bridger tested and the concrete-type mixer specifically built to mix fertilizer. The concrete-type fertilizer mixer is usually an expanded version of a standard concrete mixer but its capacity may vary from 2 to 10 tons and the axis of the mixer is usually at a lower angle to the horizontal than in the standard concrete mixer. The flights are also sometimes narrower.

Several tests by TVA in cooperating plants using materials directly from plant bins indicated that the concrete-type mixer blended almost as well as the cylindrical mixer[3]. Results obtained from two of these tests are shown in tables 1 and 2. However, the raw materials used in the two plants varied greatly in analysis, size, shape, and density. There were also questions about the mechanical condition of the mixers, which were more than 20 years old. Methods used in obtaining and preparing the samples were also different. Thus, the tests did not provide a sound basis for evaluating effectiveness of the two kinds of mixers.

Although data indicate that concrete-type mixers do not do a good job of mixing, most bulk blend plants in the United States use them because they cost less than cylindrical mixers. Also, package units are available complete with weigh hopper and feeding and discharge devices which can be easily and inexpensively installed. Because of the number of concrete-type mixers being used, the limited nature of Bridger's tests, and the unexpected results of random field tests, another set of controlled tests to compare the cyclindrical mixer with the concrete-type mixer was performed.

The tests were conducted in two mixers located near TVA's National Fertilizer Development Center (NFDC). Both were relatively new and in good condition. The cyclindrical mixer (figure 1) was a 1-ton mixer at the International Fertilizer Development Center (IFDC) pilot plant in Muscle Shoals, Alabama. This mixer had been used only once. The mixing time recommended by the manufacturer (90 seconds) had been used in the previous run and results were not as good as expected. To overcome this problem, the mixing time was increased to 180 seconds for the current tests.

The concrete mixer (figure 2) was recently installed in a plant near Athens, Alabama. Although the mixer had a capacity of 8 tons, only a 1-ton batch was mixed to lower costs and preparation time. Also, a better comparison could be made if both mixers were mixing the same size batch rather than operating at capacity. The manufacturer of the concrete-type mixer confirmed that the mixer should have about the same mixing efficiency with a 1-ton batch as with an 8-ton batch.

Raw materials were taken from storage at two local fertilizer plants and from the TVA pilot plant. These materials were urea, diammonium phosphate (DAP), triple superphosphate (TSP), and granular potassium chloride (KC1), all manufactured by different companies. Urea was obtained from the TVA falling curtain granulation pilot plant. The DAP was shoveled manually from bulk piles into bags. All other materials were prebagged. Two samples of each material were obtained with a sampling cup during the riffling procedure from bags picked at random. A chemical analysis was obtained on each sample (table 3). The formula was prepared by mixing 500 pounds of each material per ton of fertilizer produced. Based on the chemical analyses the grade formulated was 15.9-23.2-15.0.

Each raw material was divided into A and B portions by riffling (Figure 3). The A portions were used in the cylindrical mixer, the B portions in the concrete-type mixer. A screen analysis of each portion was made and the percent and cumulative percent size distribution of the raw materials were determined (Tables 4 and 5). The largest deviation in size in each case was between the urea and the potash, 31.88 percent on side A and 28.56 percent in side B. Laboratory results indicate that blend materials which diverge more than 20 percent result in blends with high segregation tendencies[2]. Therefore, the materials were chosen so that there was enough divergence for coning to occur (if there was a problem during discharge of the concrete mixer), but not so extreme that such divergence would not be experienced in common used raw materials.

To insure that differences in weighing did not occur, raw materials for all tests with both mixers were weighed on an Electronic Flexure Base Platform Scale, Model 4848 manufactured by the Electrical Scales Corporation, Santa Rose, California. It has an accuracy guaranteed to 1 part in 5,000. The weighing operation is shown in Figure 6.

After weighing, 500 pounds of each raw material was taken to the 1-ton cylindrical mixer at the IFDC pilot plant, placed by hand in the mixer, and mixed for 180 seconds. The mixer was then discharged and samples obtained using AOAC procedures for stream sampling with a recommended stream sampling cup. The adding of materials to the mixer and the sampling process are shown in Figures 7 and 8.

As each cup of material was obtained, the cup was dumped onto 3-inch PVC pipe split in half and subsequently into sample bottles. The split PVC pipe was used so that the sampling cup could be emptied quickly without spilling. The sample could then be placed in a numbered sample bottle without slowing down the sampling process and without danger of spilling the sample. As many samples as possible were obtained. After sampling, each sample was submitted to the NFDC general analytical laboratory for *N*, P_2O_5, and K_2O analysis. Only total P_2O_5 was determined since this was adequate for this experiment. This explains the high P_2O_5 analysis of the *TSP*. After all samples were obtained, the test was repeated with a second set of riffled, preweighed, raw materials.

After the cylindrical rotary mixer tests were completed, the second portion of riffled preweighed materials was taken to the plant with the concrete-type mixer and the sequence of mixing and collecting samples repeated exactly as with the cylindrical mixer. Mixing time was 5 minutes with this mixer rather than 3 minutes to conform with recommended mixing practice.

Analyses of samples obtained from both mixers are shown in Tables 6 and 7. The formulated amount of nitrogen was 15.9 percent. Average nitrogen content of the cylindrical horizontal mixer samples was 15.4 percent for the first test, and 15.7 percent for the second; both are slightly lower than the formulated amount. For the concrete-type mixer nitrogen content was 15.3 percent for the first test, and 15.6 percent for the second; these are also slightly lower than the formulated amount of nitrogen. The standard nitrogen deviation for the cylindrical mixer was 0.45 for the first test and 0.49 for the second. For the concrete mixer the standard nitrogen deviation for the first test was 0.42 and 0.68 for the second. On nitrogen the cylindrical rotary did slightly better.

The formulated amount of P_2O_5 was 23.2 percent. Average P_2O_5 analysis for the cylindrical mixer was 24.0 percent in test 1 and 24.2 percent in test 2. Standard deviation was 0.41 for test 1 and 0.91 for test 2. For the concrete-type mixer the average P_2O_5 in test 1 was 24.2 percent and the average in test 2, 24.0 percent. The standard deviation for the first test was 0.33 and 0.41 for the second. The P_2O_5 analysis for both mixers was about one percent higher than the formulated amount. Means for P_2O_5 samples from the two mixers were exactly the same; standard P_2O_5 deviations for the concrete-type mixer, however, were slightly better than those for the cylindrical rotary mixer.

The formulated amount of K_2O was 15.0 percent. The mean for the first test with the cylindrical mixer was 14.7 percent and for the second test, 15.1 percent. Standard K_2O deviation for the first test was 0.60 and for the second test, 0.67. For the concrete mixer the means were 15.1 percent and 14.8 percent, respectively, and the standard deviations, 0.58 and 0.57. For K_2O the concrete-type mixer did slightly better.

The sample analyses shown in Tables 5 and 6 are plotted on Figures 9, 10 and 11.

Although these tests show little difference between the two mixers, it should not be concluded that all cyclindrical rotary mixers and concrete-type mixers do an equally good or bad job. These tests were performed only to add more data to that already available. More tests must be made to provide a statistically accurate conclusion and data that can be used to design the best mixer possible.

In the meantime, owners of different kinds of bulk blend mixers should be encouraged to try to determine the efficiency of their own mixers.

Table 1

Analysis of 10-10-10 Grade
Bulk Blended Fertilizer Exit
Cylindrical Rotary Mixer (Plant A)

Sample Time[a] (sec)	% N	% P_2O_5	% K_2O
10	10.5	10.7	12.5
20	9.9	9.8	11.1
30	9.7	10.6	10.3
40	10.3	11.3	10.1
50	10.3	11.4	9.7
$\bar{X}^b$	10.1	10.8	10.7
S^c	0.33	0.64	1.11

a. Sample obtained as mixer discharged
b. Average
c. Standard deviation

Table 2

Analysis of 15-10-10 Grade
Bulk Blended Fertilizer Exit
Concrete-Type Mixer (Plant B)

Sample Time (sec)	% N	% P_2O_5	% K_2O
4	14.1	10.2	9.2
9	14.2	10.8	8.9
16	14.2	9.7	10.0
21	14.0	10.6	10.3
26	14.0	10.1	10.7
31	14.6	10.3	11.1
36	14.4	10.2	11.3
40	14.7	9.3	12.2
45	15.2	10.1	12.8
51	13.8	13.6	11.2
$\bar{X}^a$	14.3	10.5	10.8
S^b	0.415	1.17	1.23

---

a. Average
b. Standard deviation

Table 3

Chemical Analysis of Materials Used for
Tests of Bulk Blending Mixers[a]

Material	% N	% P_2O_5	% K_2O
Triple superphosphate	-	47.0	-
Triple superphosphate	-	47.0	-
Potash	-	-	60.1
Potash	-	-	60.1
Diammonium phosphate	17.5	46.2	-
Diammonium phosphate	17.4	45.9	-

---

a. Samples taken from two bags chosen at random

Table 4

Screen Analysis
TVA/IFDC Bulk Blend Tests
Side A Raw Materials

Screen Scale				Urea			DAP			TSP			KCl		
Openings				Time: 10 Minutes			Time: 10 Minutes			Time: 10 Minutes			Time: 10 Minutes		
Inches	Millimeters	Tyler Mesh	U.S. No.	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieves)
0.131	3.327	6	6	0.1	0.04	0.04	1.4	0.50	0.50	0.2	0.07	0.07	7.3	2.99	2.99
0.093	2.362	8	8	71.1	28.23	28.27	62.9	22.42	22.92	52.4	18.16	18.23	64.4	26.38	29.37
0.065	1.651	10	12	151.7	60.22	88.49	139.1	49.59	72.51	150.3	52.08	70.31	66.5	27.24	56.61
0.056	1.389	12	14	22.4	8.89	97.32	41.8	14.90	87.41	46.5	16.11	86.42	31.8	13.03	69.64
0.046	1.163	14	16	5.6	2.22	99.54	19.6	6.99	94.40	23.6	8.18	94.60	29.6	12.13	81.77
0.0323	0.833	20	20	1.0	0.40	99.94	12.4	4.42	98.82	14.2	4.92	99.52	33.0	13.52	95.29
0.0000	0.0000	Pan	Pan	-	-	99.94	3.3	1.18	100.00	1.4	0.48	100.00	11.5	4.71	100.00
Totals				251.9	99.94	99.94	280.5	100.00	100.00	288.6	100.00	100.00	244.1	100.00	100.00

Table 5

Screen Analysis
TVA/IFDC Bulk Blend Tests
Side B Raw Materials

Screen Scale				Urea			DAP			TSP			KCl		
Openings				Time: 10 Minutes			Time: 10 Minutes			Time: 10 Minutes			Time: 10 Minutes		
Inches	Millimeters	Tyler Mesh	U.S. No.	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieve)	Weight Between Sieves	% Between Sieves	Cum. % (Total % on each Sieves)
0.131	3.327	6	6	0.1	0.04	0.04	1.7	0.66	0.66	0.5	0.20	0.20	7.8	3.52	3.52
0.093	2.362	8	8	72.1	29.17	29.21	63.3	24.49	25.15	48.1	18.98	19.18	62.3	28.11	31.63
0.065	1.651	10	12	147.2	59.55	88.76	132.8	51.37	76.52	133.0	52.49	71.67	63.3	28.57	60.20
0.056	1.389	12	14	22.1	8.94	97.70	34.2	13.23	89.75	39.3	15.51	87.18	29.4	13.27	73.47
0.046	1.163	14	16	5.0	2.02	99.72	15.9	6.15	95.90	19.6	7.74	94.92	25.8	11.64	85.11
0.0323	0.883	20	20	0.6	0.24	99.96	8.6	3.33	99.23	11.4	4.50	99.42	25.3	11.42	96.53
0.0000	0.0000	Pan	Pan	0.1	0.04	100.00	2.0	0.77	100.00	1.5	0.59	100.01	7.7	3.47	100.00
Totals				247.2	100.00	100.00	258.5	100.00	100.00	253.4	100.01	100.01	221.6	100.00	100.00

Table 6

Analysis of 15.9-23.2-15.0 Bulk Blended Fertilizer From Cylindrical Rotary Mixer at IFDC

Test 1				Test 2			
Sample Time (Sec)	% N	% P_2O_5	% K_2O	Sample Time (Sec)	% N	% P_2O_5	% K_2O
1	15.4	24.4	14.2	2	16.3	23.1	15.5
5	15.9	23.9	14.1	5	16.0	22.7	16.3
8	15.4	24.1	14.7	10	16.3	23.1	15.6
11	15.0	24.7	14.3	16	15.9	23.8	15.2
14	15.8	23.4	14.9	23	16.3	23.7	15.2
17	15.4	24.3	14.1	28	16.5	23.5	15.0
22	15.4	24.0	14.6	34	15.5	23.7	16.0
27	15.9	24.6	13.6	39	15.2	25.0	15.0
30	15.5	23.3	15.2	45	15.6	24.2	15.1
33	14.6	23.9	15.1	51	15.9	23.8	15.6
37	15.6	23.9	14.8	58	16.1	24.8	14.1
40	14.8	24.5	14.6	63	15.1	25.0	15.2
44	15.5	23.9	14.4	70	15.3	24.6	14.7
48	15.2	24.0	15.0	76	15.4	25.2	14.2
52	15.1	23.7	15.3	83	15.4	26.0	13.8
56	15.7	23.5	15.2	88	14.9	24.9	14.9
58	14.8	23.9	16.1				
76	15.9	24.2	14.2				
82	16.4	23.4	15.5				
$\bar{X}^a$	15.4	24.0	14.7	$\bar{X}^a$	15.7	24.2	15.1
s^b	0.45	0.41	0.60	s^b	0.49	0.91	0.67

---

a. Average
b. Standard deviation

Table 7

Analysis of 15.9-23.2-15.0 Bulk Blended Fertilizer From Concrete-Type Mixer at Athens, Alabama

Test 1				Test 2			
Sample Time (Sec)	% N	% P_2O_5	% K_2O	Sample Time (Sec)	% N	% P_2O_5	% K_2O
7	14.9	23.8	16.0	12	15.3	24.8	14.2
11	15.1	24.7	15.1	16	17.0	23.5	13.6
14	15.4	24.0	15.3	21	15.9	24.5	14.2
18	15.9	23.9	15.1	25	15.9	24.0	14.6
21	15.5	24.3	14.9	28	16.3	24.0	14.4
24	15.2	24.2	15.7	32	16.2	23.6	14.5
28	15.4	24.1	14.8	36	15.7	24.2	14.7
31	15.4	24.6	14.6	39	15.7	23.8	15.1
34	15.9	23.5	14.1	43	15.3	23.9	15.1
38	14.8	23.6	16.3	48	14.2	23.9	15.7
42	15.7	24.4	14.9	51	14.8	24.1	15.3
46	15.5	24.4	14.5	55	14.8	24.6	15.1
49	15.7	23.9	15.3	60	15.2	23.4	15.6
53	14.6	24.2	15.9	65	15.7	23.5	14.8
58	15.5	24.3	14.8	70	15.4	24.0	15.2
65	14.6	24.2	15.0				
$\bar{X}^a$	15.3	24.2	15.1	$\bar{X}^a$	15.6	24.0	14.8
S^b	0.42	0.33	0.58	S^b	0.68	0.41	0.57

---

a. Average
b. Standard deviation

FIGURE 1
CYLINDRICAL ROTARY MIXER

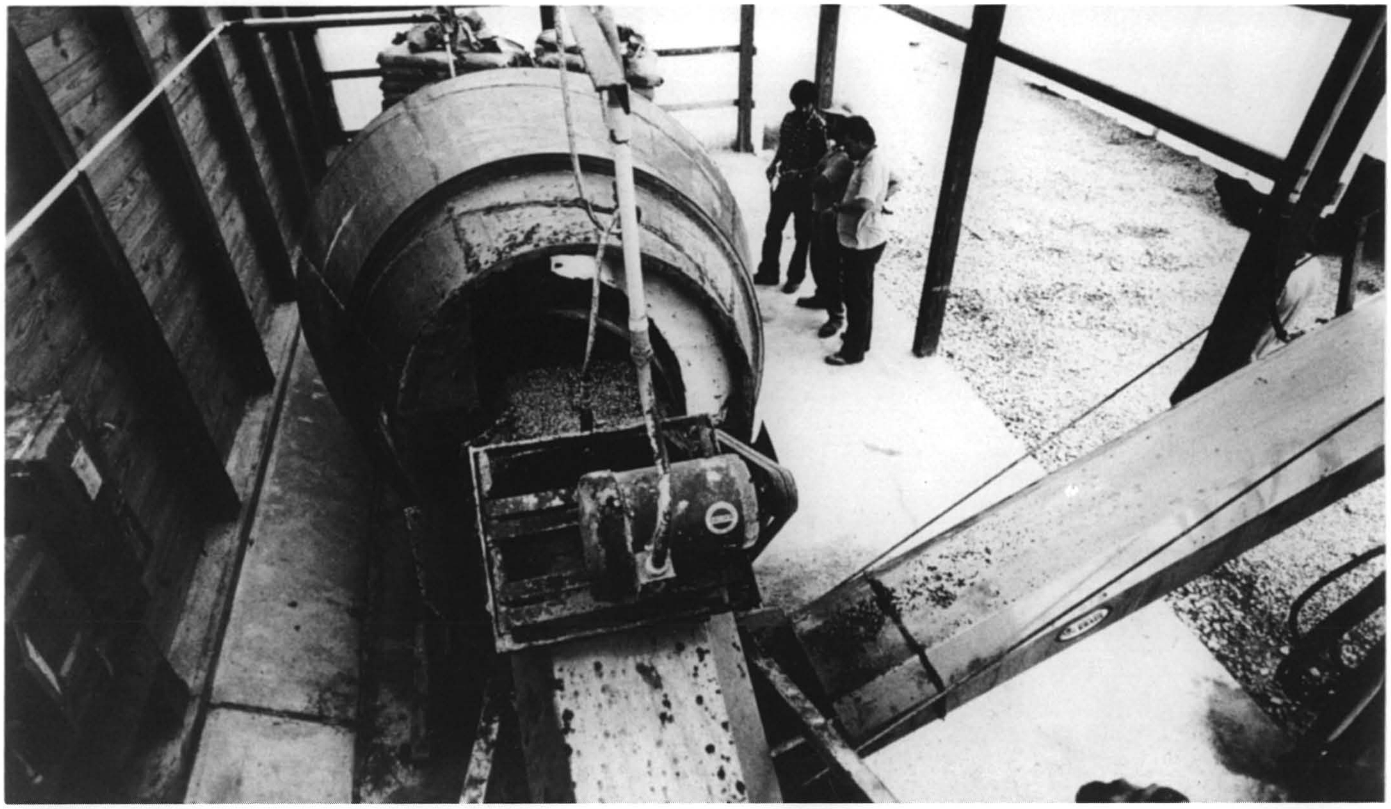

FIGURE 2
CONCRETE-TYPE MIXER

FIGURE 3
DIVIDING RAW MATERIALS

CUMULATIVE SIZE DISTRIBUTION FOR FOUR COMPONENT
BULK BLENDED FERTILIZER
" SIDE A " *

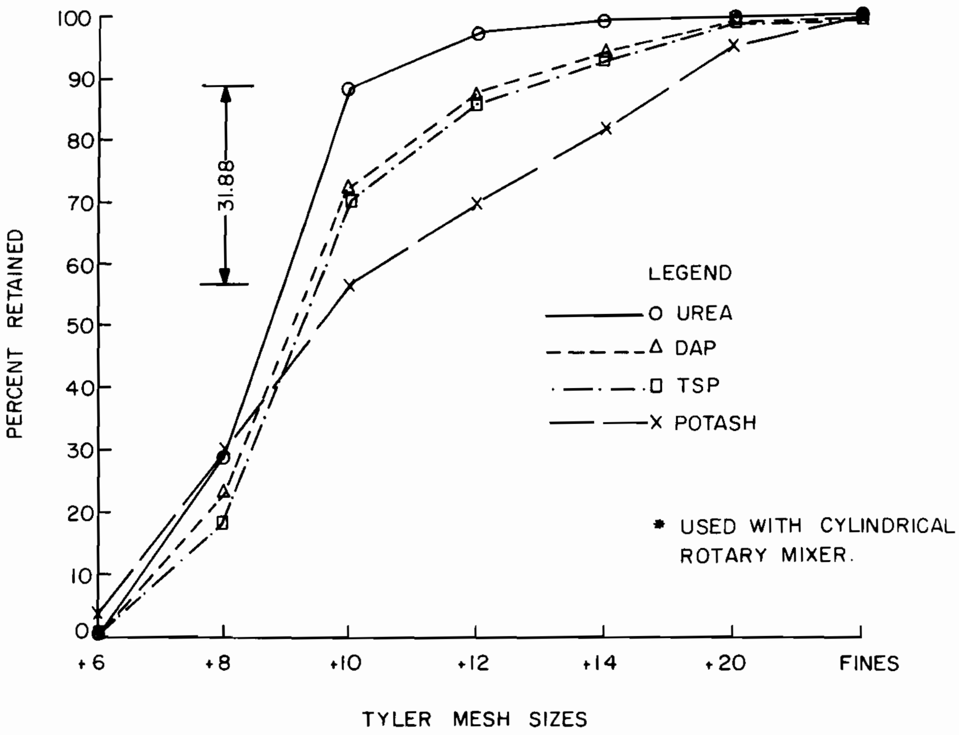

FIGURE 4

CUMULATIVE SIZE DISTRIBUTION FOR FOUR COMPONENT
BULK BLENDED FERTILIZER
" SIDE B " *

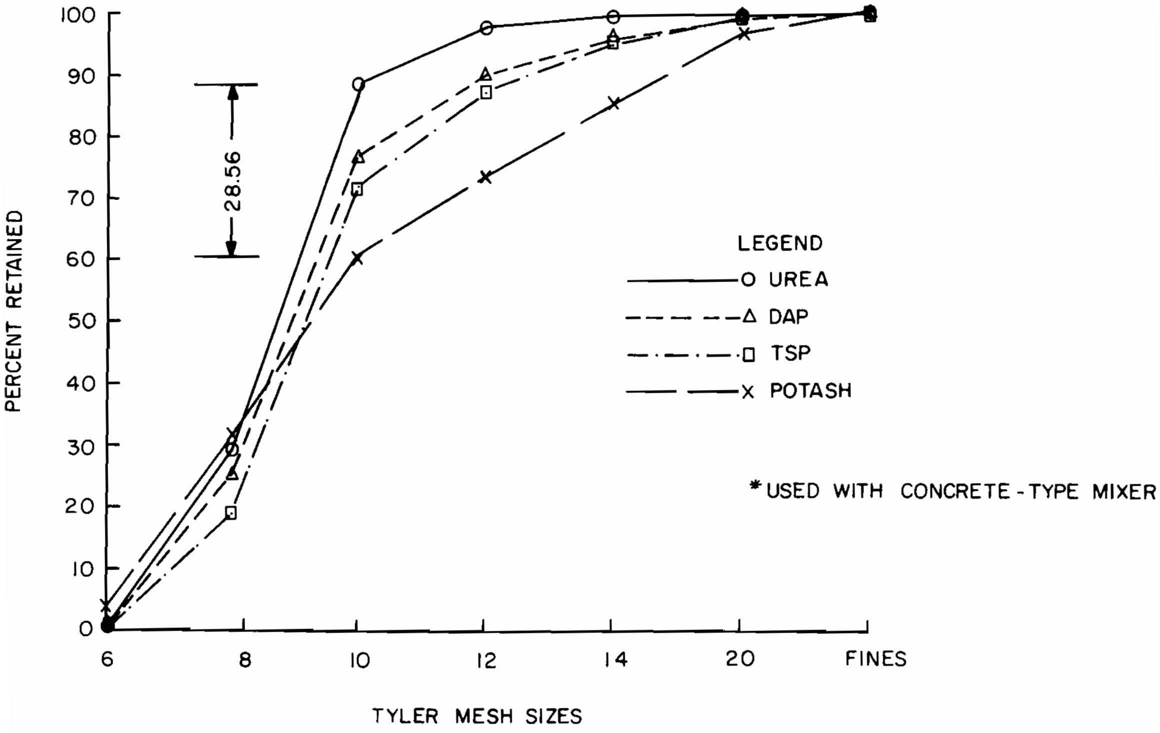

FIGURE 5

FIGURE 6

WEIGHING RAW MATERIALS

FIGURE 7

CHARGING ROTARY MIXER

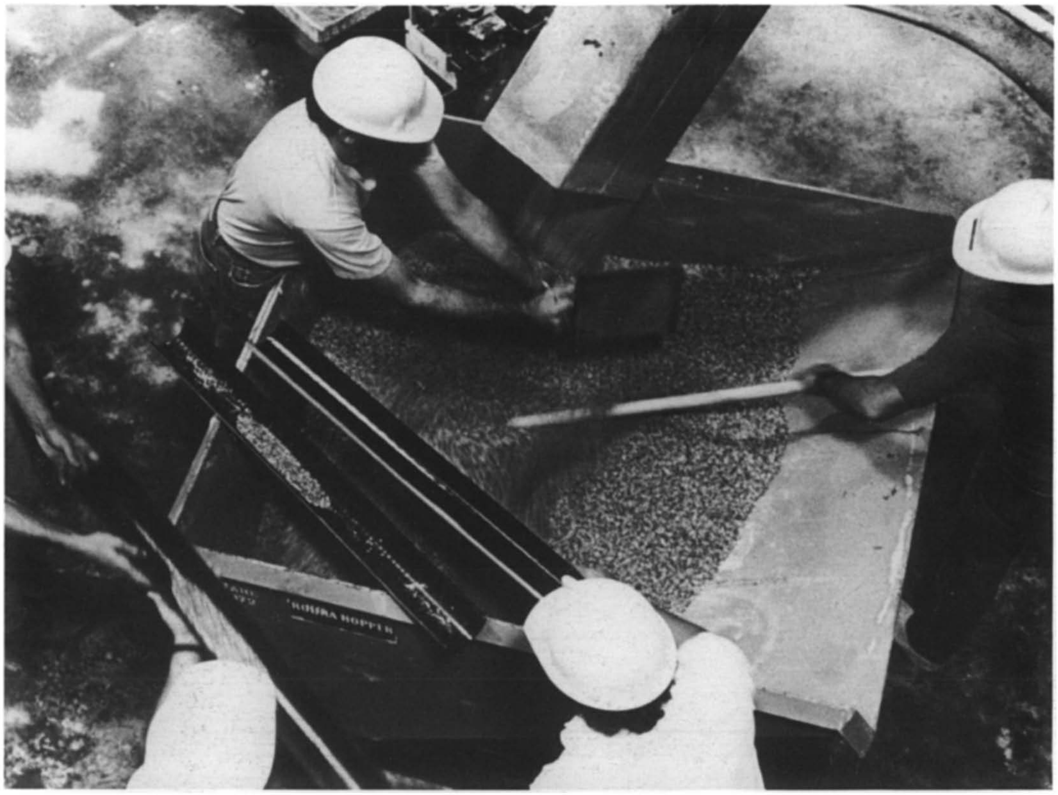

FIGURE 8
SAMPLING ROTARY MIXER

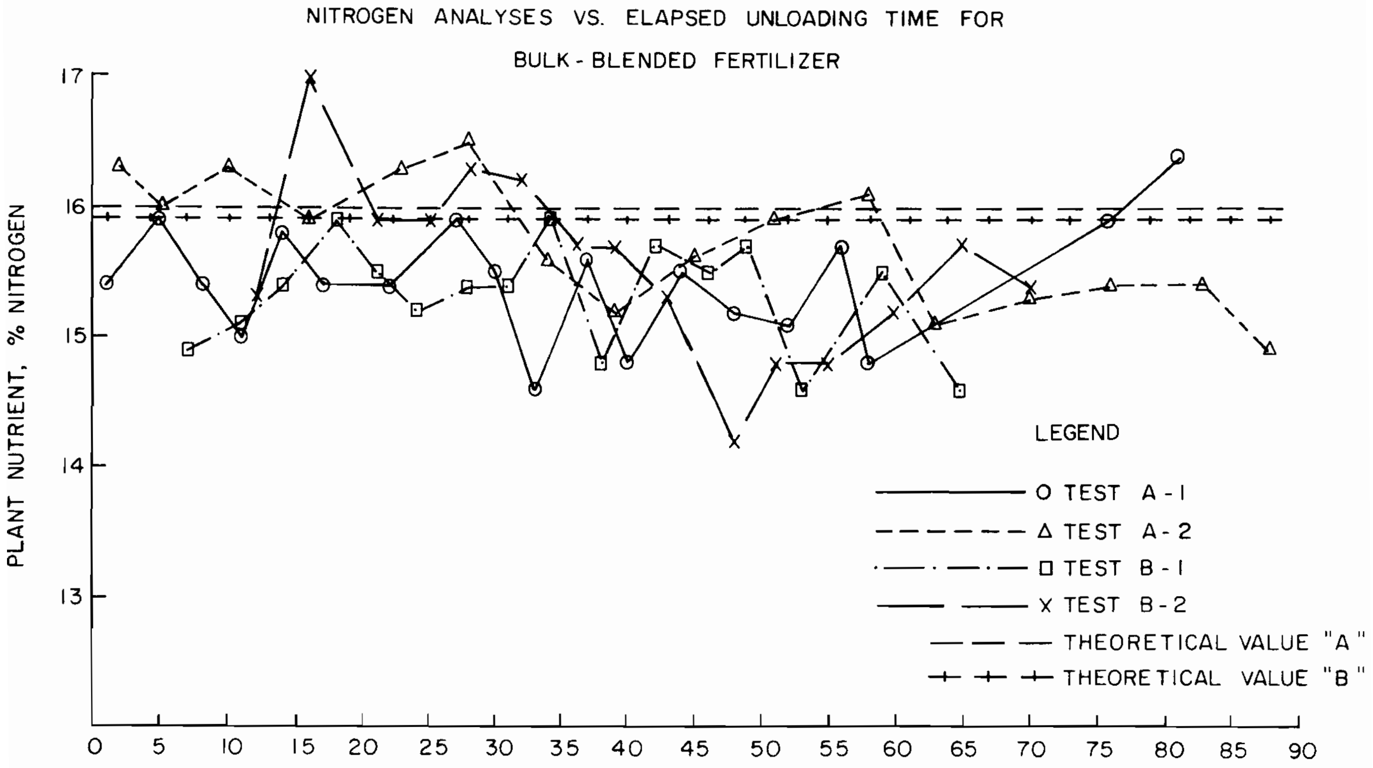

FIGURE 9

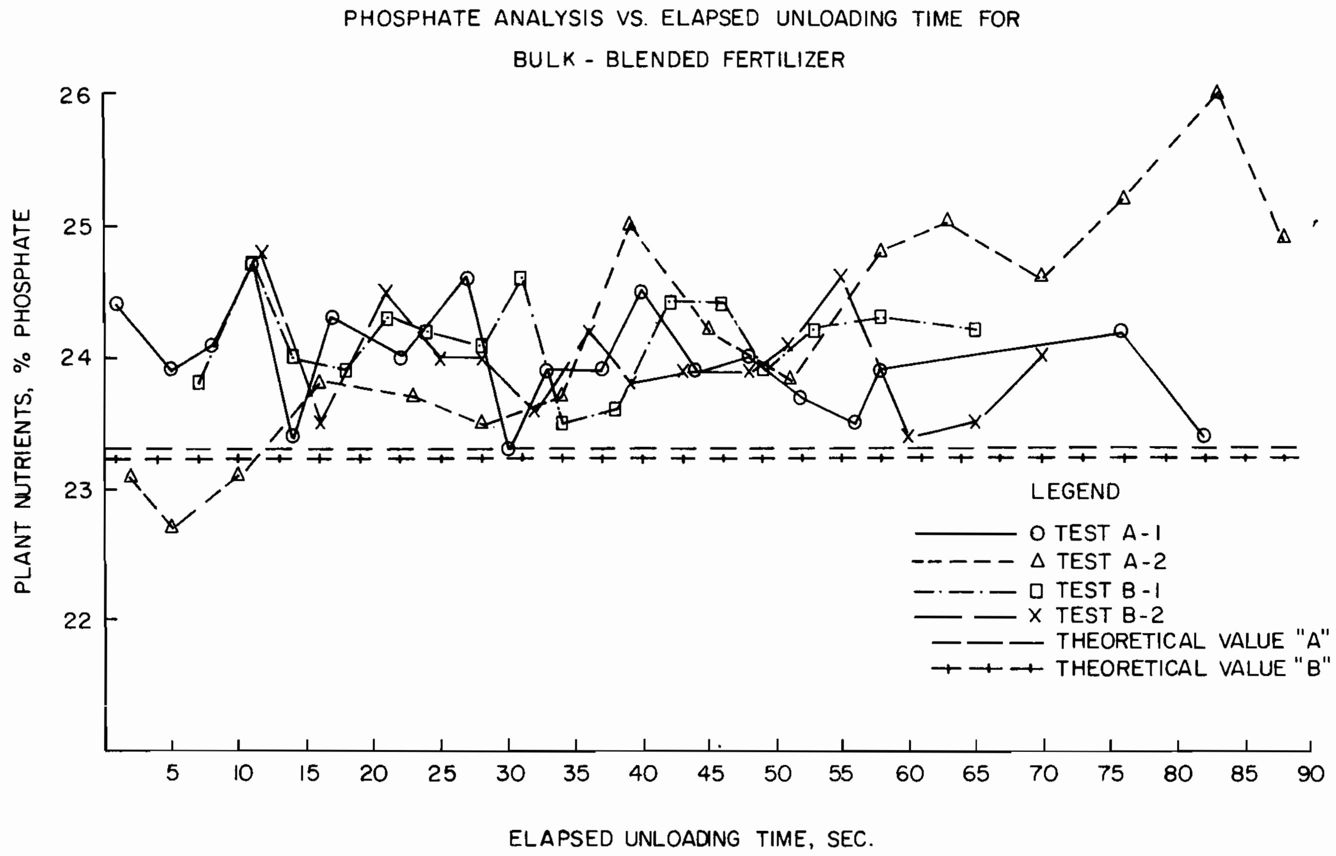

FIGURE 10

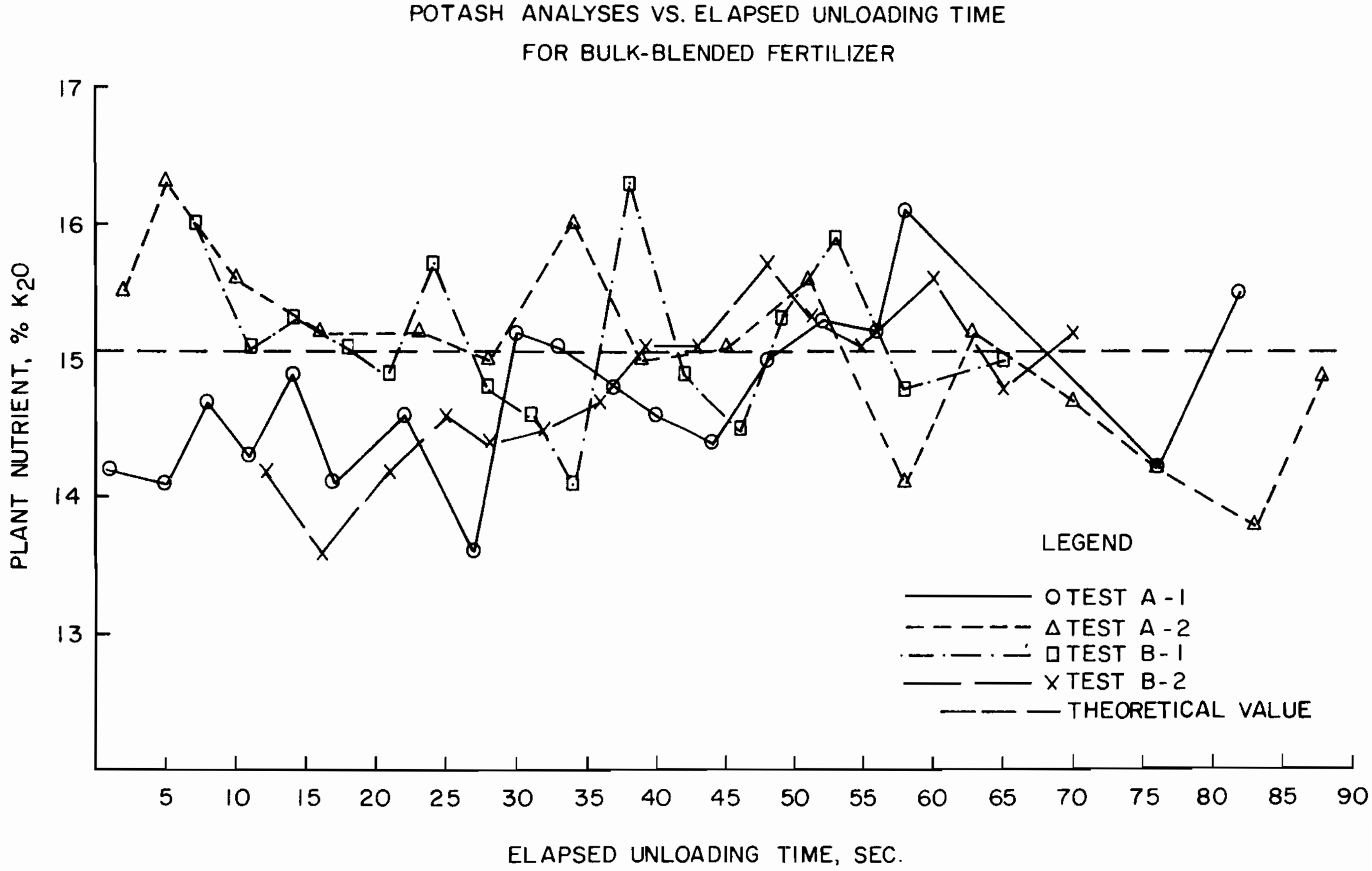

FIGURE 11

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2. Hoffmeister, George, 1973. "Quality Control in a Bulk Blending Plant," *Proceedings of the TVA Bulk Blending Conference,* TVA Bulletin Y-62, pp 59-69.
3. Internal TVA report, H. L. Balay to F. P. Achorn, March 1980.

MODERATOR MALONE: Thank you, Carl, for an interesting, timely and informative paper. It provides documentation in an area of importance to many of us involved in "Bulk Blending." (Applause)

Our next speaker is W. Bennett Spratlin and he has conquered the following creativity killer phrases:

> *Somebody would've suggested it before, if it were any good.*
>
> *Too Modern.*
>
> *Too Old-Fashioned.*
>
> *Let's discuss it at some other time.*
>
> *You don't understand our problem.*
>
> *We're too small for that.*
>
> *We're too big for that.*

W. Bennett Spratlin is president of Johnson City Chemical Co., Inc., Johnson City, Tennessee. He was born in Florence, Alabama, and has a B.S. degree from Auburn University. He was employed by Agrico from 1959 to 1974 in various manufacturing, sales and technical service positions. He founded Johnson City Chemical Co. in 1974. It has grown from one plant and seven employees and one million in sales to 15 plants and warehouses, 90 employees and in excess of 12 million in sales. He is founding director and past president of the Tennessee Plant Food Educational Association. He is past president of Rotary Club. He is a member of the Board of Directors for Commerce Union Bank and is a member of the President;s Association. He was elected to Who's Who in the South and Southwest. He is married and has three children. He will be talking about "How to Produce Bulk Blends That Meet State Tolerances." We are happy to introduce you to the Round Table. (Applause)

How To Produce Bulk Blends That Meet State Tolerence

W. Bennett Spratlin

I would like to begin my presentation with a brief introduction to Johnson City Chemical Company and why I became so interested in meeting state tolerences.

My career in the fertilizer industry began in 1959 with the old American Agrico Chemical Company as a production trainee, I gained experience in all phases of fertilizer manufacturing including sulfuric acid production.

In 1974, the opportunity to become an independent business person presented itself and I purchased an Agrico plant in Johnson City, Tennessee. The plant had been converted from a dry mix plant to a blending operation in 1970 and was one of the first blending operations in that part of the country.

For those of you who are not familiar with East Tennessee, Southwest Virginia, and Western North Carolina, we have a very unique agricultural economy. We have small farms, a wide variety of crops such as corn (for silage), tobacco, cattle, dairy, vegetables, apples, small grain, etc. A large portion of our farmers are part time, and depend heavily on assistance from the universities on what to do.

The terrain in this area is mountainous; therefore, we cannot bulk spread a lot of this area nor are the farms large enough to justify bulk loads. We also still have people that do not mind work, and a lot of the farms are a family effort.

I tell you this so you can picture in your mind the environment we operate in.

The blending operation was unique because 90 per cent of all tonnage was bagged. I became very concerned when penalities began to flow in for deficient analysis. Our reputation was at stake. Also, it was getting too expensive.

My plant manager, Newell Taylor, and myself knew that the material was in the bag. We pulled numerous resamples. We invited the state officials to visit our plant. We begged for help. What profit we were making was going out to the states in deficient analysis. Also word was getting around that we could not make good fertilizer.

My friend, Curtis Brummitt, TVA, introducted me to Bud Balay and George Hoffmeister who were doing some work on segregation in bulk blends. They agreed to come to our plant and assist us with equipment changes in order for them to conduct their tests under actual field conditions.

We were using an *IC* Open Mouth Bagger with a four ton holding hopper. After the hopper modifications were made, the tests were made and our segregation problems were solved.

We went from one of the worst records in our area to one of the best in one year. We were confident that our product would meet state specifications regardless of who sampled. We had the results to prove it. Particle size had very little to do with the result. We found that if the material was weighed right and mixed right, it would stay mixed even after traveling 100 miles by truck.

Now for total frustration. In order to improve our productivity, we decided to install a valve packer bagging machine. All of a sudden the deficiencies began to pour in. We could not believe what had happened. We knew that the valve machine was causing the problem but we did not know why.

We again called on our old friends from TVA. They were very reluctant to again spend time to beat a dead horse. I was able to convince them that this was a live horse and it was an industry problem, not just a JCC problem.

Prior to contacting TVA, we at JCC had spent many hours trying to find out what had happened. My experience in the fertilizer business has taught me to go back to the basics when you have an analysis problem crop up. We started with our scales. They were rechecked for small problems that may not be obvious to the weigher. We then check the person weighing to see that he is not getting sloppy, and then inside our hoppers to be certain there are no holes between compartments that would allow contamination. We check our raw materials to be certain they are on specifications. After doing this, we found we had problems elsewhere.

The problem was in the bag. We were convinced.

We could sample the complete bag and get good analysis; however, when we probed the bag, the analysis was erratic. We were convinced the material was segregating in the bag. We seem to create a cyclone effect. We were lost as to what to do.

TVA again came to our rescue and performed some more tests. I will try to explain how the tests were conducted and show some data on the findings.

As far as I am concerned, the problems we have using the force-flow bagger is the major problem facing our company today, therefore, I would like to explain the test and show you the findings.

The objective of the experiment was to determine if the force-flow bagger was segregating blends worse than the open-mouth bagger and to ascertain the effect of size and density on fertilizer bagged in these two machines. To eliminate size as a factor, urea and limestone were hand screened so that the sizes of the granules fed into the bagging machines were about the same size. Limestone and urea were used because they were the materials available with the greatest difference in density. The bulk densities of the materials used in the experiment are as shown in Table 1. The limestone had a bulk density of 98.6 lb./Ft^3 and the urea 47.9 lb./ft.^{3}, the screen analysis of the sized urea and limestone is shown in Table 2 and a cumulative plot of this information in Figure 1. A two-ton batch consisting of 2,000 pounds of sized urea and 2,000 pounds of sized limestone was prepared, passed through the mixer and bagging hopper, and bagged in paper bags using the open-mouth bagger. Samples were obtained from these bags using standard AAPFCO methods and analyzed in the TVA laboratory. A second two-ton batch was also prepared, sampled, and analyzed. The laboratory results from both tests are shown in Table 3. The urea used had 45.7 per cent nitrogen content. A similar mixture was also prepared, bagged in polyethylene bags using the force-flow mixer to determine if the composition of the bag would affect analysis. These results are also shown in Table 3. Only seven samples from the polyethylene bags were analyzed to decrease the cost of analysis and because it was thought that seven samples would provide an adequate comparison with the paper bags.

The average nitrogen analysis of the samples of the sized urea-limestone mixture obtained from 21 paper bags bagged by the open-mouth bagger was 23.5 percent. The samples had a standard deviation of 1.48. The average analysis of 25 samples from the force-flow bagger bagged in paper bags was 23.3 with a standard deviation of 2.15. The average for the polyethylene bags was 23.2 with a standard deviation of 1.99. Since the average analysis of the samples obtained from the open-mouth bagger and from the force-flow bagger was similar to the formulated analysis, it appears that the mixing and sampling procedures used were satisfactory. The standard deviation for the force-flow bagger was significantly higher both for paper and polyethylene bags than the mixture from the open-mouth bagger. From this it appears that some variation due to density occurred in the force-flow bagger. This would, of course, be exaggerated more than normal because of the large difference in density of the materials used; however, it does indicate that the force-flow bagger is responsible for some of the variation in the analysis of samples of bagged fertilizer. To check the effect of the bagger when both size and density were similar, two-ton mixtures of granular triple superphosphate and potash were prepared and bagged with each machine. The triple superphosphate and potash were not screened because material at the edge of the piles used was similar in size and care was taken during the experiment to obtain grannules from the edge of the pile which were as closely sized as possible. The density of the triple superphosphate and potash used is shown in Table 1 and the screen analysis in Table 4. A cumulative plot of the screen analysis of the potash and triple superphosphate are shown in Figure 2. Due to fortunate circumstances, the triple superphosphate and potash selected were more closely sized than the hand-screened limestone and urea. The batches were passed through the mixer, bagged, and analyzed. Results are shown in Table 5.

Since only triple superphosphate and potash were involved, only the P_2O_5 was obtained by analysis. The chemical analysis of the triple superphosphate is shown in Table 1. A mixture of equal weights of potash and triple superphosphate should have given a blend with a P_2O_5 analysis of 23.9. The average P_2O_5 analysis as shown in Figure 5 for 26 bags of material bagged with the open-mouth bagger was 24.3 and the standard deviation 1.33. The average P_2O_5 analysis for 26 bags of material bagged with the force-flow bagger was 24.7 and the standard deviation 1.61. Since the granules were closely sized, it is assumed that the slightly higher deviation in the force-flow bagger was due to the slight difference in density of the raw materials used.

To further test the effect of density and size, the fines from hand screening the limestone and the oversize from hand screening the urea were mixed in equal amounts by weight and bagged. The results are shown in Table 6. A slightly smaller sample was obtained from the force-flow bagger because not enough material was available to make a two-ton batch. As would be expected from materials so widely different in weight and size, the average analysis was poor and the deviation high. The standard deviation of the samples from the force-flow bagger was slightly lower than the standard deviation from the open-mouth bagger. It is thought that this was caused by size segregation due to the extremely small size of the limestone.

Samples of the regular raw materials were also obtained from the pile and a cumulative screen analysis chart prepared. The screen analyses are shown in Table 7 and plotted in Figure 3. From this it can be seen that the triple superphosphate and urea are fairly closely sized and the potash slightly smaller, although not excessively so. The limestone, however, is much smaller and is thought to be a major cause of off-analysis blends. Data obtained, however, from sized urea and limestone samples and sized triple superphosphate and potash mixtures indicate that in addition there is some density effect when the materials are passed through the force-flow bagger.

To compare results obtained using regular raw materials with sized materials, two 2-ton batches were made using equal amounts of urea, triple superphosphate, potash, and granular limestone taken directly from the storage bins. One batch was bagged in each bagging machine and samples obtained from every third bag were analyzed for N, P_2O_5, and K_2O. The analyses obtained are shown in Table 8. These results show somewhat more variation in the P_2O_5 and K_2O from the open-mouth bagger than from the force-flow bagger. In both cases, however, the nitrogen is low and its standard deviation higher than that of the P_2O_5 and K_2O. This may be caused by segregation due to density difference in light urea and heavy limestone in the mixture, the smaller deviation in these samples can probably be explained by the smaller amount of limestone used.

To determine if segregation in bags might affect sampling, two samples were obtained by inserting the sampling probe along the valve side of the bag. These samples were analyzed and compared with samples from the same bag obtained by using AAPFCO procedures. The results are shown in Table 9. Considerable difference is shown in samples obtained from the same bags using the two different sampling procedures. A formulation analysis of the samples was made by calculating formulas for the chemical analysis shown in Table 9 and comparing them with the formulated analysis. The results are shown in Table 10. In sample 1A obtained by placing the probe along the side of the bag, 100 pounds too much urea, six pounds too little triple superphosphate, two pounds too little potash, and 92 pounds too little limestone were found. Sample 2B from the same bag obtained by AAPFCO procedures showed eight pounds too much urea, 52 pounds too much triple superphosphate, 24 pounds too much potash, and 84 pounds too little limestone. Samples 2A and 2B obtained from the same bag and analyzed using the method described above showed that samples obtained using both sampling procedures contained too much limestone. The trends for each bag sample were similar for both sampling methods; However, the samples obtained using AAPFCO procedures were closer to the formulated analysis. The K_2O in all four samples was close to the formulated amount although it was slightly higher in the samples obtained using AAPFCO procedures.

The conclusions are that samples from blends bagged in the force-flow bagger do vary more than samples from blends bagged in the open-mouth bagger and that this is due mainly to differences in the density of the raw materials. Also there is no significant difference between samples from paper bags and samples from polyethylene bags when they are bagged with the force-flow bagger.

Samples obtained using AAPFCO methods are closer to the formulated analysis than those obtained by probing along the valve side of the bag, but there is considerable difference between the analysis obtained by the two methods. Formulation analysis, however, does not reveal any trend and many more samples would be required to evaluate this difference.

It appears that more on-analysis grades could be produced if limestone more closely sized to the other raw materials could be obtained. Also when large quantities of limestone and urea are required, more on-analysis samples would be obtained if the open-mouth bagger were used. However, minimizing the amount of limestone used would help in both machines.

My conclusion from the many hours of work that we at Johnson City Chemical and TVA invested in this problem, is the fact that we have a problem that will continue to be expensive to industry and cannot be completely corrected with what we have to work with.

I also contend that the various states are not giving the industry a fair shake with their tolerances being so close, and the number of core samples being pulled by an inspector.

I think the Florida test that many of you are familiar with proves the point that industry is not getting a fair shake on sampling. Bulk samples drawn off the belt of a conveyor as it is being fed into a spreader truck have much better results than one that is probed from the bed of the truck. However, the results to the farmers will be the same. I, the manufacturer, will have to pay.

Check your year ending state reports and look at the overall value of the analysis—very close to 100 percent and in many times, over 100 percent. Yet we pay thousands of dollars in deficient analysis. We should be allowed credit for overages.

I realize this is a whole new topic and I will not attempt to address it at this time; however, I will not quit complaining and continue to advocate changes at the state level. I have traveled to a great number of fertilizer facilities in my 25 years in the business and am proud to say that I have never been to a place where I felt that the person would deliberately cheat the farmer. And, with the sampling procedures and rules by many of our states, they tend to give that impression, and I don't like it.

Table 1

RAW MATERIAL ANALYSIS

Raw Material	Plant Food Analysis	Bulk Density[a]
Urea	45.7% N	47.9 lb/ft^3
Triple superphosphate	47.8% P_2O_5	74.1 lb/ft^3
Potash	69.7% K_2O	72.4 lb/ft^3
Limestone	-	98.6 lb/ft^3

[a] Slightly packed to simulate bagged material.

Table 2

CUMULATIVE SCREEN ANALYSIS OF SIZED UREA AND LIMESTONE

Screen Size	Urea	Limestone
ON 4	0	0
ON 6	0	0.2
ON 8	49.2	53.7
ON 10	92.1	97.0
ON 12	97.7	99.1
ON 14	99.2	99.4
ON 20	99.7	99.7
THRU 20	100.0	100.0

Table 4

CUMULATIVE SCREEN ANALYSIS OF SELECTED GRANULAR TRIPLE SUPERPHOSPHATE AND POTASH

Screen Size 1	% Triple	% Potash
ON 4	0	0
ON 6	4.9	5.7
ON 8	50.1	60.2
ON 10	87.3	86.5
ON 12	94.6	95.8
ON 14	97.7	97.8
ON 20	99.3	98.8
THRU 20	100.0	100.0

Table 3

SIZED UREA AND LIMESTONE BLEND

Sample No.	% N in Mixture From Open-Mouth Bagger[a] (Paper Bag)	% N in Mixture From Force-Flow Bagger[a] (Paper Bag)	% N in Mixture From Force-Flow Bagger (Polyethylene)
1	26.4	24.5	22.8
2	24.3	20.6	24.9
3	24.1	19.0	23.3
4	23.8	19.8	22.7
5	23.6	23.6	21.8
6	23.3	20.8	27.7
7	23.3	20.9	22.9
8	22.4	25.8	
9	22.5	25.5	
10	22.4	22.9	
11	23.7	23.8	
12	27.8	21.3	
13	22.1	23.2	
14	23.1	21.8	
15	24.4	23.0	
16	24.6	25.2	
17	21.4	21.8	
18	22.7	27.9	
19	22.0	24.0	
20	22.9	22.9	
21	22.8	24.5	
22		25.8	
23		24.8	
24		24.0	
25		25.1	
Mean[b]	23.5	23.3	23.7
S	1.48	2.15	1.99

[a] By chemical analysis

[b] Formulated analysis 22.8% N

Table 5

GRANULAR TRIPLE SUPERPHOSPHATE POTASH BLEND

Sample No.	% P_2O_5 in Mixture From Open-Mouth Bagger	% P_2O_5 in Mixture From Force-Flow Bagger[a]
1	22.2	19.0
2	23.6	24.0
3	24.3	24.3
4	25.1	23.0
5	26.2	26.4
6	25.7	24.0
7	26.1	23.4
8	25.3	24.1
9	24.2	23.9
10	24.1	25.3
11	24.4	24.6
12	25.5	25.9
13	25.2	24.4
14	22.7	26.9
15	22.8	25.8
16	21.7	25.9
17	22.8	25.1
18	25.1	25.8
19	24.3	24.0
20	25.0	25.3
21	24.8	27.2
22	21.6	26.2
23	23.4	25.9
24	26.0	23.6
25	24.8	24.9
26	24.7	24.2
Mean	24.3	24.7
S	1.33	1.61

[a] By chemical analysis

Table 6

LARGE UREA AND FINE LIMESTONE BLEND

Sample No.	% N in Mixture From Open-Mouth Bagger[a]	% N in Mixture From Force-Flow Bagger[a]
1	14.5	21.9
2	25.8	23.8
3	25.3	14.6
4	20.9	16.3
5	12.1	24.2
6	15.8	12.0
7	17.0	18.8
8	24.8	27.7
9	21.9	17.5
10	23.8	20.7
11	14.6	18.5
12	16.3	18.2
13	24.2	15.0
14	12.0	
15	18.8	
16	27.7	
17	17.5	
18	20.7	
19	18.5	
20	18.2	
21	15.0	
Mean	19.3	19.1
S	4.67	4.39

[a] By chemical analysis

Table 7

CUMULATIVE SCREEN ANALYSIS OF REGULAR RAW MATERIALS

Tyler Screen Size	Limestone	Triple Super-Phosphate	Potash	Urea
ON 4	0.1	0	0.1	.1
ON 6	1.8	5.9	15.7	2.0
ON 8	15.7	55.5	50.2	63.3
ON 10	45.8	89.9	76.5	95.0
ON 12	61.3	96.3	85.8	98.7
ON 14	76.2	98.7	91.3	99.5
ON 20	91.9	99.6	95.4	99.7
THRU 20	100.0	100.0	100.0	100.0

Table 8

Complete Blend Analysis from Regular Raw Materials (Grade 11.4 - 12.0 - 15.2)[a]

Sample No.	Open-Mouth Bagger (paper bag)			Force-Flow Bagger (paper bag)			Force-Flow Bagger (polyethylene bag)		
	% N	% P_2O_5	% K_2O	% N	% P_2O_5	% K_2O	% N	% P_2O_5	% K_2O
1	11.3	12.3	17.5	9.9	11.7	16.4	7.0	11.4	15.1
2	11.6	13.2	15.9	12.9	12.2	15.2	11.5	11.3	13.5
3	11.0	11.7	15.5	11.2	11.6	14.0			
4	12.1	11.8	14.9	8.3	10.8	14.2			
5	9.4	10.3	15.7	11.9	12.6	14.8			
6	9.3	12.3	15.4	12.4	12.1	13.8			
7	11.0	12.3	14.6	11.0	12.3	14.5			
8	9.1	13.4	14.2	11.0	11.8	14.8			
9	8.2	10.4	13.6						
Mean	10.3	12.0	15.2	11.1	11.9	14.7			
S	1.35	1.07	1.12	1.46	0.55	0.82			

[a] Made from equal amounts by weight of urea, triple superphosphate, potash, and granular limestone

Table 9

Samples Obtained by Sampling Using AAPFCO Procedures and Probe Placed Along Valve Side of Bags from Force-Flow Bagger (Formulated Grade 11.4 - 12.0 - 15.2)

Sample No.	Sampled Along Side[a]			Sampled by AAPFCO Procedures[a]		
	% N	% P_2O_5	% K_2O	% N	% P_2O_5	% K_2O
1A	13.7	11.8	15.1			
2A	10.2	12.6	15.0			
1B				11.6	13.2	15.9
2B				11.0	11.7	15.5

[a] From same bags as sample numbers 2 and 3 open-mouth bagger, table 8.

Table 10

Formulas for Chemical Analysis of Samples Obtained by Sampling Using AAPFCO Procedures and Along Side of Bag

Sample No. Grade	1A[a] 13.7-11.8-15.1 Lb/ton	Lbs Different Than Formulated Amount	1B[b] 11.6-13.2-15.9 Lb/ton	Lbs Different Than Formulated Amount	2A[a] 10.2-12.6-15.0 Lb/ton	Lbs Different Than Formulated Amount	2B[b] 11.0-11.7-15.5 Lb/ton	Lbs Different Than Formulated Amount
Raw Materials								
Urea (45.7-0-0)	600	+100	508	+8	447	-53	482	-18
Triple (0-47.8-0)	494	-6	552	+52	528	+28	490	-10
Potash (0-0-60.7)	498	-2	524	+24	494	-6	510	+10
Limestone	408	-92	416	-84	531	+31	518	+18

[a] Sampled along side of bag

[b] Sampled using AAPFCO procedures

[c] 500 lbs per ton of each raw material used as formulated (grade 11.4-12.0-15.2)

FIGURE 1

CUMULATIVE SCREEN ANALYSIS OF SIZED UREA AND LIMESTONE

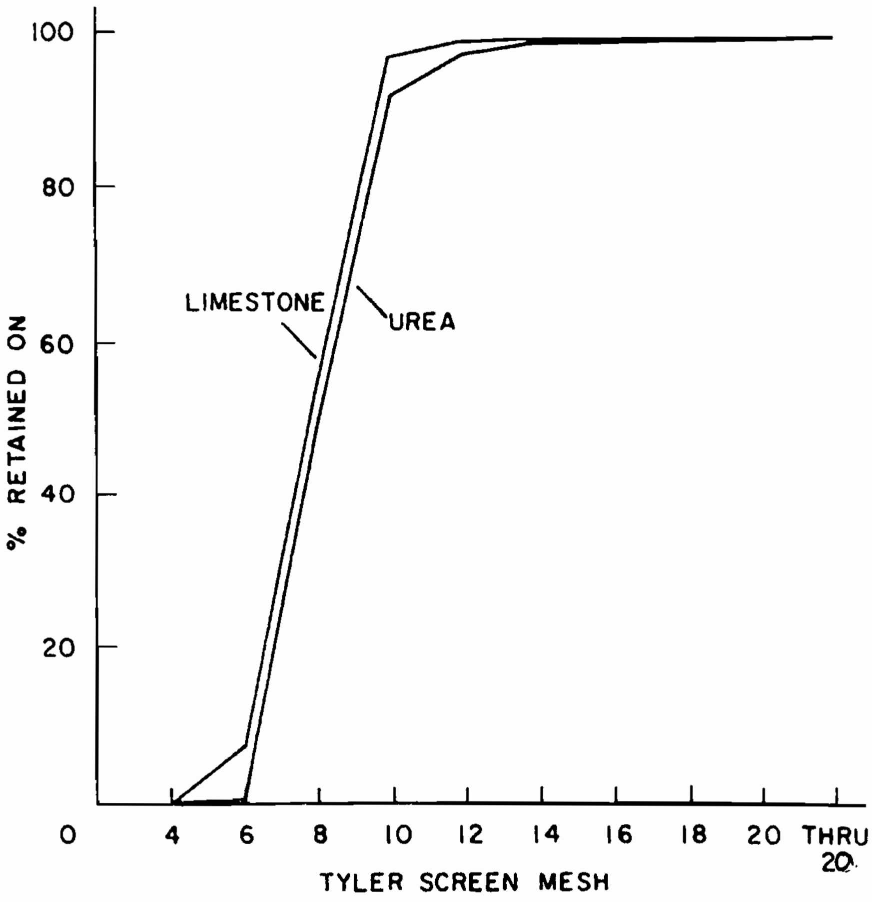


FIGURE 2

CUMULATIVE SCREEN ANALYSIS OF SELECTED GRANULAR TRIPLE SUPERPHOSPHATE AND POTASH

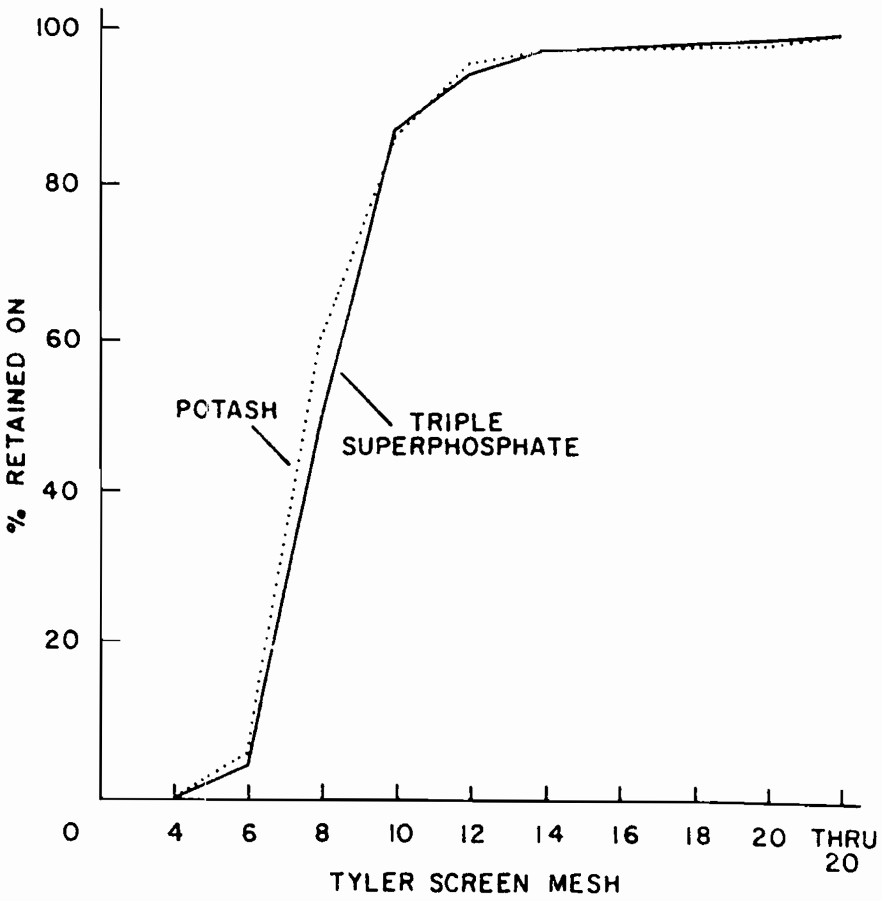
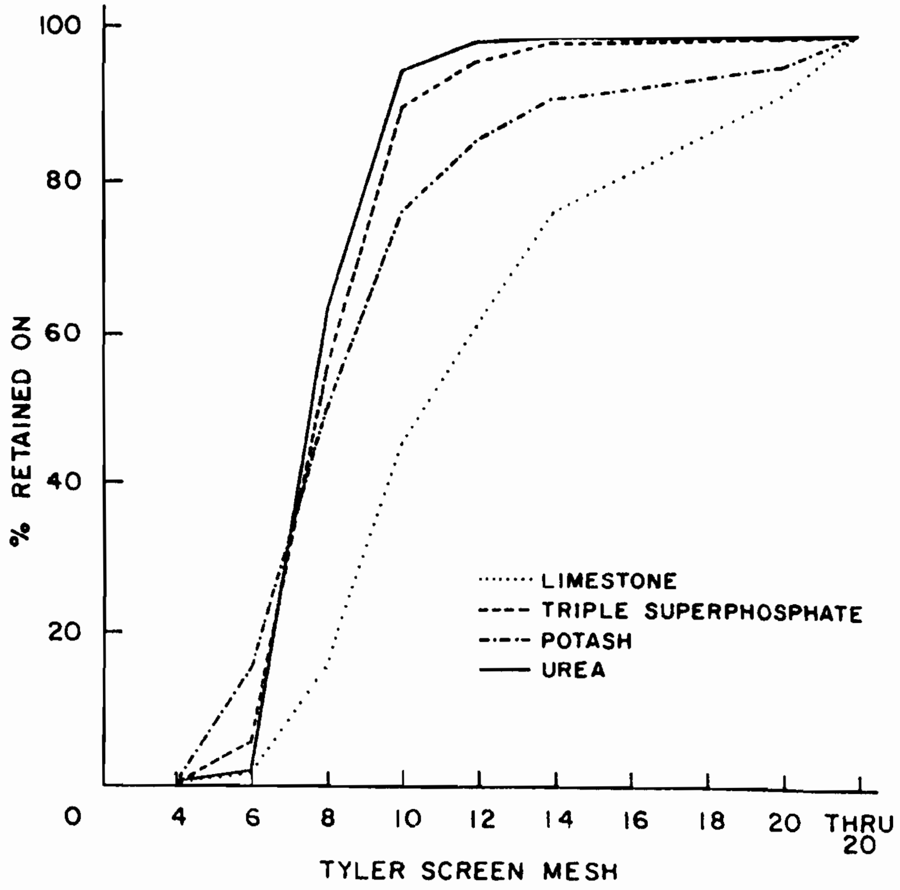


FIGURE 3

CUMULATIVE SCREEN ANALYSIS OF REGULAR RAW MATERIALS



MODERATOR MALONE: Thank you, Bennett, for sharing with us some of your problems and diligent efforts to find solutions to them. (Applause)

MODERATOR MALONE: Our next speaker is a cohort and friend of mine, Pete Turner, from Agway Inc. Pete has been working in the fertilizer industry for many years and he tells me that he is at an age when he does not go to the movies anymore because the last time he attended, he had finally come to the conclusion that all the attention he was getting from the young girls was because they were after only his popcorn!! Pete has a farming background. He was born and raised on a dairy and vegetable farm in Salem County, New Jersey. His father and brothers are still active in the farming business. Pete was first employed by Agway in 1954 and became experienced as a fertilizer spreader truck operator and maintenance worker for the fertilizer operations in Bridgeton, New Jersey. He subsequently became maintenance supervisor at the Bridgeton Plant and in July 1964 was promoted to plant manager at the plant. He managed a large Agway store and distribution center in Woodstown, New Jersey, for seven years and then returned to the Bridgeton fertilizer plant as plant manager and to head up the development of manufacturing for speciality fertilizer products. Pete has wrestled and pinned these creativity killer phrases:

We have too many projects now.

Let's make a market-research test first.

It has been the same for years, so it must be good.

What bubblehead thought that up?

I just know it won't work.

Let's form a committee.

Let's think it over and watch for developments.

Pete has been an innovator in the development of equipment and processing for the small packaging of speciality fertilizers and he will be talking to you about "Humidity and Temperature Control for the Production and Packaging of 100 Percent Soluble Fertilizers." The floor is yours, Pete. (Applause)

Humidity & Temperature Control For The Production and Packaging of 100 Percent Soluble Fertilizer

T. R. Turner

Introduction

Good morning, Ladies and Gentlemen. I am pleased to have this opportunity to talk to you about our use of climate control in the manufacturing and packaging of water-soluble fertilizers. First, I'll give a brief history of our operations and why we developed a climate-controlled atmosphere for manufacturing; then I'll describe our systems plus the special attention required for dust control and prevention of air infiltration.

Originally we were a fertilizer plant (Photo 1) with a pugmill system producing at our peak year 29,000 tons of pulverized grades. With the advent of granular technology, our operations declined to where it was no longer profitable to produce farm grades. In 1974 we changed our thrust to growth in the manufacturing and sales of home and garden fertilizers, and 100% soluble-type products now are a large percentage of total sales. The formulation of these products results in mixtures that have relatively low critical humidities. It is difficult to manufacture and package such materials without undesirable absorption of moisture unless the operation is done under controlled atmosphere conditions.

Photo 2 shows the interior of the facilities we were using to produce soluble fertilizers in 1974. At this time gross sales of home and garden products were $80,000.

Table I is indicative of problems faced without climate control in our area, where in the spring and summer months it is not uncommon for relative humidity to be 95 to 98% for several weeks at a time (note particularly June and July 1982). This humidity, coupled with temperatures exceeding 75°F., creates unfavorable conditions for producing and packaging 100% soluble fertilizers. In researching this paper, it was discovered that of 67 consecutive work days in 1974, production was stopped because of a climate-related problem that was experienced on 28 of the 67 days; 43% of available production time was lost.

Back in 1976 when we first started to plan this area for a climate-controlled environment, I will admit we had a lot to learn. We had found from a production and packaging standpoint that 50% humidity at a temperature of 70°F. was conducive to a smooth operation. After sizing up the area, it was determined we would need cooling, heating, dehumidification, and humidification at different times throughout the year. After considerable study and calculation, it was decided to go with a system with more than one stage of cooling. In the event of a breakdown, we would not lose the entire system and have to stop production every time we had a problem.

A room with volume of 84,000 cubic feet is used for both manufacturing and packaging. During a normal work day, the required operating machinery develops 100 horsepower; 10 employees are used in the operation. With these heat loads included in our calculations, it was determined that a 20-ton system (240,000 Btu) was needed. The equipment selected for this load was two packaged commercial air conditioners rated at 10 tons and split into two 5-ton stages of cooling within each unit. The first priority was cooling and dehumidification in the hot, humid summer weather. We knew that 20 tons would drop the space temperature below 70°F., so a damper system was designed to return the heat of compression from the cooling system back into the spaces for further dehumidification (see Figure 1.)

This drawing shows the operation in the cooling mode. When 70°F. space temperature is achieved, the cooling thermostat is satisfied. If the humidity is still above 50%, the dehumidistat control is not satisfied and will keep the compressors running. A further drop in space temperature (about 2°F.) below the cooling thermostat setting makes the heating thermostat call for heating. The heating thermostat closes the outside air dampers and opens the space dampers. New heat will return to the production area for maximum dehumidification. In the cooler weather when humidity is not a problem and the system is still in this heating mode, we have incorporated a humidistat control that opens an electric solenoid valve to the humidity spray nozzles to maintain 50% relative humidity at the same time the units are heating the production area.

Later in in 1979, when production increased and we went to two 10-hour shifts per day, the humidity infiltration became much higher and we decided to install a 5-ton (60,000 Btu), self-contained air conditioner as a dehumidifier. The 5-ton air conditioner (Photo 3) is installed directly above the dropped ceiling with all ductwork attached to the bottom side of the dropped ceiling over the workers' heads. Fugitive air is picked up by two air intakes covered with duraset filter medium. This air is processed through the unit for moisture removal and then returned to the production area. Diffusers have been installed to all stations to eliminate the blast from the returned air. This unit is controlled only by a dehumidistat and backs up the original system (see Figure 2).

With the two systems in operation, we have a 300,000-Btu/hour capacity, a moisture removal capacity of 100 prints/hour, and the capacity to introduce humidity with four 3-gallon/hour spray nozzles whenever necessary.

Dust Control

The two major factors in climate control, other than an adequate moisture removal system, are dust control and air infiltration.

We already had in use a multitude cloth fabric filter dust collector with an air filtering capacity of 8,500 cfm. This unit provided adequate dust removal using fifteen pickup locations placed strategically throughout the processing and packaging department. With the advent of climate control, we found we must return effluent air back to the climate control room and this created two problems.

Problem No. 1: The effluent air was returned with such force through one 12" x 24" return duct that this caused dusting. To alleviate the blast of air from the return duct, we split the return duct into two dumping stations and added diffusers to each; by doing so, the air blast was reduced considerably, and dust control was more effective at pickup points within the air-return areas.

Problem No. 2: (Table II) Finely sized grades of urea, monoammonium phosphate, diammonium phosphate, soluble potash, potassium nitrate and various chelated minor elements are milled uring processing, and the action of the mill has resulted in some leakage and uncontrolled dusting. This occurs during the batching process and at intervals as often as every 10 minutes. The local dust pickup points are not as effective in this turbulent area, and some dust is returned to the air conditioners which handle 16,000 cfm. This created plugging of the condenser and evaporator coils (Photo 4), making moisture removal impossible. After we purchased two replacement coils at a cost of $500 each, we fabricated filters and installed one at all air intake locations in the climate control system. Two-inch duraset medium was our choice for dust filtering because of its ability to hold 265% more dust than the comparable thickness of fiberglass. Since this medium is a dry type with no oily coating, it can be washed and reused for many years.

After two more years of operation and the purchase of two more replacement coils at $800 each, we totally enclosed the air conditioners (Photo 5), leaving an access door for maintenance. The enclosure filtration wall consists of 25 fiberglass filters 20" x 25" x 1" thick. This wall of filters precleans the air before it reaches the duraset filters on the machines. Since this change, the coils are dust free and continue to operate at peak efficiency.

Since the above changes have been implemented, the machines are serviced every Saturday by a local air-conditioning and heating firm for a fee of $30 per week. Parts and special work are extra. With this type of preventative maintenance, machine dowtime is minimal and moisture removal is adequate.

Air Infiltration

Our quest to convert an old fertilizer plant to a climate-controlled environment proved most difficult and at times seemed impossible. At the start of the project in 1976, air infiltration was tremendous. The development of air-infiltration control has been a 7-year project. I will attempt to detail the various steps taken to develop a suitable system.

Of the four walls in the production and packaging area, two are constructed of 8-inch masonry blocks, the inner wall is of wood construction, and the fourth wall is a 12-inch wall constructed of brick.

Steps taken to ready Wall A were as follows: First, two coats of moisture sealant were applied. Over this, 6-mil poly film in 40' x 100' sheets was attached above the masonry wall and extended to the floor, having no seams whatsoever. Next, 2" x 4" studding was applied to the wall, with 6-inch fiberglass insulation placed between the studs. Overall, we attached 4' x 8' plywood sheets 1/4-inch thick to protect the insulation.

This proved satisfactory for Wall A because it is an inner wall of the factory; but when the same procedure was used on Wall C, which is an outer wall, air infiltration still remained a problem. In 1980, we removed the plywood on Wall C and adeed 1-inch Thurmax over the 2" x 4" studs; then replaced the plywood. This solved the problem.

As shown, Wall B is an inside wall of wood construction. The material proved to be adequate. After building the wall, we also used 6-mil 40' x 100' poly film. This was attached to the rafters and extended to the floor leaving no seams. On the outside of this wall, 1/2-inch Temlock insulation board was attached; then, between the studding, 6-inch fiberglass was fastened and plywood was used for added protection.

Wall C also illustrates the roof construction, showing the fiberglass insulation and 1½-inch Styrofoam board.

The dropped ceiling could extend only to the production area because of the height of elevators and machinery. Above this ceiling we installed 2" x 4" studs with 3½-inch fiberglass insulation. To keep the insulation from deteriorating from exposure, 6-mil clear plastic was attached.

Recently completed is a 12-inch brick wall between the climate-controlled area and the fertilizer factory. Thurmax insulating board 1" x 4' x 8' was attached to the outside of the brick wall by using a tile adhesive. At the seams of the thurmax board, foam insulation from an aerosol can was applied and smoothed out with a trowel. This procedure has definitely contributed to keeping the inside wall dry.

Air infiltration from vehicle traffic proved the most severe challenge in our 7-year project.

A prefabricated air lock is used for vehicle traffic to the packaging side of the climate-controlled room. Both ends of the air lock were installed with 12-inch, two-thirds overlapped flex strips for closures. The flex strip entries have proven unsatisfactory in stopping air infiltration, plus they are expensive to maintain. It became necesssary to add electrically operated overhead doors (Photo 6) on both the exit and entrance of the air locks in this area to stop air infiltration.

The entrance to the production area proved a challenge as the air lock was in constant use by production vehicles. The entrance from the outside was protected with an electrically operated foor. After the door had been repaired twice, a green flashing pass light was installed. It is triggered by a solenoid switch when the door is open, indicating safe passage. This door is in the closed position at all times except when vehicles are passing through. We also had used flex strip on the interior side of the production room air lock, which proved inadequate. Now in place are 2-inch-thick rubber swinging doors.

The air lock designed with overhead doors and rubber doors was still not adequate. In 1981 a 10,000-Btu air conditioner was added so its discharge air delivered to the production air lock increased the pressure of the interior of the air lock above the pressure to the climate-controlled areas. When a vehicle passes through the air lock, the pressure differential causes a slight outflow of air from the lock and prevents any major flow of moisture-laden air from the old fertilizer factory to the drier air in the climate-controlled area.

Table III shows the rewards that can be realized when money and time are spent on control of air infiltration. Though we are operating more hours and producing more fertilizer, we are using less energy. As the chart shows, we reduced power use in 1981-82 by almost 100,000 kWh as compared to 1979-80. This is about a 27% decrease. If we had continued to use the same amount of kilowatt hours as consumed in 1979-80, with costs escalating as they have, the actual cost for 1981-82 would have been approximately $11,500 more. Coincidentally, this figure is also the total installed cost of the 20-ton air-conditioning system in 1976.

Summary

In summary I would like to say that our development of a climate-control system has been a most rewarding and beneficial project. Some of the benefits of this work are as follows:

1. We now have the ability to produce soluble fertilizer 20 hours per day, 5 days per week at any time of the year.
2. We can wash our mixers and grinders at 4 p.m. and be prepared to begin producing fertilizers at 6 a.m. the following day.
3. It is now possible to change colors of the products, such as blue to red, without discarding the first batch because of product discoloration.
4. Our plant has been able to meet the projected manufacturing and distribution goals set in 1976. For fiscal 1981-82 home and garden products with a value of approximately 2 million dollars were produced.
5. Product quality control is excellent — rejects and returns have been minimized.
6. Employee productivity has been improved.

Thank you. (Applause)

TABLE II

RAW MATERIALS SIZING

WATER SOLUBLE FERTILIZER PRODUCTS

PRODUCT	GRADE	SCREEN ANALYSIS (TYLER MESH) % CUMULATIVE RETAINED					
		20	35	48	60	65	100
Soluble Potash	0-0-62	0.4	13.3	37.6		83.2	91.1
Uncoated Urea	46-0-0	1.6	76.7	87.4		95.7	97.7
Mono Potassium Phosphate	0-52-34	1.3	46.5		75.7		94.7
Mono Ammonium Phosphate	12-62-0	7.1	47.2		78.2		94.7
Std. Potassium Nitrate	13-0-46	1.3	6.6	21.7		46.2	61.1
Di Ammonium Phosphate	21-53-0	6.5	38.5		67.6		89.3
Sol. Sulfate of Potash	0-0-50	1.3	7.1		63.2		90.6

TABLE I

CHART OF HUMIDITY AND TEMPERATURE

	December '81		February '82		June '82		July '82	
Day	Hum. Hi/Lo	Temp. Hi/Lo	Hum. Hi/Lo	Temp. Hi/Lo	Hum. Hi/Lo	Temp. Hi/Lo	Hum. Hi/Lo	Temp. Hi/Lo
1	98/63	57/21	78	63/45	98/56	84/61	98/36	75/58
2	98/36	57/39	98/92	58/29	98/54	74/58	98/31	78/53
3	95/45	46/33	98	48/33	98/48	75/55	98/61	75/60
4	98/68	48/35	98/89	57/44	98/74	65/57	98/37	76/56
5	98/24	42/32	98/58	40/24	98	69/59	98	77/53
6	98/30	42/37	98/24	46/34	98/51	73/58	98/38	80/62
7	98/45	48/38	98/62	28/16	98/76	64/55	98/62	84/62
8	70/37	40/30	98	35/21	98/60	69/53	98/54	90/70
9	67/40	34/26	56/25	43/31	98/48	79/56	98/44	89/71
10	67/40	34/26	98/95	31/32	98	72/53	98/36	87/69
11	98/40	38/20	90/24	60/20	98	67/50	98/62	85/70
12	95	40/23	98	51/25	98	69/51	98	85/69
13	95	40/19	98	49/27	98	64/53	98/33	85/66
14	98/36	35/32	98	48/30	98/55	71/55	98/48	84/66
15	98/94	36/33	98	52/30	98/56	82/56	98/56	85/70
16	98/50	38/28	98/51	55/47	98/60	86/69	98/52	88/69
17	73/45	39/21	98/48	50/42	98/50	82/65	98/56	89/66
18	72/38	39/11	98/70	50/36	98/46	80/66	98/52	92/75
19	93	28/14	98/50	47/30	98/67	77/64	98/52	91/75
20	95	26/13	98	47/32	98/40	74/61	98/68	82/67
21			98	44/22	98/70	81/60	98/34	79/63
22			71/44	44/31	98	81/59	98/36	86/60
23			98/80	50/25	98/24	82/53	98/86	77/68
24			36/25	42/29	98	80/54	98/34	85/64
25			98/32	42/17	98	80/57	98/42	85/60
26			98	46/19	98	80/56	98/49	89/70
27			98	44/22	99	80/58	99/36	89/69
28			98	51/20	98/60	80/62	98/67	85/67
29					98/76	82/70	98/36	81/62
30					98/62	78/65	98/62	74/62
31							98/47	81/61

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TABLE III

ENERGY USE AND COST

July 1979 to July 1982

	1979-1980		1980-1981		1981-1982	
	Electric $	K.W.H.	Electric $	K.W.H.	Electric $	K.W.H.
July	1,494.35	32,200	1,667.19	28,600	1,995.56	27,000
August	1,376.90	30,040	1,730.00	30,200	1,954.68	26,000
September	1,517.08	33,160	1,495.12	24,600	2,081.34	22,720
October	1,343.06	29,080	1,581.28	21,880	1,760.43	18,280
November	1,441.94	22,600	1,489.94	19,200	1,915.00	19,600
December	1,714.56	29,320	1,427.22	18,920	1,958.04	20,760
January	1,915.46	31,200	1,529.20	17,360	1,827.90	18,040
February	1,994.66	32,760	2,324.69	30,480	1,740.78	18,800
March	1,715.16	28,000	1.778.48	22,560	1,534.34	18,040
April	1,803.40	30,760	2,142.19	28,200	1,716.16	19,920
May	2,064.90	35,000	2,278.47	30,720	1,899.10	24,320
June	1,740.26	28,560	2,088.92	28,360	2,224.96	31,440
Totals	20,121.72	362,680	21,532.70	301,080	22,608.29	264,920
Average	1,676.81	30,223	1,794.39	25,090	1,884.02	22,076
Cost/K.W.H.	.055		.071		.085	

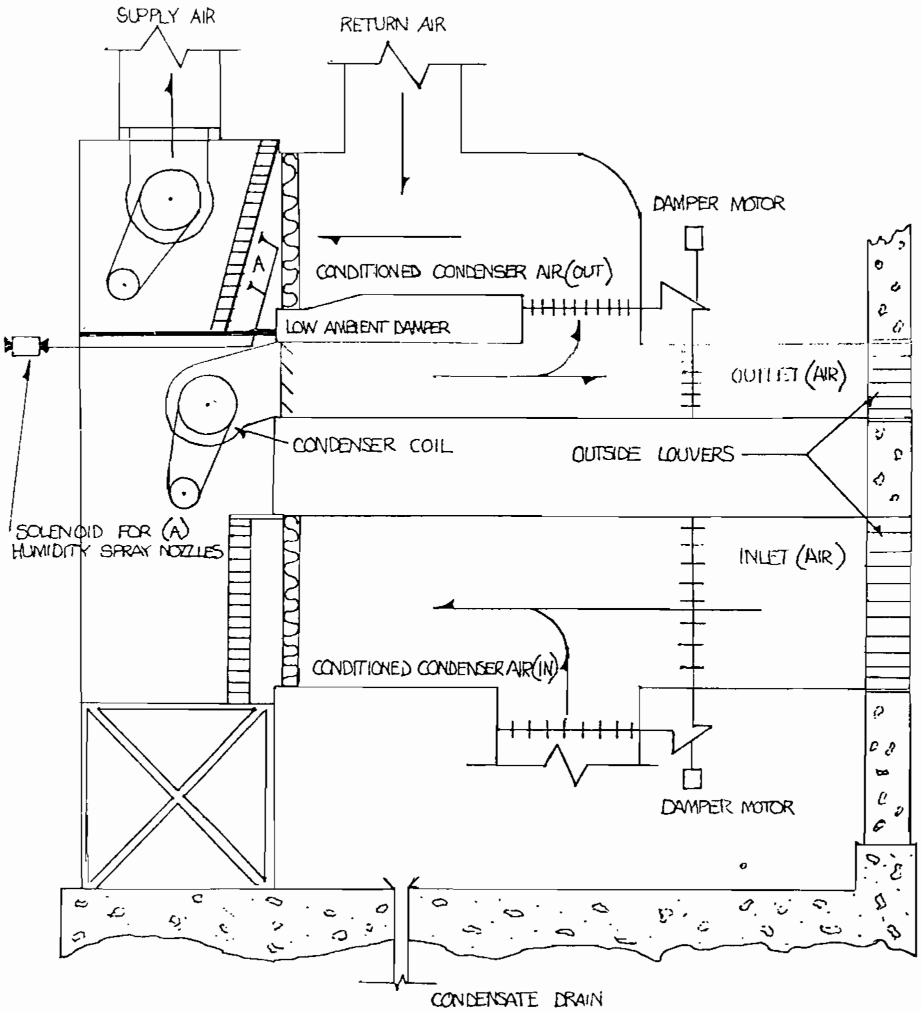
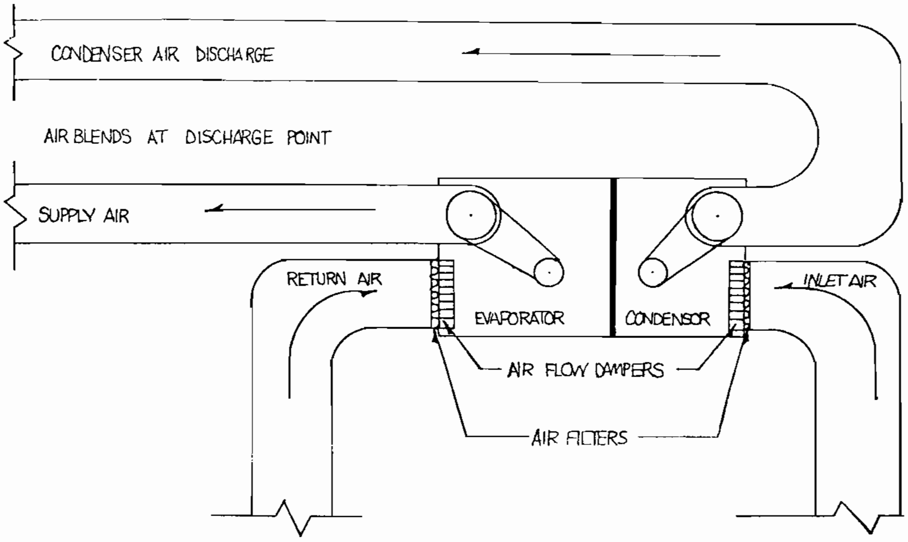


FIGURE 1 - Temperature and Humidity Control System Prepared by: D. Turner

Figure 1



SINGLE PACKAGE TYPE AIR CONDITIONER DUCTED TO PRODUCTION AREA USED AS A DEHUMIDIFIER FOR MOISTURE REMOVAL LOADS ABOVE NORMAL- THIS EQUIPMENT BACKS UP THE PRIMARY SYSTEM.

Figure 2

PHOTO 1 — External of Original Facility

PHOTO 2 — Interior Before Renovation

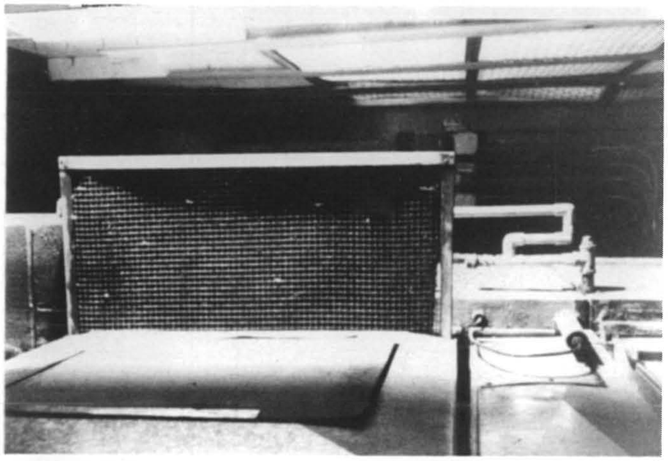


PHOTO 3 — 5 Ton Air Conditioner

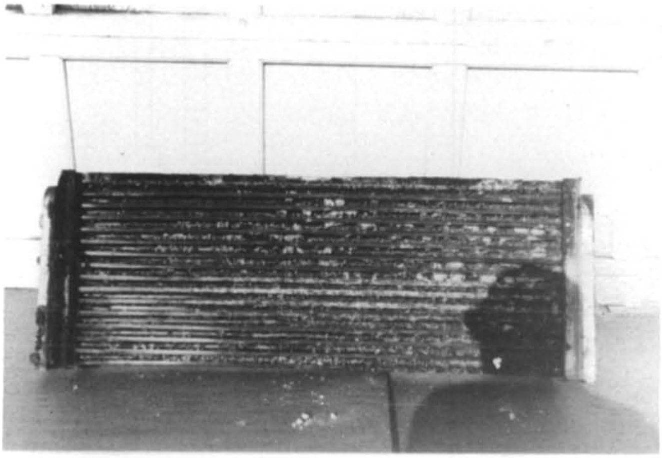


PHOTO 4 — Plugging of Condenser Coils

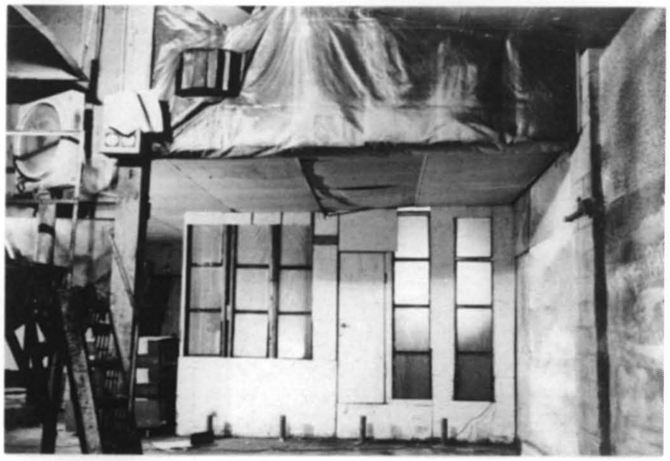


PHOTO 5 — Totally Enclosed Air Conditioner

PHOTO 6 — Electrically Operated Overhead Access Door

MODERATOR MALONE: Thank you, Pete, for your interesting and well documented presentation. Your diligence in finding solutions to a complicated set of interrelated temperatures and humidity problems in production and packaging of specialty fertilizers was certainly brought out. (Applause)

MODERATOR MALONE: Our next speaker has also shipped a bunch of creativity killer phrases. They are:

That's not our problem.
Production won't accept it.
They'll think we're longhaired.
Engineering can't do it.
Won't work in my territory.
Customers won't stand for it.
You'll never sell that to management.

A. M. (Gus) Peesker is manager of The Fertilizers Business area of the Agricultural Chemicals Division of Canadian Industries Limited (C-I-L), London, Ontario, Canada. Gus was born and raised on a farm in Saskatchewan, Canada, and was graduated from the University of Saskatchewan with a bachelor of science degree in agriculture in 1961. He joined Chipman, Inc., in 1961 and later transferred to the Agricultural Chemicals Division of Chipman's parent, C-I-L, Inc. Today, he is manager of the Fertilizers Business Area for the Division, a position he has held since 1979. In addition to his regular duties at C-I-L Inc. he is the current president of The Fertilizer Institute of Ontario, a member of the Board of Directors of The Canadian Fertilizer Institute, and Chairman of that organization's Engineering and Technology Committee.

Gus hails from our good neighbor Canada, and he was telling me about his recent visit to Toronto when he was walking down a street and saw a very inebriated native hanging to a lamppost and shouting over and over, "It can't be done," Gus stopped and inquired as to his problem and asked what is it that can't be done. The guy pointed across the street to a large billboard and yelled "Drink Canada Dry."

He will be talking about "The SGN System of Materials Identification." Guss, I'm glad you're foregoing golf during this nice weather and talking with us. We welcome you to the Round Table (Applause)

The SGN System of Materials Identification

A. M. (Gus) Peesker

The SGN system of materials identification was introduced in Canada in January of 1982, to assist blenders in the selection of compatible fertilizer materials for blending.

The system was developed by the Canadian Fertilizer Institute as a voluntary program in order to improve on the deficiency rate experienced in Canada on mixed fertilizer over a number of years.

What Is It?

It is a system of fertilizer materials identification which uses a single number, referred to as the Size Guide Number, to indicate the relative particle size for a material to be used in blends. It is a number which represents the median particle size. (Figure 1)

Background Leading Up To Development

It has been widely recognized that the considerable difficulties in meeting tolerances in analysis experienced by bulk blenders since blending began in the 50's, are due in large part to segregation. Experience further shows that one of the major causes of segregation is the mis-match in the particle size of blend materials. This relationship was confirmed by TVA over 20 years ago and continues to hold true today.

The wide variation in size distribution of materials available in the early days of blending occurred because the materials used for blending were not originally sized for this purpose. Variation in equipment and methods of producing granulated materials made it difficult to standardize particle size. Limits of —6 +6 Tyler mesh, which generally developed for granulated materials were for other reasons — 6 mesh or 3.3 millimetres diameter because of the difficulty of handling a larger particle through some equipment, and 16 mesh or 1 millimetre in diameter because finer material tended to be dusty and caked. The range was generally acceptable until blending developed in popularity, and these same materials were being utilized for blending with each other. Blenders soon discovered that segregation of the blend occurred unless particle sizes of the component materials more closely matched one another.

Following the discovery of the importance of particle size of the component materials for blending, the first approach developed for matching of materials was the matching of particle size distribution curves. Figure 2 is an example of distribution curves for two materials based on Tyler screen specifications, and in this particular case, well matched for blending with each other. This is a technically sound approach and when followed, results in blends in which segregation is normally not a problem. It proved difficult, however, to define the method understandably and to communicate it. This method, therefore, has not been generally accepted by blenders in Canada as a means by which to match particle size and avoid segregation.

In fact, very few blenders understand how to plot distribution curves or to match materials for blending using Tyler Screen specifications.

Based on sampling by the Plant Products Division, Agriculture Canada, there has not been any improvement in the percentage of acceptable samples over a period of the last 11 years. (Figure 3). Overages have been used by blenders as the means by which to get a reasonably acceptable mix. The problem is that it would require an uneconomical level of overages to achieve a high level of acceptable samples without matching particle size of the materials used for blending carefully (Figure 4). This figure shows the CNL (Combined Nutrient Level) levels that have been required to achieve percent on-spec levels in the Ag Canada test program since 1971. On average a CNL of over 102 was required to achieve on-spec levels above 83%.

Two years ago the Engineering and Technology Committee of The Canadian Fertilizers Institute, responding to ongoing concern from both industry and the regulatory officials in Agriculture Canada over no improvement in the record, set out to develop a better way, one which can be more easily communicated to and understand by blenders and producers alike. The result was the development of the SGN system.

SGN System

The SGN system of materials identification employs a single number, known as the Size Guide Number or SGN to indicate the median particle size of the material and this number is displayed as such on the manufacturer's specification sheet (Figure 1).

The SGN is determined by locating the 50% cumulative retained point from particle size distribution curves, recording the particle size in millimetres at that point, and multiplying by 100. A rounding to the nearest 005 is then suggested to arrive at the final SGN. Figures 5-1 through 5-5 show the development of SGN's for materials for which the Tyler screen specifications are known.

The suggestion is that a blender should use materials with SGN's matched as closely as possible in order to avoid a problem with segregation of resulting mix. For example, 200 with 200 and 200 with 205 or 200 with 215 are all matches within an acceptable range (Figure 6). If the difference is more than 10%, then some segregation is likely to occur — for example, a 200 material with a 230 material. This 10% conclusion is drawn primarily from some guidelines that were previously developed by TVA regarding deviation from the +8 mesh portion of a material for blending, but is thought to apply equally when the SGN system is used.

Other Factors

There is no suggestion on my part here today that matching of particle sizes using the Size Guide Number system will spell the end of problems with off spec for blenders. Other factors like the type and condition of blending equipment being used, the optimum mixing time, and yes, the level of overages used all contribute to the ultimate quality of a mix. The SGN system alone will not solve the problem. There needs to be a realization that a good mix is a result of optimizing all of these factors. All SGN's do is make particle size specifications more understandable and easier to use for blenders. Figure 7 shows a specification sheet for granular DAP that lists its SGN.

When Introduced

The SGN program was introduced to the Canadian industry by The Canadian Fertilizers Institute in January of 1982 on a voluntary basis. Since that time, some provincial fertilizer trade associations have held training sessions for their blender members, others plan to complete their training over the next six months. Many manufacturers have been busy reviewing sizing of their materials, and have made changes — for example, one potash company with several mines has been busy trying to standardize their production of coarse potash to one SGN. Another company I am aware of, increased the size of its ammonium phosphate in order to accomplish a better match between its ammonium phosphates and its granular urea product, and still retain an appropriate relationship between its ammonia nitrate and its ammonium phosphates. Other producers have simply determined the SGN's for their products and published this information for their blender customers on their specification sheets.

Matched particle size marketing programs are now possible using a single number or closely matched numbers for several materials offered. The idea of selling matched materials is not new, but it's made easier by this readily identifiable reference point.

What Are The Results To Date?

To date, results from the use of the SGN program through improved deficiency reports from our regulatory agency, are not yet evident. The average deficiency for the fertilizer year ended in June, 1982, has not in fact shown any improvement, for several reasons. Among these are the fact that the program is just getting underway in Canada. However, several retailing organizations who have implemented the system have come through this past year with an improved performance.

This system is not technically perfect, but is simple enough to be understood and it works. You can use it to improve your performance too. An information brochure outlining details on the SGN system is available from The Canadian Fertilizer Institute, Suite 602, 350 Sparks Street, Ottawa, Ontario K1R 7S8.

Thank you very much for this opportunity. (Applause)

REFERENCES

1. Hoffmeister, George. 1982. "Particle Size Requirements for Bulk Blend Materials". Presentation to thirty-sixth annual meeting of Plant Food Control Officials, Columbus, Ohio, August 3 - 4, 1982.
2. SGN — A System of Materials Identification. 1982. Brochure available from The Canadian Fertilizers Institute, Suite 602, 350 Sparks Street, Ottawa, Canada K1R 7S8.

MODERATOR MALONE: Thank you very much, Gus, for this fine presentation. We certainly appreciate your sharing this information, and the program you have developed with us. (Applause)

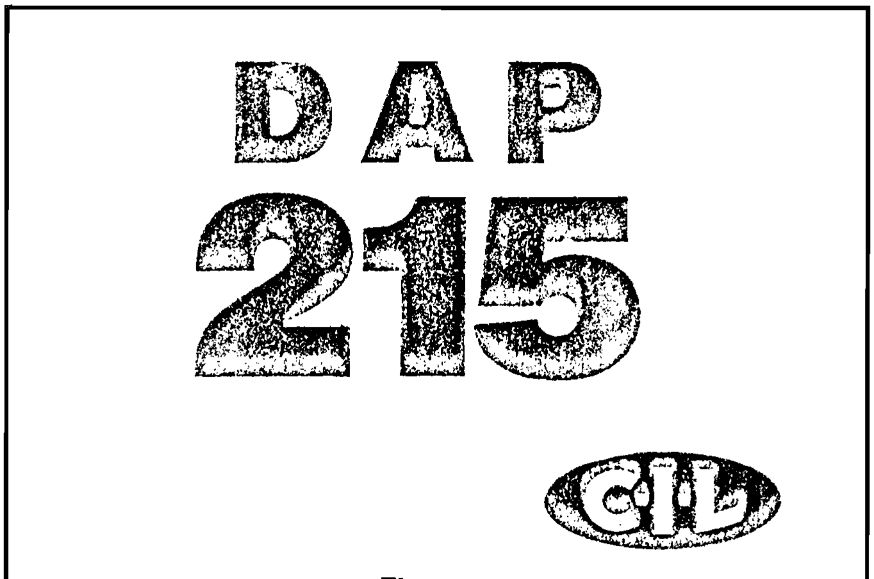
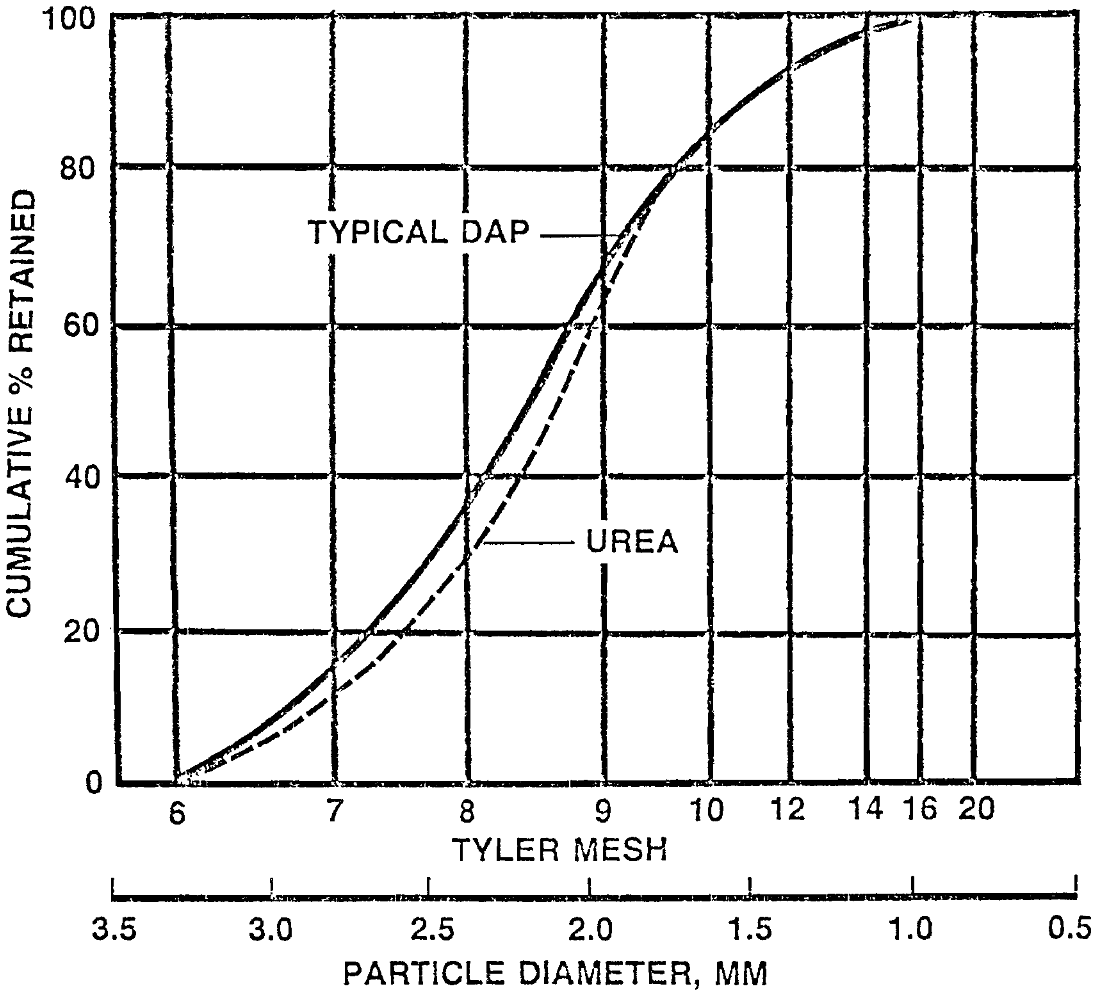
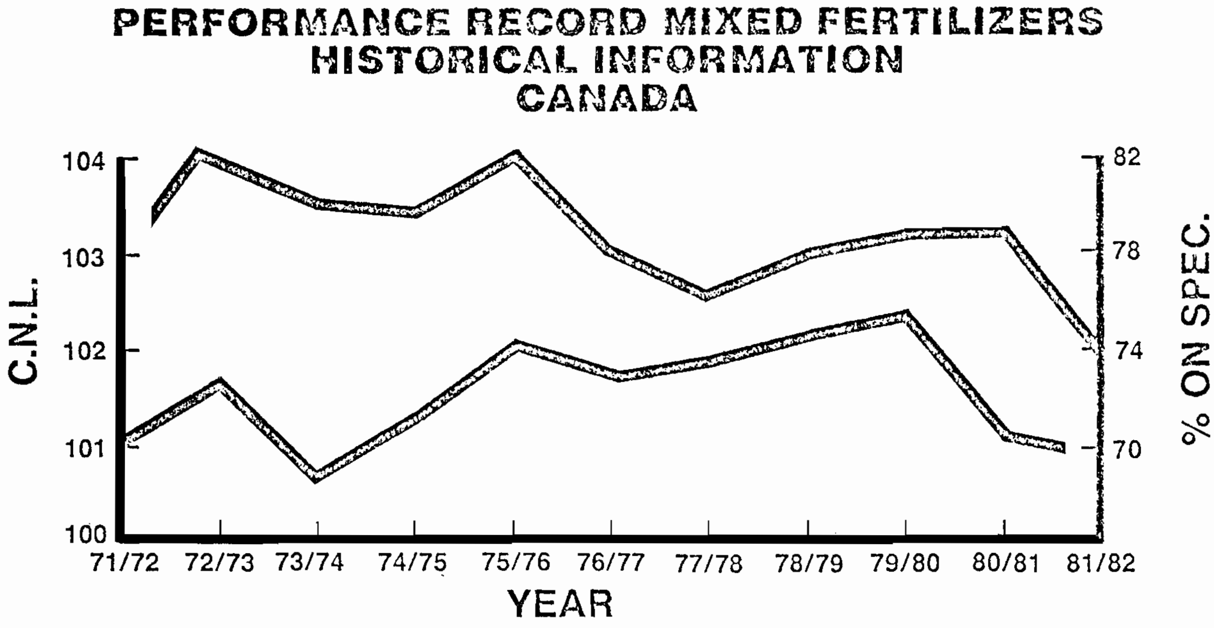


Figure 1



NOTE: EXAMPLE ONLY; NOT C-I-L PRODUCTS

Figure 2

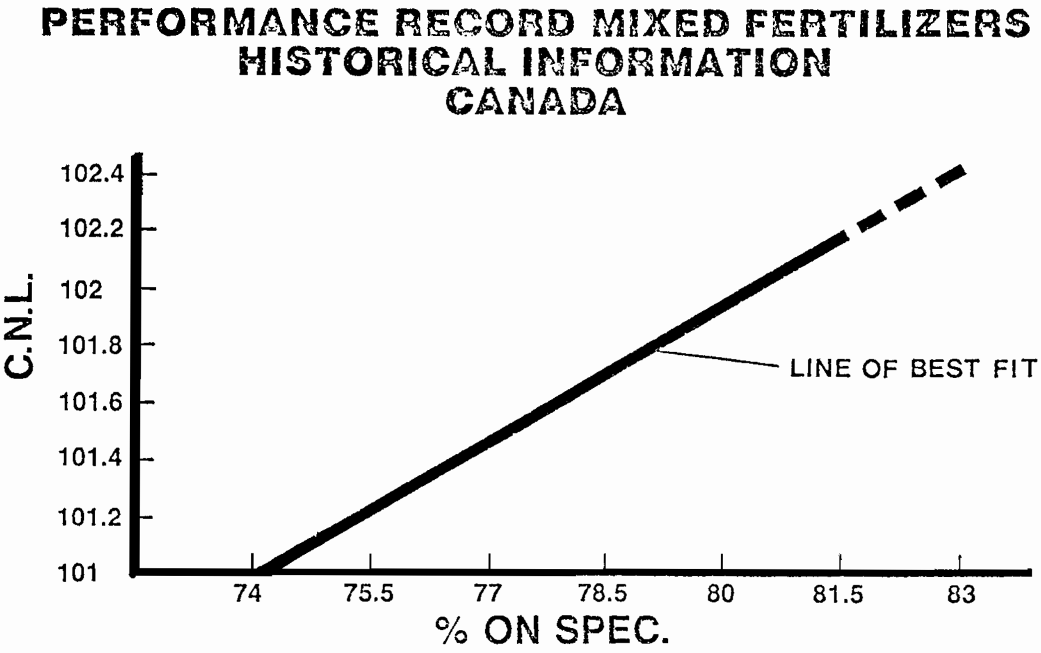


C.N.L. – COMBINED NUTRIENT LEVEL [N × 2.5 + P_2O_5 × 2 + K_2O ×1]
% ON SPEC. – PERCENTAGE OF SAMPLES ACCEPTABLE

Source Ag. Canada.

82-09-22 London, Canada.

Figure 3



C.N.L. – COMBINED NUTRIENT LEVEL [N × 2.5 + P_2O_5 × 2 + K_2O × 1]
% ON SPEC. – PERCENTAGE OF SAMPLES ACCEPTABLE

Source Ag. Canada.

82-09-22 London, Canada.

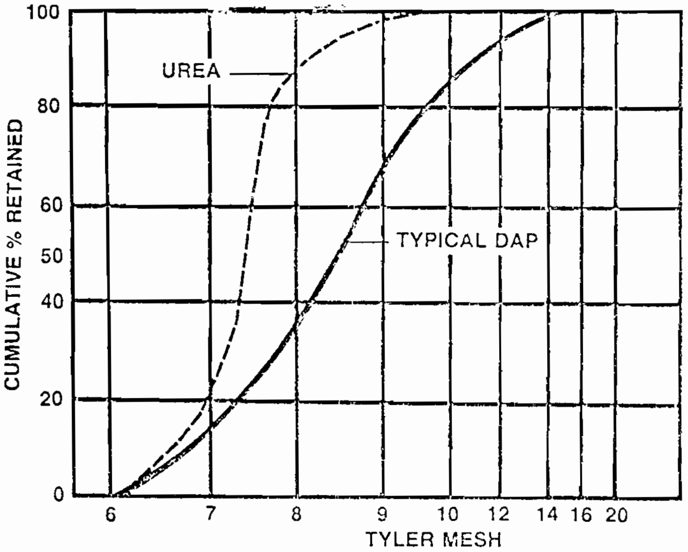
Figure 4

Figure 5-1

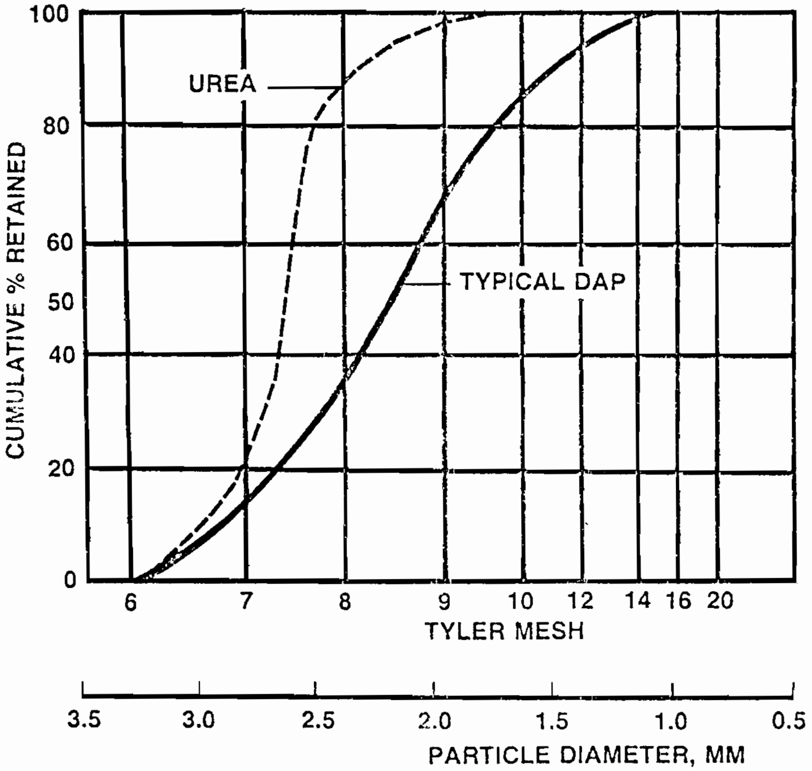
CUMULATIVE % ON TYLER SCREEN

	+6	+8	+10	+12	+16
TYPICAL DAP	1	36	86	95	100
UREA	1	88	100	100	100

Figure 5-2



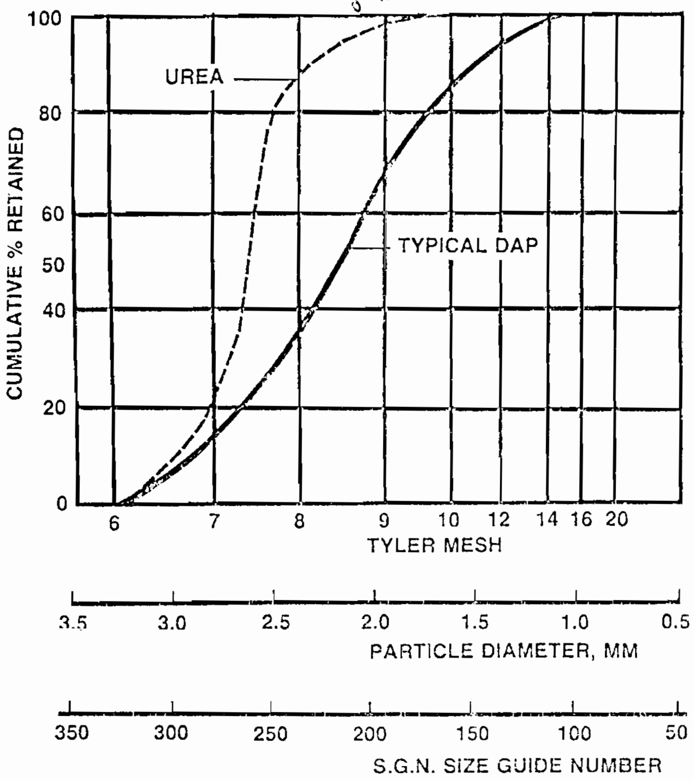
NOTE: EXAMPLE ONLY: NOT C-I-L PRODUCTS



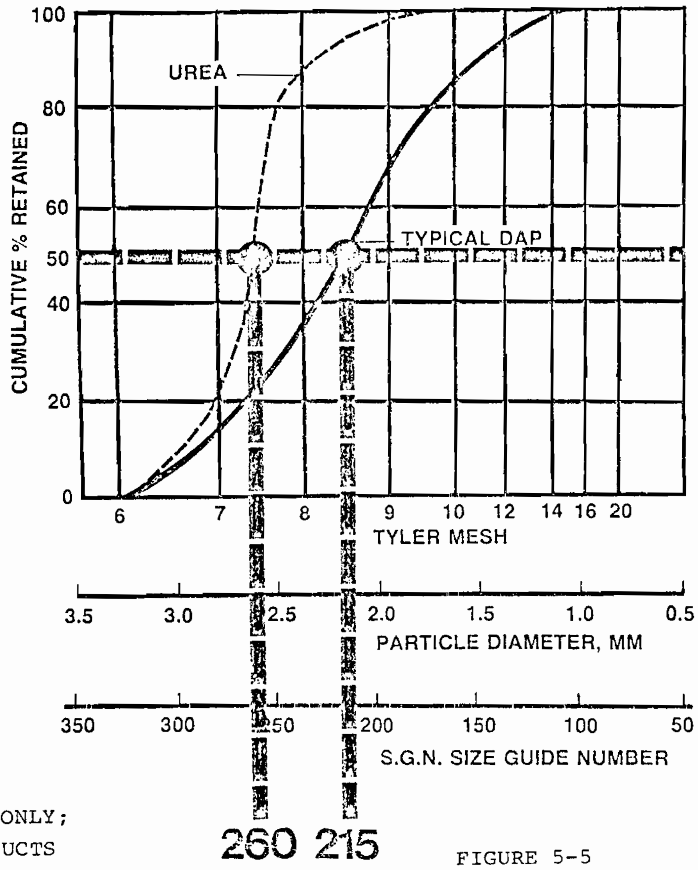
NOTE: EXAMPLE ONLY: NOT C-I-L PRODUCTS

FIGURE 5-3

Figure 5-4



NOTE: EXAMPLE ONLY; NOT C-I-L PRODUCTS



NOTE: EXAMPLE ONLY;
NOT C-I-L PRODUCTS

FIGURE 5-5

FIGURE 7

TECHNICAL DATA

C-I-L Granular Urea

46-0-0

Typical Chemical Analysis

Nitrogen	46% min.
Moisture	0.15% max.
Biuret	1.0% - 1.1% (1.5% max.)
Colour	5 APHA Units for 50% Solution
Turbidity	3 Jackson Units
Iron	1 - 2 ppm
Ash	50 ppm
Odour	None
Melting Point	132° C
pH of 10% Solution at 20° C	9.0
Internal Anticaking Agent (Methylenediurea)	0.3 - 0.5%

Typical Screen Analysis

(Tyler — % Cumulative)

+6	0.1
+8	39.9
+10	97.9
+14	99.9
+20	100.0
—20	0.0

Size Guide Number (SGN) 230

Typical Bulk Density

Loose 770 kg/m_3 (48 lb/ft^3)
Packed 830 kg/M (52 lb/ft^3)

Angle of Repose

31

FIGURE 6

COMPATIBLE S G N'S

200		200		200
+	or	+	or	+
200		205		215

Our next speaker is Bob Fulwider and he has smitten these particular creativity killer phrases:

> *Here we go again.*
>
> *Don't move too fast.*
>
> *Why try something new, our sales are up.*
>
> *Let's wait and see.*
>
> *The union will scream.*
>
> *Let's put it in writing.*

Bob is the sales specialist and master salesman for the Monsanto Ag Chemical Products Company in Illinois. He's spent several years in the fertilizer industry manufacturing and sales activities. Prior to his work with Monsanto, he had worked with companies like Swift and Armour. Ottawa Strong & Strong Inc., is one of Bob's customers and he has worked closely with them in the documentation of the fire that destroyed their facilities. Bob will be telling us about this fire and, Bob, we are certainly pleased that you could be with us. (Applause)

Autopsy of a Fire[1]

R. W. Fulwider[2]

William Strong[3]

Presented By R. W. Fulwider

Up until this fire near Ottawa, Illinois, apathy had generally prevailed in the midwest with regard to fires involving agricultural chemical warehouses. Most people felt that since a large amount of this material was stored in steel drums, a major fire was unlikely. With the magnitude of the Ottawa Strong & Strong fire, probably the largest in the United States, the industry and insurance companies have learned what liabilities they can face. The fire at Ottawa Strong & Strong has become the example in the midwest for fire companies, insurance companies, distributorships, dealerships, and industry to learn from. The necessity for this information is sharply underscored by the fact that since April 1980, there have been eight pesticide warehouse fires in Illinois alone, and four of them presented significant problems.

The Fire

At approximately 2 a.m. on Saturday, February 21, 1981, two motorists on the State Highway 23 stopped and determined that there was a fire inside the Ottawa Strong & Strong agricultural chemicals warehouse. They drove 2½ miles to Ottawa and notified the sheriff of the fire. A call was made to a patrol car, and after investigation the Ottawa Fire Department arrived with a pumper. A questions arose over the validity of the fire contract (which later was determined to be valid) with Ottawa Fire Department. So the adjoining department from Serena, Illinois, was called; over 40 minutes had passed from the initial discovery of the fire to the time Chief Berggren from Serena Fire Department arrived. His travel to the fire was complicated by the early morning dense fog.

The Serena Fire Protection District starts only a fourth mile up the road; however, since the structure was not in his direction, Chief Berggren had not fire-planned the warehouse. Upon arriving, there was a scorch line approximately three feet down from the roof line which indicated a lot of heat inside. He chose entry to the building at the main door by the office. This proved to be one of the most difficult areas of entry.

The building was a 10,000-square foot pole building with steel siding, approximately 40 percent with heated storage and a wooden office structure attached to the south end next to the loading docks.

The warehouse area was filled to maximum capacity. In the corn and soybean area of the midwest, which Ottawa Strong & Strong services, spring planting was less than 6 weeks away. The warehouse contained over 800,000 pounds of pesticides. There were over 100 kinds of commercial farm chemicals on inventory; however, the vast majority were herbicides, with corn soil insecticides being the second largest group.

It was fortunate that Archie Boe, the fertilizer warehouse manager, had attended a school conducted by Monsanto Ag Products Company on warehouse fires. We had on file the names and numbers of the state EPA people and advised them of the magnitude of the situation. He also started decontamination procedures by diking the large road ditch.

Chief Berggren initially tried to cool and contain the fire and save the contents of the office area. Despite the rural area and lack of water on the site (only a 4-foot well), water was no problem. Plenty was available from assisting rural fire department tankers hauling from Ottawa. Approximately 40,000 gallons was applied; but after the fire vented through the roof, it intensified and explosions started, so he pulled his men back. Chief Berggren also teaches other fire departments firefighting techniques through the University of Illinois extension. Realizing the gravity of the situation, he decided that more water would only lead to more runoff. Since life was not endangered he allowed the fire to burn. The few people within 2 miles downwind were evacuated as a precaution.

By midday Illinois State EPA (IEPA) and Emergency Response units were arriving on the scene. Geoff Langley from IEPA coordinated control of the operation. His first concern was containment of the contamination of dinitroaniline (DNA) herbicides in Negro Creek, a fourth mile north of the warehouse. Unknown

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[1] Proceedings, 32nd Annual Meeting of the Fertilizer Industry Round Table, October 26-28, 1982.

[2] Sales specialist, Master Salesman Monsanto Ag Products Co., Deccatur, Illinois 62521.

[3] Owner and President of Ottawa Strong & Strong, Ottawa, Illinois 61350.

to us, there was a drainage tile from the loading dock area that entered the field tile system that bypassed our road dikes.

Negro Creek is a major field drainage way that entered the Fox River, which is only 4 miles from the Illinois River. The containment of runoff in Negro Creek was accomplished by damming a ravine at a county bridge. The initial highly contaminated water was pumped into and retained in 10,000-gallon portable lagoons and available tank trucks. This material contained 160 ppm of DNA. The balance of the water was being treated at the location by two 20,000-pound twin-celled activated carbon units. This reduced the DNAs to 12 ppm during the first 12 hours and to 3 ppm over the next 4 days. At one time it was estimated that between 4 to 5 million gallons was impounded over the 2-mile area.

The fire and resulting numerous explosions were allowed to continue, with the fire consuming the solvent chemicals thus resulting in less cleanup; however, by 3 p.m. the fire intensity had dropped, resulting in a deterioration of air quality. This along with a forecast of 1 inch of rain pressured all concerned to try to extinguish the fire. With water ruled out due to the pollution problem with Negro Creek, it was decided to use silica sand. Ottawa has a large silica sand quarry, so plenty was available at low cost. Sand was applied by field spreader truck, fertilizer conveyor belt, and pneumatic hoses. By 10 p.m. three 90-ton semis of sand had been spread on the fire and with the rain starting, it was hoped that it would smother the hot spots. Firemen had now been on the scene for 20 hours and were exhausted.

Bad weather and legal negotiations consumed Sunday the 23rd and Monday the 24th of February. It was also apparent that the hot spots would not extinguish, so it was decided that high expansion (1.5% protein) foam would be used and this was brought in from Springfield, Illinois. Because there was no building structure left, chicken wire was put around the old wall area and the enclosure was reinforced by scrap metal. Favorable wind condition of less than 10 miles per hour were available on Tuesday and Wednesday. Both tries with foam failed because of foam breakdown over the hot spots.

Because destruction was so great, the State Fire Marshall said he could not determine the exact cause, so with his permission the debris was entered. With heavy equipment and with pneumatic sand trucks, Ottawa Strong & Strong employees applied two more semis of silica sand to the hot areas. The fire was officially out on Wednesday at 3 p.m.— 4½ days after it was discovered.

Cleanup - On and Off Site

Liquid cleanup and decontamination of the water impounded behind the dam on county road 1951 continued during and after the fire till Wednesday. At that point the water in Negro Creek was clean and the highly contaminated water held in lagoons and tankers was moved to the onsite location for processing.

A closed-loop water treatment center had been established onsite consisting of a 10,000-gallon portable storage lagoon, a flocculator, followed by a sand filter. Then two twin-cell, 20,000-pound activated carbon units were used and cleaned water was stored in another 10,000-gallon portable storage lagoon. The water was tested and then released to Negro Creek. Over 900,000 gallons of water was processed in this manner before the job was completed.

Regarding solid waste, the onsite solid waste was divided into three categories by Illinois EPA.

The *noncontaminated* solids, consisting mainly of wood and metal in the office and warehouse area, were trucked to the local landfill. Any metal, such as roofing, that might be contaminated was laser-washed. This is a high-pressure washer using 2500-pound-per-square-inch water pressure.

The *moderately contaminated* wastes, which were mainly the sand and some wood shredded wastes, were loaded into VisQueen-lined dump trucks covered with activated charcoal, tarped, and transported to an approved chemical landfill. It was then placed in specially prepared trenches, covered with activated carbon, and then with soil the same day. There was 354 cubic yards of this type of material.

The burned pesticide containers were hand separated out of the sand debris. They were processed through a special shredder, designed by O. H. Materials, Inc., the company doing the cleanup. A lot of the containers had a small amount of unburned solvent, so as they passed through the shredder, this liquid was removed from the bottom of the shredder by a vacuum truck. This liquid was then processed through the water treatment center.

Highly contaminated waste. This material was mostly dry organic phosphate, some wood and paper from the soil insecticide portion of the building, and also the sludge and other waste from the water treatment operation.

A total of 496 steel drums (55 gal) was used to containerize this most hazardous material. The drums were labeled, loaded, and transported to an EPA-approved landfill.

Summary

The Ottawa Strong & Strong fire is an excellent example of what could have been an environmental disaster had it not been for the concern of Bill Strong, the owner, to do what was environmentally sound. His loyal employees and their actions, along with the good judgment and cooperation of Geoff Langley from Illinois EPA and Jim Berggren from Serena Fire Protection District, also contributed greatly. It was estimated that over 4,000 man-hours were volunteered during the fire and cleanup. Loss of chemicals totaled about $1,700,000 and equipment losses another $300,000. The cost of cleanup, onsite and offsite, was about $500,000.

Many lessons have been learned from this fire and have already been incorporated in other operations in the midwest business and insurance people. Hopefully, this will assure that another fire of this magnitude does not occur again.

MODERATOR MALONE: Thank you a lot, Bob, for this great presentation. A lot of us in the fertilizer industry, in conjunction with those operations, also do operate pesticide warehousing and handling facilities with facility size quite similar to Strong & Strong. You are certainly to be commended — you, Bob, and Strong & Strong and Monsanto — for providing this kind of service in the interest of safety and environmental protection to our industry. We want to thank you very much. You can see why his title also includes "master salesman." (Applause)

MODERATOR MALONE: Our next speaker is Dr. Jon L. Nevins, and he has eradicated these last creativity killer phrases:

I don't see the connection

It won't work in our industry

We can't do it under the regulations

Nuts!

Political dynamite

Sounds good but don't think it will work

Jon was born in Little Rock, Arkansas, and grew up around the fertilizer industry. After a B.S. degree in management science from Case Institute of Technology in Cleveland, Ohio, he received his Ph.D. in economics from North Carolina State University. His present position is Supervisor, Systems Research and Development Section, Division of Agricultural Development at TVA's National Fertilizer Development Center, Muscle Shoals, Alabama. Jon joined TVA in 1965 as an agricultural economist. He has conducted various fertilizer economics and marketing studies, developed the fertilizer distribution models and TVA's order processing system. He served as OACD systems dcevelopment representative and has developed fertilizer formulation and other technology transfer systems under the TVA service mark Form-U-Share. Several of you remember Jon's father, Sam Nevins. Many considered him the father of high-analysis fertilizer in the U.S.A. As a result of this family relationship, Jon's early experience also involved activity in the fertilizer industry in the various Olin plants, laboratories, and offices. Jon will be talking about microcomputer applications to fertilizer formulations. Jon, we are real happy to have you with us today. (Applause)

Microcomputer Applications To Fertilizer Formulations[1]

Jon L. Nevins[2]

Background

The use of computerized formulations as a technical service to industry cooperators has been an important part of the TVA fertilizer introduction program for many years. In 1971, our formulation activities were moved to General electric time sharing to allow the fertilizer industry access to TVA software technology. Several fertilizer companies used TVA computer programs through their telephone and time-sharing terminals. This relieved the TVA staff of having to provide this service and permitted each company to do its own dormulating. As this practice grew, FORM-U-SHARE was registered as a TVA service mark.

In 1975, TVA introduced a world fertilizer information system through the same time-sharing network. In addition to sharing formulation systems, TVA began sharing data on world fertilizer production capacity and annual world fertilizer production, consumption, and trade. By 1977, there were about 40 subscribers in the United States and other countries.

While helping companies use TVA technology to do their own computer formulations made sense, smaller companies weren't interested in subscribing to a time-sharing service.

In 1977, TVA began using programmable calculators to make formulation tools available to more fertilizer dealers. Our activities were intensified in response to increasing numbers of requests. We selected the Texas Instruments Model SR-59 for use in our field programs. We worked closely with several fertilizer dealers to determine their formulation needs. These dealers viewed formulation from a nutrient-per-acre rather than a traditional grade and ratio perspective. Soil testing was increasing and more states were changing their fertilizer laws to accommodate custom mixing. Since each order could result in a unique formulation, the card box of proven formulations and formulation manuals and other computer listings to support the use of TVA fertilizers were becoming obsolete.

The capacity of the TI-59 calculator could not handle the full formulation needs of the fertilizer dealer. Also, TVA was supporting 27 standard programs, plus more than 50 unique unsupported programs.

Advances in microcomputer technology were approaching the point where even the smallest fertilizer dealer could cost justify his own computer. In 1978, the decision was made to transfer TVA computer formulation technology to a microcomputer. TVA bought its first microcomputer, an Apple II, in January 1979. Field testing at dealer locations began in November 1979 and the first supported product was made available in May 1980. Field testing on a large scale continued along with

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[1] Presented at the Fertilizer Industry Round Table Conference in Atlanta, Georgia, on October 26-28, 1982.

[2] Supervisor, Systems Research and Development Section, Division of Agricultural Development, Muscle Shoals, Alabama 35660..

more technical developments such estimating of salt-out temperatures, densities, viscosities, and application calibration systems. Feedback from fertilizer dealer users was incorporated into the system design. Finally in February 1982, the final product was packaged for large-scale distribution. It is called Micro FORM-U-SHARE® .

Micro FORM-U—SHARE® , abbreviated MFUS, was designed to help the fertilizer industry use TVA-developed technology and other educational programs. It not only accomplishes the engineering and technical missions specified by TVA engineers, but also reflects the business interests of those dealers who participated in its development.

MFUS is available from TVA for $100 for use on an Apple II or Apple III. A nonsupported version for the Radio Shack TRS-80 model II computer is also available. A TRS-80 model III version is available from Farmland Industries to its members. A Commodore version is also available from Indiana Farm Bureau Co-op.

Advantages of Least-Cost—MFUS uses a linear programming technique to provide least-cost-per-acre or pre-ton formulations. The least-cost feature is highly desirable for several reasons. The most obvious is that no other formulation technique can result in a lower cost formula; if no raw material alternatives are available, the least-cost formula may be the only formula. However, with many general cropping situations the $3,500 computer investment can be recouped the first week. This is particularly true where fertilizer grades are guaranteed, and the most economical "filler" is ammonium sulfate or triple superphosphate rather than dolomite.

Perhaps the most important feature of a least-cost approach is simplicity and speed of use. Non-least-cost approaches, such as we use in our calculator programs, require the user to choose such factors as the sources for nitrogen, phosphate, potash, sulfur, and magnesium. These kinds of questions can be annoying and time consuming. The alternative is to order the program which only supports your nutrient sources. That is why TVA has 27 standard and over 50 nonstandard TI-59 programs. This kind of system is simply too expensive to support and maintain. With a least-cost system, the nutrient source is selected for the user. For example, is TVA's 28-28-0 a nitrogen source or a phosphate source? The answer to this question may vary from order to order, and in a 1:1:1 ratio, it may be both.

While MFUS is fast and easy to use in calculations formulations, considerable time and effort are required in preparing to use the system. However, changing prices and costs or even adding or deleting a material or nutrient guarantee is not difficult. TVA has invested much effort in making MFUS suitable for use by those who do not have programming capabilities. Every choice is made as easy as possible by selecting from a menu of choices. The product is supported by Example, Reference, and Technical Manuals. We have held five regional workshops on the use of MFUS and have several TVA field staff thoroughly trained in the effective use.

The main concept behind the design of MFUS is to have a product that can be supported by technical service personnel whether they be in engineering, sales, or agronomy. This design also specifies that there is no need for computer programming personnel to be involved in maintaining the system. In other words, the user must be able to make MFUS perform to his specifications by putting different data in the computer as opposed to actually changing the computer program. Once a computer has been changed, it becomes unique and nonsupportable except by the person who made the change. But changing data, possibly with help from a technical service person according to directions, can be supported because it can be reproduced by others. This point cannot be made too strongly, and is a major reason why a least-cost system is desirable.

Flexibility is Power—The power of MFUS comes from the flexibility a particular dealer has in fitting MFUS into his business system. This flexibility comes not only from the capacity to describe most any mixing process but also in designing printed reports to best merge with manual or computerized systems.

MFUS permits selection of several raw material systems: bulk blend, suspension, and five different true solution (liquid fertilizers) systems. MFUS permits blending to specific grades or concentrations without filler. With fluids, factors in addition to the least-cost-per-acre consideration affect the desired concentration.

By selecting the suspension option, calculations automatically result in a product with viscosity of about 500 centipoises. The technology of suspension viscosity is built into the program. The user can quickly change this suggested concentration.

If a true solution option with a particular material system and salt-out temperature is selected, MFUS will calculate the concentration. Change the concentration and a new salt-out temperature will be indicated.

More advanced features permit the user to add his own density estimates. This option also applies for blends. In fact, some companies who bag dry blends use this feature to control density and to make sure the bag is full. Advanced features permit adding of ammonia, heat, polyphosphate, and water balances where applicable. Some companies use MFUS for ammoniation granulation and pipe-cross reactor formulations.

Flexibility is important because programs to solve such problems would be very expensive if tailored to a dealer's specific needs. MFUS is also valuable for solving unanticipated problems. Here are some examples: One dealer added seed in the fertilizer mixing process; another dealer split added water to get a good clay gel; another was able to ensure that dry zinc sulfate was adequately dissolved before it came in contact with ammonium phosphate suspension; another dealer was able to control a problem with the zinc complex while ammoniating to make 10-34-0. One dealer was able to allocate equitably a limited supply of 18-46-0 to his customers until a shortage problem eased. Several dealers have used the technology to determine the feasibility of using offgrade or byproduct materials.

With MFUS, the dealer only needs to learn those operations required for mixing his products. For example, bulk blend dealers may ignore the suspension capabilities. Technical service personnel can be trained to help dealers with more complicated mixing situations. This will become increasingly important as the use of MFUS spreads. The ability to do new things without having to hire a programmer is very important. A significant advantage is the freedom dealers have to invent ways to deal with specific problems more effectively and tailor results to their way of doing business.

An Educational Opportunity—The use of personal computers by fertilizer dealers provides those who have an educational mission new and exciting opportunities. Economic conditions are limiting the technical services formerly provided by many fertilizer suppliers, including TVA. Personal computers can multiply remaining technical service resources. While TVA's pioneering efforts have proven the feasibility of this concept, a tremendous amount of training and development will be required to make it a widespread reality.

TVA is also working with land-grant universities to make soil-test recommendations available to dealers and farmers. Most universities, also faced with tight budgets, are also looking for better ways to disseminate technical information to farmers and agribusiness.

The personal computer is rapidly becoming the most cost effective and powerful educational medium ever invented.

MODERATOR MALONE: Thank you, Jon, very much for that excellent presentation. Jon and his staff certainly offer you who want to be more creative some opportunities in this area of data processing and records keeping. (Applause)

We are going to have time for some questions. We want to finish at noon like the schedule says. But, before the questions, Jim Brown wants to visit with you.

JIM BROWN — Potash Corp. of America: We made the announcement earlier. We do have a session starting sharply at 1:30 this afternoon centered around fluid fertilizers - marketing and the physical properties of the liquid business. Not all of my speakers have checked in and have made their papers available. Prior to leaving this morning's session, I wish you would take a minute and meet with me in the back so we can start sharply at 1:30.

QUESTION: TOM HOWE — Howe-Howe, Inc.: I have a question for Mr. Bob Fulwider. What was the insurance company's attitude about the fire cleanup? Why did they have you separate costs onsite and offsite?

ANSWER - BOB FULWIDER — Monsanto: Well, the segregation of the onsite, offsite was a consideration in the legal aspects, I guess, of the insurance company's policy. The way it is written, so much coverage is for onsite and so much is for away from the physical property. In this case, it involved the creek and the roads that were damaged, the bridge, and such.

As I mentioned, Sunday and Monday were lost due to legal negotiations and because of the magnitude of the fire. It was a major insurance company in the United States, an old reputable house, but this was a case-setting situation there; they had never been involved with so much money and the magnitude of the cleanup. Since that time, a lot of insurance companies have readjusted their policies and coverages, I guess, and I am not an insurance man. They have taken a further look at their policies and their coverages and have rewritten some things. Most of them, I think, now agree, like this major company did, that they are responsible for the cleanup as well as the loss of facilties and merchandise. I have worked with several companies over the course of the last two years in the fire presentations. Several of them now are assisting the dealers as to fire planning goals and in keeping records, which make it much easier nowdays to do fire planning. Knowing quickly whom to call and the like is important, because if they do call the proper people at the proper time, it saves them a lot of money. So, they have incorporated this in their policy selling. Does that answer your question?

QUESTION - FRANK ACHORN — T.V.A.: I have a question for Bennett Spratlin. After Bennett got through doing all of his blending tests and all these improvements and all, how well have his grade records with the state improved? Have his penalties gone down? How much have they gone down? I know they have gone down some.

ANSWER - BUD BALAY: I don't have any numbers. I know when Bennett first put the dividers into his bin, that was with the gravity flow bigger, his penalties decreased by about 85 percent. As bennett said in his talk, it was quite frustrating, after he put the new bagger in, to see those penalties begin to increase. The increase never got as bad as it was originally. I really don't have any numbers. I do know that we are still able to do better with the gravity flow bagger in his plant than we are with force flow. I assume he mentioned these little hoppers above the sprouts of the force flow. He mentioned the possible centrifugal separation effect as the material goes into the bag.

Now, Bennett's convinced that the force flow is the source of his problems. Statistically, I think we can say that the stream that the force flow is on definitely is doing worse in his plant than the gravity flow bagger. But, we really haven't put our finger on the source of the problems. As far as numbers are concerned, Bennett has kept records. I haven't seen last year's. Most of the things he was talking about were done five or six years ago. I do know that his record now is much better than it was before we started doing this work, which we take some pride in. As I said, we are frustrated because we haven't been able to solve the problem completely.

Possible, if Bennett were here, he could give you some numbers. If anybody is interested in those, I am sure they could contact Bennett. He's pleased to talk about it. Or, contact me. Possibly, I could get those from Bennett.

MODERATOR MALONE: Thank you, Bud. I am sure that Bennett's going to be around. Any more questions?

QUESTION - BUD BALAY — T.V.A.: I would like to ask Mr. Turner, in his humidity-controlled room, if the vehicles entering that room (you may have told us this, but I missed it) were gas-powered and if there were any problems with carbon monoxide or other pollutants building up in the room.

ANSWER - PETE TURNER — Agway: All of the machines are LP gas powered, in and out of the room. We have no buildup of smell or carbon monoxide in the room at all. We just had OSHA in a couple of weeks ago and had tests.

CHAIRMAN ACHORN: I certainly thank Al Malone and his crew for doing such a fine job this morning. I assume you got all of the papers, Al. We are going to get these proceedings out sooner, I hope. Part of it is getting the papers. Now, I want to tell you something about this afternoon's session. I have been on and off associated with the fluid fertilizer business, and I find it a very rapidly frowing segment of the fertilizer industry. It is now about 25 percent of the total tonnage and about 17 percent of plant nutrients. Fluids have the most rapid growth rate of any segment of the fertilizer industry. As I tell the fluid people, the solid and fluid fertilizer industries are tied together. .They can help to support each other. I hope that you will get back here at 1:30 and here these nice presentations that these gentlemen have. I believe you will find their enthusiasm very infectious. I'll see you all at 1:30. (Applause)

Wednesday, October 27, 1982

Afternoon Session
James C. Brown, Moderator

CHAIRMAN ACHORN: Jim Brown is one of our leaders on the Board of Directors. He is Sales Representative for Potash Co. of America and we are proud to have Jim with us to moderate this Session. (Applause)

MODERATOR BROWN: We are really gratified that this portion of the program has generated as much interest as it has. It is obvious by the attendance this afternoon.

The Round Table afforded us this opportunity some years ago, in Washington, D.C., when we diviated from the technical aspect of the program, or the nuts and bolts, as somebody said the first day, and looked at other aspects of fertilizer marketing and manufacturing. Those areas at that time were just touched on primarily by representatives from N.F.S.A. This morning we had presentations on blends and now we would like to follow up with information covering:

1. Processing and Economics of Fluid Fertilizer.
    - A. Phosphoric Acid Systems.
    - B . MAP Suspension Systems.
2. Marketing and distribution of Fluid Fertilizers.
    - A . Phosphoric Acid Systems.
    - B . MAP Suspension Systems.
3. Current Status and Future of Fluid Fertilizers.
4. Physical and Chemical Properties of Sulphur Containing Materials for Soil Addition and Fertilizer formulations.

Our first Speaker this afternoon, Keith A. Erney, of Erney's Fertilizer Service, in two locations - Walton, Indiana and Galveston, Indiana. Keith attended Franklin Indiana University College for awhile until Uncle Sam nabbed him. Currently he participates in the dry and liquid fertilizer business and has continued in this for approximately 25 years. Starting with a single spreader truck, Keith has grown to be a very significant factor in the Fertilizer Industry in Indiana. Keith served as Vice President of N.F.S.A. in 1972-73 and has also served on the Boards of T.F.I. and N.F.S.A. He has spoken at the I.M.C. World Trade Conference. It is my pleasure, at this time, to introduce you to Keith Erney. (Applause)

Processing and Economics of Fluid Fertilizers

Keith A. Erney

This presentation will provide details and ideas over 10 years of manufacturing high Poly 10-34-0 and 11-37-0 clear liquid fertilizer from wet-process superphosphoric acid SPA and some of the "economics" involved.

The mere fact that SPA must be shipped in insulated stainless steel cars and the temperature maintained above 70°F. to insure handling should be your first indication that specialized and expensive equipment will be required to produce good quality products. Stainless steel type 316 pumps, plumbing and meters are required to handle SPA from rail car to the "T" reactor.

Type 316 stainless plumbing is essential throughout the processing procedure. The heart of the reactor consists of a 6" diameter type 316 pipe approximately 10 feet in length with the lower 3' having an iconal liner to prevent the chemical reaction from corroding the stainless steel. This pipe is vertically mounted and fitted to receive vaporized ammonia and SPA. As ammonia and SPA converge, a violent, instantaneous reaction occurs and great quantities of heat are released driving out water forming poly phosphates. It also converts the water to steam. As the temperature rises a molten ammonia polyphosphate forms. At room temperature this "melt" is a glass-like solid and the analysis is approximately 10-63-0.

We have found that the square box shown here immediately below the reactor pipe has been beneficial in allowing the hot liquid "melt" to be immediately cooled and dissolved into the pool by recycling large volumes of 10-34-0. A stainless pump driven by a 75 HP pump with the capacity of 800 gallons per minute, recycles 10-34-0 and "melt" to the top of the unit.

As we have discussed SPA from the railroad car has been combined with vaporized ammonia (note the use of a heat exchanger to effect this vaporization) Typically approximately 2/3 of the ammonia required to make 10-34-0 is fed to the pipe reactor and the balance is added to the recycle solution. However we have found to consistantly have a poly content of 75 to 80% the amount of vaporized ammonia being introduced to the pipe is extremely critical as the "melt" temperature must be above 675°F. to maintain this level of poly.

We have also found that for smooth operation of the unit and to reach our maximum capacity of 40 tons per hour, it is desirable to convert the balance of the make-up ammonia to aqua as shown in this simple aqua convertor. Water of course is metered into the system to control the product concentration of 34 or 37% P_2O_5.

To constantly produce high poly (75 to 85%) 10-34-0 maximum melt temperature is (I repeat) critical. Just as important or possible even more so, is the proper and immediate cooling of the 10-34-0 before going to storage. We have found these wood slate coolers to be very efficient in allowing us to maintain a product going to storage below 80°F., and are responsible for our ability to maintain high poly products with a long shelf life.

Economics, Reputation, Quality, and Storage Life are also guaranteed by good quality control. Good production equipment such as we have mentioned is no more essential than good manpower quality control. This man has produced 10-34-0 for nearly 10 years. His record of quality and "on grade" analysis is excellent. He is also supported by a modern and up-dated laboratory where results are obtained on a daily basis.

Poly Phosphate Quality Benefits are many:

Clear sludge-free products.
Extended product storage life.
Higher cutrient content.
Low freezing points.
Increased micronutrient solubility.
Lower viscosities.
Inhibit crystal formation & growth.

Now let's go one step further and use the "T" reactor for the production of a less quality product to compete more readily with suspensions and MAP products. We have successfully used "wet-process" 54% acid and spent acid for up to 50% of our P_2O_5 needs in 10-34-0. Obviously one can not expect the same quality or storage life with this product, however, for use when storage life is not critical and a low cost P_2O_5 is needed they have proven themselves effective.

Let's take a quick look at these characteristics:

Characteristics of 0-54-0.

Cheap form of P_2O_5.
Many suppliers
High impurity levels
Forms sludge
Corrosive

Characteristics of Spent Acid:

Advantages — Low Cost.
Disadvantages — Erratic Supply.
High often unknown impurity levels.
Must be used with caution care and monitoring.
Highly corrosive.

In "normal" years the use of 54% & spent acid will enable the liquid manufacturer to compete in the market place with the bulk blender on a cost basis and the decision of "cost" or "quality" will vary greatly from area to area.

High initial cost of specialized equipment, high maintenance cost, specialized storage facilities, and large volume facilities often are forgotten in today's competitive market but the liquid industry will always continue to be inovative and will survive. (Applause)

MODERATOR BROWN: I thank you Keith. Those were excellent and valuable discussions and well done.

Moving on, the next Gentlemen told me he was shy, like I am, and has not participated as a Speaker in too many programs. This is his second meeting. It is my pleasure to introduce to you William A. Whitmire, President of his own company, Agricultural Chemicals, Inc., Bishop, Georgia. He has been in the business 18 years, ten of his own and prior to that eight years with Allied Chemical. He is a graduate of the University of Georgia. Bill has a nessage to give to us about MAP Suspension Systems. (Applause)

MAP Suspension Systems

William A. Whitmire

I operate a fluid fertilizer business south of Athens, Georgia. For some time, a combination of factors, not the least of which was economics, indicated it would be prudent to develop an additional or alternative source of phosphate. TVA advised that a fluid product of acceptable quality and shelf life could be made from MAP. A major consideration was the possibility of sales of fluid phosphate product to other nearby dealers. We finally decided that for our business, MAP would be the most suitable.

Having decided to use MAP, the how and where we could store it was given considerable attention. Our plant is only four years old. It was designed and built to devote all of the solid storage capacity to potash. From a limited storage area, we couldn't devise an efficient and economical system of getting MAP into the mixing tank. In addition, we felt that the time factor of ammoniation of solid MAP for direct use in complete mixed grades would slow our operation down too much.

Since our business is fluids, and having a comfortable amount of fluid storage, we decided to build a separate facility to convert MAP and store it as a fluid suspension.

We built a dump pit under a railroad with an auger transferring direct to the mixing tank. We can unload either railroad cars or trucks. A 100 ton car requires about 15 hours to convert into 10-30-0. The manpower requirement is a plant operator and someone to help in repositioning the cars. I utilized more or less standard components or easily obtainable items in plant construction. The resulting batch size is 6 tons. The batch tank is, of course, scale mounted.

In the start-up phases, we made different analyses — 11-33, 10-30, 9-27, 8-24 — to study storage quality. We were not able to keep the 11-33 from becoming too thick. The analysis we have more or less settled on is 10-30-0. Our procedure is water first in the batch tank and then the MAP. We use aqua NH_3 for ammoniation. The aqua under pressure is introduced into the recirculation line. The batch temperatures are usually around 138° - 143°. The formula amount of aqua is scale metered. The amount of aqua is somewhat critical to satisfactory shelf life. Over-ammoniation will speed up the breakdown of the MAP, but the finished product will become umpumpable in storage in a matter of hours. We rely on litmus paper to monitor the pH of the batch. Our best results seem to be with a pH of about 6.7.

We have an agitation system with high shear characteristics turning at 1800 rpm. The agitator is somewhat like a circular saw with one tooth down at 90° and the next one up at 90°. It is powered by a 50 hp. motor. The turbine or propeller type agitating device that is normally used in NPK grades is not required for circulation or dispersal. Centrifugal force and speed of the disc produce all of the batch circulation that is needed. When all of the MAP granules have disappeared and correct pH achieved, we add fluid clay at the rate of .8 just before we pump the product into the cooling cycle.

The cooler is an aeration type. Two tube axle fans are on top of the cooling tower. Free air movement is 22,800 cfm each. The 10-30-0 is pumped through two cone-shaped nozzles at a 19 ft. height. Air intake area is over the catch basin into the bottom of the tower.

The cooling efficiency is greater than the ammoniation rate per 6 ton batch. On all production runs the temperature of product to storage was at approximately ambient temperature or 8 - 10° lower.

We have kept product in storage for 2½ months without any difficulty when withdrawn from storage for use. Polyphosphate was blended at different rates of total P_2O_5 to see what effect it would have on shelf life. So far, the only effect the polyphosphate had was on the cost. To date, we have had virtually no crystal growth.

Our storage tanks are flat bottom. Some have air spangers installed; however, agitation has not been utilized. A tank agitation system is of little value unless it is complete with an automatic control system. Prolonged storage of fluid MAP would be benefited by regular agitation.

We have noted variations in the breakdown and storage of MAP from one shipment to the next from the same supplier. The amount of aqua required for ammoniation has varied as much as 15%. MAP from different producers behaves differently.

10-30-0 as a suspension base for mixing to produce complete mix grades has been excellent. Grades of about 40 units plant food per ton makes up most of our volume. Fluid MAP has also gone into some starter system, lawn care operations and fish pond fertilization.

MAP as a fluid phosphate source has been cost effective in comparison to other phosphates for fluid NPK dealers.

Plant cost was favorable to cost of solid storage construction. Our plant has the advantages of being adaptable to other uses. We have product fluid clay and anticipate producing 10-30-0 from DAP and acid if this combination has a lower cost. (Applause)

MODERATOR BROWN: Bill, we thank you. That is an excellent presentation of the same end result with a different approach. (Applause)

We will now move to marketing and distribution of fluid fertilizers with the first presentation pertaining to the phosphoric acid systems and the second to the MAP suspension system. Our next speaker Peter Shoemaker, Jr. is with Valley Fertilizer and Chemical Co., Inc., at Mt. Jackson, Va. They also have operations in Luray and Winchester, Va. and have four cold mix satellite plants in the Shenandoah Valley. Pete has been in the business for a good number of years. He has had 12 years experience with Chevron Chemical before joining Valley Fertilizer and Chemical Co. in 1969, as Executive Vice President. He became President in 1971. Pete, please. (Applause)

Marketing Fluid Fertilizers

Peter D. Shoemaker, Jr.

Valley Fertilizer & Chemical Co. is a regional fertilizer and chemical distributor. The primary fertilizer sold from 1937-1969 was a pulverized blend. A batch granulation plant was built and operated from 1969 til 1972. At that time, a dry blend unit was installed to handle our dry fertilizer business. Also in 1972 Twin States Engineering designed a hot mix suspension fluid fertilizer plant with a "T" reactor integrated into the control system. We have marketed both dry bulk blend fertilizers, clear fluid, grades, suspension fertilizers, and 10-34-0 since 1972.

Why did we expand into fluids when we had a successful dry business? Fluid fertilizers gave us a change to sell *"benefits"* rather than 5-10-10 or D.A.P., POTASH & NITRATE. Fluids allowed us to offer unique products and unique services. *"Unique"* usually translates into "more profitable" in our fertilizer world.

Our basic farmer sales program revolves around a complete soil test including analysis of minor elements and micro nutrients. The results of the test extablish the fertility level of that field and allow us to talk to the farmer about the potential production as well as the costs to achieve it. The farmer's plans for the entire year is important - the Spring herbicides can affect the Fall crops, for example. This test is repeated every three years unless a special problem shows up.

A complete fertility program is then designed for each field. many times it results in a different analysis fertilizer in each field as well as different herbicides and insecticides. Fluids allow us to handle this problem easily.

Once we have established a customer, we set up his file to include: aerial maps of all fields, soil test history by field, problems of that field, production goals and yearly results, plus records of all fertilizer, herbicides, and insecticides used.

We inspect all fields during the growing season to identify problems the farmer might overlook.

We strive to know more about each field we service than the farmer does.

As we move into a new dry fertilizer marketing area, our fluid program meets buyer resistance because it costs more per acre and we are running contrary to the recommendations of the County Agents and state universities. It took 9 years for VPI to recognize how a Sulfur deficiency was limiting the yields in Virginia. A very effective sales approach to those customers who won't change it to use a *"Split Field"* request.

We ask the customer to follow our complete program on half of a given field to include the complete soil test — consultation - and the total fertility package needed. The other half is tested and treated as usual.

We consistently find a 12% - 15% yield increase in the fluid portion of that field. Even nutrient application, minor element shortages, and perhaps a different phosphate form all make a contribution to this increase but the increase is there and our customer ends up with cheaper corn or alfalfa or whatever, than with his standard program.

Valley Fertilizer has sold this program for 10 years and find dramatic fertilizer sales increases as well as greater farmer benefits. Shenandoah County, where we started, is a good example. The average corn yield in 1970 was 60 bu./acre which increased to 90 bu./acre by 1980. Our fertilizer sales increased from 3800 tons in the County to 6900 tons during that same period. There were many factors effecting this increase during those 10 years but our fluid fertilizer program certainly was a major factor in raising the farmer's yields as well as our own sales.

At the same time we were developing our fluid fertilizer program, we found soil Ph to be a critical element in weed control - especially in No-Til situations. The dry lime application was slow to change the Ph and the applicators were even slower to fill orders. We began searching for information about applying the lime with a water carrier. We received valuable lab help from Floridan Corp. and within 2 years had the information and systems needed to market a stable fluid lime suspension.

We currently manufacture a 50% or 60% limestone suspension containing finely ground agricultural limestone in a attipulgite clay and water solution. We can apply up to 660# of 5-15-30 in a 50% limestone suspension during the Fall. This will take care of most of the farmer's P and K requirements along with adjusting the soil Ph to an optimum level for the Spring crop. The remainder of the P and K plus nitrogen, herbicides, and insecticides are applied in the Spring.

We now utilize our truck applicators longer each year - we can raise soil Ph in a field by more than a full point in less than 3 weeks - we find the fluid lime sales profitable - and most important, we provide another special service to our farm customers.

Our ultimate goal is to be able to adjust the soil Ph exactly enough to assure the maximum benefit from the herbicides and fertilizers - and keep the soil Ph at that level year after year by using a maintenance amount of fluid limestone suspension every season. Perhaps we will apply as little as 200#/300# fluid limestone per acre. No dry limestone spreader can give that kind of service or Ph control.

What's new on the horizon now? Banding fluid fertilizers rather than broadcasting is our next major breakthrough in customer service.

Banding involves the application of the needed field nutrients in strips. The usual nozzle spacing is 20" and drop tubes concentrate the material into narrow strips on the field. Research shows that organic matter in the soil surface tie up a certain amount of broadcast nutrients. Banded materials overcome this because the same material is applied on less surface area resulting in more nutrients down to the root zone.

Ohio Research in 1981 and 1982 consistantly showed 9 to 10 bushels of corn per acre increase over broadcast fluids. A 5 year study by Purdue University showed an average yield increase of 11 bu./acre when banding was compared to broadcast fluids. We started tests in the Spring of 1982 to develop local county data for use in our 1983 farmer meetings. It appears this technique is successful in our area, and, while requiring some adjustments in our methods and sales approach, will be another tool for us to use.

Fluid fertilizers have had a major impact on our Company since 1972. We moved into Program selling easily and have insisted on a premium for our retail sales tonnage. Our field salesman have become much more sophisticated in their herbicide recommendations, and what goes into total crop production. We have opened 7 satellite fluid plants in different areas and worked our Program selling techniques in each with similar results. It requires more work to sell fluids in the field but I believe the effort is worth while. We give our customers a strong reason to buy from us and it becomes very difficult for a competitor to move in. I also believe that any company not offering more than cheap prices on commodity fertilizer goods are very vulnerable to the first aggressive sales organization that offers a complete fertility program to their customers. (Applause)

MODERATOR BROWN: Pete, that is an entirely new approach for this group and I think it was very well received. (Applause)

MODERATOR BROWN: Our next speaker Everett McBride operates McBride Gin and Fertilizer Company at two locations, Waynesboro and Rosier, Georgia. Everett started his own company about 15 years ago to sell dry blends but within a few years, he had branched into liquid fertilizer. In 1973 he started to use 11-37-0 with water-soluble potash and in 1976 he went to the MAP process. It gives me great pleasure to introduce Everett McBride. (Applause)

MAP Suspense Systems

Everett McBride

Thank you Jim. We started in the fertilizer business about fifteen years ago, handling two dry materials, 5-10-15 and 0-20-20. We were making a dollar or two on ton. We were moving a lot of material, were running seven or eight spreader trucks all over the county, were ginning cotton in the fall and thought we were doing good.

One day a customer came in and said: "If you do not get into the liquid business I am going to move my business. (Before he gets through paying his account, this fall, he might wish he had!) That year we started with a satellite plant. The first year we went to 50% liquids, the next year we updated our plant some and went to about 80% liquids and now we are running about 95% suspensions. We were moving a high tonnage of suspensions, but we were not making the profit we thought we should have, so we switched to MAP suspensions after looking at all the aspects of the suspension market.

We bought a Ferguson Fertibatch in 1976 - one of the first ones. It had a lot of bugs. I think we were the guinea pigs). After a year we got those bugs worked out. Now we are on a program that we feel is best and works real good for an independent dealer. The fertilizer program that we have is probably the best thing that has happened to our customers. About this time every year we start to obtain soil samples. Our county uses the State Laboratory more than any county in the state. We now have four people taking soil samples. We will continue to take soil samples right on through to the end of the year. The state sends one copy of the soil analyses to the farmer and one to us. The farmer and we then sit down and make the recommendation about his fertilizer requirements.

The majority of our customers do not know what we are putting on their fields. All they know is they are getting the NPK they need. We have tried to use the best spreader equipment that we could buy. All of our equipment is floatation equipment, and in our sandy soils, where compaction is a major factor, we are taking a lot of business from competition because we have floatation equipment. It costs us a little more, but we offset that by a per acre charge. We are charging $3.50 per acre to spread fertilizer. A lot of our customers have sharply reduced their fertilizer usage rates because of the poor economic condition that we have had since 1977, when we had our first drought. As they cut back on their rates we were still getting our money for spreading the fertilizer. We feel that in the last two years it has been profitable for us to apply fertilizer.

We hired some of our competition's best people. We have people as good as there are in the business, in our area. We are using those people to gain the confidence of the farmers.

We offer a full, complete service from fertilizer, seed and chemicals to cotton ginning. I guess one of the main things that kept us going through 1977, when a lot of our competitors closed their doors, was that we probably did a better job of collecting than we did of selling. We worked with the lending institutions. We have taken on some accounts that our competitors did not want, then after working with FHA and the banks and different people, to guarantee our money, we went ahead. So far this approach helped us. I hope this time next year we will be in the same shape.

We went to a 5% discount if paid by the tenth of the month. Now, if a man doesn't come in and take that 5%, you better start watching him before next year. You might want to cull him, because anybody can figure out a percent and a half service charge is going to cost him a lot more money than that 5%. That 5% is probably going to make him the most money he made all year.

We feel that in marketing suspension fertilizers from MAP, we are able to do a better job, because we can go to such high analysis and we can give a farmer exactly what he needs, not five pounds more or less phosphorus or ten pounds more or less of potash. We can give him just what he needs for that acre. We fertilize field by field. Under some of the center pivots, we are fertilizing probably five seven, or ten acre plots. We take soil samples in those plots and then mix the fertilizer for those plots. We try to plan to get at least a six-ton load for the two or three plots to keep from having to haul a small load. Giving the farmer exactly what he needs has been our biggest selling point. Our farmers don't come in and ask us what the price of fertilizer is anymore, although, they might ask us how much the price is increasing this year. We have gotten away from the (dog items) that were keeping our backs against the wall. We are now offering farmers a service, we are making maoney out of it, and he is, too.

When he comes in and tells us what field he wants fertilized, we can mix it immediately and send it out to him.

One of the things we feel is a plus factor in our favor is that we have added all the storage we could possibly find. We brought gymnasiums, old warehouses, anything. We try to have a big portion of our raw materials on hand before the season. We don't have to worry about liquid storage because every load is mixed as needed. During shortages and the rush season we always have material on hand.

By working closely with the farmer, working long hours, and getting good results, we feel we have developed a long-lasting relation with our customers. Thank you. (Applause)

MODERATOR BROWN: Thank you, Everett. I do not think it is done any differently down there in Georgia than it is up in my neck of the woods. (Applause)

MODERATOR BROWN: Well, it seems like our next speaker has been in the business for 20 years, but ironically, he is a newcomer to the fertilizer industry and also to the fluid fertilizer industry. G. Waddy Garrett is President of two fertilizer dealerships, Alliance Fertilizer Corporation of Mechanicsville, Virginia and Plant Food Products Inc. of Hopewell, Virginia. Waddy is a graduate of the United States Naval Academy. He was 10 years aboard a nuclear submarine and received his NBA from Harvard University. Waddy is the current president of the National Fertilizer Solutions Association and singly, has been one of the very strongest driving forces behind the NFSA and its success. It gives me great pleasure to introduce to you Waddy Garrett. (Applause)

Status of Fluid Fertilizers

G. Waddy Garrett
David Salladay

Presented by
G. Waddy Garrett

The status of fluid fertilizers is in doubt. The doubt is whether or not the usage will *triple* in the next 20 years, or merely double. Questions of survival and/or growth are moot. The topics of growth and survival have been debated for thirty years as fluids grew from zero to 27% of the fertilizer market. Rather than launch on yet another defense of fluids, I will briefly outline their thirty year history.

First, what is a fluid fertilizer? My simple definition of fluid fertilizer is any liquid, fluid, suspension or solution which contains one or more soil nutrients to be applied at the farm, with the exception of compressed gases such as anhydrous ammonia. However, the first fluid was a relatively simple nitrogen solution.

In the late 1940's, a 32% urea-ammonium nitrate solution was developed and could be applied directly to the soil. This product, commonly known as nitrogen solution, enjoys widespread popularity today. The concept of a mixed fluid (containing more than one nutrient element) was born in the early fifties with the use of furnace grade phosphoric acid. The soap industry had excess acid production capacity and a fluid fertilizer could be produced by neutralizing this acid with ammonia. Eventually, the innovative fluid dealer learned he could add a little potash and carry a complete N, P, K grade to the field.

As the dealer's production techniques were evolving, the fluid dealer was *marketing* the fertilizer he was capable of *producing*. Consequently, his survival and success were directly linked to his talent as a manufacturing innovator. The production process evolved almost daily and these changes captured the dealer's attention. However, as in any maturing industry, the strategic emphasis of any business changes with age. I feel that future production changes will be incremental rather than major transitions. If this is true, market responsiveness will become the dealer's focus in the future. He must *produce* the fertilizer he is capable of *marketing*. His success will hinge on production *flexibility* rather than innovation.

Most of the advantages of fluid fertilizers over dry fertilizers which existed in the 60's and 70's will endure. Some, such as the lower cost of capital investment for fluids, may disappear. Also, with the advent of dry bulk blends, the fluids no longer enjoy the advantage of flexibility of analysis, but fluids remain equally as flexible as dry and now have gained two new advantages over dry blends. Namely, the fluids are not subject to gravity segregation in handling as dry blends are, and fluids spread uniformly over the field rather than suffer ballistic segregation as dry blends are prone to do.

Advantages which contributed to the growth of fluids included:

1. Combining operations for less trips over the field (pesticide and micronutrient application with the fertilizer)
2. Ease of handling (use of pumps and hoses versus bags and augers)
3. Higher gross margins (unique product in the marketplace, hence less competition)
4. Agronomic superiority of some forms of nitrogen and phosphate availability

Some of these benefits may diminish over time, but others seem to be emerging. Those advantages which are becoming more significant include:

1. "Banded" placement in surface or sub-surface applications in various tillage practices
2. Fertigation
3. Foliar feeding
4. Combining nitrogen and potash application with fluid lime
5. Flexibility of using liquid *or* dry raw materials with advent of MAP/DAP fluid fertilizers.

It is interesting to note that most of the more recent fluid advantages are market related (placement, foliar, fertigation, uniform application) rather than production related. Likewise the historical benefits of fluids in production related items seem to be on the wane, e.g. lower cost of capital, analysis flexibility, ease of handling, combining operations. I predict that this trend towards *market* advantages for fluids will continue. An examination of the farmer-market and the role of the fluid dealer will reveal where the fluid market is headed.

Today's farmer can succeed only if he is reaching aggressively for maximum economic yields. Soil fertility is but one part of the dynamic and complex system needed to achieve higher yields. There are additional critical inputs required such as pest control, tillage, hybrids, planting date, water availability, soil structure, pH, micronutrients, etc. It is woefully inadequate for many farmers simply to increase the NPK per acre without simultaneously improving other farming practices. He cannot merely throw money (in the form of fertilizer) at a problem that cries out for intelligent management of *all* available resources. The complexities of the management challenge may overwhelm most farmers. Thus the dealer has an opportunity to fill the management and knowledge voids created by the drive for maximum economic yields.

In order for the dealer to fill these voids, he must concentrate on marketing, specifically technical know-how and customer service. At the same time, he cannot ignore production (or finance), or he will find himself in a cost squeeze which no amount of shrewd marketing can overcome. Therefore, the dealer must create a production system which will support, at a reasonable cost, his marketing efforts. The only manufacturing strategy which will adapt to rapid change will be a very flexible one. If he bases his selling program on the broad concept of fluids, he can devise a production system which will allow fluid fertilizer to be manufactured from almost any available source of raw materials, thereby enabling him to achieve a purchasing versatility, free from dependence on any single material source.

The retail fertilizer dealer not only determines how the product moves to the farm, but also determines the price the basic producer gets for his raw materials. Fertilizer is unique in this regard among farm supply materials. Most others, e.g. pesticides, seed corn, farm machinery, are priced by the basic producer and pulled through the retail dealer to the farmer-customer by heavy advertising and brand identity. This is not so with fertilizer. Therefore, as more dealers achieve the purchasing versatility I mentioned earlier, the trend will force the raw material marketplace to minimize price differentials which frequently exist among various sources of plant nutrients.

Given this market oriented environment, what production technology is pertinent? The answer to this question may vary depending on which market is served, e.g. wholesale versus retail, or broadcast versus starter.

For the purpose of this discussion, I will focus on the retail market of broadcast fertilizer. Fortunately the *retail* starter fertilizer market can be served with the same basic production facility as the broadcast market, although the sales characteristics of the two markets may differ greatly.

In my experience with fluid dealers in the U.S. and Canada, I have seen or heard of untold combination and permutations of plant layouts, production equipment and operating procedures. The innovative production genius of the more than 3,000 retail fluid fertilizer plants is awesome. It is impossible to describe the "average" fluid operation. However, I have used broad generalities in describing below six different types of fluid plants. I have categorized these plants by the generic product they produce. Several of these plants possess the capability of producing more than one generic product, and in two cases they can produce all six generic products.

There are three basic plant configurations:

1. *Cold mix* — This plant generally uses three basic materials and water to produce its fertilizer. These materials may consist of a urea-ammonium nitrate solution (nitrogen solution), an ammonium poly phosphate (usually 10-34-0) and soluble grade potash. The potash may be in the dry bulk state, or in a base material such as 5-15-30. When these materials are mixed together, the resulting fluid solution remains at or goes below ambient temperature, hence the generic term "cold mix".
2. *Hot mix* — This plant normally uses between four and seven basic materials and water. These materials may consist of nitrogen solution, ammonia (anhydrous or aqua), phosphoric acid (54% wet process or spent acid), fine potash (soluble or standard) and occasionally an ammonium phosphate base material (frequently 10-34-0). When these materials are mixed, the ammonia is used to neutralize the phosphoric acid in an exothermic reaction, hence the generic term "hot mix". A hot mix plant can also be used as a cold mix plant, simply by using the cold mix ingredients.
3. *Fluid blend* — This plant frequently uses between four and nine basic materials plus water. These materials may consist of the same as a hot mix plant plus a mono-ammonium phosphate (MAP, typically 11-53-0) and di-ammonium phosphate (DAP, 18-46-0). Neither of these products is used in the same mixture. The MAP is reacted with ammonia and finely ground in this process. The DAP is reacted with phosphoric acid and also finely ground. The generic term "fluid blend" is derived from the fact that a fluid is the final product, yet two materials, MAP and DAP, normally associated with a dry blend, are used in the process. A fluid blend plant also can be a hot mix or cold mix plant, simply by using the appropriate ingredients.

There is an additional variation that each of the above plants can employ. Each of the three can be a clear liquid or suspension plant. A clear liquid, or true solution, is a generic term for the fluid in which all of the nutrients are dissolved. Normally, the maximum units of total NPK are between 25 and 35. A suspension is a generic term for the fluid which suspends most of the nutrients. A gelling agent such as an attapulgite clay holds the undissolved materials in suspension. These gelling agents are finely ground clays with needle-like crystals form a liquid gel when cheared and hydrolized. The only difference in a plant making clear liquids and one making suspensions are the addition of the gelling agent and the mechanical shearing of the clay. Any suspension plant (hot mix, cold mix or fluid blend) can produce clear liquids; however, the reverse may not be true.

All of the fluid plants described above can accommodate some sulfur sources as well as some micronutrients and pesticides. In many of the plants, other nitrogen sources are used, such as ammonium sulfate and urea. In fact, in the fluid blend suspension plant practically any source of plant nutrients can be used with some experimentation.

Presently, the fastest growing segment of the retail fertilizer industry is suspension fertilizer made from MAP/DAP in a fluid blend plant. Several dry bulk blenders and users of 10-34-0 high poly solution are making the switch to MAP/DAP suspensions. In many cases the dry bulk blender who already has dry bulk storage facilities can begin producing suspension fertilizers with less capital investment than a true solution fertilizer dealer. In the Midwest we have seen an increasing number of fluid fertilizer dealers who store MAP/DAP for use in both dry bulk blend and suspension fertilizers. Although current annual United States production of DAP is about 11 million tons, while the production of MAP is about 2 million tons, we expect these quantities to equalize during the 1980's. Also, the MAP will most likely drop in analysis during the coming years and will probably contain a small amount of polyphosphate which can be produced using TVA conventional granulation technology in conjunction with the TVA pipe-cross reactor. While a typical MAP grade currently is about 11-53-0-2S, in the coming years we may see grades such as 11-51-0-3S, 15% poly.

An increasing number of dealers, as their suspension operations grow in size, are using polyphosphate true solutions or polyphosphate suspensions to improve the quality of the MAP/DAP base suspensions which they are selling. The attached table shows the marked improvement of MAP suspensions that include polyphosphate suspension. The retail suspension fertilizer dealer is increasingly using small quantities of higher priced solution or suspension fertilizer to improve the storability and salability of his base suspension MAP/DAP fertilizer.

These base suspension fertilizers are finding uses in once-across-the-field broadcast application schemes in which the NPKS-micronutrients and herbicides are applied at one time. Also, suspension fertilizers are finding increased use in row application utilizing squeeze pumps and in the no-till or minimum-till conservation practices. (No-till and minimumtill crop acreage is apraching one-third of the total acreage planted in the United States each year.)

The fluid blend suspension plant seems to be a good production system which provides the flexibility required by the market-oriented retail fluid dealer. This is not to imply that either fluid blends or suspensions will necessarily be the optimum product at any given time in the future. But today it does allow the fluid dealer to build his marketing strategy around two powerful concepts — the strengths of fluids and the needs of his farmer-customer. And at the same time he retains his purchasing versatility through a production plant which supports rather than dictates his marketing efforts. No longer will the production tail wag the marketing dog.

The advent of the fluid blend plant may reduce the cost of the basic materials as concern for the dealer, but transportation, storage and handling will still be considerations. Today dry bulk phosphates enjoy a transportation cost advantage over liquid phosphates. We also have the dilemma of the regional producer/wholesaler of 10-34-0 and whether there is a space for him in the economic daisy chain from the mine to the farm. We also face the escalation of natural gas (feedstock for ammonia) which forces nitrogen costs up in the face of sagging demand and low grain prices. No amount of production flexibility will solve all of these problems. But the market-oriented fluid dealer will embed himself even deeper in the farm supply economy, thereby insuring intelligent use of fluid fertilizers in pursuit of maximum economic yields at the farm. (Applause)

MODERATOR BROWN: It's no secret to me why the National Fertilizer Solutions Association has grown and fluid fertilizers are gaining such a position in the total marketplace today. It is through the efforts of people like Waddy. Thank you so much Waddy for your good presentation. (Applause)

MODERATOR BROWN: We move now to fourth phase in our program, a talk about the physical and chemical properties of sulfur-containing materials for soil addition and fertilizer formulations. Flake L. Fisher is a native of New Mexico, with a farm and ranch background. He graduated from the New Mexico State University with a BS in soil science, spent three years in the Army Air Corps, and went back to school in 1947 at Texas A. and M. University to obtain a Ph.D. in soil fertility and soil chemistry. He taught at Texas A. and M. in soil fertility and soil chemistry and has published some 80 papers from his research. He worked as an agronomist for Occidental Chemical for about ten years and served as Director of the Feed and Fertilizer Control Service for some eight years. As an Agronomist and Technical Director of Chemistry Enterprises, Inc., Houston, Texas, he has written six articles and technical papers for trade journals. Dr. Fisher is married, has three children and six grandchildren. It gives me great pleasure to present Dr. Fisher at this time. (Applause)

Base Suspension Grades from W. R. Grace MAP (PCR 11-53-0) and TVA Polyphosphate Suspension (9-32-0)

Raw Materials	10-30-0-1.5 Clay Lb/ton	10-30-0-1.5 Clay Lb/ton	10-30-0-1.5 Clay Lb/ton	11-33-0-1.5 Clay Lb/ton	11-33-0-1.5 Clay Lb/ton	11-33-0-1.5 Clay Lb/ton	12-36-0-1.5 Clay Lb/ton	12-36-0-1.5 Clay Lb/ton	11.5-34.6-0-1.44 Clay Lb/ton
Water	510	384	257	364	225	87	218	66	-
Clay (Minugel)	30	18	7	30	17	4	30	16	2
Grace (11-53-0)	1132	849	566	1245	934	623	1358	1019	680
23-0-0 (Aqua)	328	280	232	361	308	255	394	336	278
9-32-0-2.5 clay	-	469	938	-	516	1031	-	563	1125
Percent P_2O_5 in grade from 11-53-0	100	75	50	100	75	50	100	75	50
Percent P_2O_5 in grade from 9-32-0	0	25	50	0	25	50	0	25	50
Temperature after NH_3 addition (°F)	124	128	125	134	140	150	140	142	140
Temperature after 9-32-0 addition (°F)	-	114	107	-	118	110	-	114	105
Initial viscosity (cps)	220	190	130	260	230	170	640	230	280
1 week viscosity (cps) (70°F)	440	160	130	540	230	200	1840	400	260
3 week viscosity (cps) (70°F)	650	170	130	960	220	200	2000+	380	250
3 week pourability (%) (70°F)	95	98	98	thixo; 65	98	98	thixo; 0	98	98
pH (70°F)	6.5	6.6	6.7	6.4	6.4	6.5	6.3	6.3	6.3
Specific gravity (70°F)	1.34	1.37	1.37	1.41	1.41	1.40	1.45	1.45	1.43

All raw materials were approximately 80°F.
9-32-0 used was 3 months old containing 25% poly and 2.5% clay.

(furnished by David Salladay, TVA)

Sulfurs For Use In Fertilizers

Flake L. Fisher

Efficient agricultural production in the decade ahead will be a must for U.S. Agriculture to remain healthy. The past two years is prime evidence of this, only the really efficient producers have made money. The Schmidt Brothers (Nebraska) corn production program is an outstanding example of how to make a profit by increasing input to reduce production costs per unit (Tables 1 & 2). The Schmidts' have an excellent, well planned production program which includes the uses of adequate N-R-K plus sulfur, zinc and other good management practices. The Schmidts' had to plan for sulfur to their fertility program because modern fertilizer manufacturing has generally removed sulfur. Much of the fertilizer manufactured in the past had 3% or more sulfur as an inert. For example, the best estimates of sulfur in fertilizer used (1955) had a ratio of S to $(N + P_2O_5 + K_2O)$ of 1 to 3.5 while in 1980 this ratio was in excess of 1 to 20 (Figure 1). For efficient, effective use of N-P-K other nutrients must be present in adequate amounts so as not to limit production. Sulfur is unique in its role in efficient crop production because it functions not only as a plant and animal nutrient but as a pesticide and soil amendment. All of these functions generally improve plant vigor and rate of growth.

Let's look at planned ways of returning sulfur to fertilizers. First, and the most used form of sulfur is sulfate from sulfuric acid, and ammonium sulfate which is used in the manufacturing of nitrogen, phosphorus and potassium fertilizers (Table 3). Unfortunately, the volume of these manufactured fertilizers has been decreasing, while fertilizers with higher N-P-K and lower S content have been increasing as shown in Figure 1. Another phenomenon in the fertilizer industry that has contributed to change has been the development of bulk dry blend and liquid mix plants at the fertilizer dealer level. This growth stems from the development of better soil tests and the need to have more fertilizer closer to the consumer. Local dealers are limited on number and size of storage bins. Local dealers therefore, demand materials with the highest possible N-P-K content. This has developed a large volume commodity type (urea, nitrate, UAN, DAP, etc.) fertilizer material market that has in general been a disaster for the basic manufacturers.

The rest of this paper will be addressed to sulfur products that can be added to blended or mixed fertilizers, other than basic manufactured materials or mixed grades, since these materials use sulfate from ammonium sulfate and sulfuric acid. Sulfur products can be divided into three broad classes:

FLUIDS

1. Dry
2. Liquid
3. Suspension

Most of the available sulfur products used in dry bulk blending of fertilizers are listed in Table 4. Each of these materials has some unique qualities that encourages the use of that material. For example, if you need magnesium and sulfer in a blend, generally it can be supplied by using potassium-magnesium-sulfate. Under most conditions where magnesium is needed there is also a need for potassium. There are many cases where soil pH, potassium and magnesium are high and where only nitrogen-sulfur and possibly nitrogen-phosphorus-sulfur are needed. Under these conditions, the use of ammonium sulfate; ammonium-phosphate-sulfate or the use of granular elemental sulfur with a nitrogen or phosphate material low in sulfur can all be used. The use of granular elemental sulfur in dry bulk blending has been slow in developing, primarily because of fear of sulfur fires. With the recent development of water degradeable-low-dust elemental sulfur granules, the use of sulfur in bulk blending has increased. C.E.I. has been working with several large volume bulk blenders, who have successfully handled bulk granular sulfur with their regular bulk handling equipment for the past two seasons with no problems. Additionally, these granulars are of the proper weight and size so that segregation in the blend is minimized. These high analyses sulfur (88-92% S) granulars used with urea and or nitrate allows for higher analyses blends. These higher analyses blends, *reduce the blender's cost* in that he incurs *less freight, less mixing time* and *more acres covered per batch.* Probably the most critical factors in the use of water degradeable sulfur are its degradability (overnight in water) and sulfur particle size. For rapid oxidation, degraded sulfur most have particles small enough to allow complete oxidation of the sulfur (Figure 2). A close study of this data indicates that for sulfur oxidation to occur at a rapid enough rate to be of value to growing plants during the first 2 to 4 weeks after application, the particle size has to pass an eighty mesh or finer sieve. Particles in the +10 mesh size (Figures 2, 5-10 line) oxides at a rate of about 10% per year or too slowly to be of any real value unless excessively heavy rates are used.

The use of sulfur in liquids was difficult until ammonium thiosulfate became readily available (Table 5). Prior to the use of ammonium thiosulfate, the only source of sulfur was ammonium sulfate. The solubility of ammonium and potassium sulfate is low; therefore, only token amounts of sulfur (1 to 3%) could be used in liquid mixed grades. This actually proved to be detrimental to the use of sulfur in crop production because rarely was a sulfur response observed. Recently it was recognized that sulfur responses are much like nitrogen in that if you apply only 10 to 15 pounds of sulfur per acre, this applied sulfur is absorbed almost entirely in the soil system, leaving little or none for plant use. A review of the literature on sulfur responses indicates that most measureable sulfur responses occurred when 20 or more pounds per acre were used (Table

6). Ammonium thiosulfate allows the formulation of mixed liquids containing 5% potash and up to 10% sulfur and even higher sulfur levels in non-potash grades (Table 7).

The development of highly concentrated flowable or emulsions of sulfur has ushered to another dimension of sulfur use in fertilizer use. These emulsions ranging from 50 to 74% sulfur(S) are easily handled, safe and very effective as sulfur sources. They have been successfully used in true fluids with only mild agitation. Emulsions are a natural for suspensions. In fact, the amount of clay needed in a suspension can be reduced when 10% S or more as an emulsion is added to the suspension. Another use of emulsified sulfur is spray impregnation onto dry fertilizers. Using the 74% sulfur emulsion, up to 5% sulfur (100# sulfur/ton) has been successfully used.

Last, and certainly not because they are of less importance, are solid sulfurs for use in suspensions. Present trends of the fertilizer industry show that suspension fertilizer is the most rapidly growing part of the industry. Ground sulfur (99.5% sulfur) is the most concentrated sulfur material available; therefore, it offers freight savings and reduced volumes to handle. The disadvantages of ground sulfur are control of dust and low reactivity due to large particle size (20-200 or larger micron) (Figure 3). Some people are making their own suspension of sulfur by making a *5-0-0-(40-50S)-2% clay* by using 32-0-0, ground sulfur and gelling clay. Making a suspension from ground sulfur improves handling characteristics but does not improve oxidation rate. The particle size of most ground sulfur is such that the rate of oxidation per year will not exceed 15 to 20%, and many times is even less than 15%. Therefore, the rate of application of sulfur must be increased 5 to 10 fold to be as effective in the soil as the smaller particles (400 mesh down). Others are using fine, bentonite sulfur (88-92% S) granules in suspensions. Use of these granules helps on dust control, and depending on method of manufacturing of the granules, oxidation rate can be impoved. Granules made by slurrying molten sulfur with clay appear to be more reactive than those made by using ground solid sulfur (Figure 3).

In summary, we must join the NOW INDUSTRY-BLENDERS. To do this, a material has to be handled in bulk and be available throughout the fertilizer use area. At present all of the sulfur materials discussed fit these conditions. That is they can be handled as true bulk materials or limited bulk such as super bags or small poly-type tanks. So let's all go out and merchandise *SULFUR THE CATALYST.* Glad to be here and thank you. (Applause)

CORN PRODUCTION

LB/ACRE	1978	1979	1980
N	387	405	401
P_2O_5	125	153	86
K_2O	115	209	149
S	60	71	28
Mg	18	18	18
Zn	4	0	1.5
Mn	5.6	14	0
40 ACRES YIELD, BU/ACRE	255	285	
1 ACRE YIELD, BU/ACRE		311	240

***Schmit Bros.**

TABLE 1

CORN ECONOMICS 1979

YIELD BU/AC	PRODUCTION COSTS $/BUSHEL
130	2.19
190	1.73
230	1.47
285	1.32
311	1.25

*Schmit Bros.

TABLE 2

COMMOM FERTILIZER MATERIAL WHICH ALSO CONTAIN SULFUR

MATERIAL	SULFUR CONTENT (%)	TOTAL PLANT FOOD CONTENT[1] (%)
AMMONIUM SULFATE	23.7	45
AMMONIUM NITRATE-SULFATE	5.0	35
AMMONIUM PHOSPHATE-SULFATE	15.4	51
AMMONIUM SULFATE-NITRATE	15.1	38
NORMAL SUPERPHOSPHATE	12-14	30-34
POTASSIUM MAGNESIUM-SULFATE	22.7	44
POTASSIUM SULFATE	17-18	69

T.S.I. Bul. 17, P. 4

TABLE 3

DRY SULFUR MATERIALS

MATERIAL	SULFUR %(S)	LBS/FT^3
GRANULAR S	88-92	70-75
AMMONIUM SULFATE	24	63-65
AMMONIUM PHOSPHATE SULFATE	15	60-65
POTASSIUM SULFATE	17-18	72-74
POTASSIUM MAGNESIUM SULFATE	22	95-98
NORMAL SUPERPHOSPHATE	12-14	65-70
MIXED (N-P-K) HOMOGENEOUS	1-13	52-57

Various sources.

TABLE 4

FLUID SULFUR MATERIALS

MATERIAL	SULFUR %(S)	LBS/GAL	pH OF SOLUTION
AMMONIUM THIOSULFATE	26	11.1	7.7 - 8.2
AMMONIUM SULFATE	10	10.5	6.0 - 6.5
AMMONIUM POLYSULFIDE	45	9.5	10 PLUS
SULFURIC ACID	28-33	15-17	1.0
SULFUR SUSPENSION	40-74	11-13.5	7.0 PLUS

Various sources.

TABLE 5

TABLE 6

SULFUR INCREASES YIELDS

Crop	State	Lbs. of S Applied/A.	Yield Increase Per Acre from S
Wheat	Wa	22	18.8 bu.
Milo	Tx	39	380.0 lbs.
Alfalfa	Ca	76	3.6 tons
Cotton	SC	32	148.0 lbs. lint
Coastal	NC	50	5600.0 lbs. hay
Rice	La	60	2.4 bbls.
Corn	NC	40	11.0 bu.

Table 7: SOME EXAMPLES OF SOLUTION FORMULATIONS USING A-T™

POUNDS OF FERTILIZER MATERIAL REQUIRED TO MAKE ONE TON OF DESIRED GRADE

	Liquid Grade with Sulfur	Nitrogen Solutions		Polyphosphate	Polyphosphate	Potash	A-T™	Water
		28-0-0	32-0-0	10-34-0	11-37-0	0-0-62	12-0-0-26	H_2O
NS	28-0-0-5S		1615				385	
	24-0-0-10S		1230				770	
	24-0-0-6S	1538					462	
	23-0-0-8S	1385					615	
NPS	11-20-0-11S				1082		847	71
	11-27-0-7S				1460		540	
	16-20-0-6S		456		1082		462	
	12-24-0-8S		86		1298		616	
	17-17-0-7S		542		919		539	
	10-27-0-5S			1589			385	26
	10-25-0-5S	29		1471			385	115
	14-20-0-5S	416		1177			385	22
NPKS	8-20-6-5S				1082	194	385	339
	7-16-6-6S				865	194	462	479
	10-15-5-10S		58		811	162	770	199
	7-15-5-5S		18	883		162	385	552
	10-20-5-5S		113	1177		162	385	163
	10-20-5-5S	130		1177		162	385	146

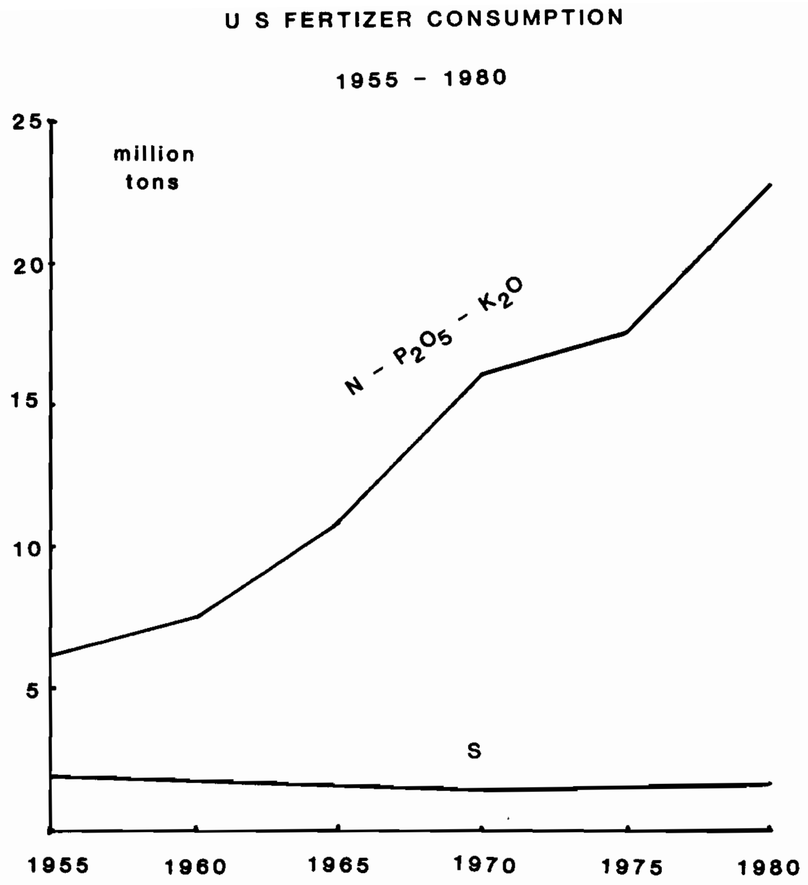


Figure 1

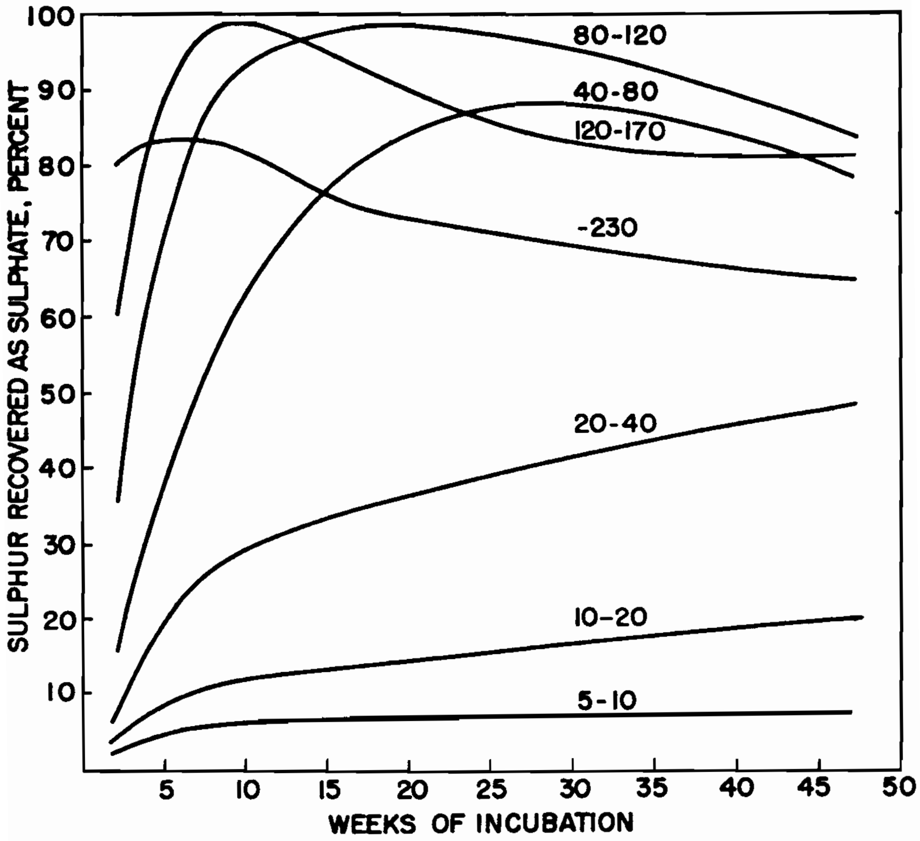
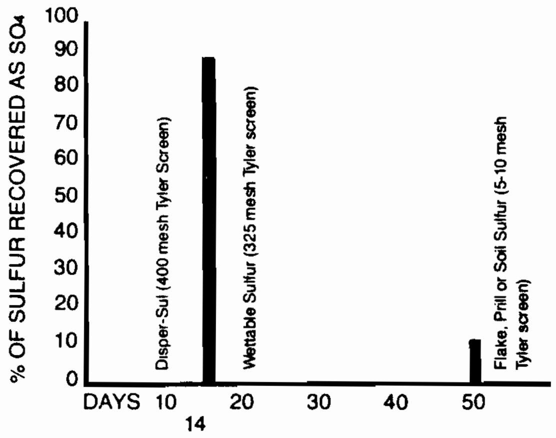


Figure 2



EFFECT OF PARTICLE SIZE ON OXIDATION OF ELEMENTAL SULFUR IN A SILT LOAM AFTER TWO WEEKS*

Figure 3

MODERATOR BROWN: Thank you, Dr. Fisher. (Applause) We will entertain, at this time, any questions that you might wish to ask. All oif our Speakers this afternoon are coming to the table platform. They are Keith A. Erney, William A. Whitmore, Peter D. Shoemaker, Everett McBribe, G. Waddy Garrett and Flake L. Fisher. Again thanks to all of you for your "Panel Presentations" covering "Fluid Fertilizers" Processing Economics, Phosphoric Acid Systems, MAP Suspension Systems, Future of Fluid Fertilizers and Physical and Chemical Properties of Sulfur Containing materials for Soil Addition and Fertilizer Formulations. (Applause)

QUESTION— BILL ADAMS - Alliance Fertilizer Co.: This is directed to Bill Whitmire. What is the average power load on the 50 HP motor?

BILL WHITMIRE: As I recall, the motor was pulling 95% of its rated average which suggests that it was more or less fully loaded.

QUESTION— FRANK P. ACHORN - TVA: In previous discussions we have heard that the ratio of plant nutrients consumed in the U.S. has shifted from 1-1-1, fifteen years ago, to a 3-1-1 this year and will possibly go to a higher ratio in the future. Do you look, in the future, for the ratio of plant nutrients consumed in the U.S. to increase in nitrogen and decrease in P_2O_5?

WADDY GARRETT: I feel the use of P_2O_5 has decreased because of the work we have done on placing the P_2O_5 correctly and the use of soil samplings in prescription analysis fertilizers. Both of those factors enable us to put down a P_2O_5 that is more closely related to the crop requirements, and is placed where the crop needs it. However, our best farmers are not cutting back on P_2O_5, if you will look at a long term trend. They did cut back on P_2O_5 from 1980 to 1981 because of a drought in 1980, less money available for fertilizers and an adequate carry over of P_2O_5. A long term trend in my area is that our good farmers are using more P_2O_5 today than they were five years ago. Now, that is not true of the marginal farmers. Unfortunately, we have government practices and policies that have kept some marginal farmers in business, and they are taking up some of our land that good farmers should be farming, so, that is clouding the issue a little bit.

MODERATOR BROWN: Does anybody else care to comment?

ANSWER— PETE SHOEMAKER: I agree with Waddy, in the sense that the soil tests and the crop being grown will determine the ratio of the nutrients. We have had probably a 15% decrease in P_2O_5 sales in a relatively stable sales area. We anticipate another five to ten percent decrease in 1983, but, basically, it's because of the economics of the crop rather than the fact that the farmer is deliberately cutting back. He is mining the nutrients that we have helped him build in his soil for ten years. There comes a time when he's got to recognize that he is cutting his yields each time he fails to replenish the amount of nutrients in that soil. So, I think the only answer is to test better, to determine what nutrients those crops need more intelligently, and have the farmer then put those nutrients on that will give him the fertility his soil will support and that the crop yield can justify.

MODERATOR BROWN: Keith Erney - can you add anything to that?

ANSWER—KEITH ERNEY: I think we will see a return to placement of product and use of product, particularly N. When the fertilizer industry becomes profitable again and fertilizer prices go up, the farmer is going to utilize his product more efficiently. We all know that ammonia is too cheap, P_2O_5 is too cheap, and all of our products are too cheap. So, when these products do increase in price, I think we are going to see a lot of changes in the utilization of our products, not only in phosphates, but in nitrogen. I see it already in Indiana a return to the practice of sidedressing our corn again to get better utilization of nitrogen. That's going to be a big change.

ANOTHER ANSWER FROM THE AUDIENCE: I think, from a academic standpoint, we have overphosphated many soils. Basically, we are not bringing new soils into production so we are not going to be building nutrients, we are more nearly at a maintenance level for phosphorus than we have been in the past. There will be increased use of phosphates, but it will be because the total productivity of all soils are going to be pushed up. The ratio of N, P_2O_5 and K, will continue to change in that there will be less phosphorus relative to N and K. But I think the total net effect will be an increase. Use of suspensions and liquids, and the ease with which farmers can put this out closer to the time the product is needed, will again improve the efficiency of phosphorus and may have a very dramatic effect on the total phosphate being used.

MODERATOR BROWN: Anybody else like to add to that?

QUESTION—CHARLES H. DAVIS: How much influence, gentlemen, do universities have on recommending NPK ratios today? Is your sales force more influential than your university in your local areas?

ANSWER—EVERETT McBRIDE: In the state of Georgia, our sales force had to compete against the state extension service for the last twelve months, because the service assumed at the start of the year that the farmers did not have money to buy fertilizer. They just recommended a cutback and placement of a nominal amount of fertilizer to get by this year. I think their motto was "get by in '82 and servive until '83".

MODERATOR BROWN: I have had the same reaction from other states. Any other comments?

QUESTION—*(apparently too far away from the mike to hear name)*: Panel, do you have some interesting data on sulfur?

ANSWER—FLAKE FISHER: At the Extension Industrial Workshop that's going on right now in St. Louis, sponsored by the Potash/Phosphate Institute and the Industrial Agronomists, a speaker reported that while Iowa did not recommend the use of sulfur, in the last five years, sulfur sales have gone from 5,000 tons to over 37,000 tons in the state of Iowa. So, I think that says the sales people are doing something.

QUESTION—BUD BALAY - T.V.A.: I would like to ask Everett McBride if he makes or uses a base grade from MAP and, if so, what that base grade is? I would also like to ask Keith Erny what methods and equipment are used to ammoniate spent acid and ortho phosphoric acid?

ANSWER—EVERETT McBRIDE: I have made anywhere from 11-34-0 to 9-27-0. Without a cooling tower you lose too much as solids in storage. I do not plan to make anymore base grades until I can put in a cooling tower. Since we are now doing most of the spreading, we can schedule production of MAP, ammonia and potash mixes for immediate distribution to the field.

ANSWER—KEITH ERNEY: Bud, maybe I didn't make clear how we use 54% phodphoric acid and spent phosphoric acid. Through the T reactor, using super phosphoric acid, we make about 50 percent of the 10-34-0. The other 50 percent is from 54% phosphoric or spent phosphoric acid added directly to the system, and neutralized with ammonia. It's all in the process at the same time. It is really a matter of raising the pH with the ammonia. Now, when we make a suspension out of spent acid or 54% acid, then we use strictly aqua ammonia to neutralize our product.

QUESTION—BUD DALAY: You are putting the spent acid or the Ortho acid into the pipe with the super acid?

ANSWER—KEITH ERNEY: That's right. Yes, sir.

QUESTION—BUD BALAY: What polyphosphate content do you get when you do that?

ANSWER—KEITH ERNEY: Naturally, you will lose some amount of polyphosphate. If we are obtaining 50 percent P_2O_5 from 54% acid, the product will be 40 to 45 percent poly. That's the reason it's not going to store very long. However, there are people now who are taking 54% adid, clay, and ammonia and making a 10-30-0 in a suspension base product. The advantage to that, of course, is the lower P_2O_5 cost. It is being done very successfully.

QUESTION—BUD BALAY: Do you have any plugging in your pipe reactor?

ANSWER—KEITH ERNEY: Yes. I did not mention that today. It's one of the problems, of course, of the T reactor. We get 18 cars through a pipe before we have to clean it. I don't think anybody has solved this problem yet, on how you unplug this T reactor. The build-up in the T reactor *is* something you live with. Every 18 cars, you tear it out and clean it up, because it will eventually plug, and then you lose the heat. When you lose the heat in the pipe, you lose the polys.

MODERATOR BROWN: Very good. This is the type of discussion we want. If anybody else has a question, we would be glad to entertain it at this time.

QUESTION—SUBODH MUKHERJEE - formerly of FERTILIZER CORPORATION OF INDIA: Dr. Fisher showed many sources of sulfur except the one on which I had some query (gypsum). Is gypsum as a source of sulfur agronomically as effective as some other sources. If so, what are the disadvantages of using gypsum?

ANSWER—FLAKE FISHER: Gypsom is a viable source of sulfur. It is one that has been used, and will continue to be used, but the transportation cost of an 18 or 16 percent sulfur material is going to limit its use.

QUESTION—SUBODH MUKHERJEE: Regarding the suspension fertilizers, are the recommendations that you are making to the farmers based on your own science data or from the University or maybe an analysis of both?

PETE SHOEMAKER: The state universities test only for NPK in Virginia. Private laboratories will also test for zinc, sulfur, magnesium, copper and iron deficiencies. Since we base our fertility program on total needs of the crop, we use private laboratories. We base our recommendation on the laboratory recommendation, modified for local conditions or for the farmer's particular needs. Perhaps he cannot afford or doesn't want to accept 60 lbs. of sulfur per acre; we would then cut back to perhaps 30 lbs. for two consecutive years. We will do this type of adaptation depending on his economic condition. Basically, our program involves complete fertility, as recommended by the laboratory and modified by us.

ANSWER—WADDY GARRETT: We primarily use private laboratories to analyze our soil samples. Generally, those samples are taken by my people. We will analyze, or have the laboratory analyze, for phosphate, potash, sulfur and most micronutrients. The things that are taken into consideration, when we make the recommendation, is the soil structure, the management talents of that farmer, the ability of that farmer to pay, whether he has irrigation or not. All of these local factors influence our total recommendation package, but we go beyond just a recommendation of quantity. We also say when the fertilizer is to be applied (whether it is to be applied in the spring or fall), and how it is to be applied (whether it is to be broadcast, banded, knifed in, put on every six months, or put on after the corn is planted). Then we follow it up with checks in the field — tissue tests of that crop, yields checks with our own weigh wagon, and our own test plots that we conduct ourself. We verify what we have recommended so that next year, hopefully, we can do a better job.

QUESTION—TRAVIS HIGNETT, I.F.D.C.: I understand that sulfur is a necessary nutrient and also a good soil amendment on alkaline soils. I wonder, in fact, how much sulfur is used as a nutrient and how much is used as soil amendment? What is the basis for recommendations for soil amendments?

ANSWER—FLAKE FISHER: Basically, I think you have asked for a semester course in sulfur soil fertility. All too often, we have heard the statement, don't ever apply sulfur when you need lime, you are already too acidic. The one slide I showed on alfalfa production, we had the maximum benefit out of sulfur was when you had to add lime, phosphate, potash and sulfur. Now, sulfur was added as a soil nutrient but may also have been of some benefit for pesticidal control. My feeling is that your question cannot be answered totally in terms of how much of the sulfur is used for each function. I think the thing we have to do is recognize that sulfur does function uniquely in the four or five areas that I mentioned; therefore, when you put it out, you have to put enough to accomplish the desired functions. Another illustration is like work of Dr. David Widhouse of North Carolina, on costal Bermuda grass. For four years he used an 8:1 nitrogen/sulfur application rate. When he decreased that ratio to the next four years to 4:1 he increased his yield and protein quality. You do not need 1 lb. of sulfur for every four lbs. of nitrogen, from a nutrient standpoint so what was the function of the extra sulfur? I guess it was soil amendment benefits. He was on an acid soil having to lime.

MODERATOR BROWN: Very good. I must call an end to this. I want to thank the audience for their participation and particularly the panel. Frank does have a few more announcements to make, but first — let us show our appreciation for the panel's efforts. (Applause)

CHAIRMAN ACHORN: Gentlemen, we really want to thank you. I hope we continue to have these type of discussions. Tomorrow is going to be devoted primarily to processes for phosphoric acid production, and, Dave Leyshon has an excellent group that's going to give us the latest technology on that. Tonight in the Atlanta Room, we are going to have a Cocktail party and everybody is invited. (Applause)

Enjoy yourselves. I will see you tomorrow norning at 8:30. (Applause)

Thursday, October 28, 1982

Final Session
Moderators:
Paul J. Prosser Jr. - David W. Leyshon

MODERATOR PROSSER: Good Morning. I will first read the "Financial Report". (Applause)

FINANCIAL STATEMENT

October 29, 1981 to October 22, 1982

CASH BALANCE — October 29, 1981		$12,377.96
Income October 29, 1981 - October 22, 1982		
Registration Fees — 1981 Meeting	$14,386.00	
Sale of Proceedings	1,202.17	
Contribution - Cocktail Party Fund	150.00	
Total Receipts October 29, 1981 to October 22, 1982		$15,738.17
Total Funds Available October 29, 1981 — October 22, 1982		$28,116.13
Disbursements October 29, 1981 to October 22, 1982		
1981 Meeting Expenses	$ 2,136.14	
1981 Proceedings including postage, etc.	22.16	
Miscellaneous Expenses including postage, stationery, Etc.	410.68	
Directors Meetings	1,016.26	
1982 Meeting — Preliminary Expenses	1,188.01	
Disbursement Cocktail Party Fund	224.57	
Total Disbursements October 29, 1981 to October 22, 1982		$4,997.82
CASH BALANCE — October 22, 1982		$23,118.31
Less Reserve for Cocktail Party Fund		223.46
Total Cash Available October 22, 1982		$22,894.85

Respectfully submitted,

PAUL J. PROSSER, JR.
Secretary-Treasurer

The major expense of the year, the payment for the 1981 Proceedings, has not been made. We have reserved $13,000.00 to apply on the final invoice. We expect to receive and mail the 1981 Proceeding within several weeks. Are there any questions about The Financial Status? (Applause)

I will proceed with "Our Business Meeting" and call on Tom Athey to give us the information on "his final arrangements" covering next year's 1983 Meeting. Tom please. (Applause)

Meeting Place and Dates Committee

Tom Athey, Chairman

Thanks Paul. As you know, each year, we have been going between Washington, D.C. and Atlanta, Georgia. Our 1983 (33rd Annual Meeting) will be held at The Shoreham Hotel, Washington, D.C. — October 25-26-27, 1983.

Moderator Paul Prosser: Thank you Tom. (Applause) Our Board and Officers have discussed the possibility of having "Our 1984 — 34th Annual Meeting" in Baltimore. Tom Athey has had several discussions with the Management of The Hyatt Hotel. They will be very happy to have us and they gave us tentative meeting dates for Tuesday, Wednesday and Thursday — during the last week in October, 1984. Tom Athey will report complete details for our 1984 Meeting when he gives us his report in Washington during our 1983 Meeting.

MODERATOR PROSSER: Tom Athey is also Chairman of "Our Entertainment Committee". Tom, please.

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. We also thank "The Hotel Management" for a magnificent well done job. All of us enjoyed the get-to-gether very much. (Applause)

HOSTS

ATLANTA UTILITY WORKS
BECHTEL, INC.
BIRD MACHINE COMPANY, INC.
COMMONWEALTH LABORATORIES, INC.
DAVY McKEE CORP.
FEECO INTERNATIONAL, INC.
FESCO, INC.
J&H EQUIPMENT CO.
JACOBS-DORRCO DIVISION
KIERNAN-GREGORY CORP.
PETROCHEMICALS COMPANY, INC.
THE PROSSER COMPANY, INC.
RENNEBERG INTERNATIONAL, INC.
THE A. J. SACKETT & SONS CO.
STEDMAN FOUNDRY AND MACHINE CO. INC.
UREA TECHNOLOGIES, INC.
D. M. WEATHERLY COMPANY

MODERATOR PROSSER: Thank you again Tom. You and our Hosts did a magnificent job organizing and arrangements made with The Hotel, etc., etc. (Applause)

Next we have Walter Sackett, Jr. Walter is President of A.J. Sackett & Sons Co. He is Chairman of our Public Relations Committee. Walter, please. (Applause)

Public Relations Committee

Walter J. Sackett, Jr., Chairman

Thank you Paul. I will make my remarks brief. We advertised, as usual this year, in the two magazines I feel give us the most exposure, *Farm Chemicals* and *Fertilizer Progress* at a cost of about $600.00. Every couple of years, I let you know which magazines we are contacting about "our Meeting Dates". I do this just in case someone has a magazine or periodical that should be contacted.

We are presently contacting the following publications:

Agr. Chem. Age - San Francisco, Cal.
Chem. & Engineering News - Washington, D.C.
Fertilizer Progress - Washington, D.C.
Sulfur Institute - Washington, D.C.
Chemical Proc. - Chicago, Ill.
Farm Supplies - Mt. Morris, N.J.
Chem. Proc. Dev. - Northbrook, Ill.
Fertilizer Solutions - Peoria, Ill.
Farm Store Merchandising - Minneapolis
Chem. Engineering - New York, N.Y.
Chem. Engineering Prog. - New York, N.Y.
Chem. Marketing Reporter - New York, N.Y.
Chem. Week - New York, N.Y.
The New Agriculral - White Plains, N.Y.
Farm Chemicals - Willoughby, Ohio
Ag. Chem. News Letter - Minneapolis, Minn.
Fert. & Ag. Chemicals Digest - Lincoln, Neb.
New Agriculture - Minneapolis, Minn.
Fertilizer Inst. of Ontario - Mississauga, Ont.
The British Sulphur Corp. - London, England
Fertilizer International - London, England
The Fertilizer Assoc. of India - Delhi, India
I.S.M.A. News Letter - Paris, France

Plaque Presentation To Frank Achorn, *Chairman* Our Round Table 1981-1982

by Walter Sackett, Jr.

Frank please come to the platform. (Much Applause!)

Frank is coming to the end of his "Reign" after serving two years as "Chairman of Our Board of Directors." I would like to present a "Plaque" to Frank in Commemoration for and Appreciation of his Dedicated Service to our Association". Frank has done one beautiful job and there is no doubt about this. (Applause)

CHAIRMAN ACHORN: Thanks to all of you for this "Beautiful Plaque". I really feel like I should give this to our Executive Council and our Board of Directors who have shared much of the responsibilities running Our Round Table. This does not mean the end of my effort with the Round Table. I think we need a good "Technical Group" in this country that speaks strictly to "Technology". Again I thank all of you for helping me. I will be seeing you. (Applause)

MODERATOR WALTER SACKETT, JR: Thank you Frank. (Much Applause) I would like to take this opportunity to Welcome Harold Blenkhorn as our New Chairman of our Board and to pledge our complete cooperation in making his two year (1983-1984 Chairmanship) pleasant and fruitful. (Applause)

MODERATOR PROSSER: I have several items I wish to discuss before we start with our nominations. The attendance at this meeting, presently, is approximately 258. As you will recall, in the last few years, we have been in the middle 300 part. We felt that this year it would be difficult to have a full attendance because difficult times in the fertilizer business. I congratulate and thank all of you for your special efforts resulting in a good attendance at this meeting. (Applause)

It is my pleasure to call on Director, Joseph E. Reynolds, Jr. to come to the platform. Joe has been a member of our Nominating Committee for many years. Our Board has very happily appointed Joe "Chairman of this Committee." (Applause)

Nominating Committee Report

Chairman Joseph E. Reynolds, Jr.

Thank you Paul. For the first time, that I can remember, someone other than Wayne King is up here chairing this Committee. I will do my best, with "our Committee", to keep "Our Round Table" moving along with the "Excellent Leadership" we have had in the past.

As has already been indicated we do have a "new Chairman" coming in for a two year term. Automatically our Vice-Chairman, Harold Blenkhorn, takes over the Chairmanship. (Applause)

We do have a vacancy for "Vice-Chairman". Our Nominating Committee places Director John Medbery's name before you. John is with I.M.C. Corporation. He is "Director of Operations and Production".

Are there other nominations from the floor?

Voices from "the floor". We move nominations for Vice-President be closed. We have all "Ays" for John. (Applause)

John Medbery you are our Vice Chairman for 1983-1984. We congratulate you. You will have our cooperation. (Applause)

NOMINATING COMMITTEE CHAIRMAN JOE REYNOLDS: We now have the sequence of "our organization" all lined up. As far as other nominations, or any other business in this area, we are going to hold off on the further structure of "our Board". If you have any suggestions, please let us hear from you. Our "Programs" are a combination of "Suggestions" from you. Next year we will have some people come before you for nominations to our Board. Thank you. (Applause)

MODERATOR PROSSER: I think we have just about come to the conclusion of our Business Session. I would like to have Frank Achorn come up here to present to you our new Chairman — Harold D. Blenkhorn. (Applause)

(Much Applause): Frank Achorn and Harold D. Blenkhorn are coming to the platform.

CHAIRMAN ACHORN: It is indeed my pleasure to present to you a Gentlemen, I am sure, will have much credibility and distinction to our Board. He always has the right thing to say at the right time. Harold I am looking forward to your "leadership". Good Luck and Congratulations from all of us. (Applause)

CHAIRMAN ELECT BLENKHORN: Gentlemen: I do not have very much by way of an inaugural address. I would regard my first duty to thank Frank Achorn for his service to our Round Table in the past and his enthusiastic leadership during his term as Chairman. This is not to imply that we are going to expect any less from him in the future. Past Chairmen of our Round Table remain on the Executive Committee. I expect Frank's presence, as in the past, to be heard at all times. I regard the Chairmanship of this organization an Honor and a Challenge. I shall do my very best. Thank you. (Applause)

MODERATOR PROSSER: Our final program this morning covers "Phosphate Technology". This is going to be very appropriately handled by our Director David W. Leyshon, Technical Manager, Jacobs-Dorroco Division Lakewood, Florida, well known in "Phosphate Circles". Dave, it is all yours. (Applause)

MODERATOR LEYSHON: Thank you Paul. Frank Achorn has his hand up and wishes to have several minutes to report that Director Pete Cox has a "Resolution" he was asked to prepare "Honoring our departed Friend, Wayne King". (Applause)

CHAIRMAN ACHORN: I would like to mention that Pete Cox's "powers of self-expression" are well known. Certainly, we could not have chosen anyone better to write this "Resolution". Thank you Pete. (Applause)

PETE COX - Edwin Cox Association: Gentlemen you have Wayne King alluded to. It's my privelege to be asked, by Frank to write a resolution which I would like to put before you and move to adoption. (Applause) Editing note: You will find this resolution on the first sheet of these proceedings.

MODERATOR PROSSER - MODERATOR LEYSHON: You now have the platform. (Applause)

MODERATOR LEYSHON: The last time I Chaired, one of these Sessions, we ran two Discussions into the afternoon! Obviously it is not going to be possible to do that today! That is possibly why I was given ble to do that today! That is possibly why I was given this Thursday Morning Session! However, I would like to think, that those of us that put this part of the Program together, have some of the best "Papers" to preto you this morning. We hope you hang on with us. I would like to limit each paper , each presentation, to about 20 minutes, so that we have a few minutes for questions after each discussion rather than at the end of our Meeting. I would also like to suggest: If anyone wants a copy of a paper, presented this morning, please leave your card or an address in the little basket on the registration desk. Either the Author or Jacobs Engineering will see that you get a copy. This is in case we have to limit any particular presentation. I would like to make one comment on our Meeting this year. We may have a slightly lower number of participants, however one of the aims in The Fertilizer Industry Round Table, is to make a Meeting as important internationally as possible. We are very much encouraged by the very fine international attendance at this Meeting. We note there are "Representatives" here from Australia, The U.K., Ireland, Brazil, India, Israel, South Africa, Finland, France, The Netherlands, Venezulea, Greece, Columbia, Belgium and Japan. In the past we have not had a better representation worldwide. Several of our Authors on this morning's Program are from outside the United States. We appreciate their interest in The Round Table. We hope this will enhance the reputation and status of our organization.

The first paper this morning, is a new development which has been undergoing research for several years. We are priveleged to be able to present the first public presentation on a new process for "Magnesium Removal From Phosphoric Acid". This Paper will be presented by William E. Rushton, Assistant Division Manager, Swenson Division, Whiting Corp., Harvey, Illinois. You can say that Bill is an "Oldtimer" with Swenson, having been there some 26 years and is also well known in the Fertilizer Industry. Bill, please. (Applause)

Magnesium Oxide Removal From Phosphoric Acid

William E. Rushton
William R. Erickson
Presented by William E. Rushton

The Swenson Division of Whiting Corporation, a wholly-owned subsidiary of Wheelabrator-Frye Inc., is pleased to announce that it is the exclusive, worldwide licensor of the American Pembroke, Inc. process for the removal of magnesium oxide from phosphoric acid.

This process has the capability of:

1. Removing MgO from 30% P_2O_5 phosphoric acid to levels as low as 0.05%.
2. Reducing CaO levels to virtually zero.
3. Producing a stable merchant grade phosphoric acid with very small amounts of post precipitation.
4. Removing the MgO only and leaving the phosphate values in the phosphoric acid.
5. Producing a 98% pure magnesium sulfate byproduct.
6. Extending some of the phosphate rock reserves by as much as 25%.

This process has been reviewed by three well-known, phosphate-oriented consulting engineering firms and found to be technically sound and economically viable.

The manufacturers of phosphate acid by the wet process results in an acid that contains the majority of the impurities that were found in the phosphate rock. For many years, manufacturers essentially ignored the effect of all of the impurities except for the iron and aluminum. In more recent years, considerable attention has been paid to the other impurities that are in the acid and this has been especially true of the magnesium. Many of the phosphate deposits currently mined throughout the world are quite high in magnesium. In Central Florida where phosphate rock mining has been going on for many years, most of the older deposits are being depleted, and the new deposits which are opening up in regions south of the present mining area generally are of lower quality rock. In the new deposits, significant amounts of dolomite (calcium and magnesium carbonate) have been found. Calcium is not considered a major problem in the processing of phosphate rock other than an economic problem. The magnesium content of the new deposits is considered a potential problem because during the reaction of the phosphate rock with sulfuric acid to form phosphoric acid, most of the magnesium remains in the acid.

In the production of DAP, ammonium is reacted with phosphoric acid to make a standard grade of DAP containing 18% nitrogen and 46% P_2O_5. The phosphoric acid used to manufacture DAP must be of a quality such that enough ammonia can react with phosphoric acid to maintain the 18% nitrogen. There are various factors that are used to determine the combination and level of impurities (iron, aluminum and magnesium) that can be tolerated. These impurities effectively neutralize the phosphoric acid thereby reducing the amount of ammonia that can be absorbed by the acid. Consequently, a problem occurs in that the DAP is low in nitrogen content.

Now that substantial quantities of iron, aluminum and magnesium are expected, the problem with making DAP containing 18% nitrogen is magnified. It appears that in order to make grade in DAP that the feed rock to the system should contain less than 0.6% MgO.

In the manufacture of superphosphoric acid, it has been found that high magnesium levels result in the production of an acid having a very high viscosity. This extremely high viscosity results in serious problems with pumping the fluid after it has been cooled to normal storage temperatures. In addition, the grade of the superphosphoric acid will also be lowered because of the magnesium content.

When liquid fertilizers are made from phosphoric acid containing high magnesium, the product does not store well. In a few days the magnesium precipitates causing large amounts of crystals and in effect forming a slurry.

It is apparent from the above that removal of magnesium will result in considerable advantages to the phosphoric acid manufacturer. The ability to remove magnesium significantly increases the phosphate rock reserves by allowing the miner to mine rock with high magnesium levels which are currently bypassed. The removal of magnesium will also allow easier making of grade in the manufacture of DAP and will also result in a better quality superphosphoric acid. In several cases, the viscosity of treated superphosphoric acid was reduced by a factor of 10 when compared to superphosphoric acid produced from untreated acid.

American Pembroke Inc. located in Bartow, Florida started work approximately 4 years ago on a system to remove the magnesium from low strength phosphoric acid. As a result of this work, the Folded Bed Chemical Separation Process for the removal of magnesium and calcium has been developed. Three consulting engineering firms, well known to the phosphate industry, have reviewed the process and found it to be technically sound and economically viable. A pilot plant has been in operation for the last several years and it is currently capable of treating phosphoric acid at rates of approximately 1 liter per minute.

This new magnesium removal system for phosphoric acid is basically an ion exchange system utilizing a pulsed column. The resin used in this system is a strong acid macro-porous polystyrene resin which removes the calcium and magnesium from the phosphoric acid and is later regenerated with sulfuric acid.

The pulsing of the load column and the regeneration column occurs simultaneously. A given quantity of resin is hydraulically moved into the bottom of the load and regeneration columns, and an equal amount of resin is expelled from each column. The resin is then suitably washed, treated, and regenerated in the various receivers prior to arriving in the pulse chamber ready for the next pulse.

While the resin is being treated in the receivers, raw phosphoric acid enters the top of the load column and moves countercurrent to the movement of the pulsed resin, and exits the bottom of the load column as treated acid. In a similar fashion, the regeneration sulfuric acid enters the top of the regeneration column and exits the bottom of the regeneration column after regenerating the resin.

In the load column, the calcium and magnesium ions are removed from the phosphoric acid. It should be noted that only the cations, such as magnesium, are removed; any phosphate associated with the catium is left in the phosphoric acid. This maintains a high P_2O_5 efficiency in the process.

In a typical black acid, 5-10% of the iron and aluminum present in the acid is removed; however, 20% to as high as 50% of the sodium and potassium is removed. The exact amount of these cations removed varies from acid to acid and must be determined by actual test.

The lowest level of magnesium obtainable in the product acid is about 0.02% MgO and the CaO drops to vartually zero. MgO levels in the feed acid have been tested as high as 2.3% MgO in 30% P_2O_5 phosphoric acid. Higher levels of MgO, than 2.3%, can certainly be handled; however, we have not had a reason to investigate these higher levels. Normally feed acid MgO levels of 0.8 to 1% are purified to 0.15% in the product acid. The 0.15% MgO level allows for the production of superphosphoric acid with an MgO of less than 0.4% at 70% P_2O_5 superacid. When producing DAP, this 0.15% MgO acid can be blended with untreated feed acid to obtain any level of MgO desired for the production of DAP.

We have noted that acid treated by the ion exchange system is much more stable than acid not treated, and the amount of post precipitation is significantly reduced.

Fig. 1 shows two samples of phosphoric acid concentrated from 30% to 54%. The sample on the right shows an acid before the removal of magnesium and calcium by the Folded Bed Chemical Separation Process. This sample shows considerable precipitation of solids after aging.

The sample on the left shows the same acid concentrated to 54% after treatment in the Folded Bed Chemical Separation Process. You will note that this sample shows no precipitation of solids after extended aging.

Fig. 2 illustrates a sample of the same acid concentrated to 68.5% P_2O_5. Again the sample on the right shows the effect of aging on a sample that was concentrated before treatment in the Folded Bed Chemical Separation Process.

The sample on the left shows the effect of aging on a sample that was concentrated to 68.5% P_2O_5 after treatment in the Folded Bed Chemical Separation Process.

The treated acid also results in considerably easier evaporation since virtually all of the calcium and part of the sodium and potassium have been removed, resulting in less scaling of the evaporator heat exchangers and, therefore, longer operating times between scrub days. In addition, due to the fact that nearly all of the calcium has been removed, it should be possible to reduce or eliminate 40% acid clarification.

When the phosphoric acid is contacted with regenerated resin to remove the magnesium, a small amount of dilution occurs. The amount of dilution is dependent on the amount of magnesium removed from the phosphoric acid. When the magnesium level in 30% P_2O_5 phosphoric acid is reduced from 0.9% to 0.15% MgO, the resulting product acid will be about 28% P_2O_5 concentration.

The dilution is encountered when producing an acid of 0.15% MgO, which is suitable for the manufacture of superphosphoric acid. Should a plant desire an acid for the manufacture of DAP, the 0.15% MgO acid would be blended with the feed acid to a level of say 0.6% MgO, and the effective amount of dilution would be decreased appreciably. Each plant requirement should be analyzed to determine the optium operating conditions for each case.

Temperature of the feed acid has little effect on the efficiency of the ion exchange system. In the pilot plant, the process was run at temperatures from 90°F to 160°F, with little effect on the overall kinetics of the resin loading and regeneration characteristics. Since the resin has a maximum operating temperature of 250°F, the actual limiting temperature may be set by materials of construction. This system has no temperature excursions in the process and would use the phosphoric acid at the temperature existing in the 30% storage tank.

Now that the resin has been loaded with the impurities from the phosphoric acid, it must be regenerated before it can be reused. In this process elevated concentrations of sulfuric acid, rather than the conventional dilute sulfuric acid, are used to regenerate the resin.

The use of high strength sulfuric acid has several advantages. We have found that high strength sulfuric acid prevents the fouling of the resin by organic matter present in "black" phosphoric acid. For example, the use of a 50% sulfuric acid regeneration solution would present only 1/10th the volume of spent regeneration solution as compared to the use of a 5% regeneration solution. This greatly reduces the problem of treating and disposing the spent regeneration solution waste stream. Historically, this has been a severe deterrent to the use of ion exchange systems.

Early attempts to use high strength sulfuric acid met with the problem that the solubility of calcium sulfate is very low and when the calcium leaves the resin, it forms a precipitate in the regeneration and will plug up the regeneration column. This plugging problem can be overcome by using high velocities of regeneration solution in the column, thus preventing any plugup, but then high consumption of regeneration solution is encountered and low concentrations of MgO in the regeneration solution make treatment of the spent regeneration solution, to remove the MgO, difficult.

These problems are solved, by this process, in the first stage regeneration system. In this stage, sulfuric acid is recirculated very rapidly past the resin, so that when the CaO leaves the resin and forms a precipitate, the velocity is high enough to prevent any plug-up. The precipitated calcium sulfate is then swept from the system and removed by a thickener and may be disposed of on the main gypsum filter. This system has the added advantage of washing the resin of any sand, dirt, and other insoluble components present in the feed acid.

Essentially all of the CaO is stripped from the resin in this stage and the CaO leaves the system in the settled underflow as calcium sulfate. Little if any MgO is stripped from the resin, since the MgO is very soluble in sulfuric acid, its concentration is allowed to buildup to an equilibrium concentration wherein any MgO stripped from the resin is replaced by MgO from the first stage regenerant, due to its high MgO concentration, usually about 1.5% MgO.

The resin at this point is stripped of CaO, which would cause plugging and loaded with MgO. It enters the regeneration column where it is stripped of MgO, by small quantities of high strength sulfuric acid, thus producing a spent regeneration solution of small volume and high MgO content.

When using sulfuric acid of high concentrations, special care must be taken to prevent osmotic shock and cracking of the resin. Severe cracking of the resin will occur, if a resin, which has been exposed to water is suddenly exposed to sulfuric acid of 55% concentration. However, if the resin, which has been exposed to water, then encounters a 30% sulfuric acid, before going into 55% sulfuric acid, the amount of cracking is virtually eliminated. The pilot plant has sused the same resin for over a year, under this system, with the amount of cracking too small to measure.

Having removed the impurities from the phosphoric acid and regenerated the resin, we are now faced with the age-old problem of "what do we do with the spent regeneration solution?". Fortunately, our problem, volume-wise, is only about 1/10th that which we would have had if we had used the normal 5% sulfuric acid regenerant instead of the 55% solution. However, we have a spent regeneration solution of about 35% sulfuric acid containing 1.5% MgO and very little CaO, for which we had to find a use.

We have learned that if the sulfuric acid concentration is raised to approximately 73%, the solubility of the MgO drops to about 0.2% and the MgO precipitates as magnesium sulfate. Fortunately a phosphoric acid complex uses large quantities of sulfuric acid and, therefore, concentrated sulfuric acid is available to mix with the 35% sulfuric acid to raise the spent regeneration solution to 73% sulfuric acid. This 73% sulfuric acid is then used in the attack tanks of the phosphoric acid plant to react with the phosphate rock.

This mode of operation has the following advantages:

1. Sulfuric acid consumed in the ion exchange operation is only the stiochiometric amount for the calcium and magnesium removed from the system.
2. P_2O_5 losses from the system are only the small amount lost with the calcium sulfate and magnesium sulfate streams, which are very small.

The P_2O_5 in the spent regeneration solution is returned to the attack system. As a result, the overall P_2O_5 recovery is better than 99%.

3. The small amount of magnesium in the 73% sulfuric acid returned to the attack tank, has the effect of increasing the rock MgO content by about 0.1 to 0.2%.
4. The amount of sulfuric acid used in raising the spent regeneration solution to 73% is usually 50-60% of the sulfuric acid available in the phosphate complex. This amount is considerably reduced when only a portion of the phosphoric acid is treated in the ion exchange unit. The exact amount must be determined for each individual case, since it is dependent on the quality of the feed acid and the end use of the treated acid. When the 73% sulfuric acid is blended with the remaining 93-98% sulfuric acid, the overall concentration to the attack tank is generally 78-85% H_2SO_4.

Extensive laboratory work on a computer operated prototype pilot plant has demonstrated the feasibility of the folded bed chemical separation process. Currently a 100 gpm demonstration plant is in the design phase and it is expected that this plant should be in operation next year. The laboratory and pilot plant testing have demonstrated that this process has several advantages over conventional extraction processes:

1. Minimal P_2O_5 loss — magnesium and calcium ions are removed as sulfate and not phosphate.
2. No hydrocarbon solvents are introduced into the plant.
3. Little interference with phosphoric acid production.
4. Low sulfuric acid consumption.
5. Increased evaporator capacity or availability because cleaner acid increases the interval between washouts.
6. It should be possible to reduce or eliminate 40% acid clarification.
7. A potentially saleable product, magnesium sulfate, is produced.

The folded bed chemical separation process is being marketed under an exclusive worldwide license by Wheelabrator-Frye Inc. The marketing is being handled by the Swenson Division of Whiting Corporation, a wholly-owned subsidiary of Wheelabrator-Frye.

FIGURE I - 54% P_2O_5

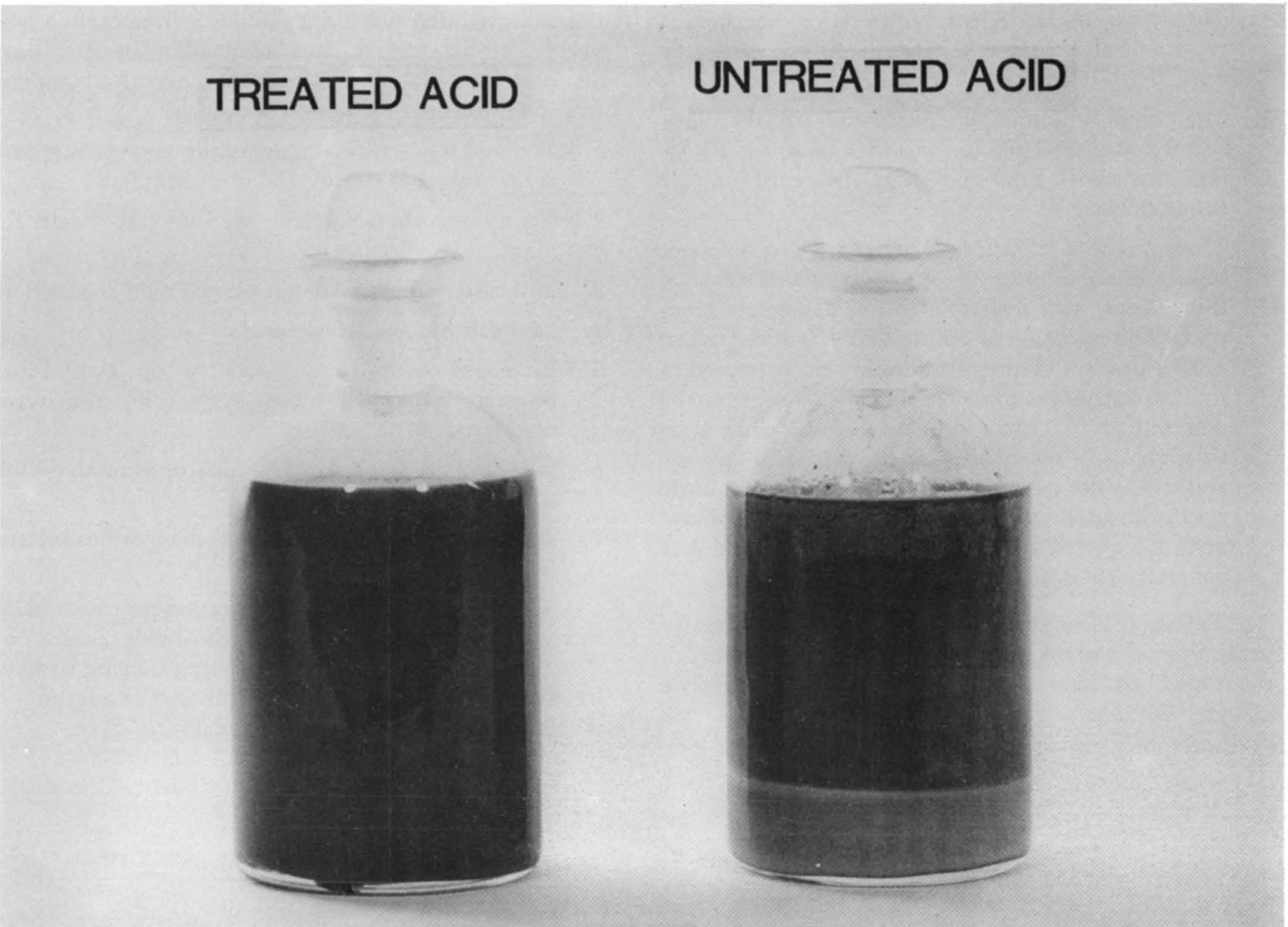
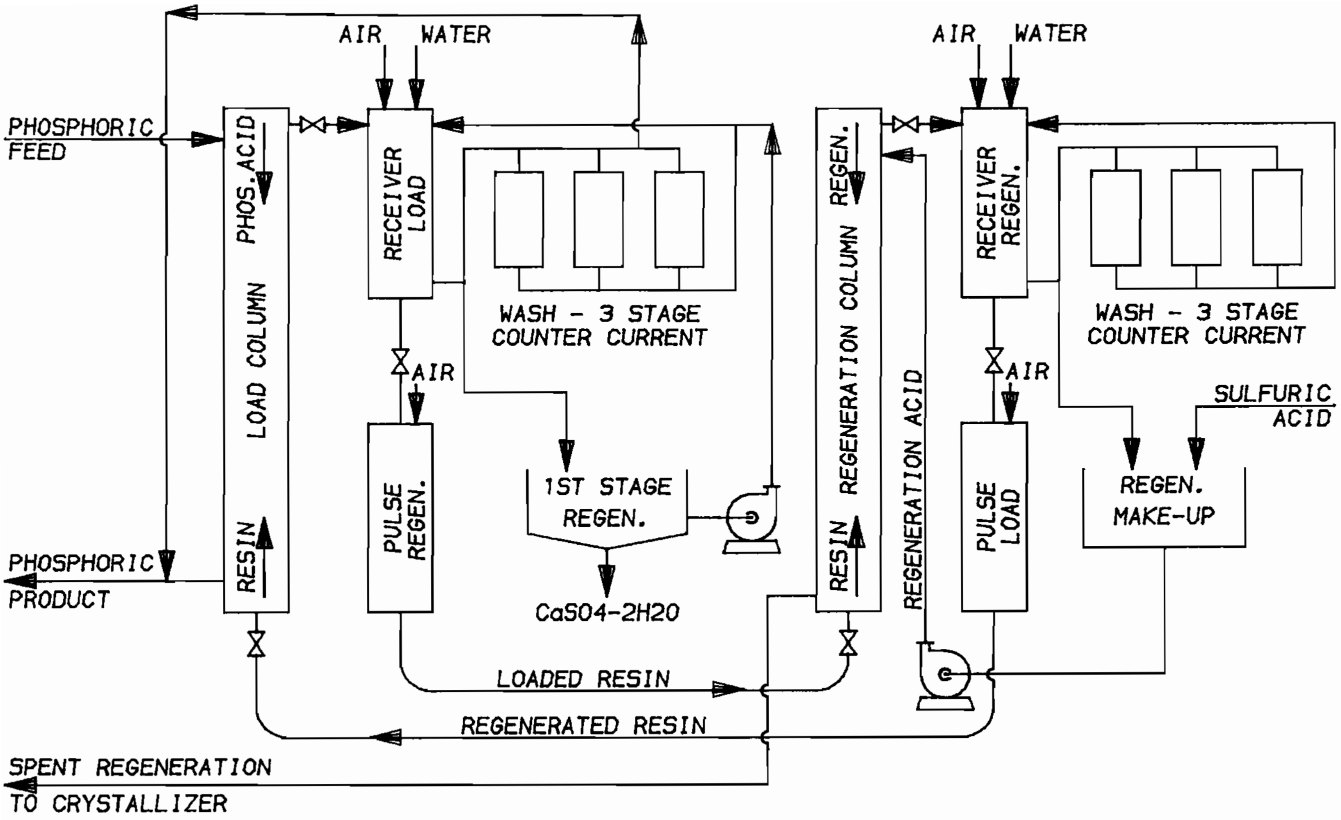
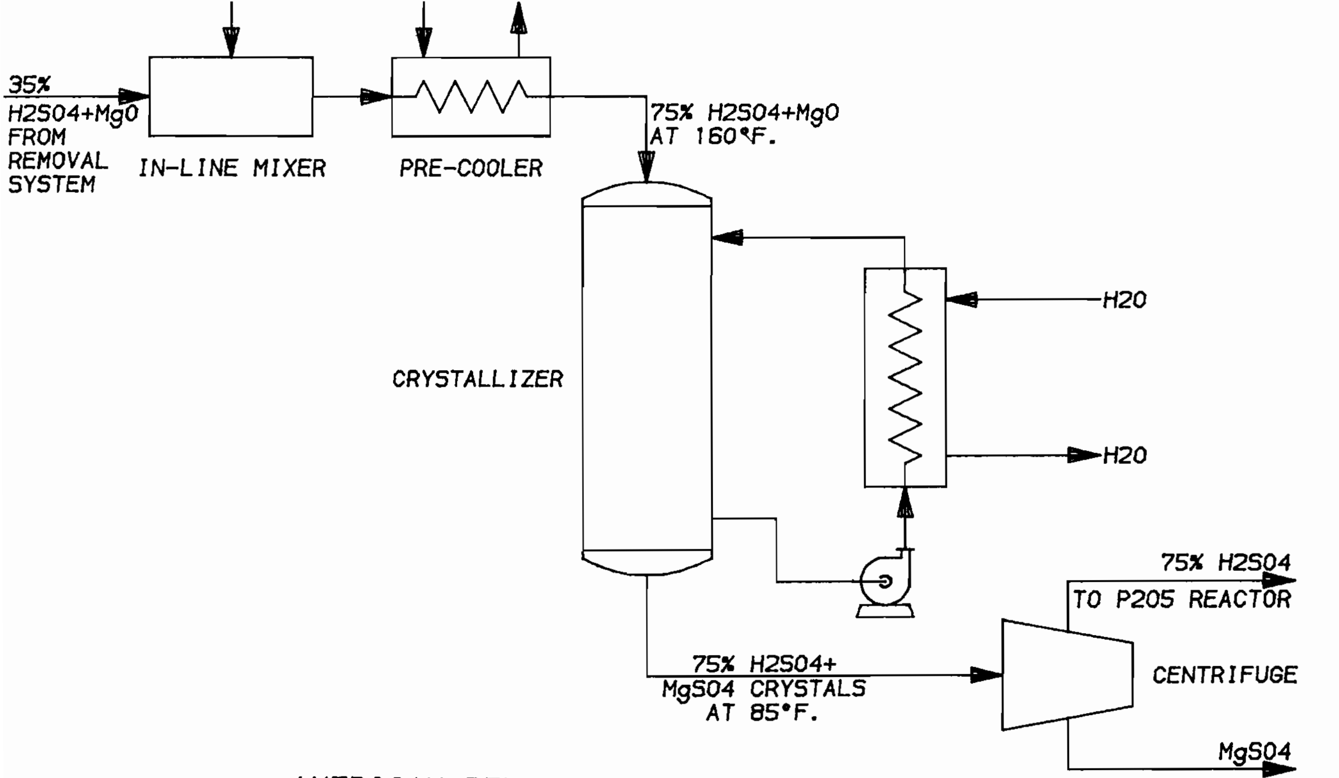


FIGURE II 69.5% P_2O_5



AMERICAN PEMBROKE FOLDED BED PROCESS

Figure 3



AMERICAN PEMBROKE CRYSTALLIZER SECTION

Figure 4

MODERATOR LEYSHON: Thank you Bill. (Applause)

We have time for a couple of questions.

QUESTIONS FROM THE AUDIENCE: Does the phosphoric acid have to be treated, in any manner, before coming to the process?

BILL RUSHTON: No, the phosphoric acid we would expect to take into the process would be typically the same acid that you would have for feeding the evaporators. It would just go through the process before being fed into the evaporators.

QUESTION FROM DOUG MYERS, TVA: Will this process remove any of the heavy metals from the phosphoric acid like uranium?

BILL RUSHTON: As far as I know there is none. It is simply the lower valence-ions removed.

MODERATOR LEYSHON: If we finish on time we may have the opportunity to have more questions. Thank you, Bill. (Applause)

MODERATOR LEYSHON: Our next paper will be by Barry Crozier of Norske Hydro Fertilizer Limited, Felixstove, Suffolk, United Kingdom. "Fisons Hemihydrate Process — A Decade of Energy Savings". That is a new organization for Barry. He is actually out of "The Fisons Licensing and Consulting Division". Barry will describe the latest information available on the "Fisons Hemihydrate Processes". Some seven plants have been installed worldwide, using this process, which promises to improve the energy relationships in the production of phosphoric acid and represents "new technology". We would like to welcome Barry. (Applause)

Fison's Hemihydrate Process
A Decade of Energy Savings

Barry Crozier

Summary

This paper describes the energy savings in phosphoric acid production achieved in commercial hemihydrate plants over the last ten years.

A review of the production cost structure for a hemihydrate and a dihydrate plant is given. Data shows that the price of steam has risen by a factor of 12 between 1971 and 1981, and as a result the proportion of the production cost attributed to steam has risen dramatically for a dihydrate plant because steam is used in the acid concentration step. Consequently the use of a hemihydrate plant which avoids this steam usage can give savings of almost 7% of operating cost compared to that of a conventional dihydrate process.

Full scale plant experience with the hemidihydrate process has demonstrated that the improved P_2O_5 recovery efficiency of approximately 98% can be combined with energy savings to reduce the operating costs by over 10% relative to the dihydrate process. For the case of a phosphate acid plant at a USA mine site location a cost reduction of over US $22 per ton P_2O_5 produced can be achieved with a hemidihydrate plant compared to a dihydrate plant.

Introduction

The first hemihydrate process plant from Fisons Fertilizers began operation in 1970 at Windmill Holland BV. Since that time, commercial and production factors have changed putting new demands on the fertilizer industry. particularly, the substantial increases in the prices of raw materials and energy have influenced the production costs of phosphoric acid. A review of the effect of these price increases shows that the proportion of the total production cost contributed by energy has risen at a higher rate than any other item.

This paper examines the production cost structure of phosphoric acid in 1971 and 1981 using data from an operating hemihydrate plant and a conventional dihydrate plant. The increasing importance of the energy saving features of the hemihydrate process is highlighted.

During the last decade the hemihydrate process from Fisons Fertilizers has also become established in commercial operation. It has been demonstrated with a variety of phosphate rocks that the substantial energy saving inherent in the technology can be combined with an improved P_2O_5 recovery efficiency. Raw material and utility consumption data is given for the use of 68 BPL Florida phosphate. Typical production costs at a mine site location are compared with those for a dihydrate plant.

Also considered in the paper are the energy savings achievable in rock grinding and by electricity cogeneration, together with process developments such as use of low grade rock and conversion of existing dihydrate plants to hemihydrate units.

Nomenclature: The hemihydrate process is known as the HH process. The hemidihydrate process is known as the HDH process.

1. Phosphate Acid Production Cost Structure: Changes Between 1971 and 1981

Over the past ten years technical innovation and technological progress have led to changes in production, and maintenance techniques in phosphoric acid manufacture. The driving force behind these changes has been the need to reduce production costs and increase profitability. This has not been easy in a period which has seen dramatic increases in raw material and utility prices.

In order to maximise the benefits of the technology it is useful to evaluate the changes in the cost structure of phosphoric acid production since the early 1970's. Considered here is an example of a fertilizer complex utilizing imported phosphate rock and sulphuric acid. The cost and production factors are relevant to phosphoric acid producers whose plant is not located at a mine site.

To ensure a realistic evaluation, data are given for *actual* raw material and utility consumptions including the often "hidden" elements which are not covered in theoretical assessments. Consumptions are based on data from Windmill Holland BV in 1981. These consumption figures have also been related to 1971 prices to show the proportional change in the cost contribution of each item for the ten year period. The prices used for phosphate rock and sulphuric acid are world market prices, the utilities are at typical Dutch prices except for maintenance and chemicals which are actual costs.

Tables 1 and 2 provide consumptions and costs per short ton P_2O_5 produced as 50% P_2O_5 acid in 1981 and 1971 via the dihydrate and hemihydrate routes, using 72 BPL Florida phosphate. The windmill operation gives an unusual opportunity to compare processes as they operate hemihydrate (HH) and dihydrate both of approximately 100,000 tpa P_2O_5 capacity (1), (2). (For process descriptions see Appendix I).

Cost increases for the important items have been extracted from the tables and are shown pictorially in Figure 1. The data indicates that the steam cost in phosphoric acid production has increased by a factor of 12 over the past ten years for both processes.

In the dihydrate process the combined energy cost has risen by a factor of 8 compared to an increase in total operating costs of 3.5.

For the hemihydrate process the total energy cost has increased by a factor of 4.7 between 1971 and 1981 compared to a factor of 12 for the increase in steam cost and a factor of 3.4 for the increase in total operating cost.

The increase in steam cost relative to the increase in total operating costs means that the contribution of steam and other energy to the cost of manufacture of phosphoric acid has grown in significance. This can be seen clearly by comparing Figures 2 and 3.

In a dihydrate process the proportion of the operating cost attributed to steam has increased from 2% to 7% in the last ten years, whereas in the hemihydrate process the increase has been from 0.15% to 0.5%. Similarly the total energy cost in a dihydrate plant has increased from 42% to 9% over the same period compared to a rise from 1.6% to 2.3% of the operating cost of a hemihydrate plant.

Consequently a review of the raw material and utility consumptions shows that there is now a substantial saving to be made in operating cost by avoiding the steam consumption required in the concentration of wet process acid from 28% to 50% P_2O_5. Such a saving which amounts to almost 7% of operating cost can mean the difference between profit and loss.

2. *Hemidihydrate Process*

Following the successful commercial operation of the hemihydrate process, Fisons Fertilizers continued its development with the particular objective of increasing the P_2O_5 recovery efficiency whilst retaining energy savings. As a result the hemidihydrate (HDH) process was established, (for process description see Appendix 1). By adding a transformation stage, the hemihydrate filter cake can be recrystallized to dihydrate and insoluble P_2O_5 is released into solution and returned to the process. Thus the P_2O_5 recovery efficiency is increased.

The first commercial HDH plant was built in 1974, and there are now four in operation[3]. Data from full scale plant experience showing the reduction in P_2O_5 losses which can be achieved in the HDH process are given in Table 3 below.

Table 3
Insoluble P_2O_5 loss from HDH Process:
68 BPL Florida Phosphate

	% P_2O_5 in dry filter cake		
	Unreacted rock	Lattice	Total Insoluble
Hemihydrate	0.166	0.984	1.15
HDH gypsum	0.032	0.192	0.224

The P_2O_5 recovery efficiency based on the insoluble losses in the HDH gypsum above is 98.9%. As with all phosphoric acid processes there is additional water soluble loss from the filter. Typical results from commercial HDH plants using 68 BPL Florida rock shows water soluble losses of between 0.2-0.29% (of dry weight gypsum) which gives total P_2O_5 recovery efficiency of between 97.6 - 98.0%.

Full scale HDH plant operation has also led to improvements in the design and operation of the process. It has allowed Fisons Fertilizers to modify the agitation system and reduce power consumption. The use of variable speed pumps for various duties also reduces power usage.

The improved P_2O_5 recoveryefficiency of the HDH process reduces the raw material consumptions significantly so that there is an important cost saving even in the case of a mine site operation. In addition the savings in steam and other utilities offer cost benefits over a conventional dihydrate plant.

Table 4 shows consumptions for a new HDH plant design based on the use of 68 BPL Florida phosphate. The raw material usages have been taken from full scale plant experience. For comparison typical consumptions in a modern dihydrate plant are given.

Table 4
Raw material and utilities consumption for the production of 50% P_2O_5 acid.
Phosphate: 68 BPL Florida (31.6% P_2O_5, 48.8% CaO)

Item	Unit	Consumption, unit per ton P_2O_5 produced	
		HDH plant	Dihydrate plant
Phosphate rock	ton	3.242	3.349
H_2SO_4 (100%)	ton	2.579	2.8
Steam l.p.	ton	0.18	2.5
Electricity	kWh	*100	*125
Process water	1000 US gall.	1.56	1.77
Cooling water	1000 US gall.	7.2	18.5
Labour	no./shift	**3+1	**3+1
Chemicals	US$	nil	nil
Defoamer	lb.	3.5	2

* assumes rock supplied according to size specification given in Table 5, therefore grinding required for dihydrate process but not for HDH plant.

** 3 operators + 1 supervisor per shift.

It is clear from the data given previously in Tables 1 and 2 that in the case where phosphate rock and sulphuric acid are imported there are distinct cost benefits derived from the operation of a HH plant rather than a dihydrate plant. However, it is also worthwhile to consider the case of phosphoric acid production at a rock mine site where sulphuric acid is also manufactured. Normally in these circumstances raw materials are charged into the phosphoric acid plant at cost price. Steam will be provided as a by-product therefore will be cheaper than steam generated from a fossil/oil fuelled boiler.

Table 5 below shows the production costs for modern HDR and dihydrate plants based on typical prices for raw materials and utilizes at a USA mine site location.

Consumptions are as per Table 4.

(Labour costs have not been included as they would be the same in each case).

Table 5
Production costs for 50% P_2O_5 acid
from a HDH plant and a dihydrate plant
at a mine site location.
Phosphate: 68 BPL Florida (31.6% P_2O_5, 45.8% CaO)

Item	US$/Unit	Cost, US$ per ton P_2O_5 produced	
		HDH plant	Dihydrate plant
Phosphate rock	20/t	64.84	66.98
H_2SO_4 (100%)	45/t	116.1	126
Steam l.p.	4/t	0.72	10
Electricity	0.05/kWh	5	6.25
Process water	0.015/1000 US gall.	0.02	0.03
Cooling water	0.02/1000 US gall.	0.14	0.37
Defoamer	0.3/lb	1.05	0.6
Total		187.87	210.23

3. *Energy Savings*

The two most important factors contributing to the energy saving in the HH and HDH processes compared to conventional dihydrate processes are the reduced rock grinding requirement, and the low steam consumption. If a phosphoric acid plant is located next to a sulphuric acid plant, there will be byproduct steam available which could be used for acid concentration in the dihydrate route. However, if this steam is saved by using a HH or HDH plant then its value depends on the alternative uses to which it can be put, for example in other units in a large fertilizer complex, or used for electricity cogeneration. The energy saving aspects of rock grinding and electricity cogeneration are reviewed below.

Rock Grinding

Because of the design of the reaction system, the HH and HDH processes may accept a coarser phosphate than a dihydrate process. When these requirements are compared with the particle size distribution of 72 BPL Florida as supplied to consumers it can be seen that it may not be necessary to grind the phosphate prior to feeding to HH/HDH plants although it requires grinding for the dihydrate process. Details are given in Table 6.

Table 6

Tyler Sieve size (Mesh)	Aperture (Microns)	Particle Size Requirement % Through		72 BPL Florida Concentrate as received % Through
		HH/HDH Plant	DH Plant	
10	1700	100	-	-
20	830	-	-	96
32	500	75	100	87
60	250	25	95	50
100	150	-	60	12
200	75	-	30	-

The use of wet rock grinding is growing in importance and Fisons Fertilizers has tested the use of wet rock in the HH and HDH processes. It has been proven that the water balance of the HH and HDH processes can accept wet rock and still maintain high P_2O_5 recovery efficiencies. The flexibility of the HDH process particularly lends itself to this option.

In wet rock grinding energy consumption is of the order 16.5 kWh per ton rock when grinding a typical Florida concentrate for a dihydrate plant as defined above. At an electricity cost of US$0.05 per kWh this amounts to US$0.8 per ton rock or US$2.8 per ton P_2O_5 produced. The use of HH and HDH processes would lend to this level of savings in costs.

Electricity Cogeneration

Most phosphoric acid producers also manufacture sulphuric acid and are therefore able to benefit from the steam produced as a by-product from the sulphuric process. When phosphoric acid is manufactured by the conventional dihydrate process route, it is common practice for this by-product steam to be used in the evaporation stage. This operation does not normally consume all the by-product steam, the remainder can be used for electricity cogeneration.

The use of a HH/HDH plant to produce phosphoric acid will, because of its minimal steam requirement, allow electricity cogeneration to be maximised. Rising energy costs make the improved cost credit from electricity cogeneration an increasingly important factor.

The value of increased electricity cogeneration can be seen by comparing the steam availability arising from a sulphur burning sulphuric acid plant associated with a dihydrate process plant and a HH/HDH process plant.

A sulphuric acid plant will typically generate 1.1 ton steam per ton sulphuric acid, at 550 psi and 400°C. With a dihydrate plant 20 psi steam is required for concentration and it is normal practice to use a back pressure turbo alternator for electricity cogeneration with pass-out steam for P_2O_5 concentration. In a HH/HDH plant there is minimal steam usage therefore a condensing turbo alternator set can be used for electricity cogeneration. The relative outputs are given in Table 7.

Table 7
Electricity generation by back pressure and condensing turbo alternators:

Phosphoric acid production	Type of phosphoric acid plant	Sulphuric acid production	Type of turbo alternator	Output
1000 t/d P_2O_5	Dihydrate	2,700 t/d H_2SO_4	Back pressure	13.7 MW
1000 t/d P_2O_5	HH/HDH	2,700 t/d H_2SO_4	Condensing	23.7 MW

The cost credit assuming that electricity costs are US$0.05 per kWh is given in Table 8.

Table 8
Electricity cost credit associated with Dihydrate and HH/HDH Plants.

Phosphoric acid production	Type of phosphoric acid plant	Electricity Cogeneration per day	Cost Credit	
			US$ per day	US$ per ton P_2O_5
1000 t/d P_2O_5	Dihydrate	329 MWh	16,450	16.45
1000 t/d P_2O_5	HH/HDH	569 MWh	28,450	28.45

4. *Developments*

Since the first hemihydrate plant from Fisons Fertilizers was built in 1970 there have been dramatic changes in cost and operating items throughout the fertilizer business. In order to respond to these changes technology needs to develop. Because of the increase in costs of raw materials and energy it has been essential to improve recovery efficiency and reduce energy consumptions. Over this period Fisons Fertilizers has made a number of process developments with the aim of reducing raw material and energy costs. Although it is not possible to detail all of them here, a number are highlighted below.

(a) Agitator power consumption: Following developments on commercial scale plants the reactor agitator system has been improved and power consumption reduced.

(b) Reaction volume: As a result of pilot and full scale plant investigations, the reaction volume has been reduced by as much as 50% for some phosphates without impairing process performance. This has also had the effect of reducing agitator power consumption.

(c) Plant utilization: Improved maintenance procedures and materials of construction have increased the number of operating days per year and thus reduced fixed operating costs.

(d) Use of low grade phosphate rocks: As the supply of good quality phosphate rock runs out, phosphoric acid producers are having to use lower grade phosphate with its inherent problems caused by higher levels of impurities. The two appraoches to overcoming the problem are either the modify beneficiation methods to remove impurities or modify the phosphoric acid process to cope with problems. Fisons Fertilizers has concentrated its efforts on the latter course of action. Successful pilot plant trails have been carried out using a number of low grade rocks in the hemihydrate process, for example 63 BPL Florida phosphate pebble, and a phosphate deposit containing around 22% P_2O_5 and 35% silica. On the commercial scale a 63 BPL phosphate containing around 7% CO_2 has been used, as has a phosphate containing around 1000 ppm chloride.

The ability to use these low grade phosphates leads to savings in the beneficiation step and can avoid excessive transport charges because if the low grade material is available locally it will not be necessary to transport high grade rock from a distant mine.

Another feature of the HH/HDH processes is that the quality of the strong acid is higher than that of equivalent dihydrate acid. HH/HDH acid coantains less solids, SO_4 and other impurities than concentrated dihydrate acid therefore savings can be made in the clarification operation[4].

A comparison of the composition of HDH and dihydrate acids from 68 BPL Florida phosphate is given in Table 9.

Table 9

Component	Florida Phosphate, % w/w	Dihydrate Acid, % w/w	HDH Acid, % w/w
P_2O_5	31.6	50.0	50.0
SO_4	1.2	4.8	2.0
Fe_2O_3	1.18	1.77	1.78
Al_2O_3	1.4	1.76	1.49
MgO	0.45	0.65	0.67
Na_2O	0.55	0.08	0.09
K_2O	0.1	0.08	0.1
F	3.6	1.3	0.7
SiO_2	7.5	0.1	0.1
Solids	-	4.5	1.0

As the quality of phosphate rock decreases, the importance of the resulting product acid quality increases if the final fertilizer specification is to be maintained.

(e) Conversion of a Dihydrate plant to a HH/HDH plant: the change in the production cost structure and the energy savings inherent in the HH/HDH process make the use of a HH/HDH plant more cost effective for many existing dihydrate plant operators. Therefore a study has been made of the design, operation and compatibility of dihydrate plant equipment with HH/HDH technology. It has shown that there is the potential for converting an existing dihydrate plant to a HH/HDH plant, to achieve savings in operating costs. The first commercial project of this nature is now underway at Windmill Holland BV. The conversion of its dihydrate plant to a hemihydrate unit is reported elesewhere[4].

5. *Conclusions*

It has been over ten years since the first HH plant from Fisons Fertilizers started operation. Since that time the cost structure of phosphoric acid production has changed so that energy costs are now a substantial part of the operating cost. Full scale operation since 1970 has demonstrated that the energy savings of the HH process can reduce operating costs by almost 7% compared to a conventional dihydrate plant.

The HDH process which has been commercially established since 1974 combines improved P_2O_5 recovery efficiency with substantial steam economies and as a result can cut the cost of phosphoric acid production by over 10% compared to a dihydrate plant even at a mine site location, thus saving over US$ 22 per ton P_2O_5 produced at current prices.

Developments in HH/HDH technology have been made during the last decade in order to meet the changing demands of the industry. Every opportunity has been taken to reduce energy consumption, the use of low grade phosphates has been successfully investigated, and the conversion of an existing dihydrate plant to a HH plant is now underway.

Appendix I

Process Descriptions

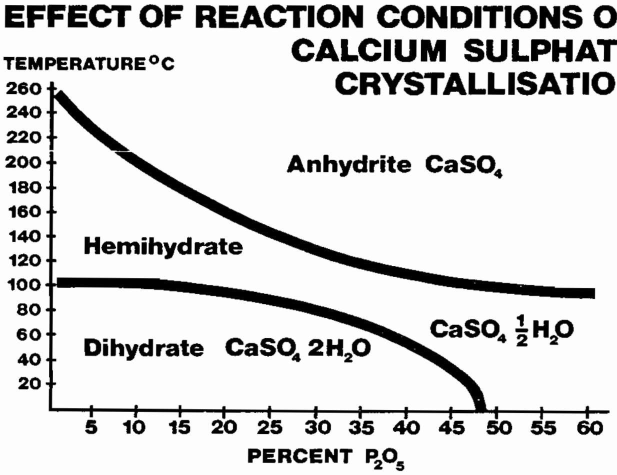
The overall chemical reaction for the production of phosphoric acid may be expressed as follows:

$$\begin{aligned} &Ca_{10}(PO4)_6F_2 \cdot CaCO_3 + 11H_2SO_4 + 11xH_2O \\ &\qquad 6H_3PO_4 + 11CaSO_4xH_2O + 2HF + CO_2 + H_2O \end{aligned}$$

where x = 0, ½ or 2 when calcium sulphate is in the form of anhydrite, hemihydrate or dihydrate respectively.

The form in which the calcium sulphate is simply dependent on the operating conditions in the reaction stage of the process which can be seen in Figure 4.

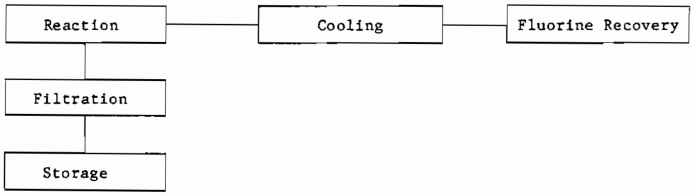
Figure 4



It is the difference in the operating temperature and phosphoric acid concentration which mainly differentiate between the hemihydrate and dihydrate processes, however, these simple differences lead to a significant reduction in energy consumption and avoid a number of unit operations when a hemihydrate process is used. Descriptions of the processes developed by Fisons Fertilizers are given below:

Hemihydrate (HH) Process[5] [6] [7]

The unit operations are:



A simple flowsheet is given in Figure 5.

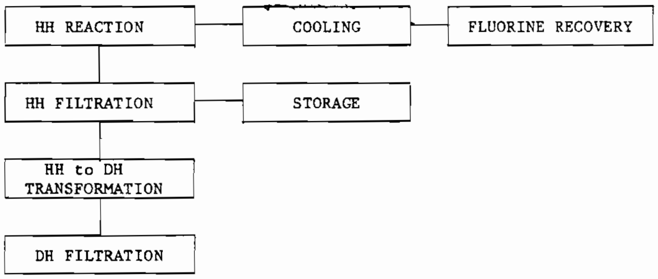
The reaction system consists of three agitated vessels or compartments, with the approximate volumetric ratio of 2:1:1. Phosphate rock is fed to reactor 1, sulphuric acid and dilute phosphoric acid ("return acid" from the filter) are fed to reactor 2. Slurry from reactor 2 is recycled to reactor 1, thus exposing the phosphate rock to sulphate ions under controlled conditions to promote the reaction. Reactor 3 is a filter feed tank, the vessel allows further time for drystal growth before filtration, and acid supersaturation is reduced.

The reaction is exothermic and it is necessary to remove heat in order to maintain the slurry temperature between 98-100°C. Cooling is normally performed by a flash cooler. Fluorine recovery or removal can be achieved by a unit installed at the flash cooler exhaust.

The product acid and hemihydrate are separated by a horizontal vacuum filter, with two or three counter current wash stages. Product acid from the filter passes directly to storage, it does not require clarification or solids removal.

Hemidihydrate (HDH) Process[8] [9] [10]

The main loss that occurs in phosphoric acid production is P_2O_5 co-precipitated in the calcium sulphate which is discharged. In the HDH process this loss is minimised by adding a second stage in which almost all of the lattice P_2O_5 is received. Unit operations are as follows:-



HH Reaction and HH Filtration

The hemihydrate operation is the same as the single stage process.

Transformation and Dihydrate Filtration

The hemihydrate cake is discharged from the first stage filter into an agitated transformation tank. In this tank the operating conditions are controlled to ensure complete transformation of hemihydrate to dihydrate and to allow sufficient time for the dihydrate crystals to grow. The rate of transformation is increased by the addition of a small quantity of sulphuric acid. The lattice P_2O_5 co-precipitated during the initial acidulation stage is released into the liquid phase.

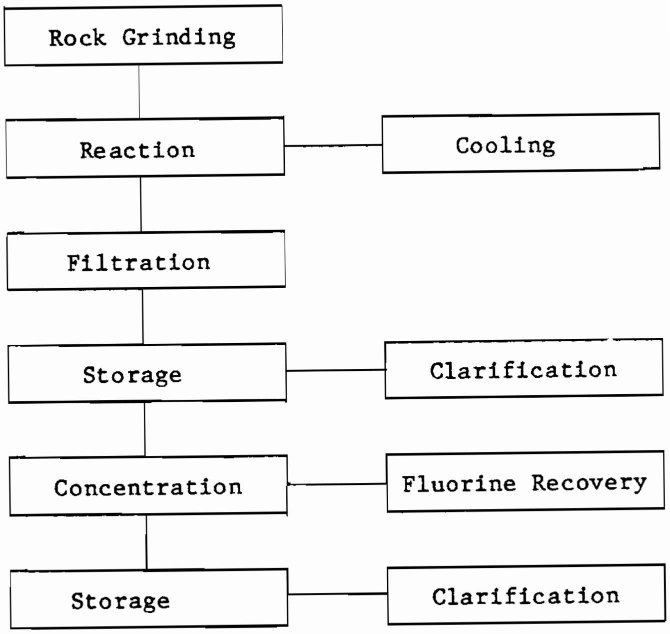
The dihydrate slurry is then filtered and the cake washed with process or pond water before being discharged. The filtrate containing the released P_2O_5 is returned to the hemihydrate reaction stage as the last wash on the hemihydrate filter.

Dihydrate filtration is rapid and can be carried out on a relatively small horizontal vacuum filter. A simple flow sheet is given in Figure 6.

Dihydrate (DH) Process

In order to demonstrate the similarities to and differences from the HH and HDH processes, details of a conventional dihydrate process are given below.

The unit operations are:



A simple flowsheet is given in Figure 7.

The reaction section consists of agitated compartments usually contained in a single vessel which is internally divided. Phosphate rock is fed to reactor 1, sulphuric acid and dilute phosphoric acid ("return acid" from the filter) are fed to reactor 3. Slurry from reactor 3 is recycled to reactor 1. Most of the reaction takes place in reactor 1 and is completed in reactor 2. Reactor 4 is a filter feed tank where the slurry matures before being pumped to the filter. Heat is removed from the reaction slurry to control the temperature between 78-80°C.

The reactor acid is separated from the dihydrate by a horizontal vacuum filter with a three stage counter current wash system.

Because the acid ex filter is usually around 28% P_2O_5, it is necessary to concentrate dihydrate acid before it can be used in most fertilizer processes. The concentration process involves acid circulation, heating and boiling, removal of the entrained acid from the released vapours, vapour condensation and vacuum control. Fluorine recovery or removal takes place from the vapours of the concentration unit. Concentration often takes place in two stages with intermediate clarification.

In most cases dihydrate acid requires clarification and solids removal prior to downstream usage. This is normally achieved by settling, centrifuging, flocculation, etc.

APPENDIX 2

PHOSPHATES USED IN COMMERCIAL FISONS FERTILIZERS HEMIHYDRATE AND HEMIDIHYDRATE PROCESS PLANTS

68 BPL Florida
72 BPL Florida
75 BPL Florida
69 BPL Morocco
70 BPL Morocco
72 BPL Morocco
73 BPL Morocco calcined
63 BPL Djebel Onk uncalcined
75 BPL Djebel Onk calcined
72 BPL Jordan
68 BPL Queensland

APPENDIX 3

OPERATORS OF COMMERCIAL SCALE HH AND HDH PLANTS FROM FISONS FERTILIZERS

CLIENT	PLANT
Windmill, Holland	Hemihydrate
HCI, Cyprus	Hemihydrate
Trepca, Yugoslavia	Hemidihydrate
A & W, UK	Hemidihydrate
CSBP, Australia	Hemidihydrate
Pivot, Australia	Hemidihydrate

REFERENCES

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(2)	Fisons Hemihydrate Process - A Decade of Energy Saving	B.T. Crozier	IFA, Greece - October 1982
(3)	Recent Experiences in Phosphoric Acid Production by Hemihydrate Routes	M.L. Parker C.R. McDonald	Fertilizer Society, London - October 1982.
(4)	Convert to the Direct Production of High Strength, High Quality Phosphoric Acid with Fisons Hemihydrate Technology	B.T. Crozier	American Chemical Society, Kansas City - September 1982
(5)	The Production of 50% P_2O_5 Phosphoric Acid directly by the Wet Process - Fisons Hemihydrate Process	N. Robinson S.M. Janikowski	ISMA, Brussels - September 1968
(6)	The Production of 50% Phosphoric Acid by the Fisons Hemihydrate Process	N. Robinson S.M. Janikowski	First Congress on Chemistry in Agriculture, Bratislava - September 1969
(7)	Single-stage Process for the production of 50% P_2O_5 Phosphoric Acid	N. Robison S.M. Janikowski	Fertilizer Society, London - December 1969
(8)	The Development of Fisons Hemihydrate Processes	B.T. Crozier	Fertilizer Round Table Atlanta - November 1978
(9)	Fisons HDH Phosphoric Acid Process, Operating Experience with a 160 tpd Plant	V. Lasovic et al	ISMA, The Hague - September 1976
(10)	Full-scale Application of the HDH Phosphoric Acid Process	H.J. Koenig E.W. Schwehr	The American Institute of Chemical Engineers, Philadelphia - June 1978

Table 1 Cost of Phosphoric Acid from a Dihydrate Plant
Phosphate: Florida (32.8% P_2O_5, 48.1% CaO)
Acid ex filter: 27.5%, concentrated to 50% P_2O_5

Item	Unit	Consumption, unit per ton P_2O_5 produced	Cost, US$ per ton P_2O_5 produced	
			1971 prices	1981 prices
Phosphate rock	*ton	3.261	44.48	207.58
H_2SO_4 (100%)	*ton	2.804	50.98	140.2
Steam	*ton	2.5	2.38	28.99
Electricity	kWh	170	2.38	9.58
Process water	1000 US gall.	1.77	1.19	4.02
Cooling water	1000 US gall.	18.5	-	-
Labour	man-hour	0.42	2.91	4.85
Chemicals	US$	-	0.42	0.85
Maintenance	US$	-	9.95	13.6
Total			114.69	409.67

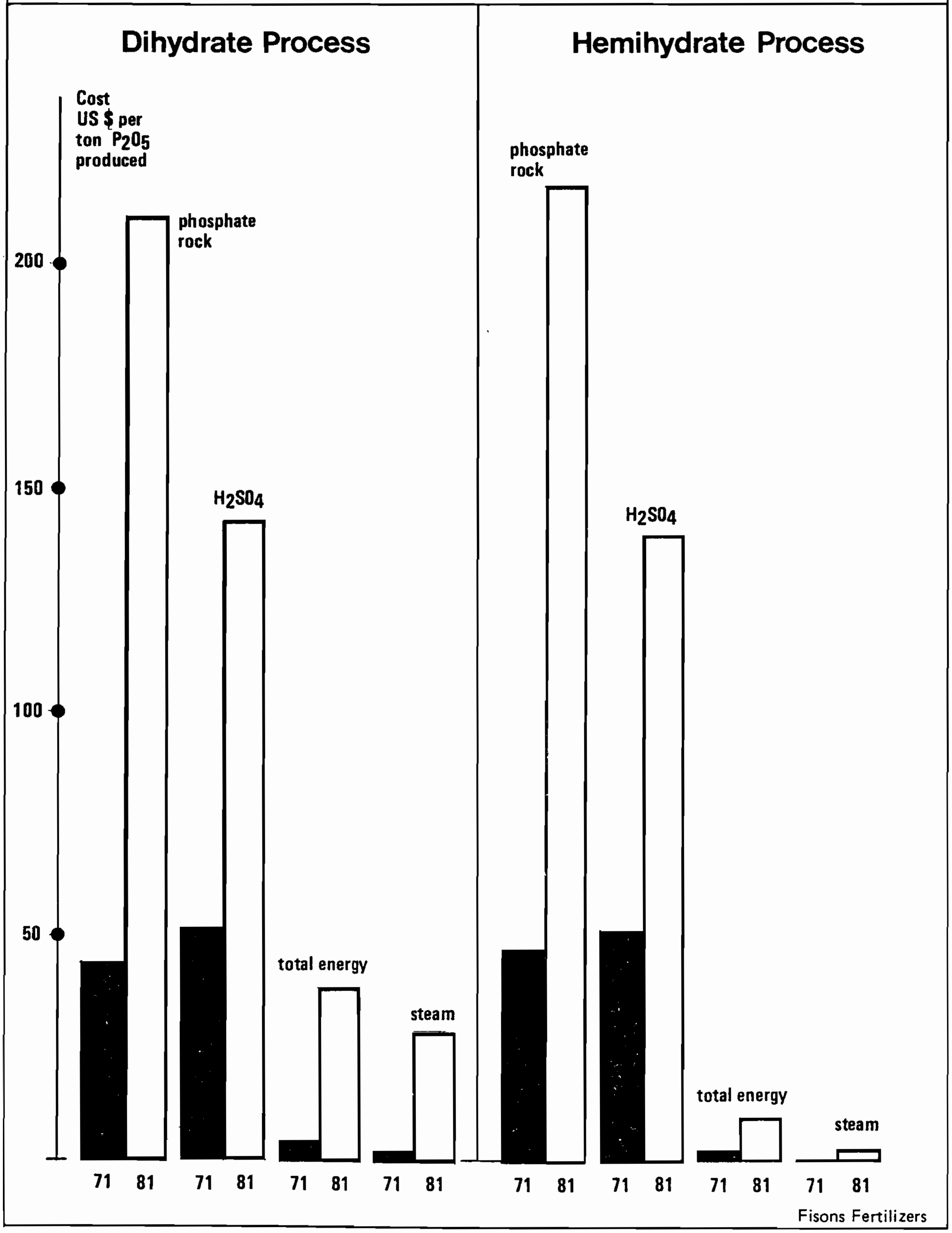
Table 2 Cost of Phosphoric Acid from a Hemihydrate Plant
Phosphate: Florida (32.8% P_2O_5, 48.1% CaO)
Acid ex filter: 50% P_2O_5

Item	Unit	Consumption, unit per ton P_2O_5 produced	Cost, US$ per ton P_2O_5 produced	
			1971 prices	1981 prices
Phosphate rock	*ton	3.369	45.95	214.4
H_2SO_4 (100%)	*ton	2.762	50.21	138.1
Steam	*ton	0.17	0.16	1.97
Electricity	kWh	125	1.76	7.05
Process water	1000 US gall.	0.85	0.57	1.92
Cooling water	1000 US gall.	10.6	-	-
Labour	man-hour	0.34	2.33	3.87
Chemicals	US$	-	5.54	5.87
Maintenance	US$	-	4.98	11.18
Total			111.5	384.36

* ton = short ton

Figure 1

Phosphoric Acid Production:
Cost of Raw Materials and Utilities 1971 and 1981



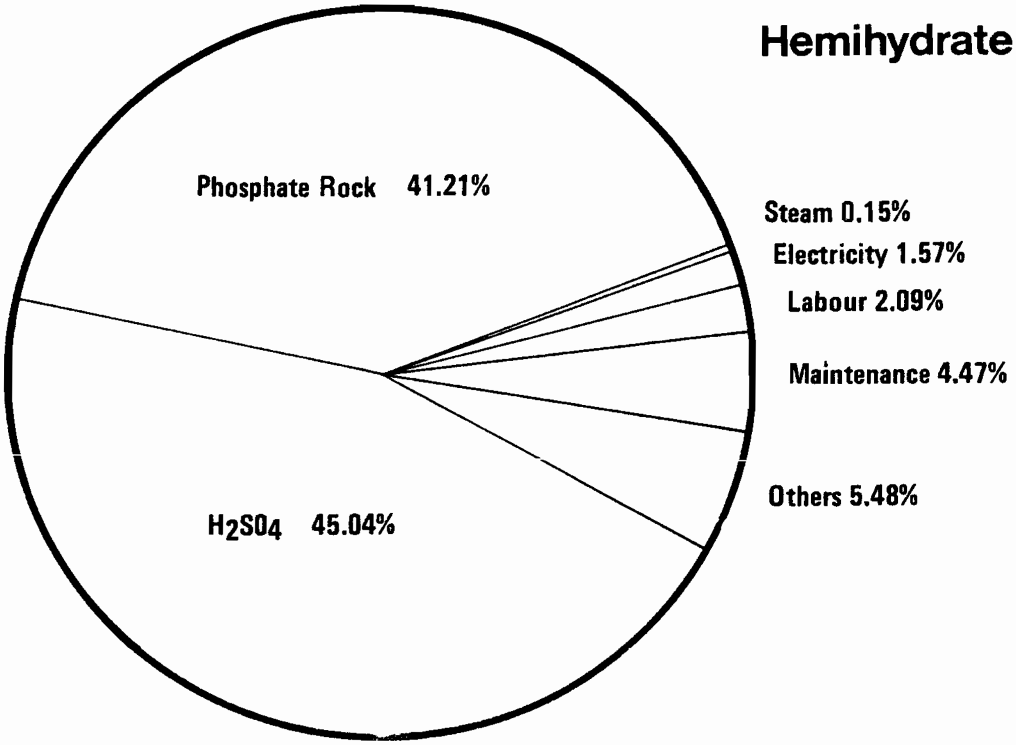
Fisons Fertilizers

Figure 2

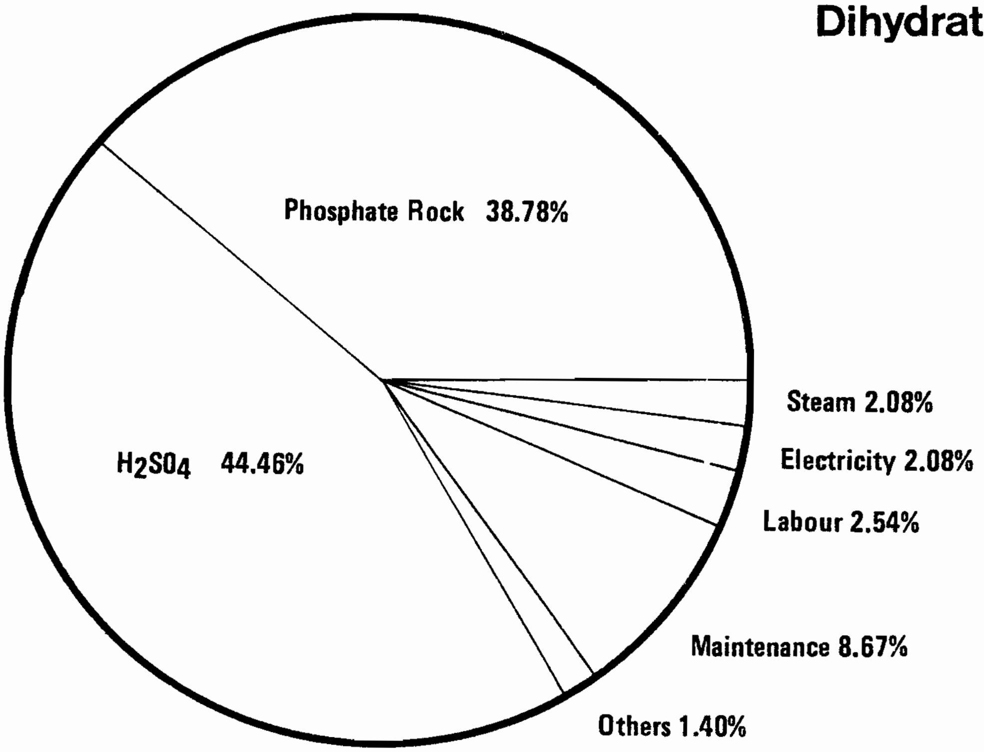
Phosphoric Acid Operating Costs in 1971

Florida phosphate 72 BPL

Hemihydrate Process



Dihydrate Process

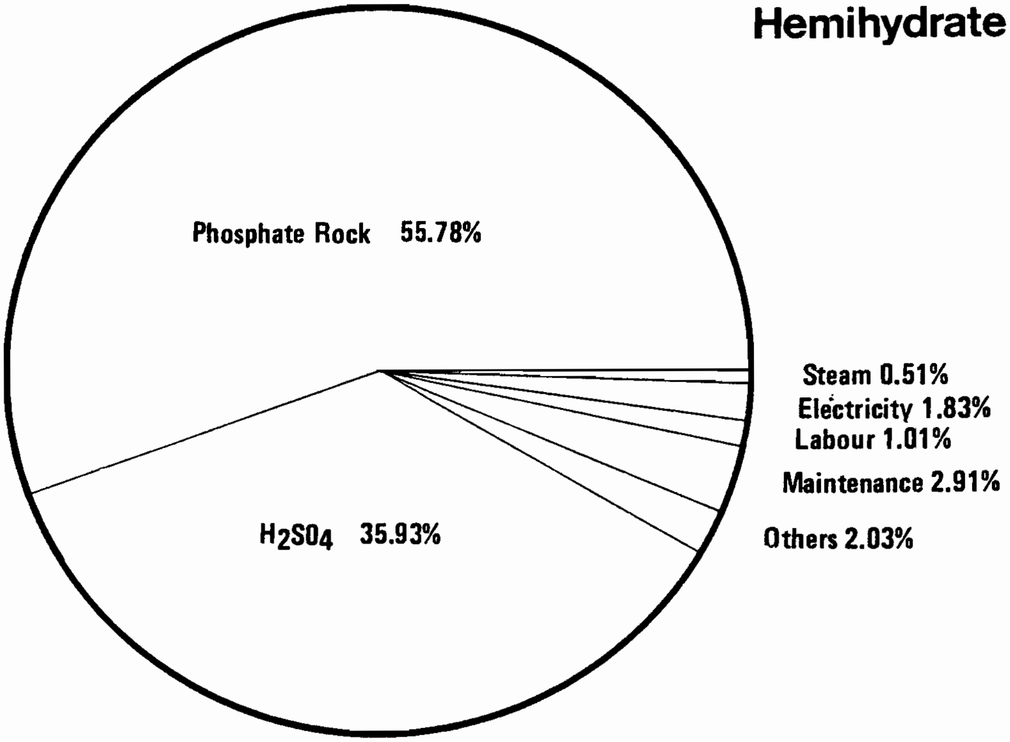


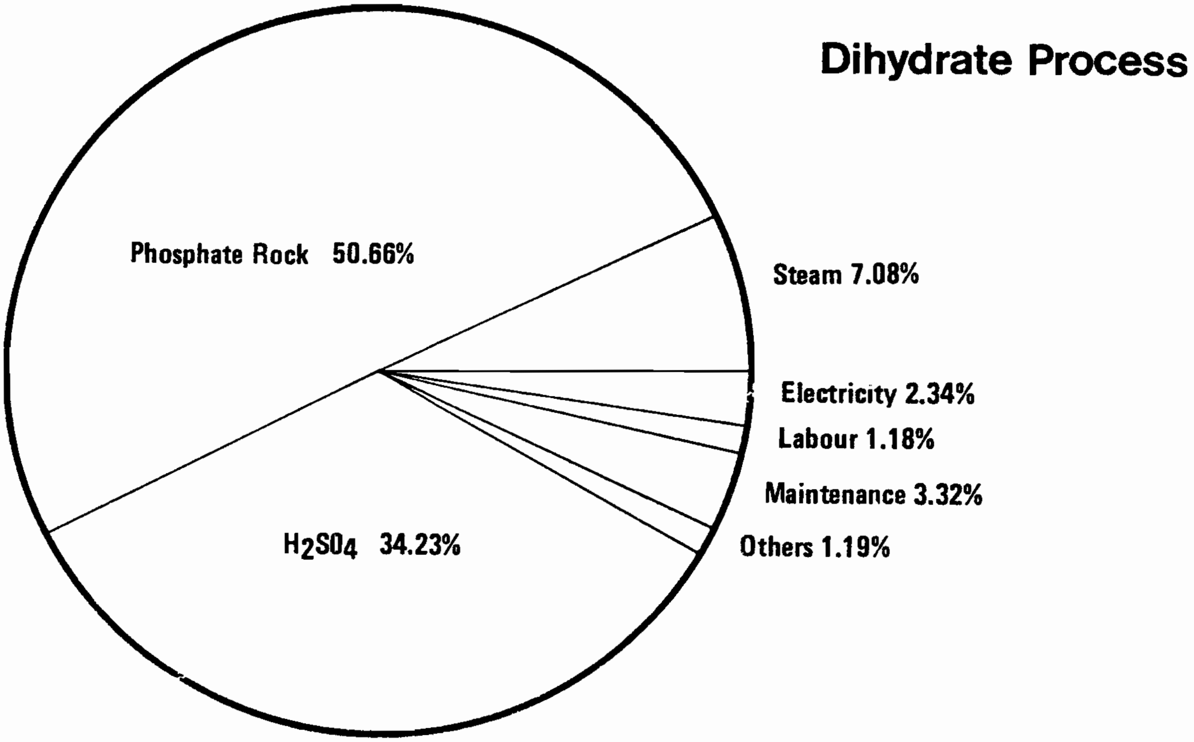
Fisons Fertilizers

Figure 3

Phosphoric Acid Operating Costs in 1981

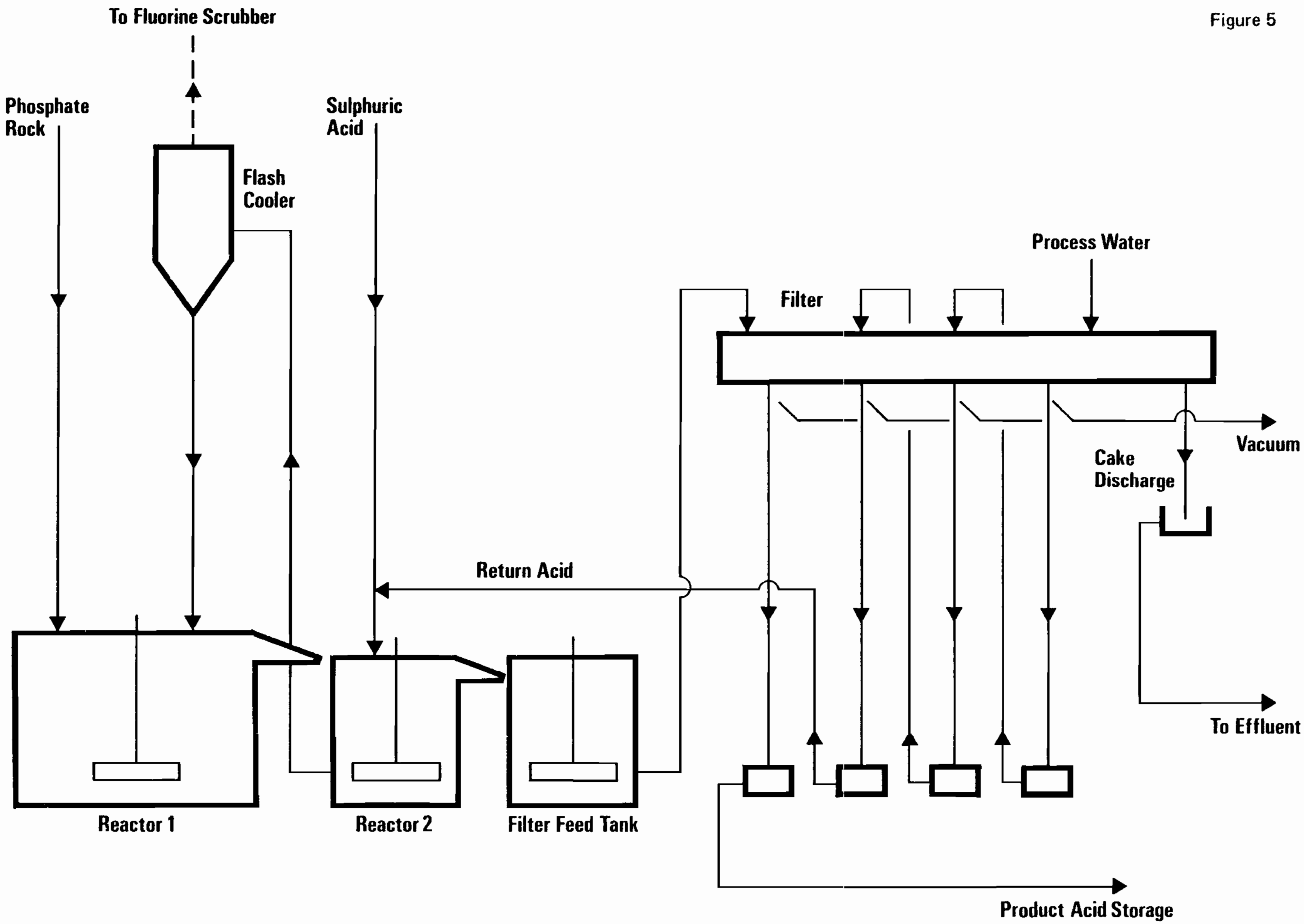
Florida phosphate 72 BPL





Fisons Fertilizers

Figure 5

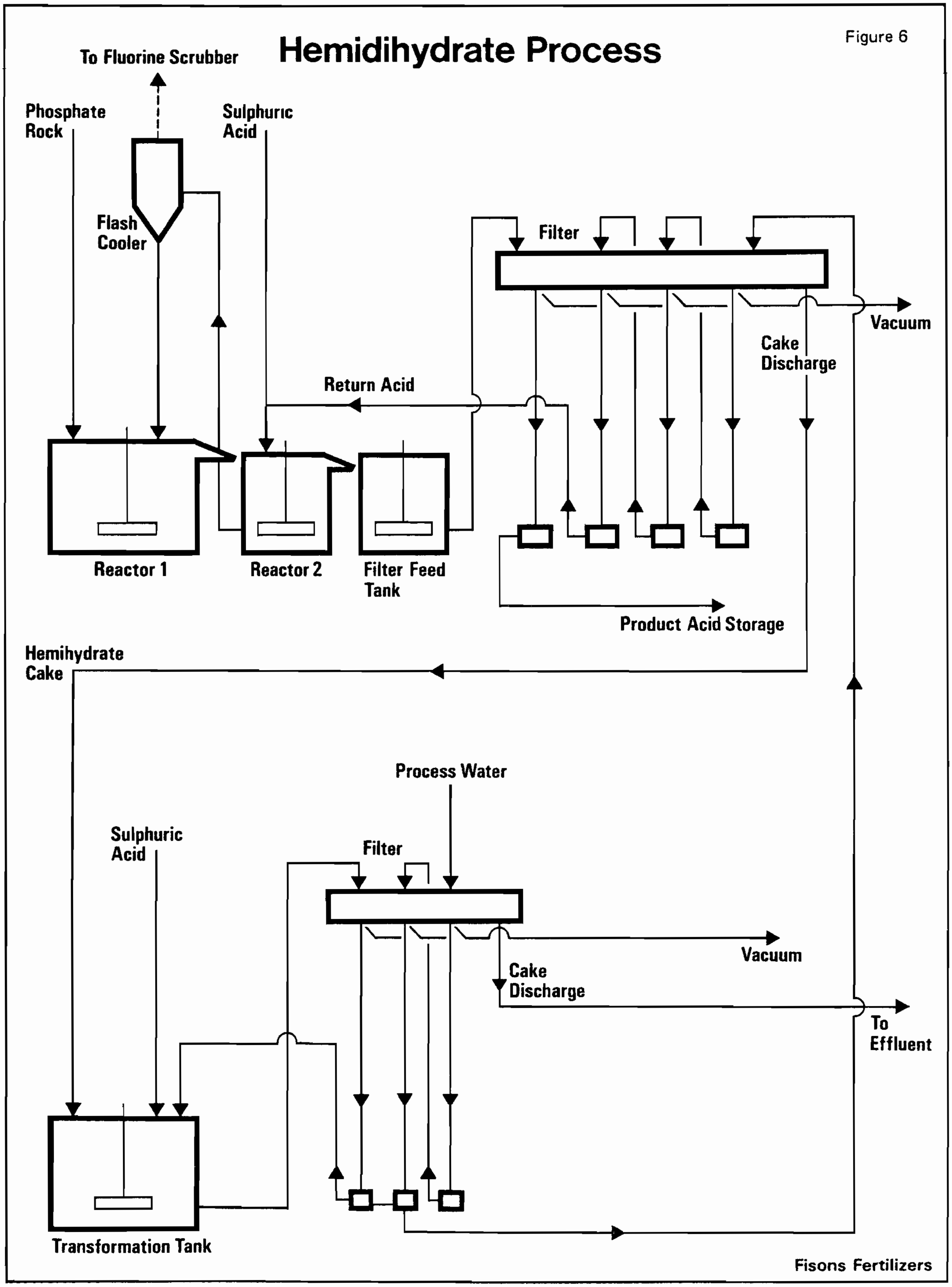


Hemihydrate Process

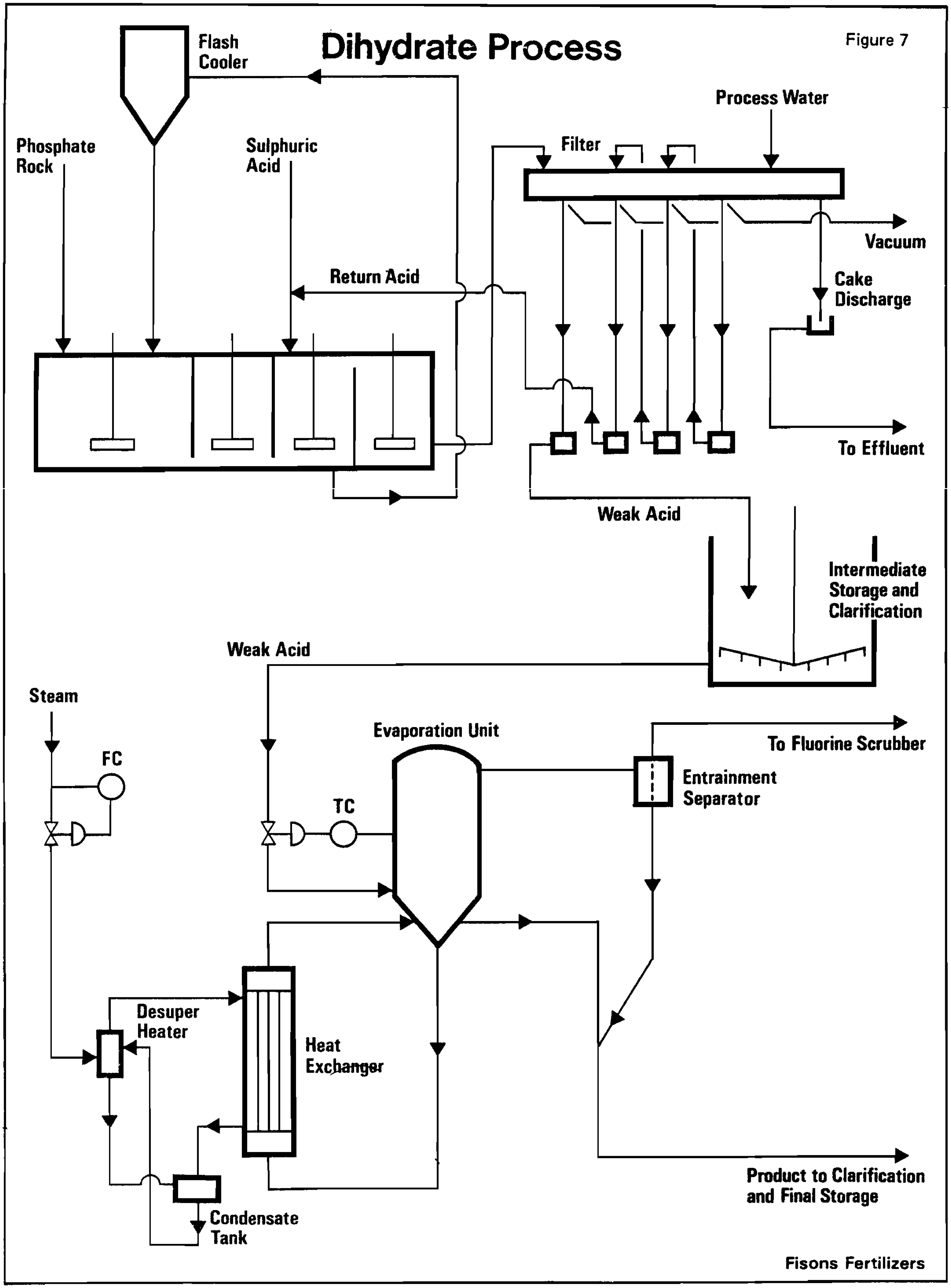
Fisons Fertilizers

Figure 6

Hemidihydrate Process



Fisons Fertilizers



Dihydrate Process

Figure 7

Fisons Fertilizers

MODERATOR LEYSHON: Thank you Barry for an excellent discussion covering "Fison's Hemihydrate Process". (Applause)

BARRY CROZIER: Thank you all. Happy to be here. (Applause)

MODERATOR LEYSHON: Our next speaker is Dr. Fernando Ore of Occidental Research. He will describe some of the recent information available from "The Occidental Hemihydrate Plants and Processes". The most recent Occidental Plant, which I believe was designed for something over 1400 tons per day of P_2O_5, is a rather remarkable "Industrial Achievement in the Phosphoric Acid Area". The plant contains the largest commercial filter in operation on "Phosphoric Acid". I think compliments are due Dr. Ore and his stafffor helping to achieve this "remarkable technical advance". Dr. Ore, please. (Applause)

Progress Report Occidental Hemihydrate Process

Dr. Fernando Ore

Four years ago, in November 1978, I had the opportunity to tell you about the Oxy Hemihydrate Process. On that occasion I discussed the Crystallization Kinetics and the Slurry Filterability, which are the basic features of the process. This time I will review the experience and performance of the Oxy Hemihydrate Process during this past four-year period. I will also cover some of our continuing research effort (we have not been static).

Before getting into this, I would like to take a few minutes to recapitulate the important points of my previous presentation to maintain continuity.

This is an outline of what I presented before. As I have mentioned in previous sessions, the emphasis in the development of the Oxy Hemihydrate Process has been focused on fundamentals. Starting with the basic chemistry of the two main reactions, and applying our knowledge of phase chemistry and crystallization technology we can produce easily filterable and stable hemihydrate crystals (Table 1).

Table 1

Summary of Previous Presentation (Nov, 1978)

USED FUNDAMENTAL APPROACH
- Basic reactions
- Phase chemistry

APPLIED MODERN CRYSTALLIZATION TECHNOLOGY
- Rock dissolution
- Crystallization kinetics

SCALEUP BASED ON KINETIC PARAMETERS

COMMERCIAL DEVELOPMENT
- First hemi plant in operation: 350 TPD P_2O_5
- Second hemi plant in design phase: 1430 TPD P_2O_5

We have developed extensive data on rock dissolution.

As you can see from this Diagram (Figure 1) rock dissolution is a function of sulfate ion concentration and particle size. You can appreciate that there is an optimum sulfate level beyond which rock dissolution rates decline due to coating of the rock. That is, the nucleation rate of hemihydrate crystals increases with sulfate ion concentration to a point that the hemihydrate covers the rock and slows down its dissolution.

Data on hemihydrate crystallization were also presented.

The process factors controlling nucleation and growth rates were established and optimized to control crystal size distribution. With this control we achieve higher slurry filterability.

We also have data on nucleation and growth rates as a function of sulfate ion concentration (Figure 2).

These data were developed using clear solutions. These graphs show that the nucleation rate varied with the third power of sulfate ion concentration; while the growth rate decreases directly with SO_4 concentration (Figure 3).

We also established that the growth rate of hemihydrate crystals was around 0.1 per min. and even under the best consitions (clear solutions) it does not exceed 0.24 per. min. On the other hand, the nucleation rate could be controlled and reduced by one or two orders of magnitude. This has a substantial positive effect on the slurry filterability, as you can derive from this graph.

I mentioned also that we had confirmed (from our pilot plant work and from the first production plant) that the kinetic parameters were consistent and independent of the size of the vessels (Figure 4). Because of this we could use large scale factors with a high degree of confidence, as you can see from this table.

Perhaps the next slide, which I have shown at a previous meeting, will give a better picture of the history of the plant scaleup on the Oxy Hemihydrate Process (Table 2).

The Hemihydrate pilot plant that we have been using throughout our development work is shown in the next slide (Table 3).

Finally, I mentioned that our first hemihydrate plant (a 350 TPD plant) was in commercial operation in N. Florida, and a second hemihydrate plant with a design capacity of 1430 TPD P_2O_5 was in the design stage and scheduled to start in November 1979.

Now, I can pick up where I left off 4 years ago.

First, I will tell you about the present performance of the two plants.

The first plant, the 350 TPD plant, has continued to operate smoothly. We continue to call it the 350 TPD plant, although its daily average product is in the 400-450 TPD range. Even so, it is a "small" plant in a production driven industry dominated by large size plants. However, operating in the hemi mode reduces its size disadvantage.

The second plant, with a design capacity of 1430 TPD, came on stream as scheduled. This was not so much a credit to the process as it was to the project team in charge of construction.

This is a view of this plant during the final stage of construction to give you an idea of size. You can compare it with commercial equipment in the same picture (a truck, a crane, etc.)

This photograph gives you a good view of the plant - some of you may have visited it.

This plant also exceeds design specifications. Some months the average production exceeds 1500 TPD P_2O_5 with peak days over 1800 TPD. The improvement is not only in production rate, but also in recovery, operating factor, ability to handle lower grade rock, maintenance, scaling problems, etc. This improvement was expected since this is a new process, moving along the learning curve and it is entering a phase where the contribution of the operating personnel is showing. As they become familiar with the process, they made the necessary adjustments for easier and more stable operation. Now they have better process control, and the operation is more routine. A number of activities and analyses necessary in the early phase of plant operation have been phased out. The operation is surprisingly simple.

Now, let's look at the hemihydrate crystals produced in the plant (Figure 5).

You can appreciate the size of the crystals. There are not many fines. The plant is using lower grade rock, around 64-65 BPL, so we should expect some silica in the cake.

Let's assess the plant performance in terms of its design specifications (Table 3).

This process was selected on the basis of economic comparison with several other process alternatives. We assumed at the time that we could achieve the design specifications. These specifications have now been exceeded - as you can see.

There are a number of benefits not reflected in these numbers. The ability to process low BPL rock, the quality of the product, little or no sludge, reduction or elimination of scaling problems, lower maintenance, etc. We hoped for these improvements but didn't expect them so soon.

Let's look at the improvements which contributed to the present good plant performance (Table 4).

The most important factor we've found in process control is that the plant does not require the tight control we sought at first. The process is quite stable and can operate for many hours without adjustment. Plant technical personnel use a very descriptive expression. "The process is very forgiving". There is enough flexibility in the range of the control variables to let them fluctuate around their control point.

We have improved our analytical procedures. We use faster and more reliable methods to determine the level of such control variables as calcium and sulfate in the dissilver and crystallizer. We have also improved on standard analytical procedures in cake analysis. Accurate data on the type of losses in the cake (WS, CS, or UR) is essential to assess plant performance.

Instrumentation and equipment associated with process control were improved in accuracy and reliability. There were minor equipment and piping modifications - nothing more than normal in any new plant. For instance, there was a scaling problem in the filtrate line, which was solved by changing materials of construction. The speed of the agitators in the reaction system was increased to meet design specifications. Mechanical problems with the removal of the cake from the filter table were corrected. There was the usual replacement of some valves and pumps as more reliable or suitable equipment became available.

One of the most important contributions to the plant performance was establishing proper maintenance and washing schedules. This assured uninterrupted operation for days, weeks, and even months, allowing the system to stabilize and the plant to perform as expected.

I do not need to repeat the importance of operator training. Although the operation of these plants is probably easier than that of conventional phosphoric acid plants, this was a new process, with new control philosophy and operators had to become comfortable with it.

In preparing this presentation, I decided that there was no need to emphasize the economic advantages of the process. It should be easy for you to make your own assessment. There is no plant size constraint. This is one of the largest phosphoric acid plants in the world and it is operated in the hemihydrate mode. The design optimizes energy use. The plant is provided with power generation, it uses lower grade unground wet rock, and its performance exceeds design specifications. As I said before, these design specifications were the bases for the selection of the process over competitive alternatives. These are not process claims, nor projections from small size plants; but full scale performance data from the operating plant.

In spite of what has already been achieved, there is room for further improvement. We are working on this. We are taking advantage of our increasing understanding of this technology to further increase the performance over our original expectations.

This is a summary of our optimization program (Table 5):

- We want to continue optimization of process control to achieve the benefits indicated in this table.

- We want to reduce the lattice bound P_2O_5 losses, the largest process losses in the hemihydrate process
- We want to reduce chemical cost by using more efficient additives

In connection with the first part of the program, we have:

- Developed from first principles a steady state computer simulation model, which accurately calculates the process flows, including sulfuric acid, cake wash requirement, recycle streams, etc. as a function of production rate, rock composition and selected level of control variables. The model includes also an internal energy balance. This will be complemented with a dynamic model of rock dissolution and crystallization to make possible prediction of CSD
- We are testing in-line analyzers to incorporate in a computer control system

Regarding reduction of lattice bound P_2O_5 losses (Table 6).

We have established that lattice bound P_2O_5 is the result of two different mechanisms: (1) substitution of phosphate for sulfate in the calcium sulfate lattice. This is responsible for 70% of the lattice bound loss. By the way, these values correspond to the time we started the program, now the substitution has been reduce. (2) The formation of a chemical complex of phosphorous-aluminum-fluorine. This might include more than one complex, which is absorbed on the surface of the crystal and is responsible for the remaining 30% of the lattice bound phosphate losses. This is true for N. Florida rock - if the rock is low in aluminum, losses due to the formation of the complex will be lower.

This gives a view of the structure of the hemihydrate lattice (Figure 6). These are calcium sulfate crystals with water of hydration that form the hemihydrate crystals. Calcium phosphate crystallizes in the same type of lattice and as you can see there is some substitution for sulfur by phosphorus.

To reduce the lattice bound losses we either have to find conditions to reduce substitution and minimize the formation of the complex, or we have to recrystallize (Table 7). We have explored both approaches.

The first route offers a bigger challenge but larger benefits, e.g., small capital, cleaner acid, simpler plant, and probably a higher operating factor. We have made substantial progress in this approach. The second route is the standard approach to recover phosphate occluded in the crystals - recrystallization.

We have piloted the hemihydrate recrystallization process and we have developed economic data and the technology required. The recrystallization process works well enough but it requires capital and is more difficult to control than the simple state hemi, which might impact on the operating factor. Recrystallization not only recovers the phosphate lost in the hemi, but also brings some impurities back into the acid that usually report with the hemihydrate cake.

We feel that the advisability of using recrystallization will depend on the impurities in the rock, the end use of the product, capital required, and other factors. If the acid must be purified (required in our case to make SPA) part of the additional recovery may be lost in the additional purification required to remove the impurities which usually report to the cake. On the other hand, if high purity gypsum is needed, and if acid purity is not a factor, or if high quality rock is available, recrystallization is a functional option.

To conclude, I want to tell you that we are happy with the benefits we have already achieved by using this technology, and that we look forward to even greater benefits as a result of our continuing R&D work.

I hope this presentation has been interesting to you, and I'd like to thank you for your attention. (Applause)

TABLE 2

PLANT SCALEUP

	TPD P_2O_5
PILOT PLANT	**0.1**
FIRST HEMI PLANT	**350**
SECOND HEMI PLANT	**1430**

OXY HEMI PROCESS

TABLE 3

PLANT PERFORMANCE

	DESIGN SPECIFICATIONS	ACTUAL PERFORMANCE
PLANT CAPACITY, TPD P_2O_5	1430	>1500 (>1840)
OPERATING FACTOR, %	75	80 → 83
RECOVERY, %	88.5	93 - 94

TABLE 4

AREAS OF IMPROVEMENT

- * PROCESS CONTROL
- * ANALYTICAL PROCEDURES
- * INSTRUMENTATION RELIABILITY
- * EQUIPMENT & PIPING MODIFICATIONS
- * PREVENTIVE MAINTENANCE
- * OPERATOR TRAINING

TABLE 5

Hemihydrate Process Optimization

PROGRAM

	BENEFITS
IMPROVEMENT OF PROCESS CONTROL	• REDUCED PROCESS LOSSES (UNREACTED ROCK AND WATER SOLUBLE LOSSES) • INCREASED PLANT THROUGHPUT • INCREASED OPERATING FACTOR
REDUCTION OF LATTICE BOUND P_2O_5	• IMPROVED PRODUCT RECOVERY • RECOVER P_2O_5 VALUES OCCLUDED IN CAKE
SELECTION OF MORE EFFICIENT ADDITIVES	• REDUCED CHEMICAL COSTS • IMPROVED PLANT THROUGHPUT

TABLE 6

Hemihydrate Process Optimization

REDUCTION OF LATTICE BOUND P_2O_5 CAKE LOSSES

BREAKDOWN OF LATTICE BOUND P_2O_5

	% OF LB	LB
LATTICE SUBSTITUTION	70	4.0
CHEMICAL COMPLEX (P, Al, F)	30	1.5
	TOTAL LB	5.5

TABLE 7

RECOVERY OF OCCLUDED P_2O_5 IN HEMIHYDRATE CRYSTALS

option 1:

Minimize formation of lattice bound P_2O_5

option 2:

Recrystallize hemi crystals as dihydrate

FIGURE 1

Rock Dissolution Rate

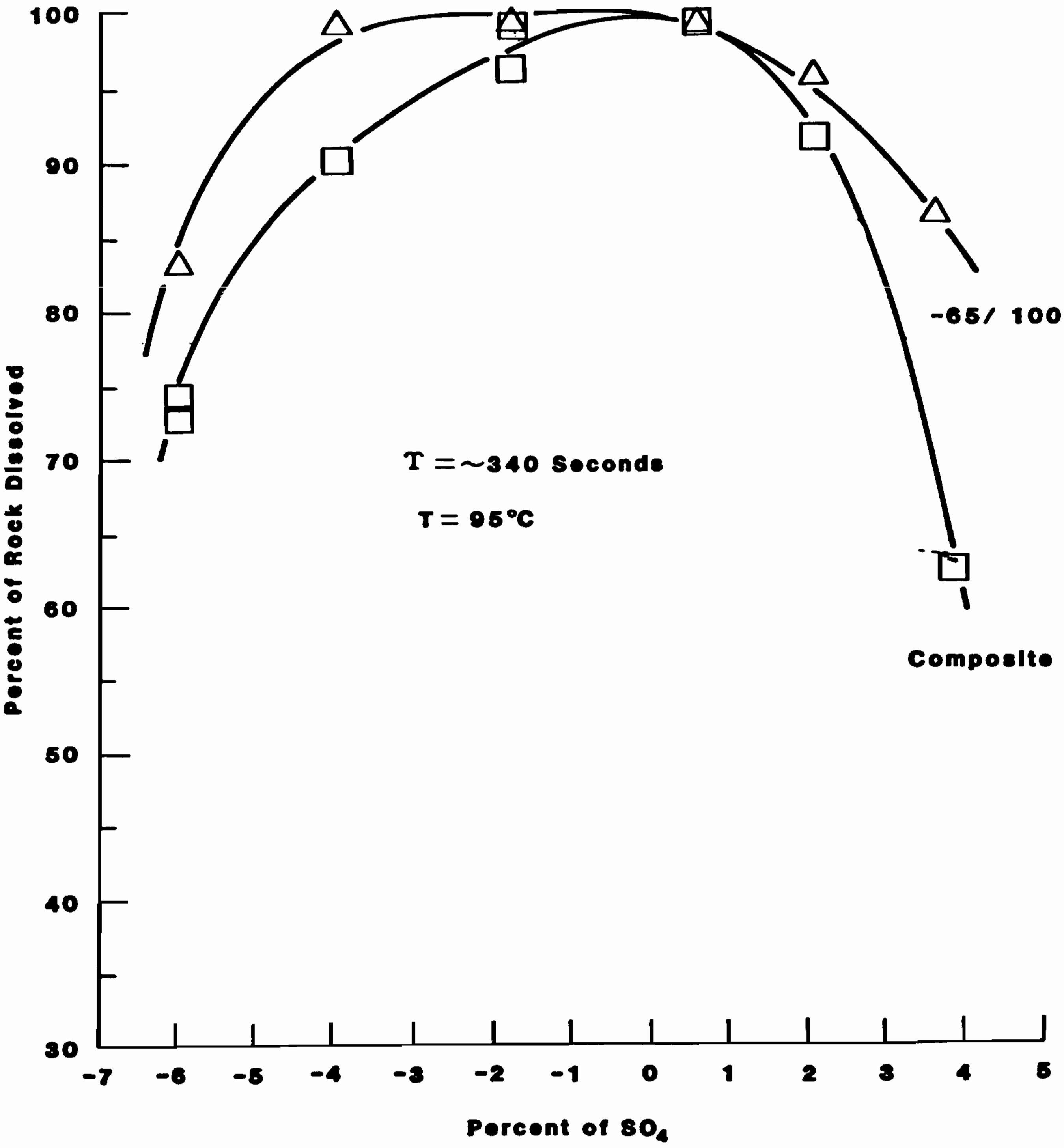


FIGURE 2

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

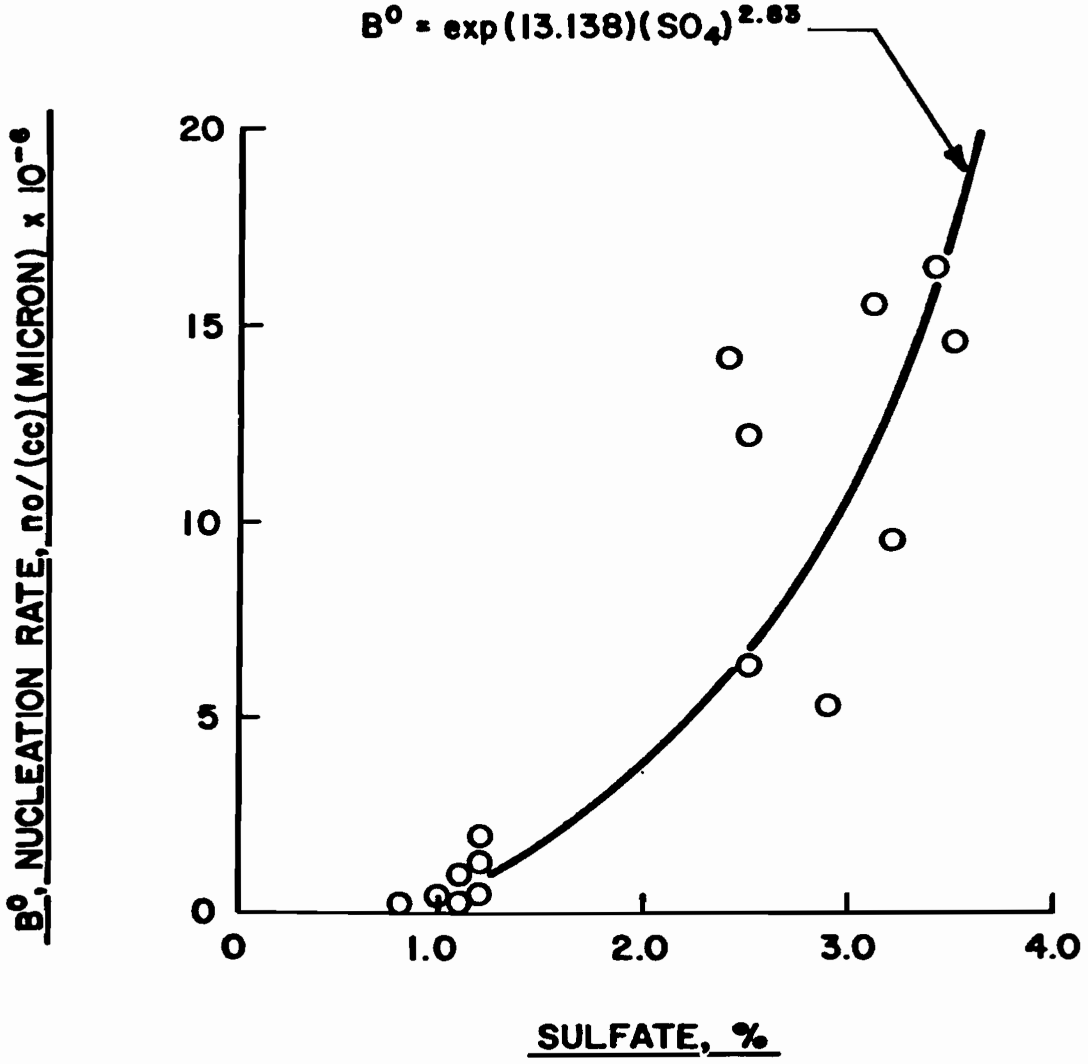


FIGURE 3

EFFECT OF SULFATE ION ON GROWTH RATE FOR MONOCALCIUM PHOSPHATE SLURRIES

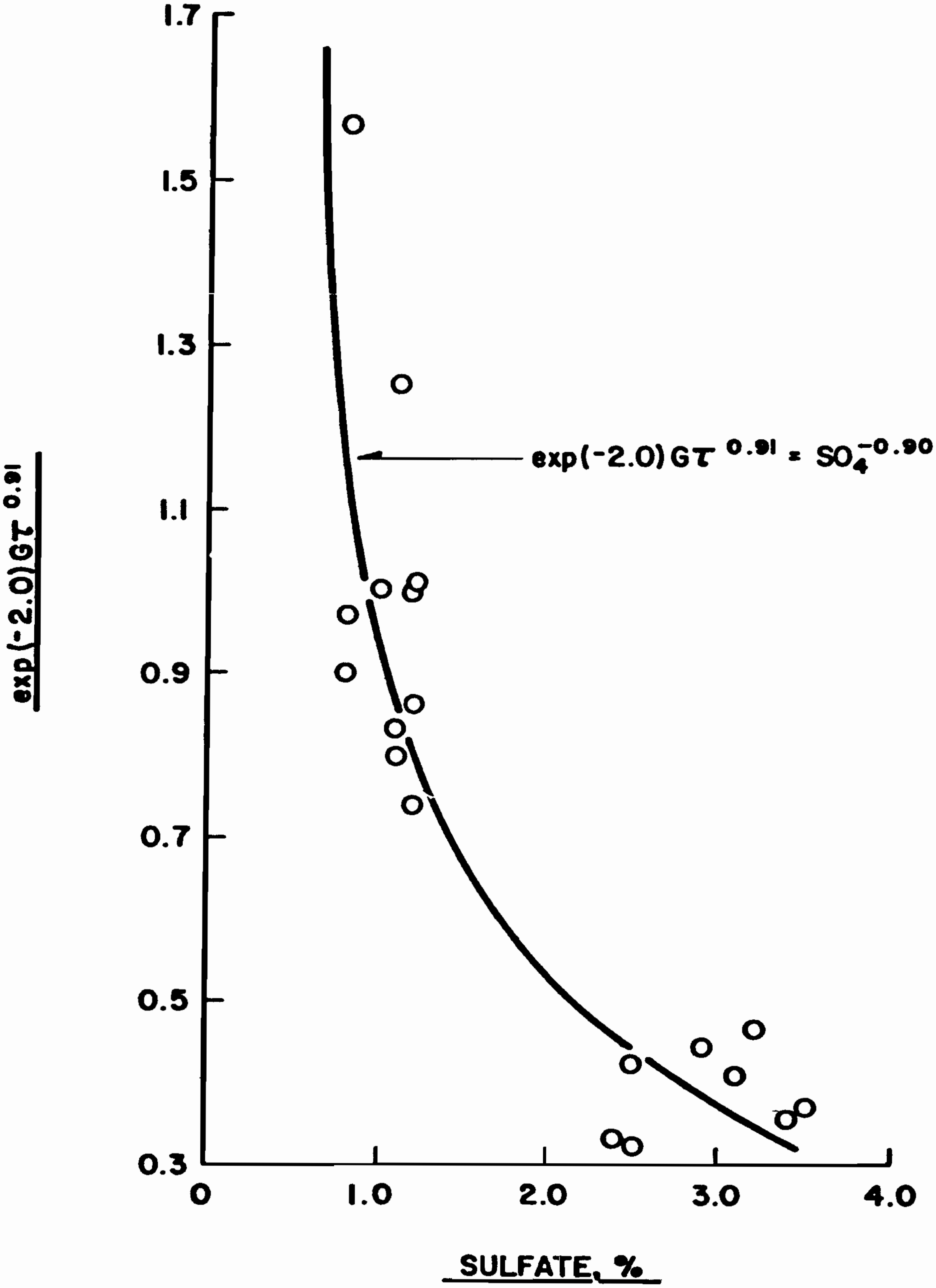


FIGURE 4

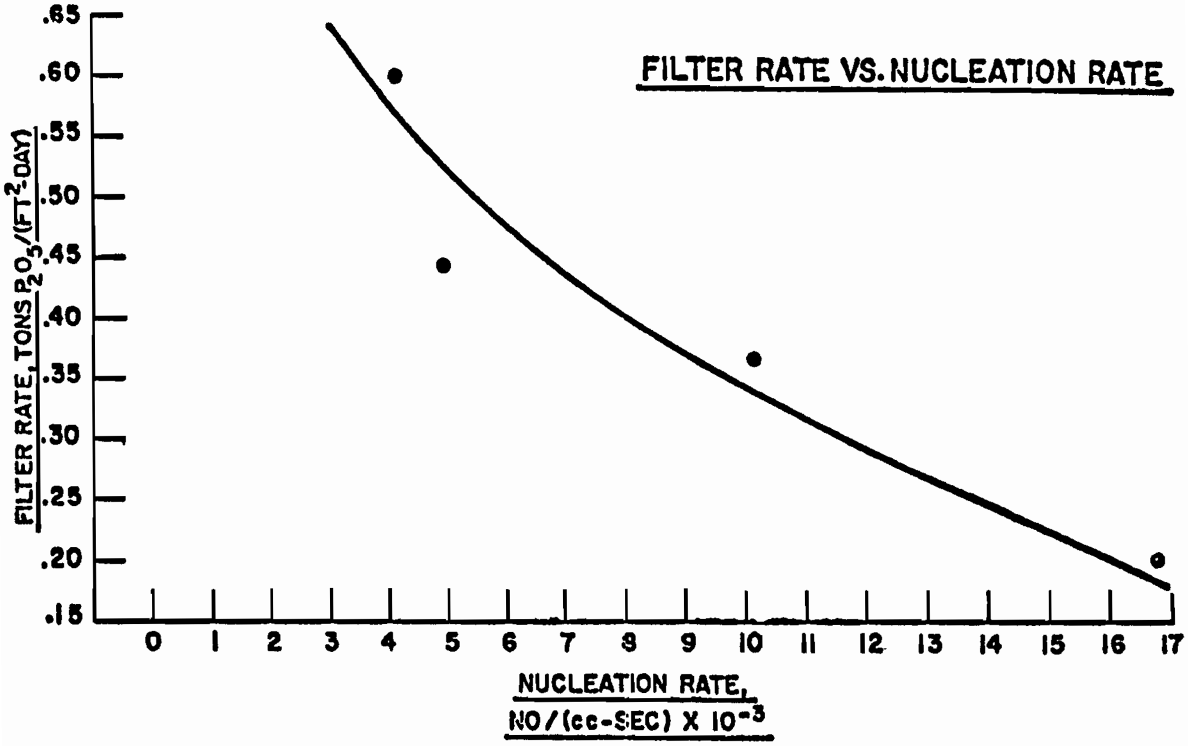


Figure 5

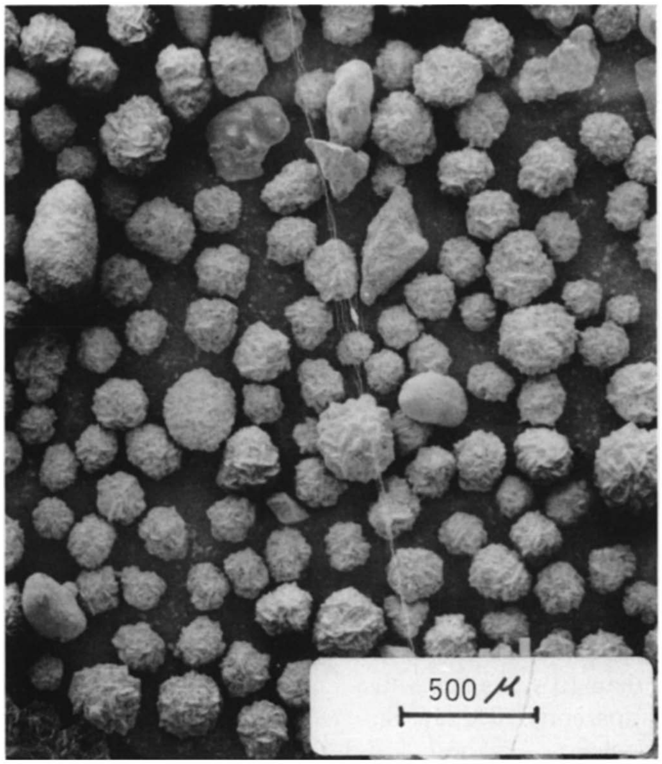
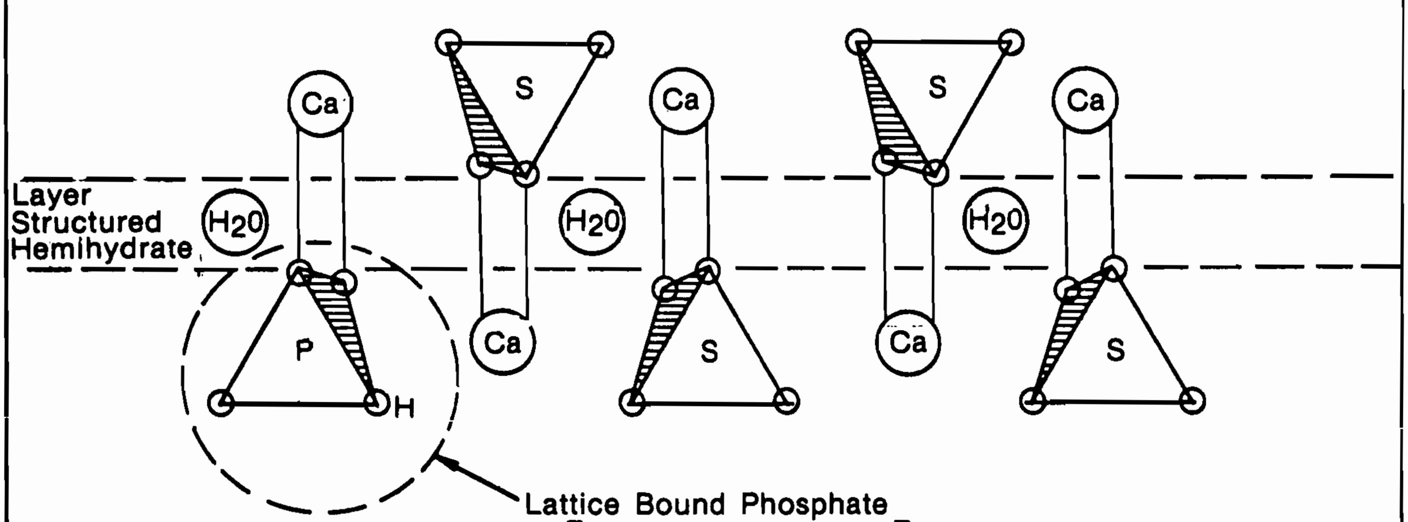

HEMIHYDRATE CRYSTALS

FIGURE 6

Schematic Diagram: Hemihydrate Lattice Structure



Lattice Bound Phosphate ($HPO_4^{=}$ Substituted for $SO_4^{=}$) (Both are Tetrahedral ions, both essentially the same size)

Actual substitution is about one $HPO_4^{=}$ for every fifty $SO_4^{=}$

MODERATOR LEYSHON: Thank you Dr. Ore (Applause)

MODERATOR LEYSHON: We now come to a discussion of effect of impurities in Phosphate Rock. This has been a continuing topic of interest as phosphate deposits deteriate in quality. We have with us, Dr. Guerry McClellan of The International Development Center at Muscle Shoals, Alabama, to present this discussion. (Applause)

Impurities in Phosphate Rock Good or Bad

G. H. McClellan

J. R. Lehr

Presented by G. H. McClellan

Many of the men in today's phosphate industry can remember a time a little more than 10 years ago when their business was based on an apparently adequate supply of premium-grade raw materials. These raw materials were the basis of the chemical process design work that established wet-process phosphoric acid as the principal intermediate product in a rapidly expanding industry. International and domestic competition among producers resulted in sales of premium raw materials and products at bargain prices to the consumer.

In 1973, a sudden increase in rock prices startled both consumers and producers. Increasing prices resulted in a rapid expansion of industry production capability as the producers tried to anticipate a sudden increase in demand. The increase in production could be set by changes in mining and beneficiation techniques in exiating deposits as well as extension of technology of technology to new types of ores that had not been processed previously. The result was a general, but inevitable, decrease in the quality of ore because previous decades of selective mining had consumed most of the high-grade and high-quality phosphate deposits.

There is no predicted shortage of phosphate concentrate or ore to be mined. Statistics clearly show large inventories of both at present. However, today's producers are confronted with a paradox. Competition in domestic and international markets will not allow them to reduce product grades; yet, declining raw material quality is making it more difficult and expensive to produce these traditional fertilizer materials. In this paper, we will attempt to summarize the impact of some of the beneficial and detrimental effects of phosphate rock impurities on processing problems and final product grades. This paper will not be a comprehensive review of the literature but will highlight findings on topical subjects. Literature references are included for those wanting more information.

Impurities Affecting Processing and Products

Commercial concentrates are a mixture of the apatitic phosphate mineral with various accessory minerals (Table 1). Variations in commercial concentrates arise because of variations in the composition of the apatites that they contain and in the ratio of apatite to accessory minerals (Gremillion and McClellan, 1981).

In a typical beneficiation treatment (Table 2), a large part, but not all, of the undesirable impurities are rejected (Wakefield, 1980). These variables thus cause concentrates to have a typical range of values rather than fixed compositions (see Table 3). The literature on phosphate rock analysis reports a large number of elements occurring in the materials (perhaps as many as 60 elements or more). We will limit our discussion to the most important impurity constituents that are derived both from the apatite and from the most common accessory minerals (Table 1). From a practical point of view, this list contains only a few elements that directly affect both processing and products.

Some phosphate rock impurities affect production rates mainly by causing operating problems. These include fluorine, carbon dioxide, organic carbon, chloride (where applicable), and acid insolubles. These constituents can cause corrosion/abrasion (F, Cl, organic C, and inerts), foaming (CO_2 and organic C), and pollution problems (F) among others. Fortunately, producers have developed considerable experience in coping with the effects of these factors. However the processing of ores from new deposits or concentrates from new beneficiation processes may result in problems as new levels and combinations of impurities are encountered.

Perhaps the more important constituents are those that affect the chemical and physical properties of the products as well as the processing. This group contains iron, aluminum, and magnesium along with fluorine as the main contributors to a variety of problems. Over the past 15 years considerable progress has been made in identifying the role of these elements in various precipitation problems during processing and storage (Lehr, Frazier, and Smith, 1966; Lehr, 1968; Frazier, Lehr, and Dillard, 1977; Frazier, Dillard, and Lehr, 1982). These studies are being continued at present, as they will be in the future, because as processes and raw materials change and evolve, new compounds will be formed and replace those that already have been described. The remainder of this paper will concentrate on describing some of the occurrences of these constituents as well as assessing their significance in production steps and product grades.

Trace and minor elements also are commonly found in phosphate concentrates. These would include heavy metals (Cr, Pb, V), toxic elements (As, Hg, Cd, Zn), and radionucleids (U, Th, Ra, Rn). Although these elements may present some special concerns for byproduct recovery or toxological hazard, their concentrations usually are too low to have any effect on either processing or product grades. Their presence is noteworthy though in the event that some unforseen step in a process might cause a sufficient concentration of one or more elements to warrant some special consideration.

Sources of the Impurities

Magnesium and fluorine are the principal impurities affecting processing and products that are derived from the apatite mineral itself. The carbonate fluorapatites that are commonly found in the sedimentary ores of the United States can contain up to 0.7% MgO and 5.0% F. These figures do not include any elemental source other than the phosphate itself. Thus the apatite can contribute significantly to at least two constituents that can cause problems.

The main sources of Fe_2O_3, Al_2O_3, MgO, and soluble SiO_2 in the concentrates are the clay minerals—montmorillonite, attapulgite, and kaolinite. Iron also can be derived from various oxides and hydroxides that occur as discrete mineral grains and surface stains. These clays tend to adhere to the surfaces of the phosphate pellets and float with the concentrate.

Limestone and dolomite are important sources of MgO and CaO in some ores. Part of this MgO can be removed by desliming to separate the fine dolomite. Present commercial flotation processes are not used to separate sedimentary phosphate from dolomite although considerable research and pilot tests have shown promising results.

Local variations in the ratios between these impurity-containing accessory minerals and the phosphate are known to the producers (Lehr and McClellan, 1973). However, reduced selective mining and lack of high-quality ores now bring many of these low-quality ores to the beneficiation plant for treatment prior to chemical processing. In some cases, the beneficiation plants are not designed with sufficient hydrocyclone capacity to handle high-slimes matrix or to remove dolomite by attrition. Thus, poorly washed materials may be sent to the beneficiation circuit for further processing. This can result in poor performance of the beneficiation process and the production of pebble fractions of variable quality. Then these pebble fractions, which often contain clays, are sent to the chemical processing plant where the impurity-containing minerals associated with the phosphate are extracted for various lengths of time and at various temperatures in a strongly acidic environment. This usually results in the solubilization of a large fraction of the impurity constituents along with the phosphate.

Present data indicate that the opening of some new deposits in the south Florida district will lead to lower grade concentrates that are high in MgO but perhaps lower in Fe_2O_3 and Al_2O_3. Although the ratio of these impurities might vary from place to place, there is general agreement that concentrate quality and grade seem certain to decline.

In the near future, producers will be confronted with various alternatives that will affect their cost of rock production. One course of action might be to make the rock meet chemical quality specifications by increasing the treatments in such a way that they would not adversely effect plant production capacity. This might include more effort to physically separate the impurities from the ore by heavy media separation and sizing, or the addition of a third stage of flotation, or both. Any of these treatments will add to the cost of the final product. Another alternative would include purification of the phosphoric acid intermediate product itself by various precipitation or solvent extration processes. All of these technologies exist but are not economic at present.

The phosphate literature often cites the levels of impurities that are acceptable in various processes. These data usually are based on engineering design company specifications and premium rocks historically available in international trade. They bear little similarity to the actual rock analyses of materials being processed in many large plants where nonpremium (usually low-grade and low-quality) rocks are the normal feedstocks. About 1975, data on the levels of impurities that can be accepted before plant production rates are affected (Table 4) were beginning to appear in print (Kouloheris, 1977; McClellan, 1980). Individual producers already had established internal limits on certain impurities of special concern in their rock feeds. These data were an early warning of the problems that are now common in both the United States and some foreign industries. Higher levels of these impurities do not make it impossible to attain product grades in large facilities; however, they often do cause a reduction in production rates and thus increase costs.

Now that the group of elements of principal interest have been identified and their tolerance levels indicated, an effort will be made to follow them in various process steps to indicate their effects on product grades and costs. Much of this effort will be qualitative because there is a general lack of quantitative data on many of the steps that are described.

Phosphoric Acid

Variations in phosphoric acid process conditions can cause differences in the precipitates formed from the impurities (Figure 1). This topic can be approached by discussing various precipitates that form in response to variations in acid concentration.

Filter-Grade Acids (28%-40% P_2O_5)

The impurities in the phosphate rock that are dissolved in a reaction mixture of phosphoric and sulfuric acid often precipitate from wet-process phosphoric acid as crystalline salts. The main precipitates in dihydrate process filter cakes (Table 5), in addition to calcium sulfate, are simple or complex fluoride salts containing Ca^{2+}, Mg^{2+}, Na^{1+}, Al^{3+}, and Si^{4+} (Frazier, Lehr, and Dillard, 1977). No phosphate salts precipitate in dihydrate process acid or filter cakes; however, small amounts of phosphate are cocrystallized when the gypsum precipitates.

The precipitation of the various fluoride salts is controlled by the concentrations of component impurities extracted from the minerals in the rock. As shown earlier (Table 3) these constituent concentrations vary somewhat within the rocks from a given area. The actual significance of impurities depends on the individual solubility properties of the accessory mineral phase in the reaction mixture.

When high-grade rock is used, NA_2SiF_6 is the most common fluoride salt in the filter cake. With a decline in rock quality, the other fluoride salts either coprecipitate with Na_2SiF_6 or substantially replace it. The precipitation of either $Ca_4AlSiSO_4F_{13} \cdot 12H_2O$ (chukhrovite) or $(Na, Mg)_xAl_{2-x}F_6 \cdot H_2O$ (ralstonite) can increase the percentage of fluorine reporting to the filter cake (Table 5).

The distribution of fluorine between the acid and the filter cake is controlled by the solubility of the salts in the acid. The solubility data of Frazier et al. (1977) show a wide range of values (up to 40-fold difference) for these salt compositions. The dissolution and lateration of these fluoride salts can take place during filter cake washing, slurry transport to the storage pond, and during pond storage. In general, any redissolved fluoride is precipitated by calcium in the pond as insoluble salts, usually fluorite (CaF_2) or chukhrovite. If Mg^{2+} levels in the pond water are high enough, either ralstonite or MgF_2 also can appear as secondary solid phases. The actual redistribution of fluoride is further complicated by the use of recycled pond water and/or fresh water during cake washing. The pond water may already be partially or totally saturated with respect to the fluoride salts, and this saturation would limit their redistribution potential during the washing and transportation steps. The use of fresh makeup water during washing greatly increases the potential for redistribution of fluorine because of higher solubilities. The chemistry of the fluorine during processing and disposal has been discussed in detail by Lehr (1978). The cations transported to the storage ponds with the fluorine often remain in the solution phase where they may become concentrated and recycled to the process.

The fluoride chemistry studies in wet-process phosphoric acid have demonstrated that the solids precipitating in the filter cake and during acid clarification can change as rock impurity levels increase and that the amount of fluorine precipitated by the complex salts can partially be controlled by altering the chemistry of the system. The material balance studies do not indicate any large amounts of unaccounted fluorine in the reaction, transport, or disposal stages. The main processing problem associated with the fluorine, magnesium, and aluminum impurities is the formation of gelatinous ralstonite from high MgO rock; these fine materials partially block the filter-cloth openings and cause reduced production rates and increased maintenance. The main benefits of these impurities are reduced equipment corrosion from the complexed fluorine salts and improved control from the process when sparingly soluble, high fluorine-containing precipitates are formed. Soluble Al^{3+} has been reported as a beneficial impurity in filter acids where it can cause changes in the shape of the gypsum crystals and improve filtration rates (Gilbert, 1966; Nielson, 1980).

The precipitation of $(Fe, Al)_3KH_{14}(PO_4)_8 \cdot 4H_2O$ may start when the acid is concentrated to 35% P_2O_5 or more (Lehr, Frazier, and Smith, 1966). These studies showed that the presence of potassium solubilized from the rock was necessary to initiate precipitation of this compound. However, after the initiation of crystallization by potassium, other monovalent ions can sustain the precipitation of this compound, especially Na^{1+} impurity derived from the rock or NH_3^{1+} that might be introduced from recycled pond water used during cake washing. These phosphates generally do not precipitate in the dihydrate process filter cakes because they are metastable in acids that contain less than about 35% P_2O_5 (Lehr, 1968). As filter-grade acid concentration increases, the solubility of these impurity phases decreases and precipitation begins.

Hemihydrate Process and Strong Wet-Process Phosphoric Acid (40%-50% P_2O_5)

Acids containing 40%-50% P_2O_5 are especially important because they represent the filter-grade concentrations obtained from various hemihydrate phosphoric acid processes and concentrated dihydrate process phosphoric used in the production of ammonium phosphates. Interest in hemihydrate processes has grown over the past few years because of their potential for saving the energy that would be required for concentrating acid. Several commercial hemihydrate processes are available that produce acids that contain 40% P_2O_5 or more. Dihydrate process phosphoric acid often is concentrated by vacuum evaporation from 28%-32% P_2O_5 to 40% P_2O_5 or more to permit the production of 18-46-0 grades by conventional ammoniation-granulation or by pipe reactors. Recent work by Frazier, Dillard, and Lehr (1982) showed that fluorine precipitation in some simulated strong acids was controlled by compounds with compositions close to $(Na, K)SiF_6$, $(Ca,Mg)Al_2F_8 \cdot 2H_2O$, and $AlHPO_4F \cdot 2H_2O$. In addition, they present data that indicate that the $Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$ salt also might be precipitating in the hemihydrate filter cake. There are some plant-scale data that show spherical particles (1-2 um in diameter) high in Fe, Al, and P embedded in hemihydrate crystals (unpublished IFDC data). The occurrence of $Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$ in hemihydrate process filter cakes is possible because this salt is stable in acids containing more than about 35% P_2O_5 (Lehr, 1968). However, it might dissolve during hemihydrate cake washing to form amorphous Fe, $AlPO_4 \cdot nH_2O$ gels and impure H_3PO_4. Thus,, two precipitated salts are potential new sources of phosphate losses in hemihydrate dilter cakes. In strong acids, the number of precipitates is reduced, compared with the weaker acid concentrations, but the solution chemistry is more complicated because both metal- and anion-fluorine complexes form as acid strength increases and free water decreases (Table 5).

Industrial experience with strong phosphoric acids (40%-50% P_2O_5) is rather broad, but little data have been published on the effects of impurities on processing. The TVA data indicate that some precipitation of the Fe^{3+}-rich $(Fe,Al)_3KH_{14}(PO_4)_8 \cdot 6H_2O$ decreases with increasing F^{1-} contents in the acid. The iron-rich member is favored because the Al^{3+} seems to be complexed by F^{1-} to form $(Ca,Mg)Al_2F_8 \cdot 2H_2O$. However, the practical application of this knowledge to plant-scale operations remains to be developed and evaluated. Hemihydrate process acids may be somewhat cleaner than dihydrate process acids if significant amounts of impurities can be precitated in the hemihydrate filter cake as the data indicate. This might increase the apparent filter cake phosphate losses but minimize sludge formation during subsequent clarification and processing. Such precipitates could be an advantage or disadvantage depending upon the producers' uses for this sludge material.

The low solubility of certain magnesium fluosilicates in hemihydrate acid has been used to an advantage in some commercial processes (Mills, 1981). Acid high in MgO is treated with solids containing CaF_2 to precipitate the magnesium as magnesium fluosilicates which improves the quality of the acid.

Merchant-Grade Acid

The solid phases collected during the clarification of merchant-grade acids (50%-54% P_2O_5) usually contain the acidic iron-aluminum phosphates that contain potassium (Table 5). The most frequently occurrigng compound is the $(Fe,Al)_3KH_{14}(PO_4)_8 \cdot 4H_2O$ salt already mentioned in the previous paragraphs. This salt shows isomorphous substitution of Fe^{3+} and Al^{3+}. The solubility of this salt decreases with increasing iron content and increases with rising temperatures at a given acid concentration. As was mentioned earlier, potassium is required to initiate the precipitation of this phase but other monovalent cations can be incorporated to sustain its formation and further lower levels of soluble iron and aluminum. Although this phase is very insoluble in merchant-grade acids and rather insoluble in water, it dissolves in dilute phosphoric acid to form a solution of potassium in the H_3PO_4 and precipitate colloidal $(Fe,Al)PO_4 \cdot nH_2O$. This is technically important because it shows that washing any filtered sludge could release potassium to the filtrate where additional precipitation can occur. This may be desirable in some cases, but generally such treatment would increase the amount of phosphate lost as sludge and increase disposal problems.

Some plant-scale studies have reported another phosphate salt as an important component of merchant-grade acid. This salt, $Fe_3KH_8(PO_4)_6 \cdot 6H_2O$, also accepts monovalent isomorphous substitutions of $L^{1+}$and $A;^{3+}$for Fe^{3+} (Lehr et al., 1967). High aluminum contents of the acids favor this salt over the $(Fe,Al)_3KH_{14} \cdot 4H_2O$ (Cate and Deming, 1970). This study showed that mixtures of the two salts did not occur in their systems nor are mixtures observed in commercial sludges. In short-term laboratory studies using simulated acid compositions, the fact that $Fe_3KH_8(PO_4)_6 \cdot 6H_2O$ was not observed may indicate that it requires longer time and higher temperatures to form than does the $Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$ salt. However, once the $Fe_3KH_8(PO_4)_6 \cdot 6H_2O$ salt is nucleated, it may become the predominant species present. This salt is a citrate-insoluble compound that is reported to be unavailable to plants (Taylor, Gurney, and Lindsay, 1960) and thus is very undesirable.

Concentrated merchant-grade acids (54%-70% P_2O_5) are used by some producers in an effort to minimize postprecipitation problems that occur in 50%-54% P_2O_5 acids. These processes are successful because iron and aluminum orthophosphate precipitates usually redissolve as the acid is concentrated and these elements do not precipitate as simple pyrophosphates. Also, problems with fluoride precipitation continue to diminish as the fluorine content decreases with increased phosphate concentration. However, there are a few problems of precipitates with these acids. The most important are the Mg-salts including $MgSiF_6 \cdot 6H_2O$ and $MgH_2P_2O_7$. The solubility of $MgSiF_6 \cdot 6H_2O$ becomes very low in acids as P_2O_5 approaches 60% (Frazier et al., 1977; Mills, 1981). Lehr et al. (1966) reported $MgH_2P_2O_7$ as a common component in superphosphoric acids (70% plus P_2O_5) that were high in MgO. The acid ferrous phosphate, $Fe(H_2PO_4) \cdot 2H_2O$, also has been seen in the solids precipitated from at least one commercial acid in this concentration range. As low emf phosphoric acids containing ferrous iron became more common, this salt may be more frequently reported in the future (Bierman and Long, 1981). When it decomposes by autoxidation, some $Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$ salt will precipitate.

Some concentrated merchant-grade acids contain suspended solids and chemical complexes that increase their viscosity (Cate and Deming, 1970). Magnesium and aluminum greatly affect viscosity and can make it impractical to attain high P_2O_5 grades with many acids. The main advantage claimed for concentrated acids that contain about 60% P_2O_5 is that they minimize the postprecipitation by increasing the solubilities of most iron and aluminum salts. The main disadvantage is the cost of the energy required to concentrate the acid.

Superphosphoric Acids

Superphosphoric acids (70% P_2O_5 or more) contain condensed phosphates (pyro-, tripoly-, and others), and their concentrations increase with acid concentration. In these acids, the precipitated iron and aluminum orthophosphates usually redissolve, and the salts of the condensed phosphoric acids begin to precipitate as highly insoluble tripolyphosphates and metaphosphates. The amount of precipitation depends on the concentration of impurities and the time and temperature of concentration. The most abundant of these precipitates is the very insoluble $(Al,Fe(H_2P_3O_{10}$. Insoluble metaphosphates can form in acids heated at more than 280°C or when contact times are longer than 15 minutes at the usual temperatures. Any MgO and several other divalent cations will precipitate as the insoluble acid pyrophosphates $(Mg, M^{2+})H_2P_2O_7$.

In some cases, the precipitates may be very fine grained and may interact with soluble impurities to increase acid viscosities to undesirable levels. In addition, any soluble impurities in these superphosphoric acids can form sludge during ammoniation that may be only partly available to plants and will decrease product grades.

Ammonium Phosphates

Ammonium phosphates, particularly diammonium phosphate (DAP), have become the most popular phosphate fertilizers because of their high analysis and good physical properties. Ammonium phosphates made from wet-process phosphoric acid with an average impurity content have the nominal grades of 18-46-0 (DAP) and 11-53-o (MAP). The products usually are made by reaction between NH_3 and H_3PO_4 (about 40% P_2O_5) in preneutralizer-granulator or pipe reactor-granulator equipment. The storage properties and ease of granulation depend on certain levels of impurity content which is usually described as $(Fe,Al)PO_4 \cdot nH_2O$ gels and function both as a granulation aid and conditioner to prevent caking. Very pure ammonium phosphates are difficult to granulate and cake badly even at low moisture contents. When the impurity level becomes too high, the nutrient content and availability of the product drop, the grade is decreased, and the physical properties may become poor (soft granules, sticky products).

Recent work (by Dillard et al., 1981, and Dillard et al., 1982) on the precipitated impurities in commercial DAP and MAP products has identified a large number of crystalline phases and their relative concentration (Table 6 and 7). These studies have shown that clarification of the acid greatly reduces the Fe^{3+}, Al^{3+}, and Mg^{2+} concentrations and decreases the impurity phases formed on ammoniation. Decreased retention time in the DAP preneutralizer and increased fluorine levels have the desirable effect of decreasing citrate-insoluble P_2O_5 by minimizing the formation of citrate-insoluble $FeNH_4(HPO_4)_2$ and favoring the formation of citrate-soluble $(Fe,Al)NH_4HPO_4F_2$. Formation of the latter also allows another mole of H_3PO_4 to be ammoniated which helps to make grade. Shorter preneutralizer retention times can be attained by decreasing the effective size of the t (decrease size or lower slurry level). Pipe reactors offer another alternative.

Pipe reactors often produce 18-46-0 fertilizer with very low citrate-insoluble P_2O_5 (0.1% or less). Examination of pipe-reactor products shows the presence of microcrystalline gel phases that have the same compositions as crystalline phases in preneutralizer samples. The difference seems to be that the microcrystalline gels are available in citrate solution. The preneutralizer products contain coarser crystals of the same compositions which dissolve so slowly they are reported to be citrate insoluble. Thus the very short retention time in the pipe reactor causes a change in physical properties (gels versus crystals) that improves the availability of the products.

The MAP products are produced by processes that are similar to those used for DAP, but they have lower N:P ratios. Not surprisingly, the work of Dillard et al. (1982) reported essentially the same precipitated impurities in commercial MAP products although the amounts varied somewhat (Table 7).

The ammoniation of superphosphoric acids to produce either solid ammonium polyphosphate fertilizers or some liquid grades also results in the precipitation of certain impurity-containing phases (Table 8). These materials are the components of undesirable sludge that settle from the liquid products and form scale on the process equipment, or they remain in the product as compounds of low citrate solubility (Frazier, Smith, and Lehr, 1966).

Orthophosphate Suspension Fertilizers

Ammonium orthophosphate suspension fertilizers can be made from wet-process acid and powdered MAP/DAP (Balay and Salladay, 1977). In these products, grades are limited by the fluidity rather than solubility. Insoluble impurities in wet-process acid, and impurities in other intermediates, usually MAP/DAP, as well as insoluble reaction products contribute to the viscosity of these fertilizers. In extreme cases, the products become stiff and semisolid. In some cases, the addition of fluorine could be used to decrease the product's viscosity to a manageable level. This indicates that the presence of fluorine during ammoniation is important in controlling the crystalline phases that form in the suspension fertilizer and directly affect the viscosity of the product.

Fluid NP fertilizers prepared from MAP and ammonia (11-33-0 product grade) or from impure wet-process acid and ammonia (13-38-0 product grade) show similar redistribution patterns of dissolved and suspended impurities introduced in the phosphate intermediates. The compositions of precipitated impurity phases are markedly affected by the fluorine concentration during manufacture and storage (Dillard et al., 1982).

Soluble Ca^{2+} sources are converted to $Ca(NH_4)_2(HPO_4 \cdot H_2O$, which is the stable solid phase in a saturated DAP solution at low fluorine levels (0.5%F) but which is soluble at high fluorine levels ((1.0%F). The solid phase $Mg(NH_4)_2(HPO_4)_2 \cdot 4H_2O$ is well as soluble Mg^{2+} are converted to the water-insoluble phase, $MgNH_4PO_4 \cdot 6H_2O$ (struvite), regardless of fluoride concentration levels.

The $(Al,Fe)NH_4PO_4F_2$ introduced in phosphate intermediates persists unaltered in fluid products. Any $(Al,Fe)NH_4(HPO_4)_2 \cdot 0.5H_2O$ present is converted to the stable $(Al,Fe)NH_4PO_4F_2$ phase at high fluorine levels. The aluminum end-member reacts more rapidly with available fluorine than does the iron analogue, so that iron tends to persist in the $FeNH_4(HPO_4)_2 \cdot 0.5H_2O$ form if insufficient fluorine is available.

At low fluorine concentrations, $(Al,Fe)NH_4(HOP_4)_2 \cdot 0.5H_2O$ and the compound $(Fe,Al)_3KH_{14}(PO_4)_8 \cdot 4H_2O$ dissolve to yield gelatinous $(Al,Fe)PO_4 \cdot nH_2O$, which contributes to high viscosity. The rate of reaction depends on the degree of crystallinity of the $(Al,Fe)NH_4(HPO_4)_2 \cdot 0.5H_2O$ phase, which is governed by prior process conditions. Well-crystallized $FeNH_4(HPO_4)_2 \cdot 0.5H_2O$ is the principal source of citrate-insoluble P_2O_5, but this phase is progressively destroyed on prolonged product storage by decomposition to $FePO_4 \cdot nH_2O$ (gel).

The silica mainly occurs as $SiO_2 \cdot nH_2O$ gel and $Ca_4AlSiSO_4F_{13} \cdot 12H_2O$, which persist as minor insoluble diluents in the fluid product grades. The decomposition of dissolved SiF_6^{2-} to furnish fluorine for reaction with $(\cdot Al,Fe)NH_4(HPO_4)_2 \cdot 0.5H_2O$ to form $(Al,Fe)NH_4PO_4F_2$ contributes to the amount of suspended $SiO_2 \cdot nH_2O$ gel, which tends to raise the viscosity

Thus, it can be seen that the presence of impurities and their relative concentration affect not only the grade of the products but also their important physical characteristics.

Superphosphates

The process chemistry of superphosphates and grades of these products are affected by the impurity element group already described. The most important elements are Fe^{3+} and Al^{3+} with much smaller effects attributed to Mg^{2+} and alkali elements. During the 1960s superphosphates underwent a change in product composition when sludge acids, high in Fe^{3+} and Al^{3+}, were used to prepare denned products (Frazier and Lehr, 1967; Ando and Lehr, 1967). The result was the gradual displacement of monocalcium phosphate, $Ca\ (H_2PO_4)_2 \cdot H_2O$, the traditional superphosphate component, by a mixture of several "new" compounds (Table 9).

Most of these compounds are citrate soluble, so there was no apparent decrease in the agronomic performance of the products. Thus superphosphates became an attractive outlet for phosphoric acid byproducts and marginal quality raw materials. The production of run-of-pile superphosphates from acids in MgO generally was not considered a problem. However, in 1980, Nielsson reported that high MgO caused ex-den products to be very sticky.

During the 1970s granular superphosphates displaced run-of-pile materials because of potentially lower production cost, improved physical properties of the product, greater product flexibility, and reduced pollution problems. In the popular slurry granulation processes, the physical properties of the freshly acidulated mix are critical. This has caused a significant reduction in the levels of impurities that can be tolerated in either the acid or the rock and still have this process operate smoothly. At present, some acceptable 0-46-0 production figures are 50%-54% P_2O_5 acid containing not more than about 10% solids as sludge and 32%-33% P_2O_5 rock (72 BPL). Thus the use of superphosphate as an outlet for phosphoric acid sludge seems rather limited unless plant production rates are decreased to handle a stickier product. Also, the production of superphosphates is decreasing while DAP production is increasing; as a result, an increased demand for clarified acid will create more sludge that is difficult to utilize.

The presence of the complex iron and aluminum phosphates in superphosphates reduces their capacity to accept ammonia (Ando and Lehr, 1967). This reduced capacity combined with a sluggish reactivity may explain some of the difficulties thast occur during attempts to ammoniate superphosphates that contain considerable amounts of iron and aluminum.

Effects of Impurities on Nitrophosphates

The principal advantage of nitrophosphate processes is that nitric acid serves the dual purpose of solubilizing the rock and furnishing some fertilizer nitrogen to the product (IFDC, 1979). This gives nitrophosphates an economic advantage over processes that use nonnutrient reagents to acidulate phosphate rock. At the concentrations of impurities normally found in commercial phosphate rocks (moles F//moles Fe + Al + Mg $\cong$ 10-12), no special processing problems occur; these oxides are solubilized by the nitric acid and reprecipitated as citrate-soluble phosphates during ammoniation. Rocks high in impurities (moles F/moles Fe + Al + Mg $\cong$ 4) cause high viscosities during the concentration steps and influence $Ca(NO_3)_2$ crystallization and supersaturation. These problems are caused by the pass-through of cationic impurities during acidulation and the general absence of an intermediate precipitation/separation step in most nitric processes. The presence of metallic impurities can consume NH_3, affect water solubility, and decrease product grades to some extent. However, some special nitrophosphate processes have been technically successful in using raw materials whose aluminum contents are very high (Hignett et al., 1957).

Discussion

The "Good" and "bad" effects of phosphate rock impurities affect the process parameters, marketing specifications, and agronomic performance of the fertilizer products. Generally the emphasis is on the negative effects because these are the most conspicuous. When positive effects occur, they often are taken for granted or are unknown to the user. Because the processing of the raw material to the final product occurs in several steps, and element that might have an undesired effect at one point might be considered an asset at a dirrerent phase of processing. Often impurity effects caused by interactions of elements are much greater than their single effects (Frazier et al., 1982). Although the overlapping and interrelated effects of impurities on the various aspects of processing, marketing, and agronomic parameters make it difficult to separate their responses to facilitate discussion (Figure 1), this separation has been attempted in the following sections. We recognize that it has definite shortcomings, but if it had not been attempted, any discussion would be difficult to present.

Beginning with the unbeneficiated rock, the presence of impurity-containing accessory minerals (mostly clays and carbonates) can cause problems due to high viscosity, which create nearly thixotropic slurries that decrease washing efficiency and increase energy requirements for pumping. These low-grade, low-quality rocks increase the consumption of beneficiation reagents and can require additional processing steps and equipment to minimize impurities in the feed to the chemical plants. The clay minerals can be beneficial by removing impurities (both water soluble and insoluble) from process water that is recycled. This removal can take place by sorption on the particles or by chemical reactions that immobilize either cations or anions.

During acidulation solubilized impurities can increase the viscosity of acid intermediates and cause operating problems in agitation, pumping, filtration steps, as well as promote reactions which may cause increased maintenance. Phosphate can be lost from the process in the filter cake (cocrystallized or precipitated) as well as by postprecipitation during clarification. Impurity elements can be very beneficial during acidulation. They form SiF_6^{2-} and AlF_6^{3-} complexes that decrease the HF in the acid and greatly reduce corrosion of the equipment. The compleses often either permit recovery of the volatilized fluorine as a salable byproduct or precipitate it as insoluble solids that are environmentally acceptable forms for disposal. Solubilized impurities, especially Al^{3+}, are known to be crystal habit modifiers for various forms of $CaSO_4$ and can be adjusted to improve the shape of gypsum crystals and improve reactor slurry filterability (Gilbert, 1966; Nielsson, 1980). In two identical plants, 68 BPL Florida rock outproduced 72 BPL Moroccan rock by 50% as a result of better filtration that resulted from the beneficial effects of impurities. The formation of precipitates containing gels can decrease filtration rates and cause blinding of the filter cloth.

During concentration of the acid, impurities precipitate as both phosphates and fluorides. The pressure of soluble impurities, especially Mg^{2+} and Al^{3+}, can cause the acids to become very viscous as concentration increases and pumping becomes difficult to impossible. In some cases, very high viscosities actually limit the attainable P_2O_5 concentration to values below 60% P_2O_5. The precipitation of solids in the recirculating acid within the concentrator and the formation of scale on heat-exchange surfaces can increase the costs of concentration impure phosphoric acids. The facilitate the use of impure phosphoric acids, various clarification schemes have been developed to separate the non acid constituents. These systems usually use various combinations of additives and temperature treatments to separate solids that precipitate as the P_2O_5 content of the acid increases (Baumann et al., 1978). Such treatments provide clarified acids that can produce on-grade products, but they also have problems in disposing of the separated sludge. This sludge can be ammoniated to produce 10-50-0 (MAP) grades and can be mixed with sulfuric acid to form a phosphatic granulation liquid feed for NPK granulation plants (Kealy, 1968). In some cases, the sludge may be recycled to the filtration section of the acid plant wshere the soluble P_2O_5 is recovered and the insoluble P_2O_5 is sent to disposal with the gypsum. This procedure may be limited to plants with oversized filters since large drops in filter capacity (up to 50%) can occur. Another potential problem is the decomposition of the phosphate precipitates during filter cake washing and the recycling of impurities to the product.

The presence of impurities in the acids ammoniation can affect the final grade of the product by the dilution and by the formation of citrate-soluble and citrate-insoluble phosphate compounds. The physical characteristics and agronomic efficacy of these impurities vary somewhat with the process used; low availability crystalline compounds form most often in preneutralizer processes and citrate-soluble gels usually form when pipe reactors are used (Dillard et al., 1981). Granulation of the products can be adversely affected by various levels of impurities that result in stickiness, high free acidity, and low granulation surface area in the drum or pan.

Impurities in phosphate rock have both beneficial and deterimental effects on processing parameters. Because the goal of an operator is to make as much salable product as is economically possible, the negative effects are the most apparent. This is because they cost him money either through reduced production rates or increased investment in larger equipment to produce at a given rate. Impurities generally add to the operator's costs by making it more difficult to stay on grade and by increasing processing difficulties including add-on process equipment and steps.

Marketing specifications on fertilizers are based on traditional grades that were established for premium-quality rocks. These grades can be met with increasing difficulty and/or costs as rock quality decreases and impurity levels increase. Difficulties in beneficiating lower grade rock seem to indicate a continuing decline in grade and possibly quality in some commercial concentrates (Louis, 1981). This may mean a change in future marketing patterns where phosphoric acid and other intermediates (such as MAP) made at or near the mine site partially replace some P_2O_5 currently sold as 72 plus BPL rock. Domestic and international shipments of merchant-grade acid might be expected to grow. Clarified and concentrated phosphoric acid will be used in such shipments to minimize handling problems and transportation costs.

Ammoniated phosphates present a more complicated picture. Commercial MAP has a unique advantage in that it has no fixed grade and can vary up to 2% on N and 5% on P_2O_5 contents (10-48-0, and 12-48-0, for example). This allows a producer to use variable amounts of ammoniated sludge acid in a MAP operation, and the practice is quite helpful in utilizing byproducts formed from rock impurities. Future growth of MAP markets as a source of "solid" phosphoric acid may be essential in processing low-quality rocks. The presence of impurities in MAP can cause problems when the material are sold for the production of suspension fertilizers. TVA work has identified a number of the compounds in these MAP and suspension fertilizer grades and has shown that the level of fluorine is an important factor in resolving some viscosity problems.

Commercial diammonium phosphate (DAP) has less flexibility in grade. The grade 18-46-0 was established as a fixed composition for this popular fertilizer at a time when high-quality phosphoric acid was readily available from high-grade phosphate rock. The presence of soluble cation and anion impurities in the phosphoric acid produced from low-quality rock results in a systematic decrease in grade (Dillard et al., 1981). The lack of available high-quality acid has resulted in certain domestic cooperatives reducing the DAP grade to less than 18% N while maintaining P_2O_5 close to 46%. Free market competition has not allowed this to become an industry-wide trend either domestically or internationally. At present producers are still able to make 18-46-0 by improving their skills in manipulating the chemical and physical process parameters. No time line has been established yet between predicted declines in rock grade and a mandatory decrease in grade below 18-46-0. The principal problem caused by the impurities lies in the decrease in N content since the precipitated solids often take up only small amounts of NH_3. The time may come when DAP is sold either as 64% nutrient content with a slightly variable N:P ratio or at the same N:P ratio but at slightly lower grades.

Historically, agronomic evaluation of fertilizers has been based on their water solubility. This tradition was established when water-soluble materials such as superphosphates and ammonium nitrate were the basic fertilizer materials in the United States and Europe. The development of ammonium phosphates during the 1950s and 1960s was not hindered by these evaluation procedures because they also were water-soluble sources. However, even in superphosphates the presence of impurities, usually Fe^{3+} and Al^{3+}, usually decreased water solubility as citrate-soluble phases formed. In many fertilizers produced from impure phosphoric acids, water solubility decreases as Fe^{3+} and Al^{3+} and other impurities increase. The difficulty comes in establishing the level at which water solubility becomes critical to agronomic performance. In many situations 50% water-soluble nutrients may be satisfactory for a number of crops and soils. Citrate-soluble fertilizers can be shown to be good nutrient sources under various agronomic conditions. Some control specifications on fertilizer may hinder any transition from water-soluble sources to mixtures of water- and citrate-soluble sources (Waggaman and Hoffman, 1967). The degree of crystallinity also is a factor affecting the solubility of some of these impurity phosphates. Some compounds are citrate soluble when precipitated as gels or in a microcrystalline state (less than 10 um) while the same materials appear to be citrate insoluble if allowed to form microscopic (about 100 um) crystals (Dillard et al., 1981). In general, most of the impurity elements in phosphate rocks with the possible exception of aluminum are either beneficial or have no effect agronomically.

Fertilizers that have little or no water solubility may be good agronomic sources of P_2O_5. Some examples would include certain phosphate rocks, calcined iron and aluminum phosphates, ammoniated superphosphates, and some nitrophosphates to mention a few. A more precise definition of agronomic specification of water-soluble versus citrate-soluble P_2O_5 that is generally accepted would help producers tremendously. Then research and production efforts could be focused on developing methods to process low-grade ores and impure acids into effective fertilizers at lowest cost rather than concentrating efforts on making products better than they might need to be.

As stated earlier the effects of rock impurities on production, marketing, and use of fertilizers cannot be oversimplified. Gradual changes are being made in the industry to use these impure raw materials in existing plants. The potential benefits of impurities retained in the final products invite a serious reappraisal of their effects. The increased use of lower quality raw materials makes this reevaluation timely and expedient lest we continue to overremphasize the adverse effects of rock impurities during beneficiation, processing, and marketing.

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Table 1. Mineral Sources of Elements of Importance in Phosphate Rock That Affect Processing

	Impurity Elements						
	Na	Mg	F	Fe	Al	K	Si
Apatite	X	X	X				
Accessory Minerals							
Clays							
Attapulgite		X			X		X
Montmorillonite	X	X		X	X		X
Kaolinite				X	X	X	X
Silica							
Quartz							X
Opal							X
Carbonates							
Calcite		X					
Dolomite		X					
Phosphates							
Crandallite					X		
Millisite	X				X	X	
Oxides							
Goethite				X			
Limonite				X			
Others							
Fluorite			X				
Organic		X		X			
Feldspars	X				X	X	X

Table 2. Distribution of Selected Elements During Beneficiation of Florida Matrix[a]

	Major Elements[b]					Minor Elements[c]		
	P_2O_5	Ca	Al	Mg	Fe	Toxics (Cd, Pb, Cr)	Micronutrients (Cu, Zn, Mn)	Uranium (U)
Matrix	100 (13.4)	100 (15.4)	100 (1.9)	100 (0.30)	100 (0.70)	100 (85)	100 (156)	100 (82)
Pebble	38	38	7	17	21	12	29	34
Concentrate	30	29	5	10	19	11	31	21
Rejects[d]	32	33	88	73	60	77	40	45

a. Recalculated from Wakefield (1980), p. 4.
b. Values in parentheses are wt %.
c. Values in parentheses are ppm.
d. Slimes plus tailings.

Table 3. Ranges of Constituents in Typical Analysis of Florida Concentrates

	Percent
BPL	68.10-75.08
P_2O_5	31.15-34.34
CaO	46.67-49.82
Fe_2O_3	1.06-1.49
Al_2O_3	1.05-1.10
MgO	0.30-0.50
K_2O	0.08-0.11
Na_2O	0.45-0.54
CO_2	3.10-3.80
SO_3	0.85-1.10
SiO_2	3.70-9.00
F	3.65-3.85
Cl	0.003-0.012
Organic matter	0.45-0.65
	Parts Per Million
As	3.2-13
Cd	5.5-16
Hg	0.06-0.11
Pb	16-20
Zn	90-100

Source: PHOSROCK, 1976.

Table 4. Levels of Chemical Quality Factors in Phosphate Rocks

1. P_2O_5 grade (28%-42%)
2. CaO/P_2O_5 ratio (1.32-1.61 in apatites)
3. $Fe_2O_3 + Al_2O_3/P_2O_5$ ratio $\leqq 0.10$
4. MgO/P_2O_5 ratio $\leqq 0.022$
5. $Fe_2O_3 + Al_2O_3 + MgO/P_2O_5 \leqq 0.12$
6. F/P_2O_5 ratio $\geqq 1.05$
7. Chlorine content (300 ppm or less)
8. Uranium (average about 100 ppm)
9. Toxic elements (Cd, As, Fe, Pb, Cr, Hg at 10 ppm or less)
10. Micronutrients (Cu, Zn, Mn variable ppm levels)

Table 5. Solids Precipitated in Phosphoric Acid

Compounds	Found in Acids Containing the P_2O_5 Grades			
	28-40	40-50	50-70	70-plus
Phosphates				
*$(Fe,Al)_3(K,Na,NH_4)H_{14}(PO_4)_8 \cdot 4H_2O$	X	X		
$(Fe,Al)_3(K,Na,NH_4,H_3O)H_8(PO_4)_6 \cdot 6H_2O$	X	X		
*$AlHPO_4F \cdot 2H_2O$		X		
$Al(H_2PO_4)_2F$		X		
$AlH_3(PO_4)_2 \cdot nH_2O$ (n = 1, 2, or 3)			X	
$Fe(H_2PO_4)_2 \cdot 2H_2O$			X	
$Al(H_2PO_4)_3$			X	
$FeH(H_2PO_4)_4$			X	
$FeH_3(PO_4)_2 \cdot 4H_2O$			X	
$FeK(HPO_4)_2 \cdot H_2O$			X	
$FeNaH_5(PO_4)_3 \cdot H_2O$			X	
*$(Ca,Mg,Fe,Zn)H_2P_2O_7$				X
*$(Fe,Al)H_2P_3O_{10}$				X
$(Fe,Al)H_2P_3O_{10} \cdot 2H_2O$				X
$Al(PO_3)_3$ (cubic form)				X
$Fe(PO_3)_3$ (monoclinic form)				X
Fluorides				
*Na_2SiF_6	X	X	X	
*$NaKSiF_6$	X	X		
*K_2SiF_6	X	X	X	
$CaSiF_6 \cdot 2H_2O$	X			
$MgSiF_6 \cdot 6H_2O$	X		X[a]	
Na_3AlF_6	X			
Na_2KAlF_6	X			
*$Ca_3(AlF_6)_2 \cdot 4H_2O$	X			
*$(Mg,Na)_xAl_{2-x}F_6 \cdot H_2O$	X		X[b]	
CaF_2	X			
MgF_2	X			
*$CaAlSiSO_4F_{13} \cdot 12H_2O$		X[c]	X[c]	
*$(Ca,Mg)Al_2F_8 \cdot 2H_2O$		X		
Others				
*$CaSO_4 \cdot nH_2O$ (n = 0, 0.5, or 2)	X	X	X	
(Sr, Ba, Pb)SO_4	X	X		

---

* Compounds that occur most often in phosphoric acids.

a. Abundant at high MgO levels.

b. Forms at high MgO and Al_2O_5, low SiO_2.

c. Metastable carryover from filter-grade acid.

Solid-Phase Composition of MAP Fertilizer Grades[a]

Water-Soluble Components	Weight %
$NH_4H_2PO_4$	60.6-74.5
$(NH_4)_2HPO_4$	0-1.7
$(NH_4)_2SO_4$	0.9-15.5
$(NH_4)_2H_3SO_4PO_4$	0-9.9
$(NH_4)_2H_2P_2O_7$	0-2.5
Water-Insoluble Components[b]	
$AlNH_4HPO_4F_2$	2.8-8.2
$FeNH_4HPO_4F_2$	0-3.9
$FeNH_4(HPO_4)_2 \cdot 0.5H_2O$[c]	0-12.0
$AlNH_4(HPO_4)_2 \cdot 0.5H_2O$	0-3.2
$Fe_3KH_{14}(PO_4)_8 \cdot 4H_2O$	0-4.4
$Mg(NH_4)_2(HPO_4)_2 \cdot 4H_2O$	2.9-7.5
$CaHPO_4$	0-2.4
$CaSO_4$ (anhydrous)	0-6.1
$Ca_4AlSiSO_4F_{13} \cdot 12H_2O$	0.1-0.5
SiO_2	0-0.9

---

[a] Representative commercial MAP product grades from Florida and western U.S. sources.

[b] The total amount of water-insoluble components ranged from 10.0% to 30.5%.

[c] Principal citrate-insoluble component; degree of citrate insolubility related to crystal size, which varies with process conditions.

Table 6. Solid-Phase Composition of 18-46-0 Grade DAP Fertilizers[a]

Water-Soluble Components	Percent	Water-Insoluble Components	Percent
$NH_4H_2PO_4$	0-3.2	$MgNH_4PO_4 \cdot H_2O$	2-3.7
$(NH_4)_2HPO_4$	62-76	$AlNH_4HPO_4F_2$	1.3-6.3
$(NH_4)_3PO_4$	0-4.9	$FeNH_4HPO_4F_2$	0.7-3.5
$(NH_4)_2SO_4$	4.9-8.2	$(Al,Fe)NH_4(HPO_4)_2 \cdot 0.5H_2O$	0-9.4
$(K,Na)H_2PO_4$	0.4-2.8	CaF_2	0-1
$Ca(NH_4)_2(HPO_4)_2 \cdot H_2O$	0-5.1	$Ca_4AlSiSO_4F_{13} \cdot 12H_2O$	0-2
$(NH_4)_2SiF_6$	0.1.4	$(Al,Fe)_3KH_{14}(PO_4)_8 \cdot 4H_2O$	(variable)[b]
Na_2SiF_6	(variable)[b]	$(Al,Fe)_3NH_4H_8(PO_4)_6 \cdot 6H_2O$	(variable)[c]

---

[a] Representative commercial DAP products from Florida, North Carolina, and Western U.S. production sources.

[b] Slowly dissolving solid phases carried over in WPA feed; amount varies with WPA source and ammoniation conditions.

[c] Slowly crystallizing phase in stored product or fluid grades; nucleation accelerated at elevated temperatures; substantial substitution of hydronium ion for NH_4^{1+} may occur.

Precipitated Impurities in Ammoniated Superacid Products

$Mg(NH_4)_2P_2O_7 \cdot 4H_2O$

$Ca(NH_4)_2P_2O_7 \cdot H_2O$

$Mg(NH_4)_6(P_2O_7)_2 \cdot 6H_2O$[a]

$MgAl(NH_4)_5(P_2O_7)_2F_2 \cdot 6H_2O$[b]

$(Al,Fe)NH_4P_2O_7$ (anhydrous)[c]

$Fe(NH_4,K)_2P_2O_7 \cdot 2H_2O$

$(Al,Fe)(NH_4)_2P_3O_{10}$

---

a. Divalent metals (Zn, Mn, Cu, Fe) substitute for magnesium.

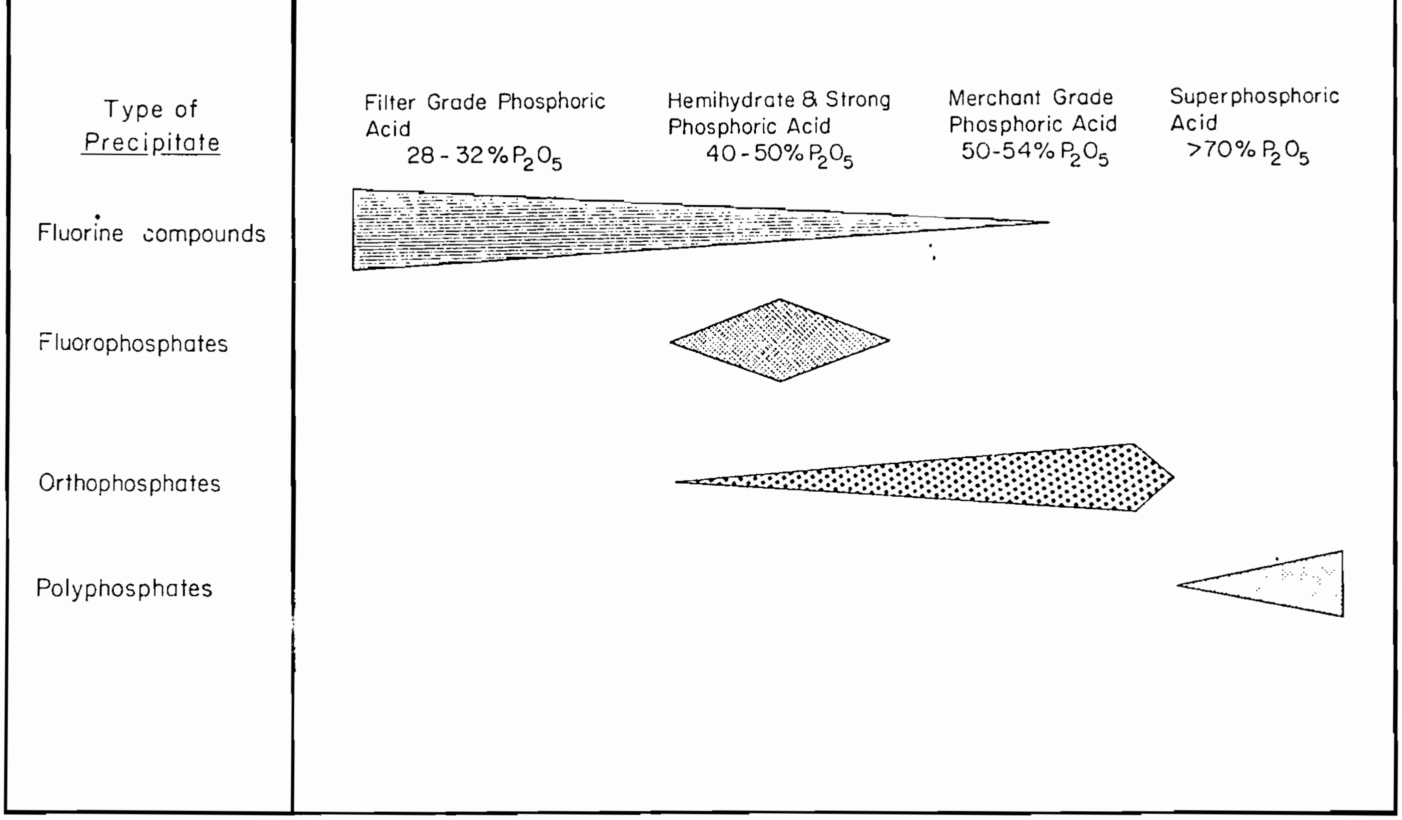
b. Most common sludge phase in APP fluid fertilizer grades.

c. Major scale-forming phase; source of citrate-insoluble P_2O_5.

Table 9. Solid Phase Impurities in Superphosphates

Compound	Impurity
$Ca(Fe, Al)H(PO_4)_2 \cdot H_2O$	Fe, Al
$(Fe, Al)_3KH_{14}(PO_4)_8 \cdot 4H_2O$	Fe, Al, K
$(Fe, Al)_3KH_8(PO_4)_6 \cdot 6H_2O$	Fe, Al, K
$(Fe, Al)PO_4 \cdot nH_2O$ (gel)	Fe, Al
$AlPO_4 \cdot 2H_2O$	Al
$CaAlH(PO_4)_2 \cdot 6H_2O$	Al
$MgHPO_4 \cdot 3H_2O$	Mg

Figure 1. Trends in Precipitation Behavior of Impurities in WPA.



MODERATOR LEYSHON: I think this is one of the papers that requires a little bit of study. I am sure that Guerry McClellan or Jim Lehr would be happy to answer any questions by correspondence, that you may come up with, after you have had a chance to study this over. Thank you Guerry. (Applause)

MODERATOR LEYSHON: Next we come to a discussion which is authorized by Dr. J. P. Kapur of D.C.M. Chemical Works of India. Dr. Kapur is a former President of The Indian Institute of Chemical Engineers. He is going to tell us about Normal Superphosphate in India. Now, this is not to say that the Fertilizer Industry in India is entirely based on Superphosphate. As a matter of fact, for those of us who have been going to India over the past twenty years, we have been astonished with the progress that has been made there in Technology of Fertilizer Production. Great strides have been made and continue to be made there. We are very interested in what Dr. Kapur has to say this morning. (Applause)

Normal Superphosphates Current Status of Process and Economics

T. P. Kapur

List of Figures

Normal Superphosphate appeared on the scene around 1850's and after a century of development, it accounted for as much as 75% of the total world P_2O_5 consumption. During the last thirty years, the share of Normal Superphosphate in the total P_2O_5 consumption has been sliding and today it accounts for 18-20% only. The reasons for such a decline are not far to seek. Technological developments in the manufacture and market response of high nutrient value fertilizers as also the development of balanced and specific complex and compound fertilizers are major factors for the product obsolescene.

For single superphosphate (SSP) manufacture, the various processes developed over a century have not radically changed but varied in details only. The process depends on reacting finely ground Rockphosphate (Fluorapatite) with dilute Sulphuric Acid, so as to solubilize the insoluble Tricalcium Phosphate, break Calcium Fluoride complex into Silicon Tetra Flouride, Mono-Calcium Phosphate Hydrate and Gypsum. The mixing apparatus used varied from vertical paddle mixers to horizontal mixers and kneaders to conical trough systems. Since the hold-up time for the complete reaction of the mixture is inadequate, it is discharged into a den. The dens again vary in mechanical design such as moving bed slat type to covered troughed belt system or even into stationary chambers.

Rockphosphate may be either in the form of chips/lumps or boulders or a blend of coarse and fine powder. The former is crushed to proper mesh before feeding to either Ring Roll Mill grinding system or Air Swept Ball Mills, depending on the capacity of the plant. For large-scale plants and harder rocks, Ball Mill is now an acceptable equipment, being amenable to easy operational controls and less maintenance problems. Whenever necessary, in-built drying sysztem is incorporated, specially where moisture content of feed is between 2-6%. The grinding media as well as liners are made from chilled manganese steel. It may not be necessary to give any details except to mention that the system operates under a closed cycle and suitable arrangements have to be incorporated to arrest fine particulates, 5 microns and below, released from the dust collecting system, may be, by set scrubbing. In the mixing chambers, materials of construction of troughs could be Stainless Steel-316 with suitable protection being provided by A.R. bricks. Even carbon-steel trough protected by lead-bonding and A.R. bricks could be used. The square shaft is so designed for paddle tightening arrangements that these do not leave any clearance for corrosive reactants to attack the shaft. Cap type Red Brass bolts or S.S. bolts are suitable as fasteners for the paddles, both for Retarders and Advancers.

All ducts for gaseous discharge are either rubber-lined Steel or PVC reinforced by FRP. The glass fibre should not be exposed to gases because of presence of HF and its compounds. The scrubbing system for gases could be either venturi scrubber, spray chamber (rubber-lined steel) or simply A.R. brock chambers with sprays of Stainless Steel. The chamber walls are protected by thick coat of coal tar epoxy emulsion paint. Arrangements for recycling of H_2SiF_6 are made, where this is recovered for further processing. The fine silica (somewhat contaminated with fine Rock) is collected from the bottom. This silica has its own use in various other industries such as descicant, or Sodium Silicate manufacturing with high Silica to Na_2O ratio or for catalyst production and even as superfine filler or as adsorbent. About 40% of the fluorine still remains in the product and wherever necessary, $SiO_2 : F_2$ ratio is established to remove maximum quantity of SiF_4.

To make the product friable and easy to reclaim after maturing and to reduce the possibility of lump formation, additive based on sulphonated hydrocarbons are incorporated in small dozes. Wherever micro-nutrients are to be supplemented like Zinc or Manganese or Boron, suitable quantities are added during the mixing operations.

Over the years, as the unit capacity has been increasing, as also to rationalize the process control systems, there is a trend towards continuous production and sophistication of all the unit operations involved, as well as in standardization of operating conditions, dependent, however, on the quality of Rockphosphate used. As the farms are mechanising, as also for use in rice and other crops, Granulated Superphosphate is preferred. Ungranulated Superphosphate is largely used as a diluent in the manufacture of mixed fertilizers and to meet the special requirement of crops like Pulses, Groundnut, or for basal dressing.

Other special requirements, such as, need for supplementing micro-nutrients, such as Zinc, Manganese, Boron, etc. are incorporated into granulated product for a more uniform distribution; soils, which require Sulphur as a supplement, find SSP as a good source. Pasture lands, growing Ry grass or Clover Regime, which require water soluble P_2O_5 and which fix Nitrogen from the atmosphere, will continue to depend on SSP. The salinity in the soil is reduced/eliminated by the presence of gypsum and the free acidity in SSP. It is worth-noting that for every 1,000 kg of P_2O_5 applied to the soil using SSP there is concurrently an addition of almost 720 kgs of Sulphur to the soil. The role of gypsum as a soil conditioner is a well-known fact. It is, therefore, necessary that while evaluating the benefits of SSP, a broader perspective of the advantages should be visualized and not just a supplier of water soluble P_2O_5 nutrient; the other supplements, such as Sulphur and micro-nutrients, which play an important role in the crop growth, should also be taken into account. If Sulphur is accounted for as an additional nutrient, then it is no longer a low nutrient fertilizer.

As regards the plant capacities for SSP, these vary from 100 tonnes/day to over 2500 tonnes/day, highlighting the magnitude and the range of operations and the significance in a particular situation. It is worth-noting that most of the plants installed are now well over ten years and over, and the most recent ones are only installed in the developing countries. Here again, this trend will continue in these countries till it is reversed by the high nutrient P_2O_5 fertilizers as has happened in the Developed World. A case in point is of the Indian situation. The total production of Superphosphate in India is increasing in tonnage at a growth rate of 5-6% per year; but its share in the total P_2O_5 production and consumption continues to drop, because of the higher rate of growth of concentrated P_2O_5 fertilizers.

The major drawbacks, which have relegated SSP to its present decline of share, are the transport, handling, storage and packaging costs. These costs have multiplied during the past decade to the disadvantage of SSP, and this trend is irreversible. Nevertheless, if SSP has to hold its own, despite these above disadvantages, it will be largely because the manufacturing technology is extremely simple, the capital cost/unit P_2O_5 is less as compared to fertilizers with high nutrients value, it does not call for a highly skilled labour force, it does not create pollution, like the disposal problems of phosphogypsum, and it does not depend on imported equipment and technology. Within a radius of 300 KM, the distribution costs are also comparable. Where Rockphosphate is locally available, it could be quite competitive. However, where a country has to import both Rock and Sulphur, then the import of H_3PO_4 will be an economical proposition due to savings in freight. Under these conditions, world trends are bound to be different in different countries countries depending upon the local conditions and technological advancement, the cost of materials, labour, storage, transport and packaging. The overall picture, as it is emerging in some of the areas, may be summarised as follows. The list is only indicative and by no means an exhaustive one:—

In the North American Continent, U.S.A. and Canada, there will be a complete shift away from SSP and during the next decade or so, SSP will be discarded as a source of P_2O_5.

In Western Europe, the production levels of SSP are also declining so much so that from 941,000 tonnes P_2O_5 in 1972-73, it declined to 793,000 tonnes in 1975-76 and to 768,000 tonnes during 1980-81, and there is no reason to believe that this declining trend will not continue (See Figure 1).

In Latin America, the trend, however, is upwards from a production of 246,000 tonnes P_2O_5 during 1972-73 to 278,000 tonnes in 1975-76 and to 408,000 tonnes P_2O_5 during 1980-81 and the likely production of 635,000 tonnes P_2O_5 in 1984-85. The reasons for increase are same as discussed earlier for developing countries. It, however, does not mean that the share of P_2O_5 is increasing, actually the increase is only quantitative but its share in the total P_2O_5 used is declining (See Figure 2).

In Australia and New Zealand, the picture is somewhat different. Its production and usage is steady and more so in New Zealand, where Superphosphate is the main P_2O_5 supplementor for pasture and grasslands, and this will continue to hold its own during the 1980's, although some other fertilizers will put a dent in its consumption. A balance will have to be struck between low grade fertilizer and considerable benefits derived from the presence of Sulphur.

Inthe Indian Sub-Continent, the production of Superphosphate is on the increase, excepting for a setback during the sudden price increase during 1977-78. There will be a continuous increase in the production of Superphosphate quantitatively and this situation will continue till 1990, largely because of a larger number of plants are in production and some more are also planned. From a production of 128,000 tonnes P_2O_5 during 1972-73, it is going to rise to 276,000 tonnes P_2O_5 during 1984-85. It may be that this trend will continue till 1989-90. All the same, the share of SSP in the total P_2O_5 production and consumption, however, has been declining. In 1950, SSP and 95% share of P_2O_5 consumption but its share dropped to a mere 15% today and by 1984-85, this figure will come down to around 11%. This is largely due to indigenous production of more concentrated fertilizers, and more so due to cheaper H_3PO_4 and DAP imports. Almost all these new plants are located at the ports.

It may be concluded that in the developed countries, where the labour and transport costs form a significant component of the distributed cost, SSP will cease to be of any significance both percentagewise as well as quantitatively. In the developing countries, the market share of P_2O_5 will continue to decline, but quantitatively it will go up excepting that the rate of growth of other P_2O_5 fertilizers will be faster than that of SSP. Countries, where they have a special situation such as New Zealand, South Africa, Egypt, will continue to depend on SSP because of local situation and requirements.

It is also worth-mentioning that per capita income of the farmers also acts as a proxy for the developmental variables and cost of inputs of the various nutrients. As long as the per capita cost to the farmers is economical for P_2O_5 in SSP, this factor plays a significant role in popularisation and use of this particular fertilizer. These factors also depend on the Government Internvention such as subsidies for farm products and fertilizers. In India these have played a very significant role in the popularisation and growth of fertilizers. Recent gesture by the Government in further reducing the price of Superphosphate to the farmers and in equalizing SSP prices throughout the country are bound to give further fillip to SSP industry. The subsidy to the farmers has been increased by almost 18% over what it was in May this year. This will also encourage capacity utilization of Superphosphate.

Tables 1 to 3 comparing costs of production of various Phosphatic Fertilizers show that both in terms of capital costs per tonne P_2O_5 as well as operating cost normal Superphosphate has an edge over other P_2O_5 fertilizers. However, it has high packing, storage and handling costs. It is the delivered cost to consumer which ultimately determine status of any particular fertilizer by the farmers unless there are other compelling reasons.

In India, Sulphur is almost wholly imported and a large quantity of Rock has also to be imported. There is now a growing trend towards import of H_3PO_4 for plants situated at the ports where DAP is largely manufactured and shipped inland. Many Rockphosphate producing countries are gradually installing large H_3PO_4 production capacity to utilis low grade Phosphate rock which are otherwise difficult to dispose of. This trend is going to pick-up and with it the displacement of shipments of Rock Phosphate. Another future trend, which is very likely to take place, is the development of Nitro-phosphate as a source of both Nitrate Nitrogen as well as P_2O_5. Countries, which have no source of either voluntary or involuntary Sulphur, will gradually shift to Nitrophosphates and reduce dependence on Sulphur. For supplementing the soils deficient in Sulphur or reducing salinity, use of gypsum or iron pyrites has to be resorted to.

In conclusion, it may be mentioned that normal Superphosphate will gradually be displaced by more concentrated fertilizers excepting where deficiency of Sulphur is a predominant factor or where Rockphosphate is locally available and the consuming centres are not widespread. Developing countries will delay complete phasing out of normal Superphosphate.

Trading in H_3PO_4 will become dominant and there will be a shift away from imports of Rock and Sulphur by importing countries in favor of H_3PO_4 imports.

Nitrophosphate will gradually start appearing on the scene both as Phosphatic and Nitrogenous fertilizers specially in countries where Rockphosphate is locally available but Sulphur in adequate quantities is not available or when Sulphur prices tend to be uneconomical. Almost 60% of the Sulphur imports are diverted towards production of Phosphatic Fertilizers in India.

It may, however, be mentioned that in many developing countries Government intervention in the regulation and subsidizing the farmers by way of fertilizer inputs plays a pivotal role and not the economics of any particular fertilizer. The situation as to when the market and the competitive forces will overtake reversal of this intervention by Government is somewhat difficult to comprehend because the importance and role of agriculture in the economy of developing countries can not be under-rated. Thank you. (Applause)

Table 1

VARIOUS SCHEMES OF PHOSPHATIC FERTILIZER MANUFACTURE

Sl. No.	PARAMETER	SCHEME-A	SCHEME-B	SCHEME-C	SCHEME-D	SCHEME-E	SCHEME-F	SCHEME-G
1.	Product (Grade)	Single Super-phosphate (16%P_2O_5)	Single Super-phosphate (16%P_2O_5)	Triple Super-phosphate (46%P_2O_5)	Triple Super-phosphate (46%P_2O_5)	Diammonium Phosphate (18-46-0)	Diammonium Phosphate (18-46-0)	Nitro-phosphate (22-22-0)
2.	Source of raw materials							
	- Rockphosphate	Indigenous	Imported	Imported	Imported	-	Imported	Imported
	- Sulphur	Imported	Imported	Imported	-	-	Imported	-
	- Phosphoric Acid	-	-	-	Imported	Imported	-	-
	- Ammonia	-	-	-	-	Indigenous	Indigenous	Indigenous

Table 2

COMPARISON OF CAPITAL INVESTMENT OF VARIOUS SCHEMES OF PHOSPHATIC FERTILIZER MANUFACTURE

(100 MT/D of P_2O_5)

Sl. No.	PARAMETER	SCHEME-A	SCHEME-B	SCHEME-C	SCHEME-D	SCHEME-E	SCHEME-F	SCHEME-G
1.	Capital Investment (Rs.-Million)	72	72	102	18	55	157	248
2.	Foreign exchange requirement for import of raw materials: (Rs./MT of P_2O_5)							
	- Rockphosphate	-	2170	2230	620	-	2030	1930
	- Sulphur	1110	1050	1100	-	-	1450	-
	- Phosphoric Acid	-	-	-	3310	4340	-	-
	- Naphtha for NH_3	-	-	-	-	990	990	5170
	TOTAL:	1110	3220	3330	3930	5330	4470	7100

Table 3

COMPARISON OF COST OF PRODUCTION OF VARIOUS SCHEMES OF PHOSPHATIC FERTILIZER MANUFACTURE

(100 MT/D of P_2O_5)

Sl. No.	PARAMETER	SCHEME-A	SCHEME-B	SCHEME-C	SCHEME-D	SCHEME-E	SCHEME-F	SCHEME-G
	Product (Grade)	Single Super-phosphate (16%P_2O_5)	Single Super-phosphate (16%P_2O_5)	Triple Super-phosphate (46%P_2O_5)	Triple Super-phosphate (46%P_2O_5)	Diammonium Phosphate (18-46-0)	Diammonium Phosphate (18-46-0)	Nitro-phosphate (22-22-0)
	COMPARATIVE COST OF PRODUCTION							
a.	Variable Cost	100.0	102.5	292.1	386.4	518.4	370.0	309.3
b.	Fixed Cost	13.0	13.0	52.1	9.7	28.0	79.2	61.6
c.	Total:							
	- per MT	113.0	115.5	344.2	396.1	546.4	449.2	370.9
	- Credit for N	-	-	-	-	-110.0	-110.0	-135.8
	- per MT P_2O_5	706.0	721.4	748.3	861.1	946.3	735.1	1068.9

NOTE: All figures are relative, based on 100 for Variable Cost in Scheme 'A'.

FIG. 1

SHARE OF SSP IN WORLD P_2O_5 PRODUCTION

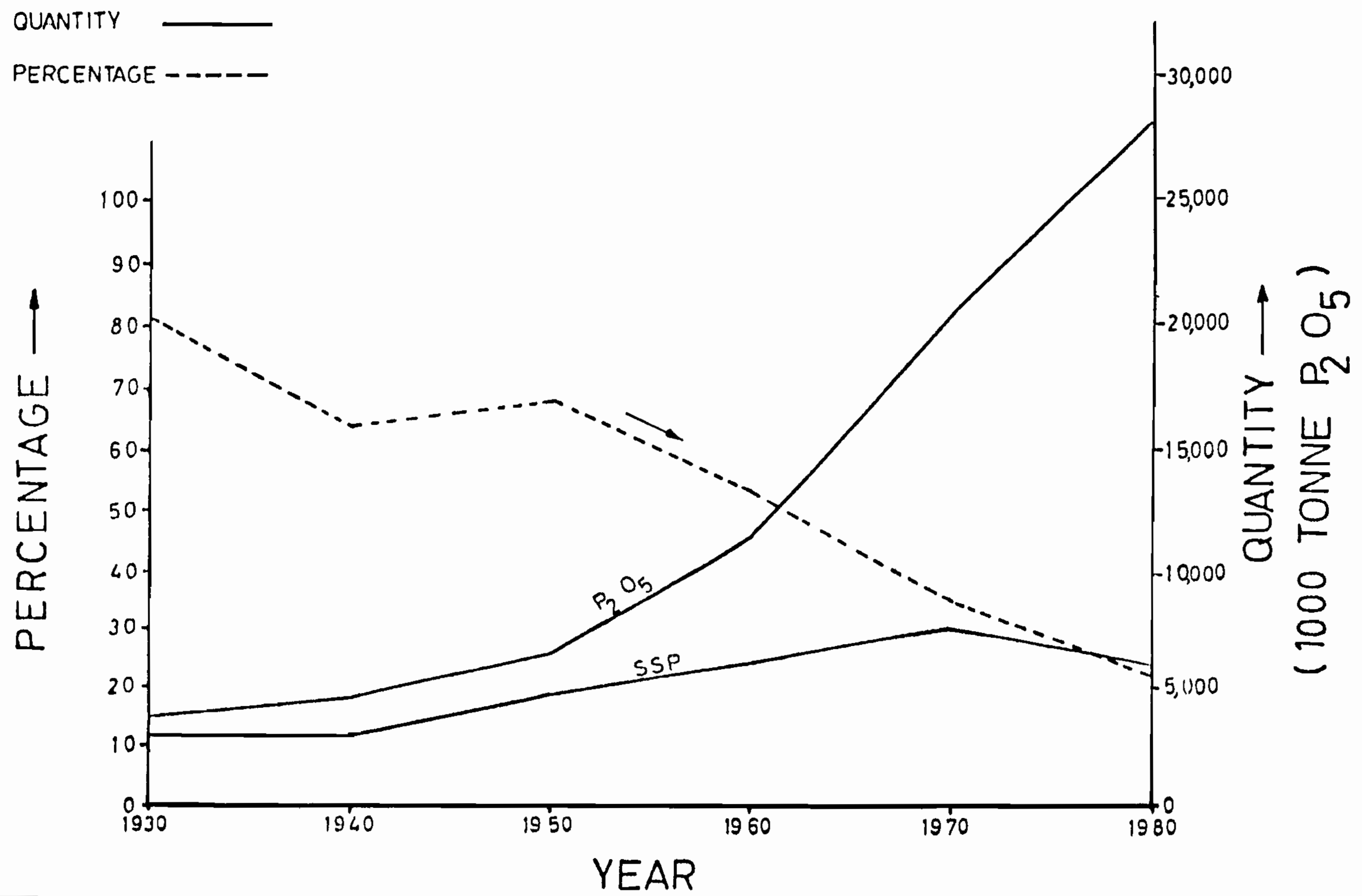
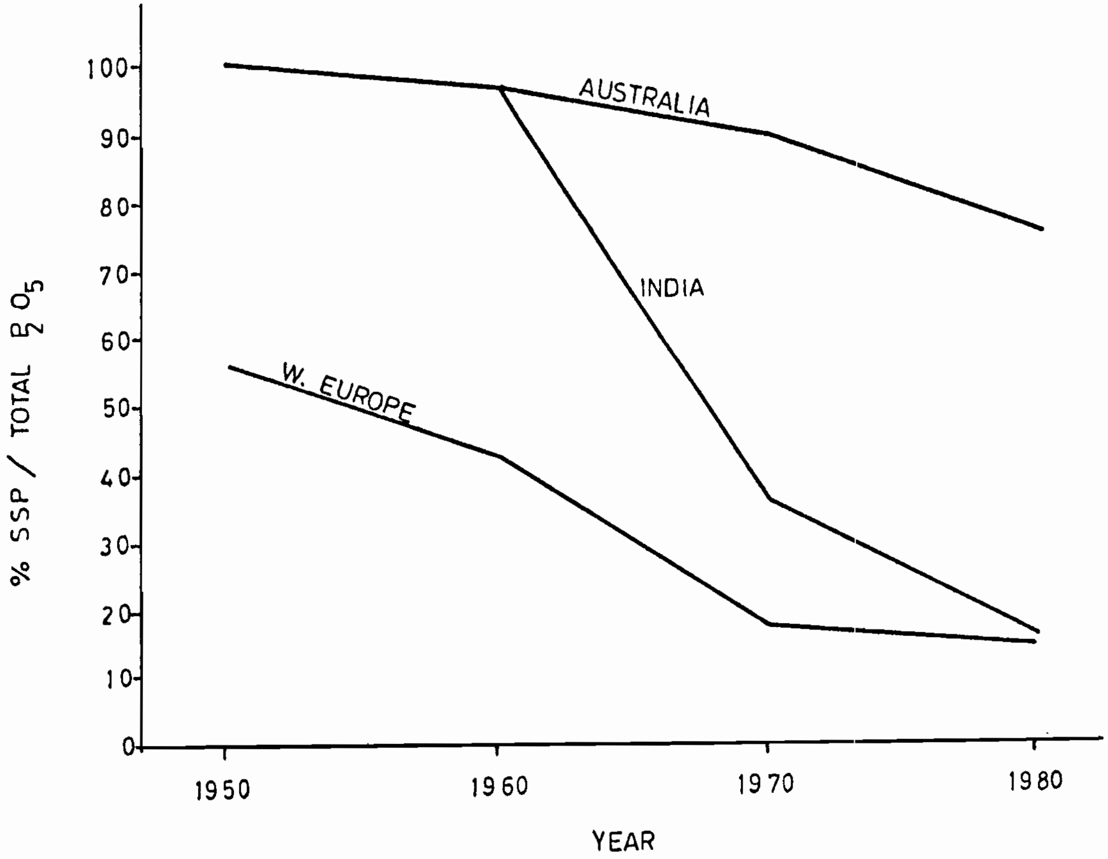


FIG. 2

SHARE OF SSP IN PHOSPHATIC FERTILISERS



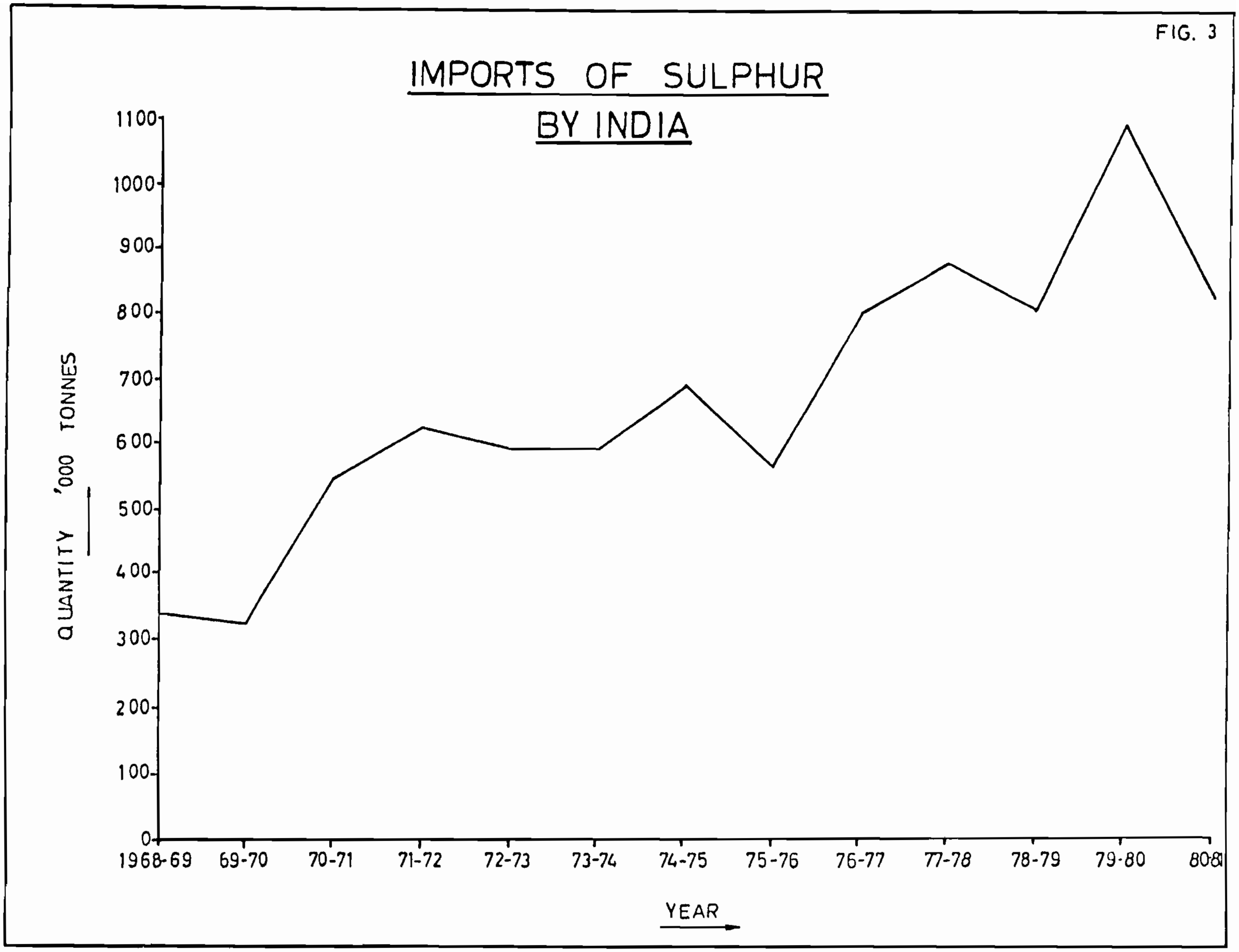
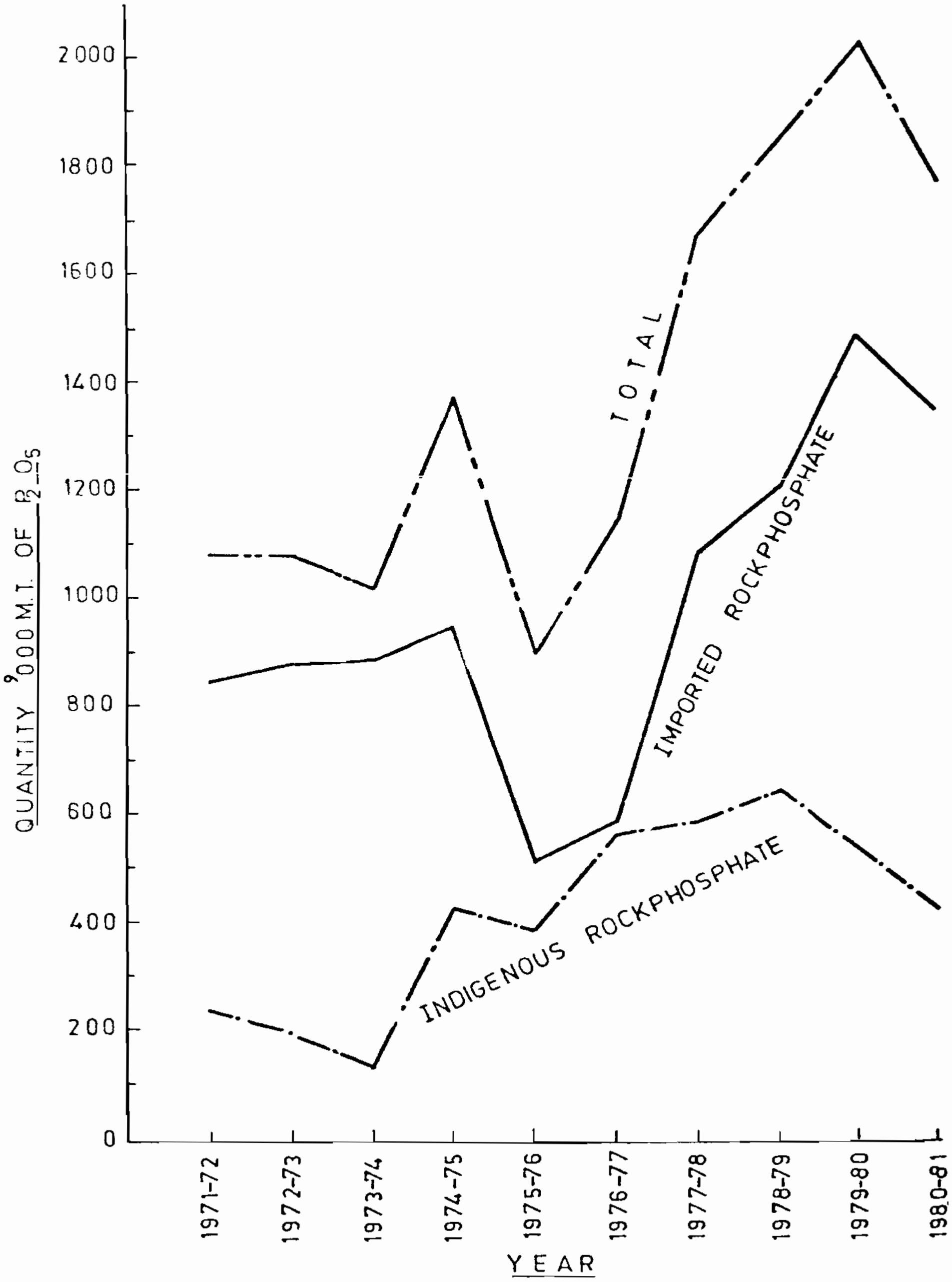


FIG. 3

IMPORTS OF SULPHUR BY INDIA

FIG. 4



ROCKPHOSPHATE IMPORTED vs ROCKPHOSPHATE PRODUCED INDIGENOUSLY

FIG.5

IMPORTS OF DAP FERTILISER BY INDIA

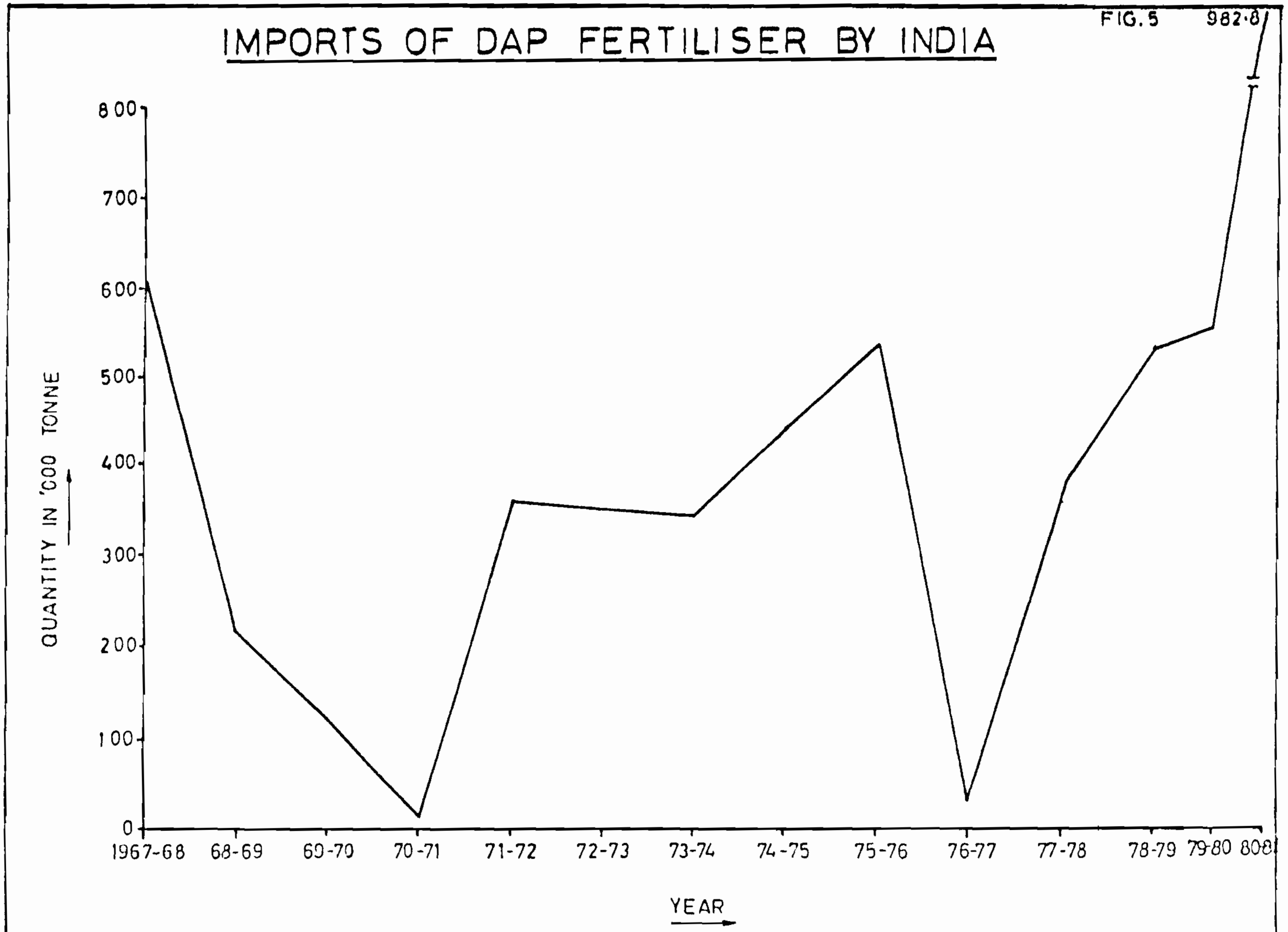


FIG. 6

PRODUCTION & IMPORTS OF PHOSPHORIC ACID

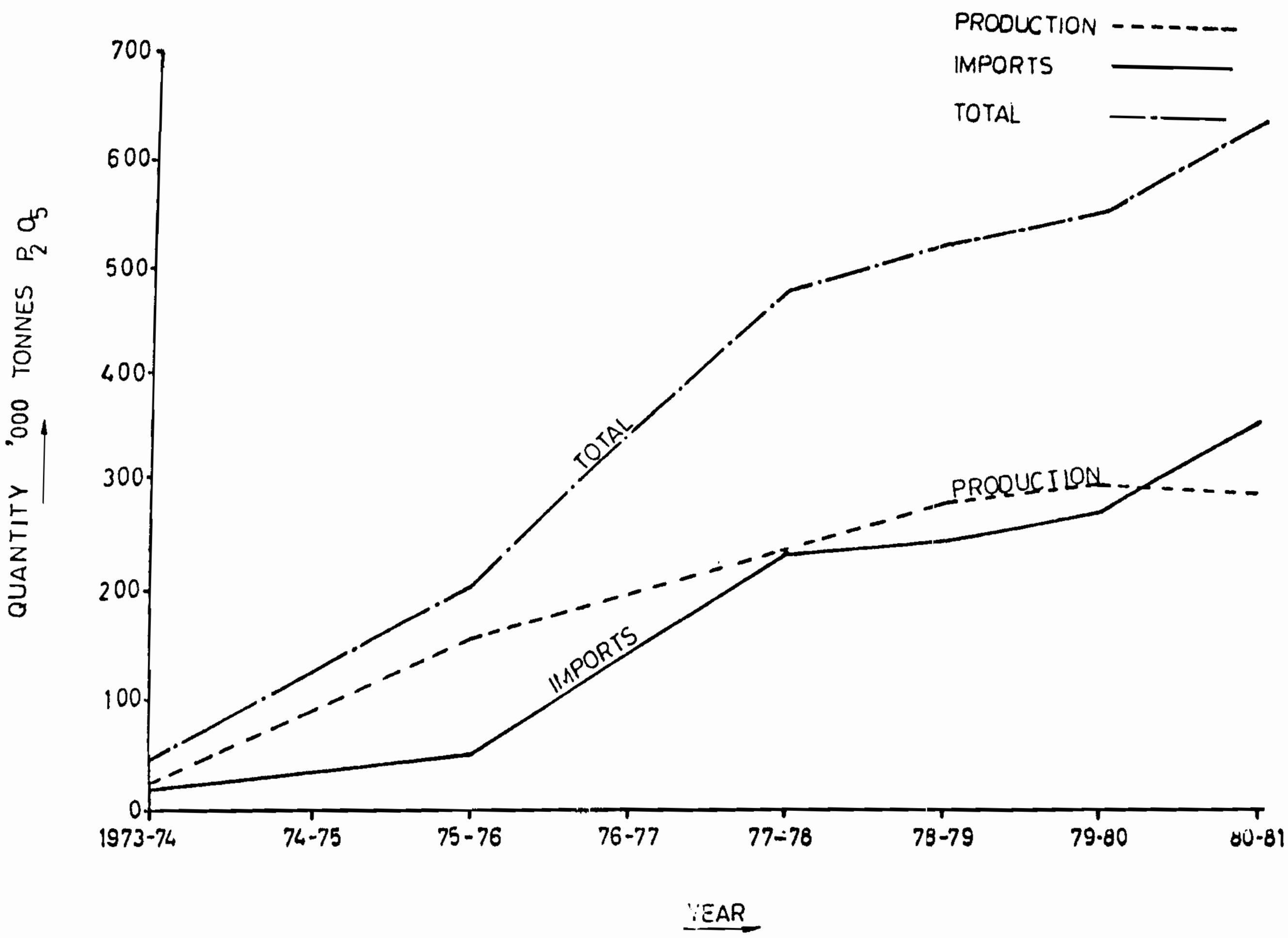
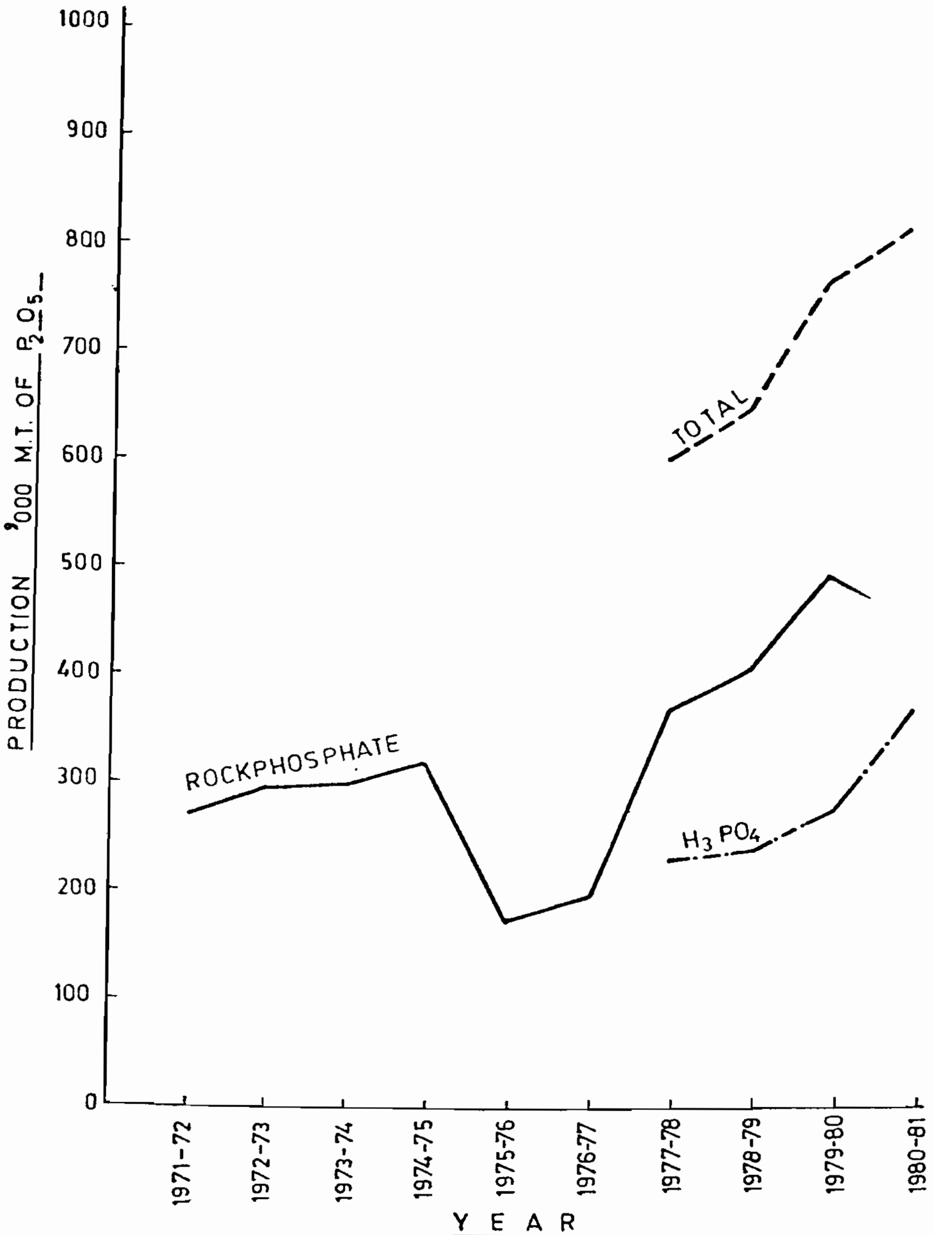


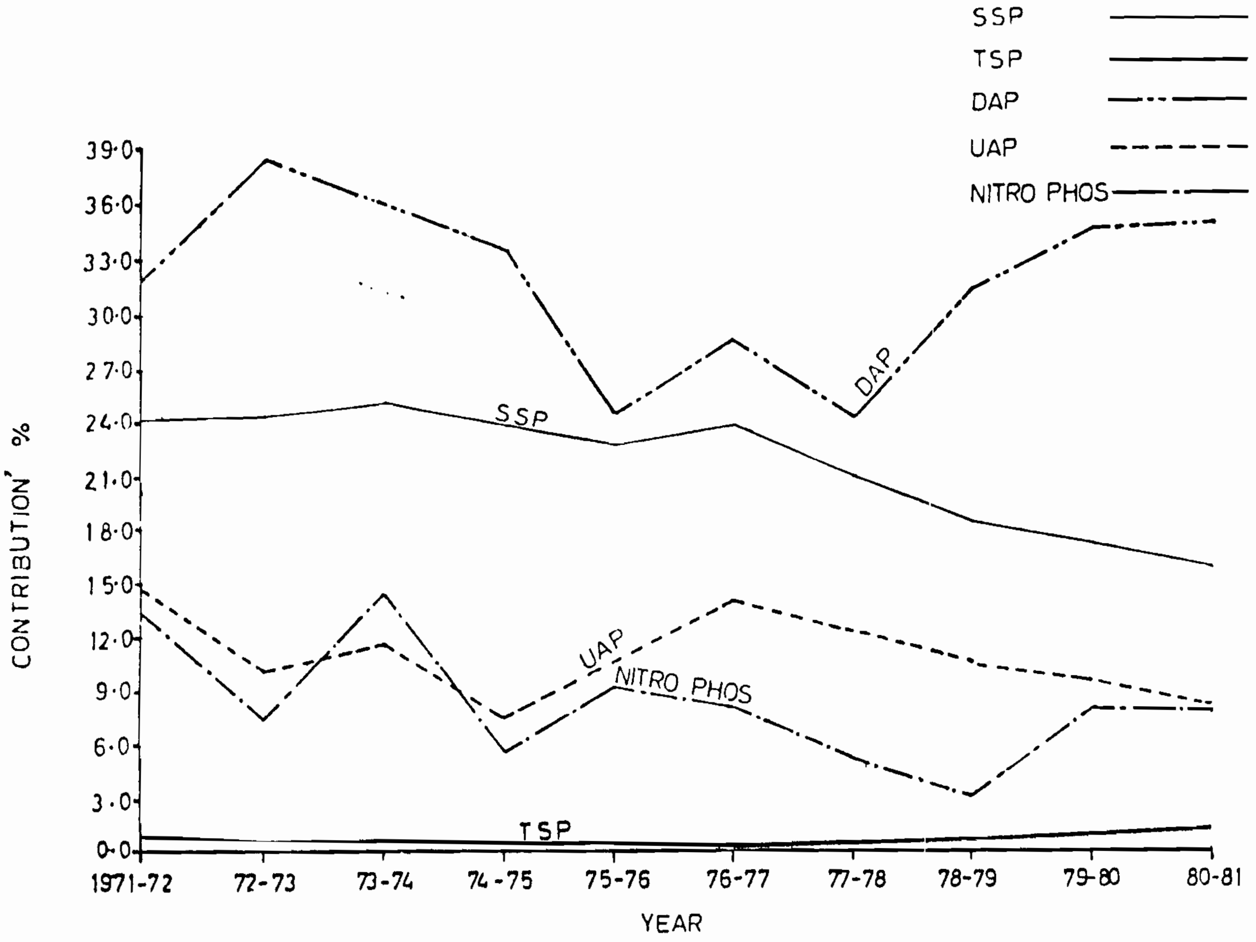
FIG. 7



PRODUCTION OF PHOSPHATIC FERTILIZERS FROM IMPORTED RAW MATERIALS

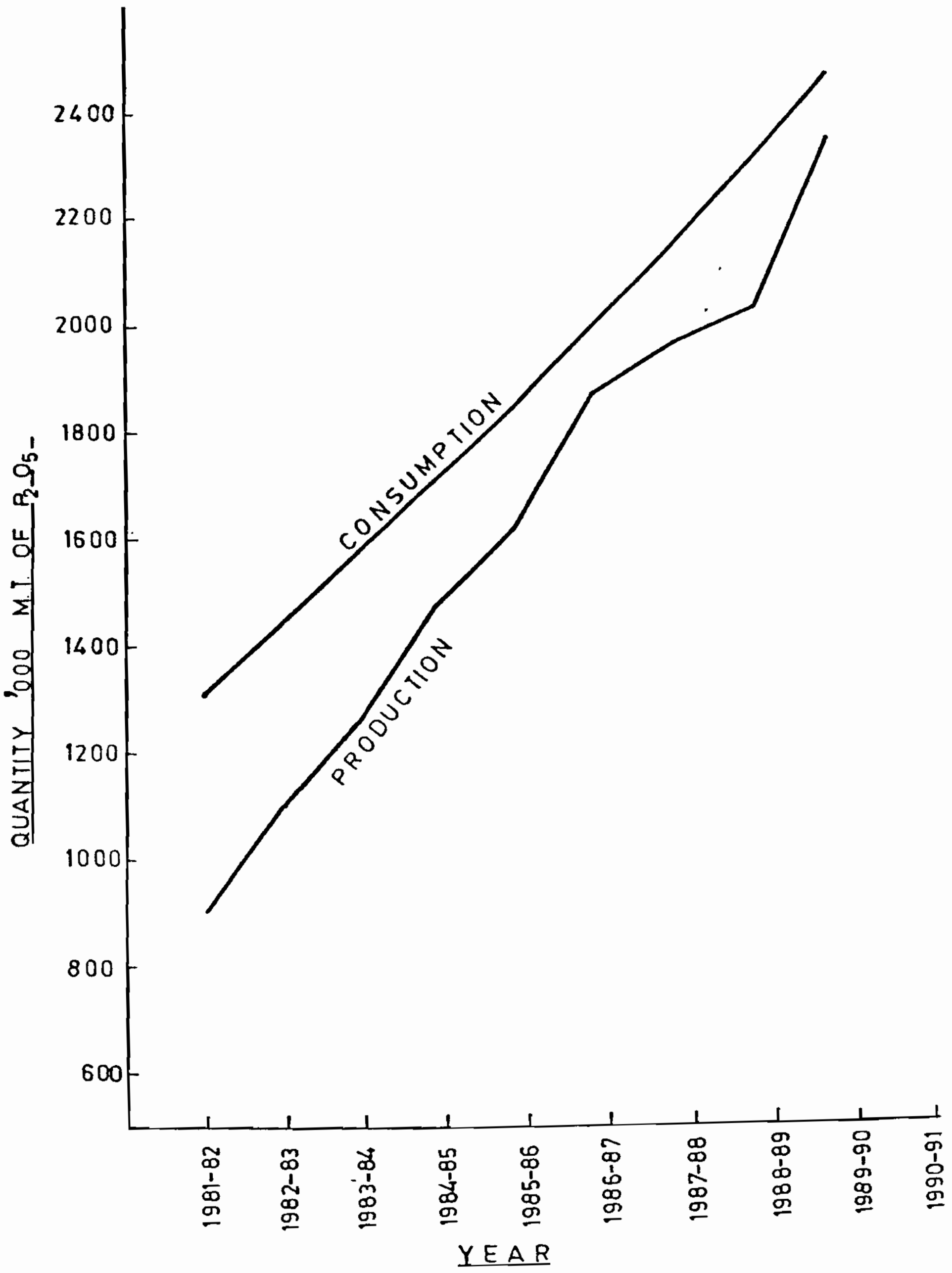
FIG. 8

P_2O_5 CONTRIBUTION OF DIFFERENT FERTILISER GRADES



PROJECTION FOR 1981 OWNWARDS SHOWS INCREASE IN CONSUMPTION OF P_2O_5 BUT IN TERMS OF SSP % CONTRIBUTION OF SSP WILL REDUCE FROM 16% TO 10-11%.

FIG. 9



ESTIMATED CONSUMPTION & PRODUCTION OF PHOSPHATIC FERTILIZERS IN EIGHTIES

MODERATOR LEYSHON: Thank you very much Dr. Kapur for your most interesting discussion. (Applause)

MODERATOR LEYSHON: Our next paper, last but not least, will be discussed by William F. van - Weenen of Kenetics Technology International - K.T.I., "A Dutch Company." His discussion should be very interesting, Viz:

New concept Ammonia Process With Higher Efficiency

William F. van Weenen
Jack Tielrooy
Presented by William F. van Weenen

Willem F. van Weenen, Kinetics Technology International Corporation, Pasadena, California.

Jack Tielrooy, Consulting Chemical Engineer, Fullerton, California.

Introduction

During the current decade, much emphasis will be placed on energy conservation, especially in the design of new plants. Ammonia plants have traditionally been high energy consumers. In the past decade and a half, total energy requirements for ammonia production have decreased significantly. At the same time, average plant capacities have increased tremendously. Since the advent of the first large tonnage ammonia plants, with capacities in the range of 600 to 2000 short tons per day, most of the emphasis on technological improvements and increased efficiency has been directed to these large plants. The smaller plants, with capacities up to 600 tons per day, did not undergo the same degree of optimization and technological improvement as did their big brothers. There are many locations in the world where the larger ammonia plants cannot be justified. Size limitations may be imposed by market size, availability of capital, availability of raw materials, or national policy. To meet the needs for any energy efficient ammonia process in the capacity range of 200 to 600 tons per day, KTI had developed a new concept ammonia process called the "PARC Process" (*"P" for P.S.A.* purification, *"A" for Ammonia,* and *"RC" for Rankine Cycle* power recovery.

Summary

The "PARC Process" has been developed by KTI Corporation in collaboration with Jack Tielrooy, Consulting Chemical Engineer, through the combination of well proven process steps. The result is an ammonia process, suitable for small ammonia plants, but with energy requirements comparable to or less than the most efficient of large tonnage plants. The efficiency has been further enhanced by the application of a steam Rankine Cycle to generate electric power.

The "PARC Process" consists of five major steps as illustrated in Figure 1:

1. Air Separation
2. Steam Methane Reforming
3. Purification in a HYSIV Polybed PSA unit
4. Ammonia Synthesis
5. Rankine Cycle Power Recovery

The simplified flow diagram does not show compression, which is of course required.

Total energy requirements, expressed in terms of Million BTU (LHV) per short ton of ammonia, compares favorable with other processes, even with the 1000 and 1150 t/d ammonia plants, as shown in Table 1.

Process Description

A simplified process flow diagram of the synthesis gas preparation section used in the "PARC Process" is given in Figure 2.

Feed Preheat and Desulfurization

Natural gas is preheated to 750°F by heat exchange with reformer product. The gas is desulfurized to less than 0.2 PPM of sulfur in passage through two zinc oxide desulfurizers. The desulfurized gas is mixed with superheated steam and heated further in a mixed feed preheater coil in the reformer convection section.

Steam Methane Reforming

The preheated feed gas-steam mixture is passed through the reformer which contains a number of vertical catalyst-filled tubes which are manifolded in parallel. The reformer is fired with burners located at the top of the furnace, firing between rows of tubes. Most of the fuel requirements are met with the waste gas from the PSA purification unit.

A small amount of natural gas (or oil) is fired for control of outlet conditions. Combustion air is oxygen-enriched with waste oxygen from the air separation nitrogen production unit and preheated in the convection section in order to improve efficiency. The reformer operates with an outlet pressure of 400 psig and an outlet temperature of 1500 - 1550°F. The reactions which occur in the reformer are as shown in Figure 3. The steam hydrocarbon reactions are favored by increasing temperature. The conversion of carbon monoxide to carbon dioxide plus additional hydrogen is favored by low temperatures and hence does not approach completion in the reformer. Reformer outlet temperature is set so that the unreacted methane plus other gas removed in the PSA unit will supply 90 to 95 percent of the reformer fuel requirements.

Reformer Heat Recovery

Reformer flue gas is cooled in the convection section to a temperature of about 300°F. The heat is utilized to preheat combustion air, to preheat reformer feed, and to generate steam. Reformer product is cooled to about 660°F prior to entering the high temperature shift converter. The heat recovered is used to generate steam, to superheat excess steam utilized in the Rankine Cycle power generation unit, to superheat process steam, and to preheat natural gas fired before desulfurization.

Shift Conversion

About three-fourths of the carbon monoxide in the reformer product is converted to carbon dioxide plus an equivalent amount of hydrogen in the high temperature shift converter which operated with an outlet temperature of about 750°F. In the conventional process, a second stage of low temperature shift conversion is used to further reduce the residual carbon monoxide. The use of PSA purification eliminates the need for a low temperature shift converter.

P.S.A. Purification

After cooling to ambient temperature, and separation of the process condensate, the gas is purified in a HYSIV® Polybed P.S.A. unit licensed and designed by Union Carbide Corporation. The P.S.A. unit consists of ten adsorbers.

Each vessel follows a cycle consisting of adsorption, stepwise depressurization, purging, and stepwise repressurization. In the conventional Polybed P.S.A. unit, hydrogen recovery is in the order of 85 percent. Hydrogen recovery is improved to about 93 percent by employing nitrogen in the purge step. At the same time, a substantial portion of the total nitrogen is "compressed" in the P.S.A. unit as the adsorbers are repressurized. Other than a small amount of argon which is introduced with the nitrogen, all other impurities are reduced to less than 1 PPM.

Figure 4 is a schematic flowsheet of the Union Carbide Polybed P.S.A. system. The system shown maximizes hydrogen recovery by effectively utilizing the hydrogen stored in the adsorber vessel at the end of the cycle to repressurize other adsorber vessels and to provide hydrogen for purging. Not shown is the nitrogen connection for final purging with nitrogen in place of hydregen. Three vessels are on adsorption at any one time while the other seven are in various stages of regeneration. The cycles are staggered so that one adsorber at a time comes on the line when another completes its adsorption step. At the end of an adsorption cycle, the vessel is depressurized in a cocurrent direction in four steps - three separate pressure equalization steps with three different adsorbers and a purge step with a fourth. During this depressurization, only pure hydrogen is removed. Following the cocurrent depressurization, further depressurization is carried out in a countercurrent direction, with the removal of some impurities. The adsorber is then purged at low pressure with pure hydrogen or in case of the "PARC Process" with pure nitrogen. The gases from the final depressurization step and purge step go to fuel. Several excellent papers have been published on the HYSIV P.S.A. process to which the reader is referred. Figure 5 shows a complete Polybed P.S.A. skid on a truck ready for shipment. This skid contains all valves and controls for the unit.

The only field installed piping are the lines to the top and bottom of each adsorber. Four other lines to be connected are the feed gas inlet, the nitrogen inlet, the hydrogen product outlet and the fuel gas outlet. Figure 6 is a photograph of a completed plant utilizing the HYSIV Polybed PSA process.

Nitrogen Production

For the purpose of this study, we have assumed that nitrogen is produced on site with the simultaneous production of an impure oxygen stream. Part of the latter is used to enrich the combustion air to the reformer. Nitrogen is produced at 30 Psig. Capital costs and utilities figures presented in this paper include nitrogen production.

Gas Compression

Air for nitrogen production is compressed by a single motor driven centrifugal compressor included with the nitrogen production unit. All other compression services are combined on the basis of two 50-percent capacity motor driven reciprocating compressors. These services are:

1. Nitrogen compression (only part of the nitrogen needs to be compressed), from 30 Psig to about 380 Psig.
2. Synthesis gas compression, from 380 Psig to about 4,900 Psig.
3. Recycle gas compression, from about 4,600 Psig to about 4,900 Psig.
4. Refrigeration ammonia is compressed from 47 Psig to 197 Psig.

Ammonia Synthesis

Figure 7 is a simplified flowsheet of the ammonia synthesis loop. The high purity of the ammonia synthesis gas make-up simplifies the ammonia synthesis loop and reduces equipment sizes. The high purity eliminates the need for a purge gas recovery system. The only purge taken is the gas which dissolves in the ammonia. This gas is flashed in a letdown drum. Part of the gas is recycled. The balance is passed through a refrigerated chiller for ammonia recovery and sent to fuel. Due to the high purity of the gas, a higher than normal conversion is obtained in the ammonia converter. The ammonia converter design employs an external feed vs product heat exchanger rather than an internal one as in many plants. The high conversion and the resulting high temperature rise, makes it economical to install a waste heat boiler between the ammonia converter and the feed/product heat exchanger. Steam production from the synthesis loop is 1.3 to 1.4 tons per ton of ammonia produced.

Rankine Cycle Power Generation

While the plant is designed to minimize fuel consumption, and hence steam generation, the design employs maximum recovery of available heat to generate steam. That amount of steam in excess of process requirements is superheated to 825°F and delivered to a multi-stage condensing turbine at 600 Psig. The steam turbine drives an electric power generator at either 3600 RPM or 3000 RPM, depending upon the frequency of the electric power to be produced, 60 Hertz or 50 Hertz. The turbine exhausts to a vacuum condenser at a pressure of 3 inches mercury absolute. With this arrangement, it is possible to supply about 65 percent of the electric power requirements of the ammonia plant internally.

If there is an actual need for a substantial amount of export steam for use in other units, the Rankine Cycle power generator may be reduced in size or completely eliminated. As will be shown in the Tables to be presented, the "PARC Process" without Rankine Cycle is even more favorable providing that export steam is given a credit equal to the fuel required to produce it.

Energy Saving Features

The "PARC Process" incorporates the following features, all of which contribute to energy savings:

1. Combustion air for the reformer is enriched with oxygen from 21 percent to 26 percent.
2. Combustion air for the reformer is preheated to 600°F.
3. Reformer fluegas is cooled to 300°F by heat recovery.
4. Maximum heat is recovered from the process streams in the reforming section.
5. The high energy consuming carbon dioxide removal system used in most plants is replaced with an energy efficient P.S.A. purification system.
6. The high purity of the synthesis gas make-up eliminates taking a purge gas stream from the ammonia synthesis loop.
7. Refrigeration requirements in the synthesis loop are reduced.
8. Substantial stream is generated in the ammonia synthesis loop. This also further enhances the amount of low level heat which may be recovered in the reforming section.
9. Excess steam produced is efficiently utilized to produce electric power.

Comparative Utilities Requirements

Detailed process designs were prepared for three cases:

1. "PARC Process" with Rankine Cycle power recovery.
2. "PARC Process" without Rankine Cycle power recovery.
3. Optimized conventional plant.

The capacity selected was 400 metric tons per day, or 441 short tons per day of ammonia. A comparison of the utilities requirements for the three cases is given in Table 2.

In order to compare the efficiencies, energy consumptions have been converted to Million BTU per short ton of ammonia. Electric power is equated at the rate of 10,500 BTU per kilowatt hour. Steam is given a credit only where export steam is needed. In the "steam credit" cases, steam is equated at its enthalpy relative to water at 80°F. In Table 3 comparisons are made between the "PARC Process" with Rankine Cycle and the optimized conventional process without credit for export steam, and between the "PARC Process" without Rankine Cycle and the optimized conventional process with credit for export steam.

To summarize, the cases compare as follows:

With zero steam credit:

"PARC" with Rankine Cycle	27.86 MMBTU/Short Ton
Conventional	32.18 MMBTU/Short Ton

With steam credit as fuel equivalent:

"PARC" without Rankine Cycle	26.84 MMBTU/Short Ton
Conventional	30.88 MMBTU/Short Ton

FOR GRAPHICAL ILLUSTRATION SEE BAR CHART

Economic Comparisons

Plant Costs

Definitive cost estimates have been prepared for the "PARC Process", both with and without Rankine Cycle, and for the "Optimized Conventional Process." Cost estimates were based on an ammonia production capacity of 441 short tons per day (400 metric tons per day). These cost estimates have been factored to other capacities. Plant cost versus capacity curves are given in Figure 8. Prices are based on January, 1980 levels and a U.S. Gulf Boast location. Appropriate adjustments must be made for other locations and inflation. Estimated costs for a 441 ST/Day plant are:

"PARC Process" with Rankine Cycle	$31,400,000
"PARC Process" without Rankine Cycle	$20,000,000
Optimized Conventional Process	$27,000,000

Plant Costs

Investment costs are for battery limits facilities, including cooling tower and local switchgear. Offsites and storage are not included.

Energy Costs

In Figure 9, energy costs in U.S. dollars per million BTU (LHV) are equated to the price of crude oil in U.S. dollar per barrel (42.0 U.S. gallons). With crude oil prices already in the range of $30.00 to $40.00 per barrel, and escalating with regularity, we must look at all energy costs in terms of crude oil price.

During periods of rapidly rising crude oil prices, such as we have been experiencing, large disparities may develop between energy sources. Such disparities are primarily due to lag in catching up with oil prices. In the long run, all energy sources must relate to the price of crude oil. In fact, if anything, natural gas should be priced higher than crude oil when used for ammonia production since it is by far the cheapest to process.

Process Economics

No attempts are made to present relative figures on actual ammonia costs since these are dependent on many local factors. However, meaningful economic comparisons, between the "PARC Process" and conventional processing, can be made. Table 4 presents economic comparisons between the "PARC Process" and an optimized conventional plant of 400 metric tons/day capacity. Energy savings and payout times for the added investment are shown for several crude oil prices. The data is graphically shown in Figure 10. Simple payout times, based on the cost of energy saved versus added capital investment required, provide a simple but valid comparison. One curve is based on $4,400,000 additional investment required for a 441 short tons/day plant using the "PARC Process" with Rankine Cycle included. This curve assumes that there is no credit for export steam. The second curve is for the "PARC Process" without Rankine Cycle. In this case, steam is credited at

Acknowledgements

The assistance received from Union Carbide Corporation in providing data on the HYSIV Polybed P.S.A. system is greatfully acknowledged.

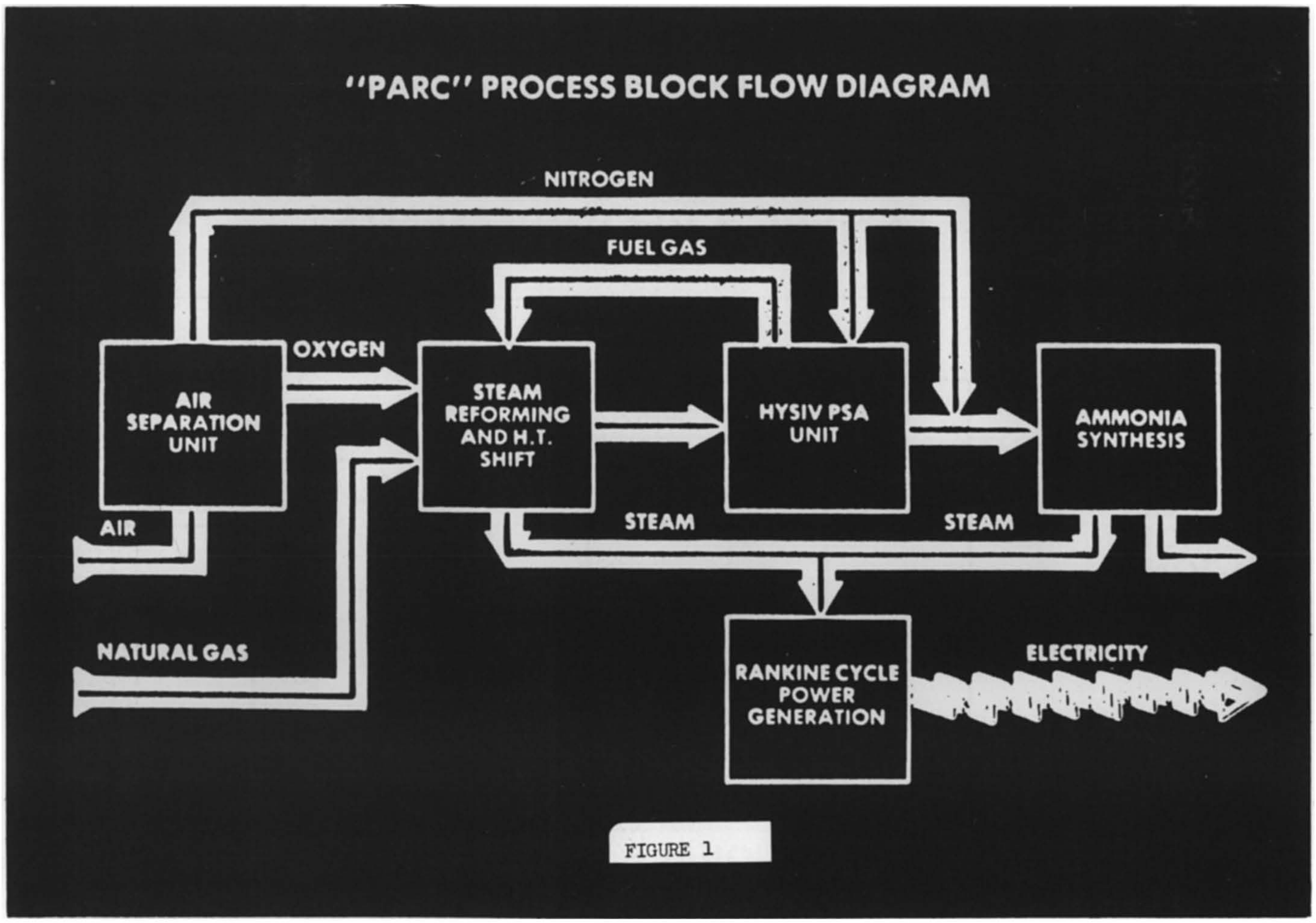


FIGURE 1

TABLE 1

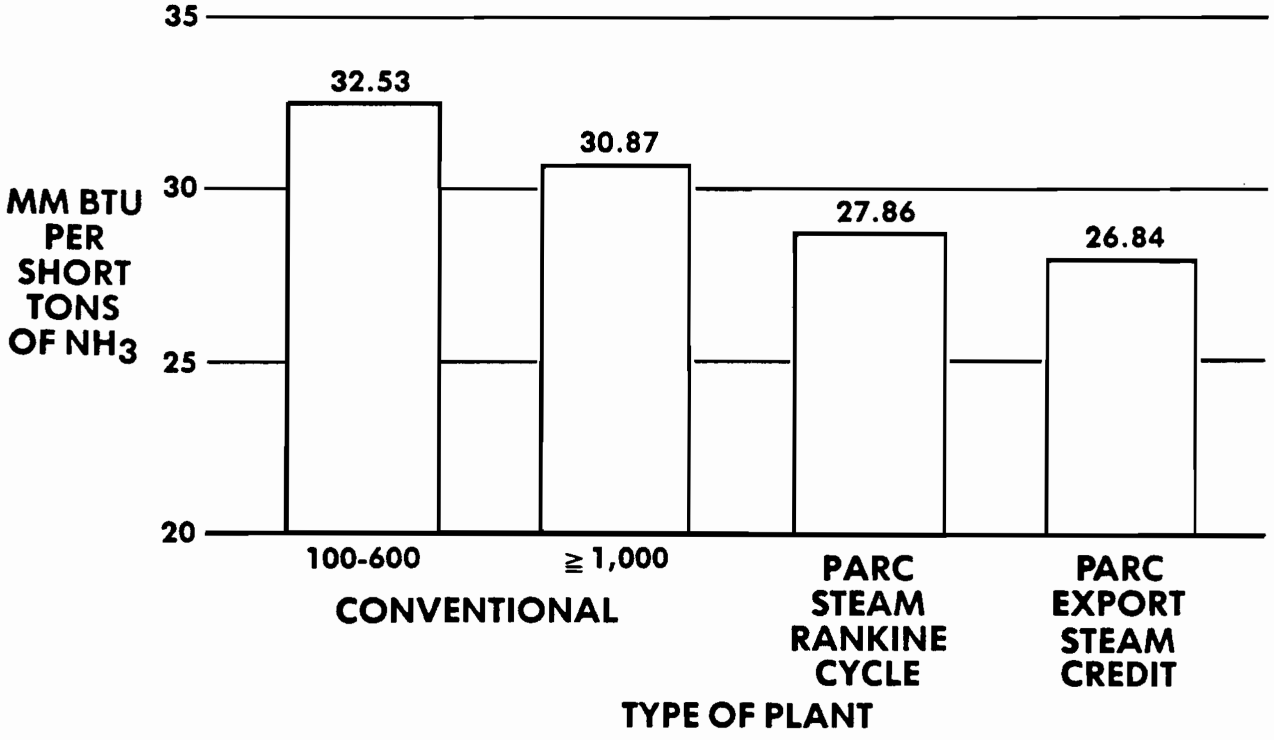
COMPARISON OF ENERGY REQUIREMENTS — AMMONIA PLANTS
MILLION BTU (LOW HEATING VALUE)
PER SHORT TON OF AMMONIA

DESCRIPTION	KTI PARC PROCESS	OPTIMIZED CONVENTIONAL	REFERENCE #1	REFERENCE #2	REFERENCE #3
CAPACITY SHORT TONS/DAY	441	441	300	1,000	1,150
MM BTU/SHORT TON (LHV)					
NATURAL GAS FEED	25.02	19.87	20.1	20.1	20.4
NATURAL GAS FUEL	0.51	5.84	6.4	10.6	10.6
ELECTRIC POWER EQUIV.*	2.33	6.47	6.03	0.17	0.16
TOTALS	27.86	32.18	32.53	30.87	31.16

*ELECTRIC POWER EQUATED AT 10,500 BTU PER KWH

REFERENCES: (#1) ENNIS & LESUR, HYROCARBON PROCESSING, DECEMBER, 1977
(#2) CZUPPON & BUIVIDAS, HYDROCARBON PROCESSING, SEPTEMBER, 1979

COMPARISON OF TOTAL ENERGY REQUIREMENTS



PARC PROCESS — SYNTHESIS GAS

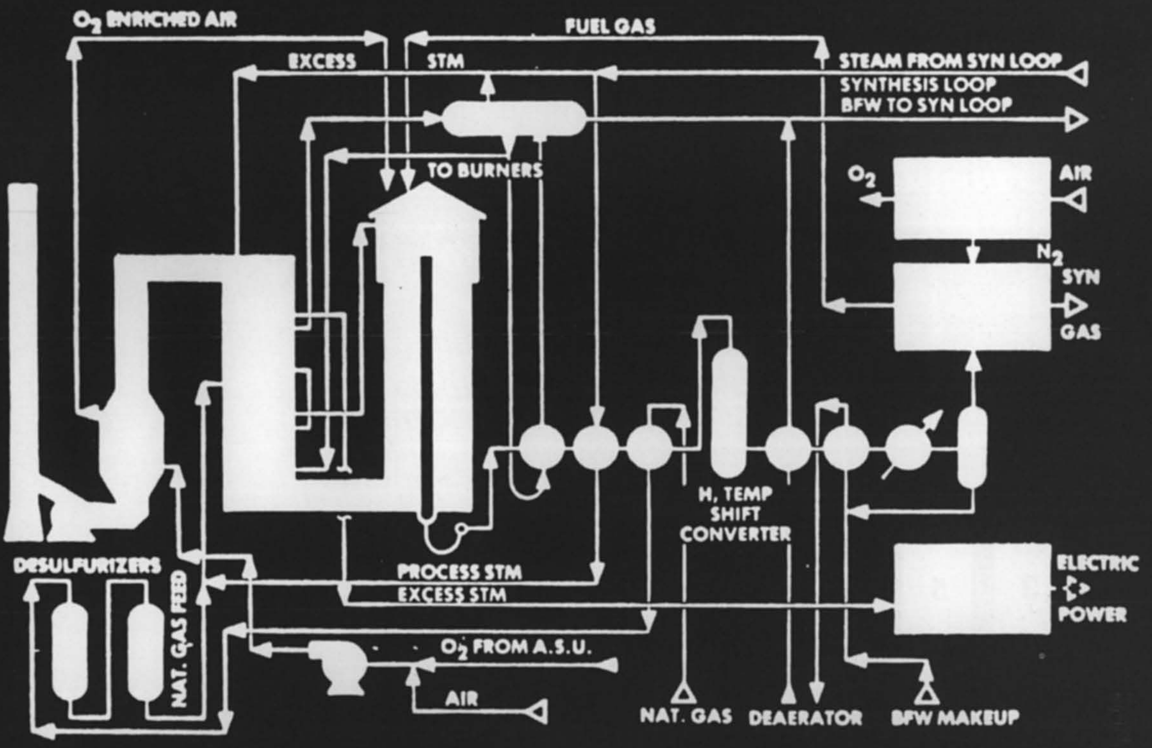


FIGURE 2

FIGURE 3
REACTIONS — STEAM METHANE REFORMING

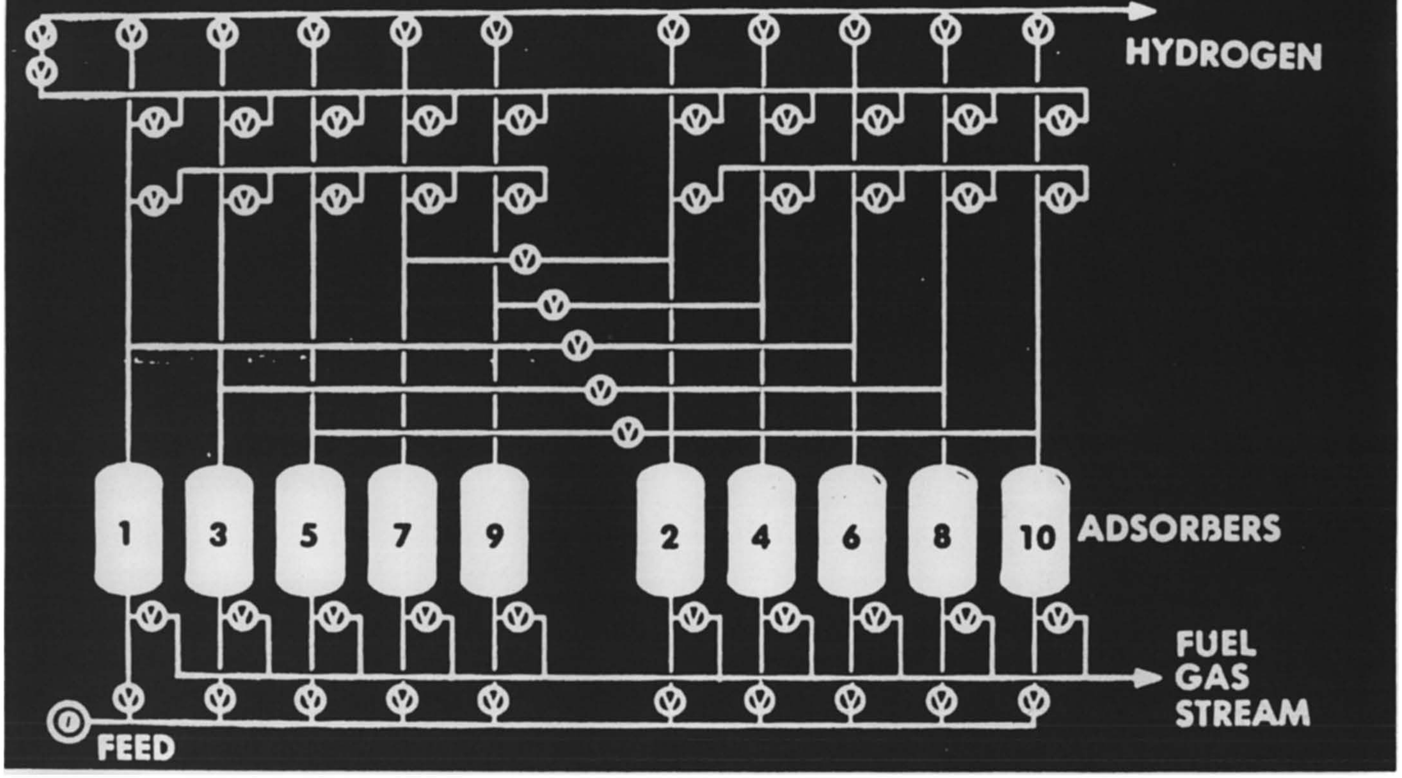
(1) $CH_4 + H_2O = CO + 3H_2$

(2) $C_2H_6 + 2H_2O = 2CO + 5H_2$

(3) $CnH_2n+2 + nH_2O = nCO + (2n+1)H_2$

(4) $CO + H_2O = CO_2 + H_2$

FIGURE 4
SCHEMATIC FLOW SHEET — POLYBED PSA UNIT



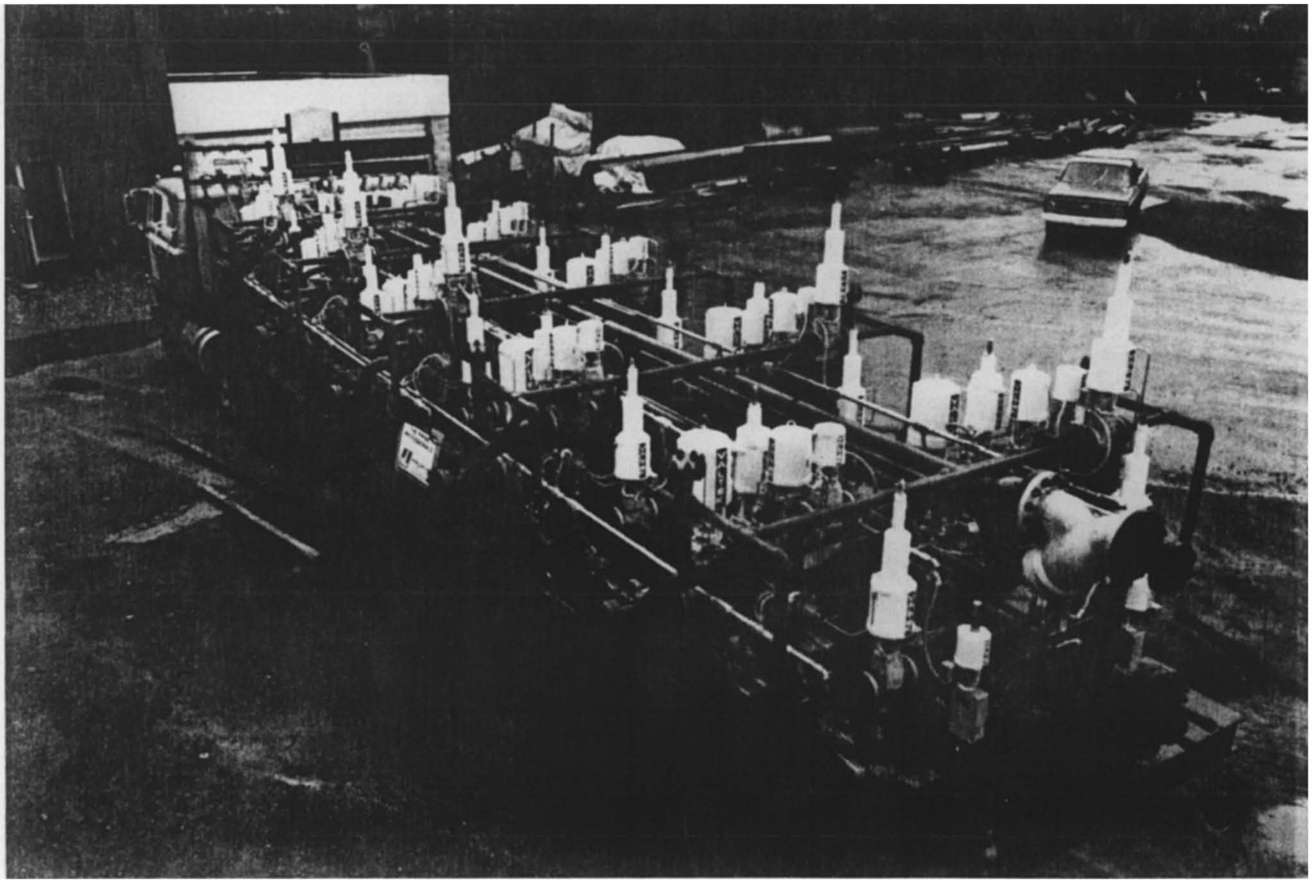


Figure 5 - PSA UNIT VALVE SKID

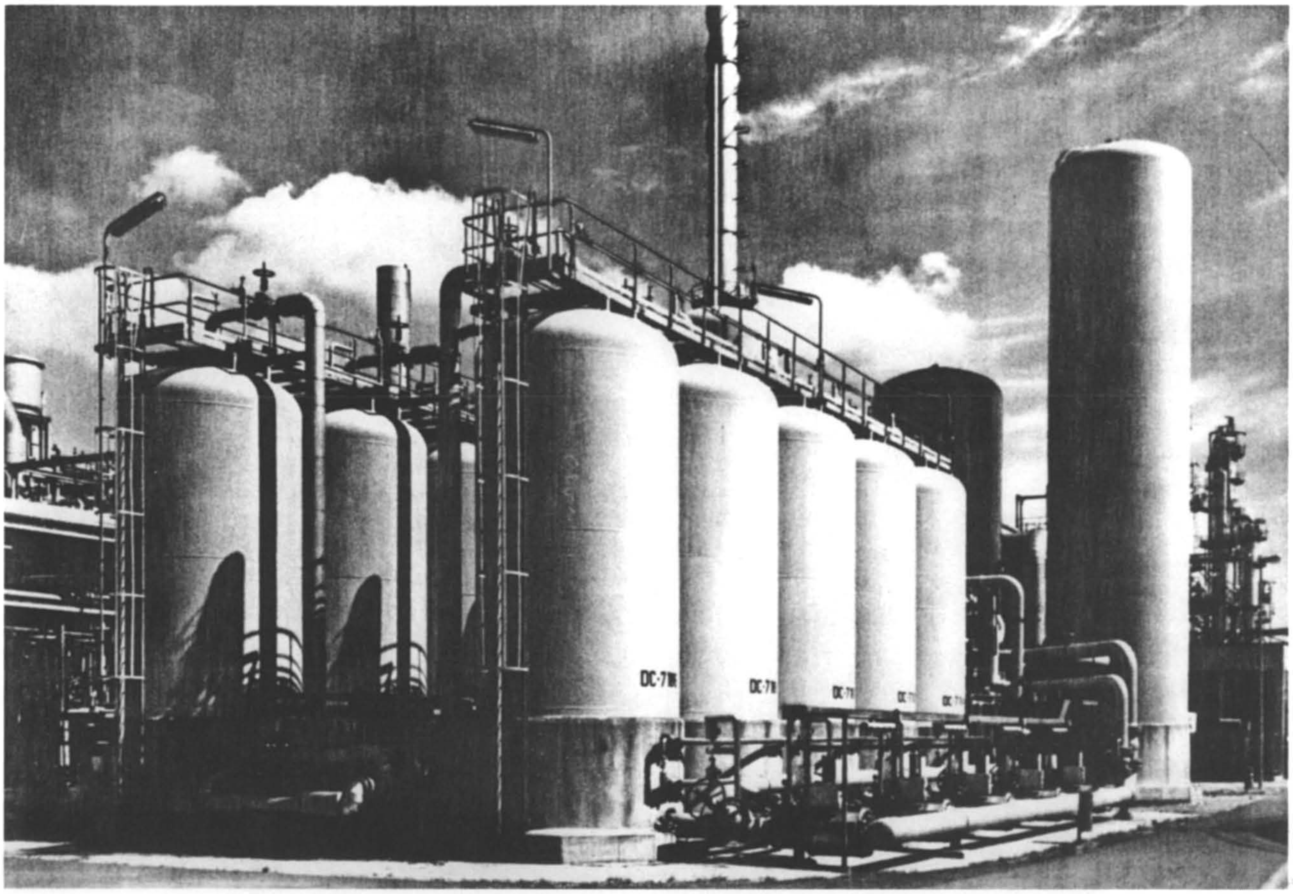


Figure 6 - COMPLETE HYSIV POLYBED PSA UNIT

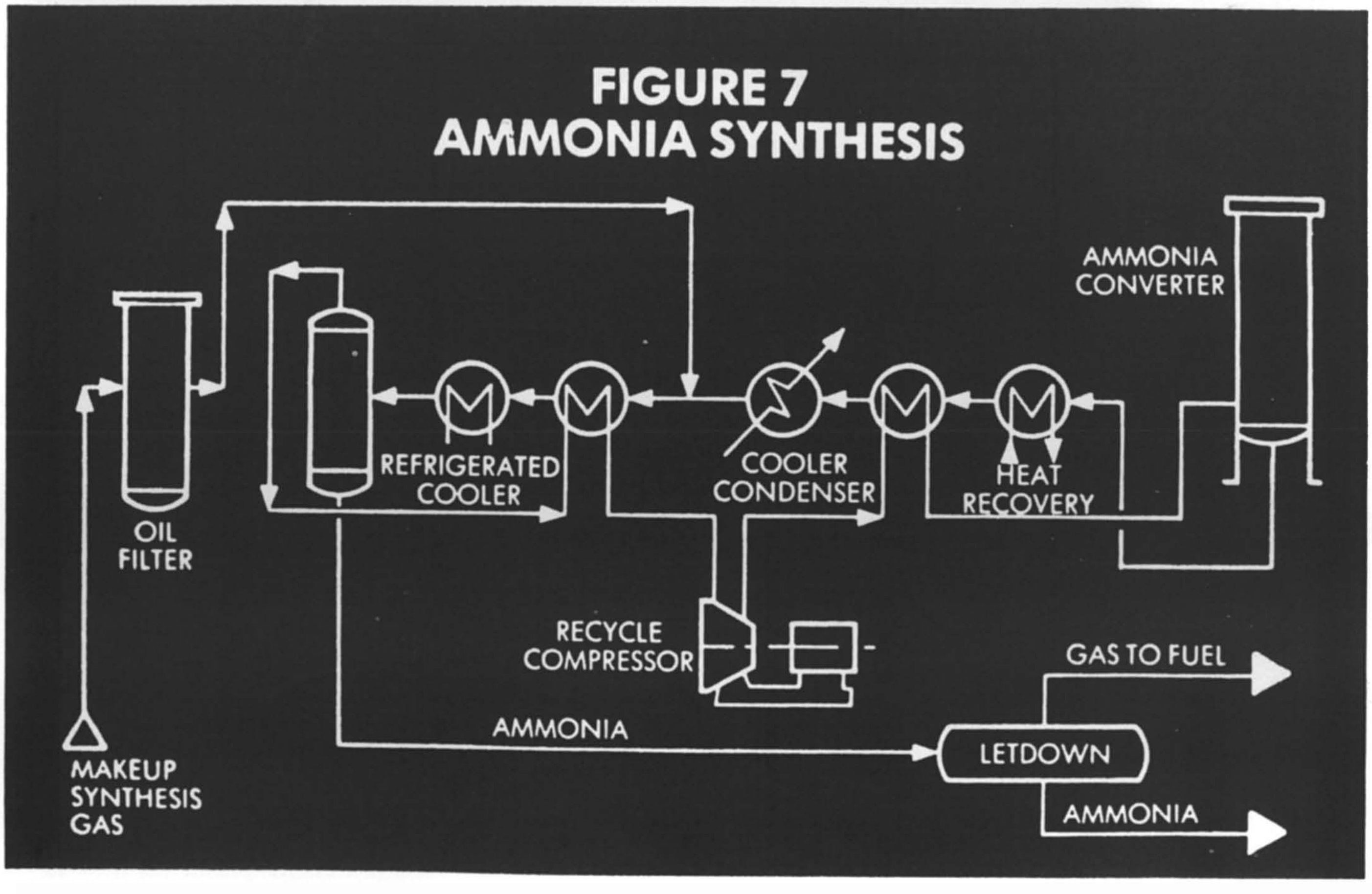


FIGURE 7
AMMONIA SYNTHESIS

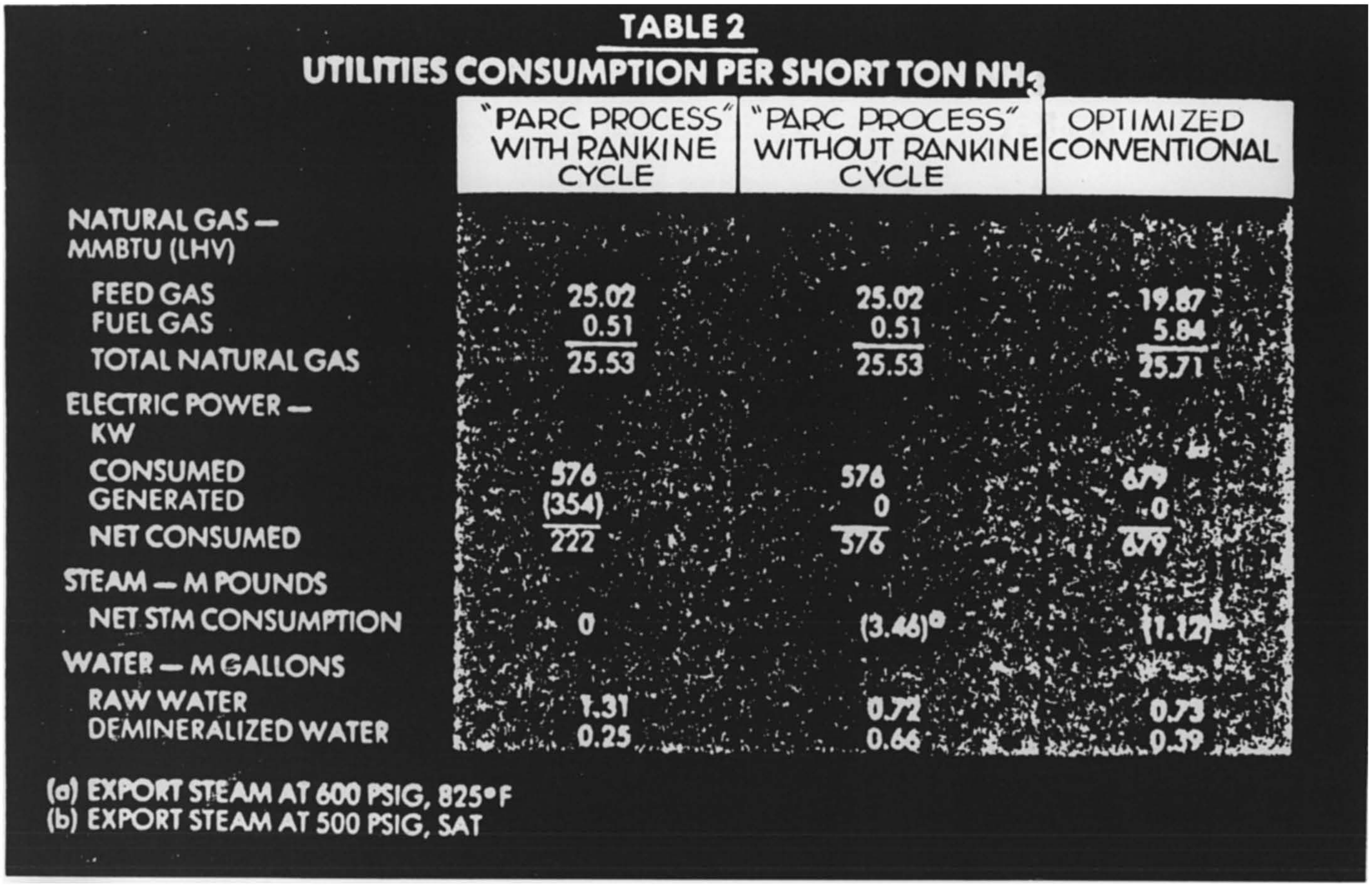


TABLE 2

UTILITIES CONSUMPTION PER SHORT TON NH_3

	"PARC PROCESS" WITH RANKINE CYCLE	"PARC PROCESS" WITHOUT RANKINE CYCLE	OPTIMIZED CONVENTIONAL
NATURAL GAS — MMBTU (LHV)			
FEED GAS	25.02	25.02	19.87
FUEL GAS	0.51	0.51	5.84
TOTAL NATURAL GAS	25.53	25.53	25.71
ELECTRIC POWER — KW			
CONSUMED	576	576	679
GENERATED	(354)	0	0
NET CONSUMED	222	576	679
STEAM — M POUNDS			
NET STM CONSUMPTION	0	(3.46)[a]	(1.12)[b]
WATER — M GALLONS			
RAW WATER	1.31	0.72	0.73
DEMINERALIZED WATER	0.25	0.66	0.39

(a) EXPORT STEAM AT 600 PSIG, 825°F
(b) EXPORT STEAM AT 500 PSIG, SAT

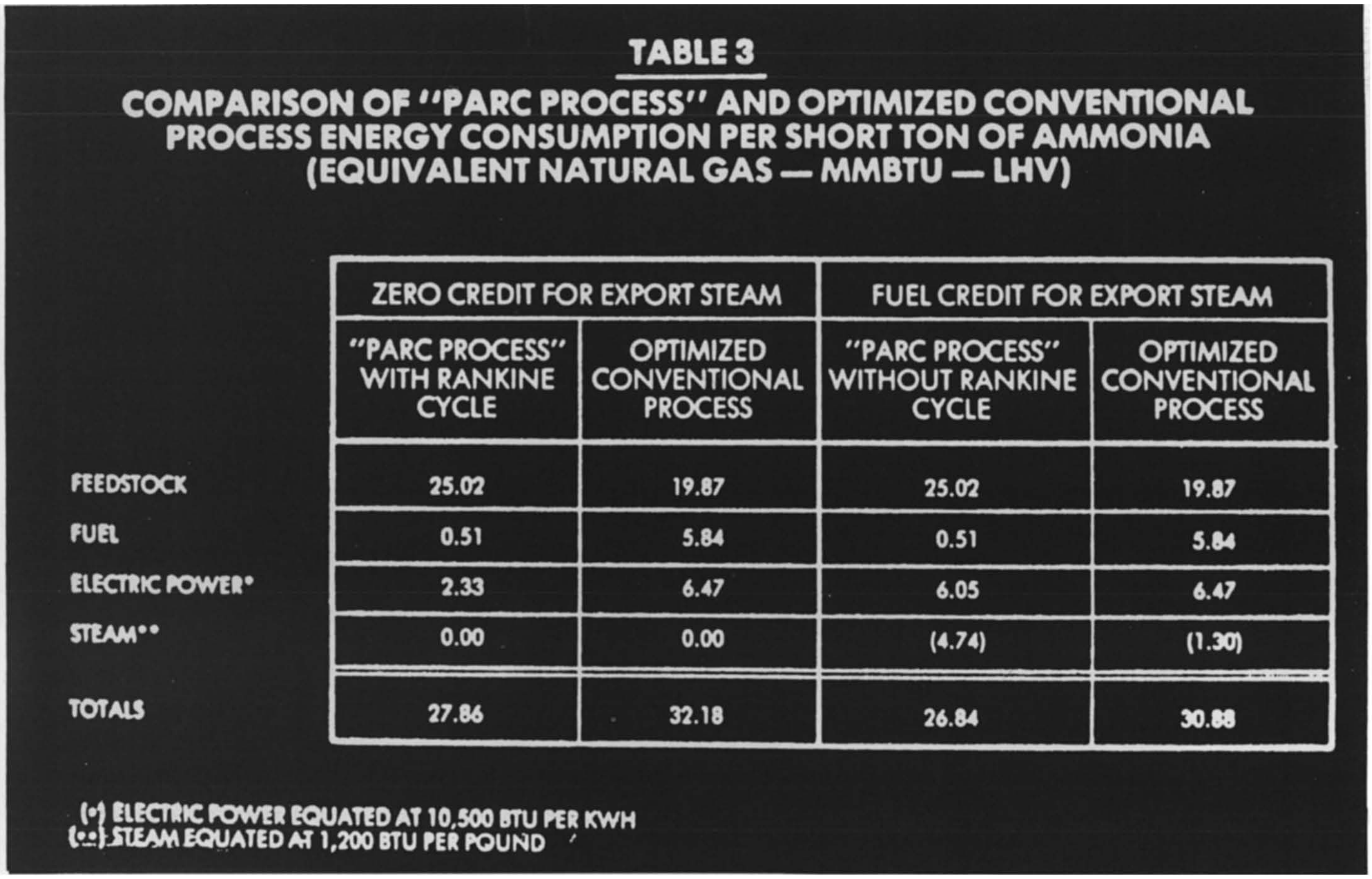


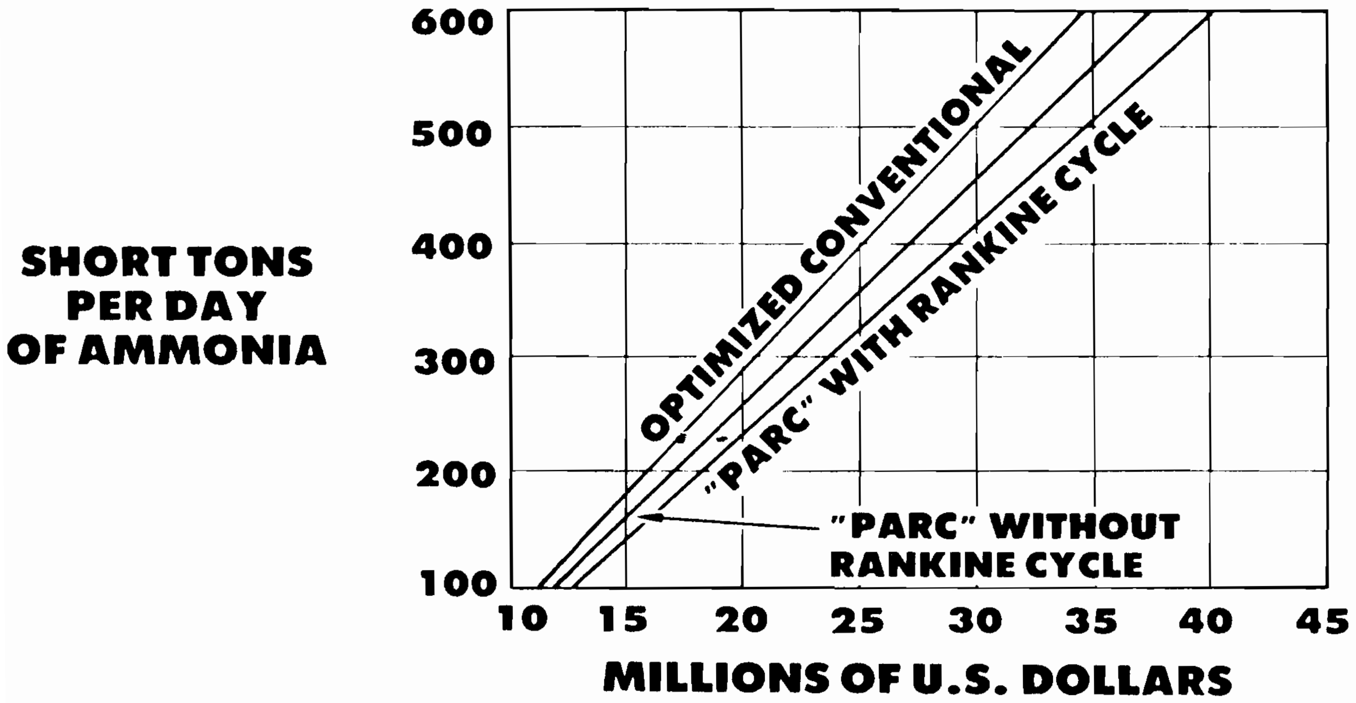
TABLE 3

COMPARISON OF "PARC PROCESS" AND OPTIMIZED CONVENTIONAL PROCESS ENERGY CONSUMPTION PER SHORT TON OF AMMONIA (EQUIVALENT NATURAL GAS — MMBTU — LHV)

	ZERO CREDIT FOR EXPORT STEAM		FUEL CREDIT FOR EXPORT STEAM	
	"PARC PROCESS" WITH RANKINE CYCLE	OPTIMIZED CONVENTIONAL PROCESS	"PARC PROCESS" WITHOUT RANKINE CYCLE	OPTIMIZED CONVENTIONAL PROCESS
FEEDSTOCK	25.02	19.87	25.02	19.87
FUEL	0.51	5.84	0.51	5.84
ELECTRIC POWER*	2.33	6.47	6.05	6.47
STEAM**	0.00	0.00	(4.74)	(1.30)
TOTALS	27.86	32.18	26.84	30.88

(*) ELECTRIC POWER EQUATED AT 10,500 BTU PER KWH
(**) STEAM EQUATED AT 1,200 BTU PER POUND

FIGURE 8
AMMONIA PLANT COST
BASIS: U.S. GULF COAST, MARCH, 1980



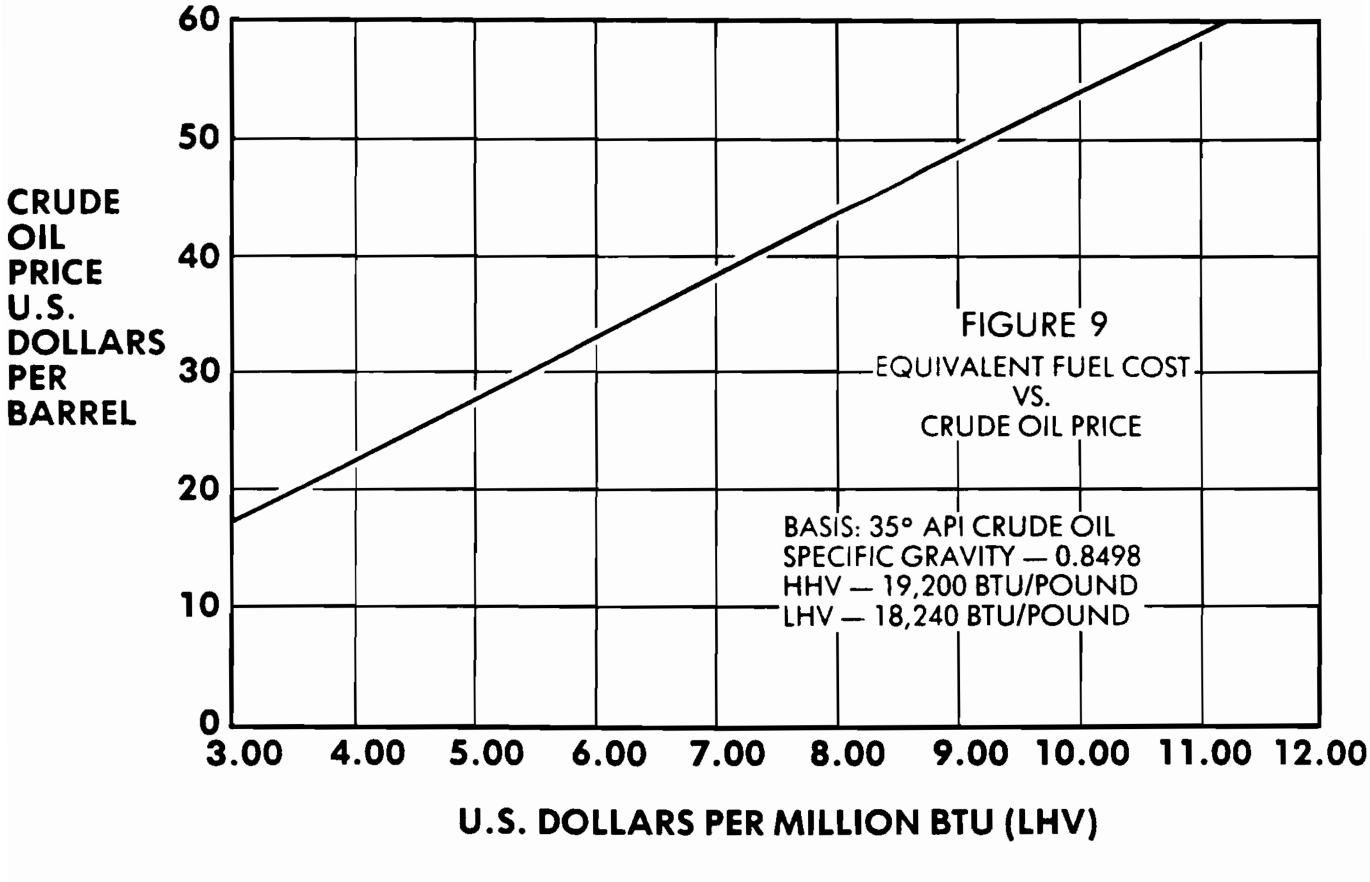


FIGURE 9
EQUIVALENT FUEL COST
VS.
CRUDE OIL PRICE

BASIS: 35° API CRUDE OIL
SPECIFIC GRAVITY — 0.8498
HHV — 19,200 BTU/POUND
LHV — 18,240 BTU/POUND

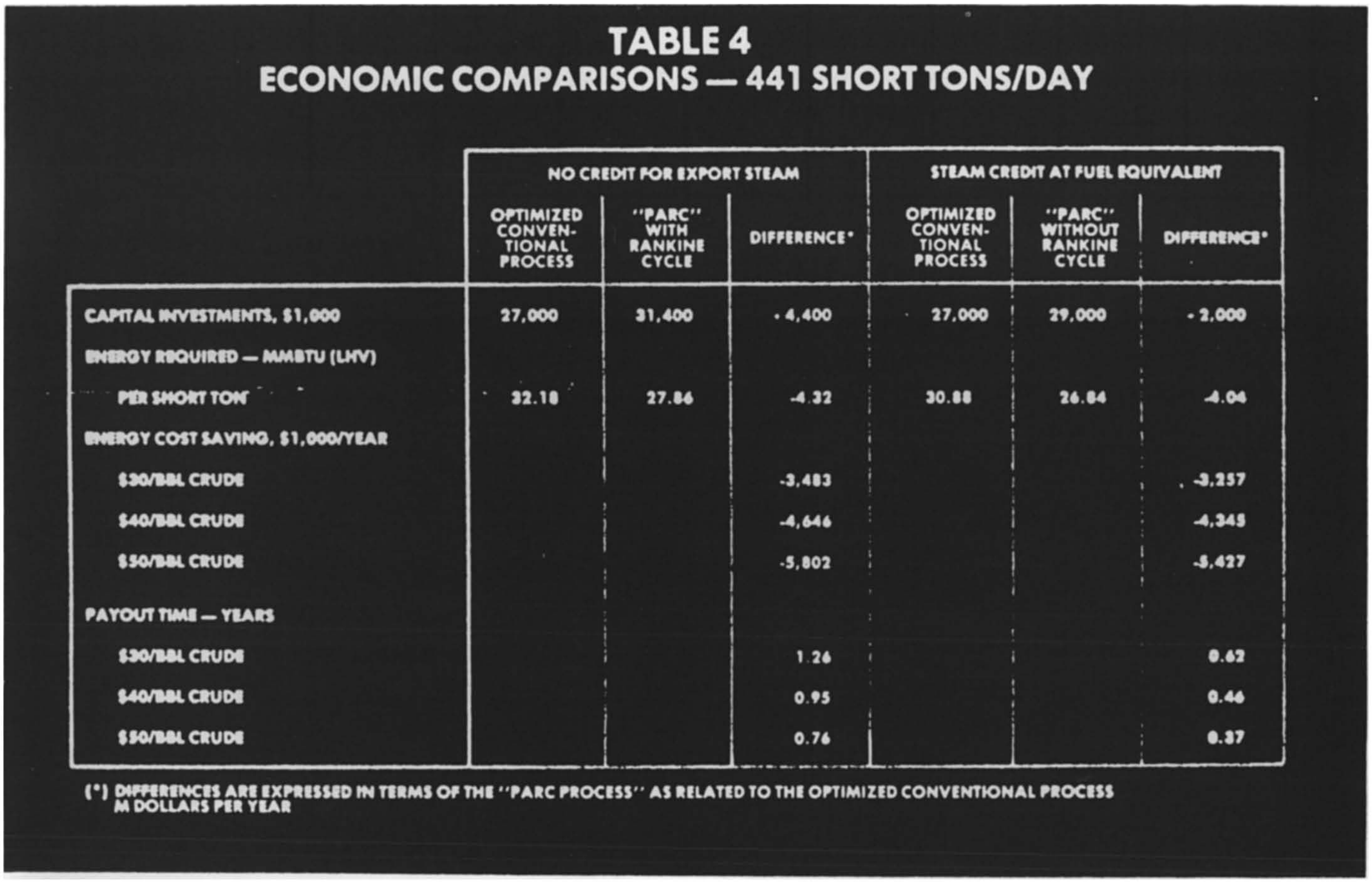
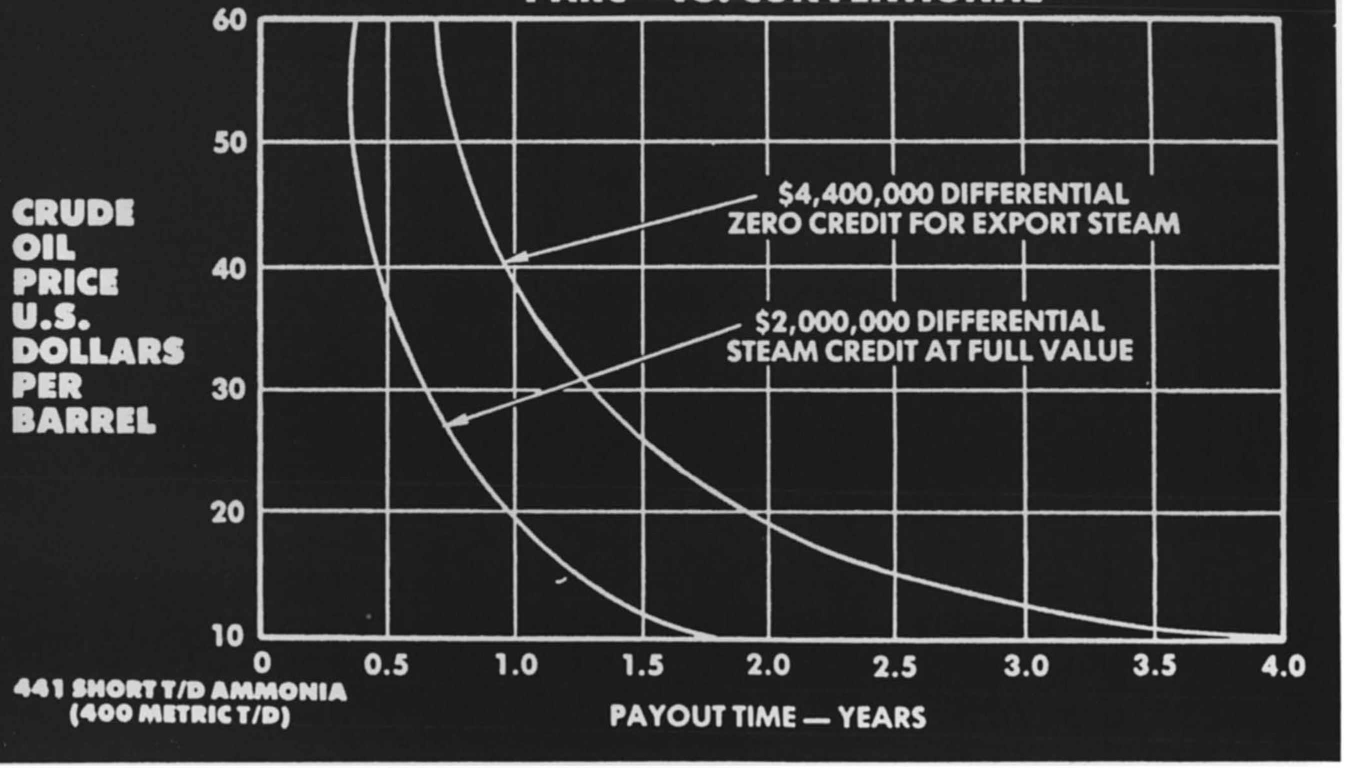


TABLE 4
ECONOMIC COMPARISONS — 441 SHORT TONS/DAY

	NO CREDIT FOR EXPORT STEAM			STEAM CREDIT AT FUEL EQUIVALENT		
	OPTIMIZED CONVENTIONAL PROCESS	"PARC" WITH RANKINE CYCLE	DIFFERENCE*	OPTIMIZED CONVENTIONAL PROCESS	"PARC" WITHOUT RANKINE CYCLE	DIFFERENCE*
CAPITAL INVESTMENTS, $1,000	27,000	31,400	-4,400	27,000	29,000	-2,000
ENERGY REQUIRED — MMBTU (LHV)						
PER SHORT TON	32.18	27.86	-4.32	30.88	26.84	-4.04
ENERGY COST SAVING, $1,000/YEAR						
$30/BBL CRUDE			-3,483			-3,257
$40/BBL CRUDE			-4,646			-4,345
$50/BBL CRUDE			-5,802			-5,427
PAYOUT TIME — YEARS						
$30/BBL CRUDE			1.26			0.62
$40/BBL CRUDE			0.95			0.46
$50/BBL CRUDE			0.76			0.37

(*) DIFFERENCES ARE EXPRESSED IN TERMS OF THE "PARC PROCESS" AS RELATED TO THE OPTIMIZED CONVENTIONAL PROCESS M DOLLARS PER YEAR

FIGURE 10
PAYOUT TIME ON DIFFERENTIAL COST "PARC" VS. CONVENTIONAL



MODERATOR LEYSHON: Thank you very much, William F. van Weenan for your most interesting presentation. My appreciation and thanks to all of "The Authors and Speakers" for being so concise and staying within the time limits this morning. You have all done a marvelous job. I will now turn the meeting back to you Frank. (Much, much and much more Applause!)

CHAIRMAN FRANK ACHORN: David Leyshon, we certainly thank you for having a very meaningful morning. It is always difficult to have the last session. Generally, we try to save the best for last. I want to say again that I appreciate all of the attendance that we have had. I think we have had a very "broad spectrum" that we are dealing with at the "Round Table now." We expect to see you at "Our 33rd Annual Meeting in Washington" - October 25th, 26th and 27th, 1983. We are adjourned. (Much Applause!)

Comments By Albert Spillman

Editing Chairman

Thanks "to our Editing Committee" for their valuable help and time "editing and preparaing our Proceedings covering this 32nd Annual Meeting".

Our 5 Sessions, 3 Day Meeting, was "well attended." Our Speakers excellently covered their most interesting Discussions. This "updated information" should be very helpful to Fertilizer Personnel in all phases of our day-to-day operations.

To "properly organize and prepare our printed proceedings" consumes much time for Meetings, Correspondence, Phone Calls, Proof Reading, etc., we try to do the "best possible job" to deliver to our printer "thoroughly checked script sheets (this year approximately 670 sheets) covering all our Program Activities.

Your Editing Committee "Thanks - to all of you," Chairman Achorn, Speakers, Moderators, Secretary Paul Prosser, Jr., his very able Secretary, Miss Alice L. Blount, The Prosser Organization, our printer, Tom Sabia, Manager of Quickee Offset, Inc., Baltimore, Md., The Quickee Personnel and many Round Table Members, for their prompt response by phone, correspondence, personal meetings, covering many of our requests for additional information required.

Your Editing Committee hopes to see you at our 33rd Annual Meeting, in Washington, on Tuesday, Wednesday, Thursday, October 25, 26, 27, 1983.

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