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<u>ENERGY REQUIREMENTS FOR ALTERNATIVE METHODS</u>
<u>FOR PROCESSING PHOSPHATE FERTILIZERS</u>

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INTRODUCTION

During the last year or so, as the problems related to securing
energy sources became more acute, TVA began to receive inquiries
related to energy needed to produce fertilizers. Investigations
revealed that very little had been published on this subject.
Therefore, a study of limited scope was initiated to begin to fit
together some data on energy requirements for fertilizer production.

Results from this work by TVA have shown that the energy needs for
producing phosphate fertilizers are highly dependent on the assumptions
relative to feed materials, processes used, and plant locations. Also,
data from a number of different sources had to be smoothed and
assimilated. Therefore, many of the values are merely approximations.

The data in this paper should be used only for general or broad
estimating purposes. Actual energy needs for any specific phosphate
processing situation should be computed individually because of wide
variations with local conditions.

Energy requirements computed at TVA are being continually updated as
more and better data are obtained. For this reason some of the numbers
in this paper are slightly different from those computed earlier. This
should explain any discrepancies that may occur between data in this
paper and previous TVA data on this subject.

After much consideration, it was decided to base the TVA energy
computations on the energy that must be imported to the processing
plant or fertiliser complex from external sources. This is illustrated
in Figure 1. The energy requirements include only that associated with
processing. The energy consumed due to human effort or to wear of
equipment and facilities is not included. Internal energy transformations,
such as heats of reaction or evaporation, are not individually included;
however, their net effect does influence the requirements for external
energy. Each raw material or intermediate carries this external energy
"charge" with it from one processing complex to the next. (Figure 1)

The external basis was used for TVA computations because it is usually
the energy that must be brought to the fertilizer plant from external
sources that is of primary concern. This imported energy is most often
in the forms of natural gas, naphta, fuel oil, and electricity. Therefore,
such energy sources would be suitable for alternative operations such as
supplying other industries, heating homes, or for transportation fuel.
This external energy also is the energy segment that represents
definite planning and operating cost items.

To set the stage for energy computations for production of phosphate
fertilizer, consumption trends were examined. World trends are shown
as Figure 2. The trend is for increasing importance for ammonium
phosphates and continued importance for concentrated superphosphate.
Normal superphosphate is steadily declining in importance. The same
trend is evident in the U.S. fertilizer system. (Figure 2)

Two facts are quite obvious from these trends. First, the energy
required to produce phosphoric acid will have a major impact because
it is needed for both ammonium phosphates and some other complex
fertilizers and also for concentrated superphosphate. Second, since
sulfuric acid is used both to produce phosphoric acid and also to
produce single superphosphate, the energy involved in its production
will also be a key factor.

While this paper is primarily concerned with energy requirements for
phosphate fertilizer processing, in some situations meaningful compari-
sons cannot be made without considering some aspects of transportation.
For movement of fertilizer raw materials, intermediates, and products,
the bases listed below were used. The data were supplied by the U.S.
Department of Transportation (1).

Type transport	Energy consumed, Btu/ton-mile
Pipeline	495
Rail	740
Water	750
Truck	2650

All data in this paper are on the metric ton basis.

ENERGY FOR SULFUR PRODUCTION

Since sulfuric acid is directly involved in production of about 90%
of the world's chemical phosphate fertilizer products, the energy
involved in obtaining and processing the sulfur must be a major factor.
The sulfuric acid and phosphate fertilizer are normally produced in
the same complex because of the difficulties and high costs of
transport of large tonnages of sulfuric acid. Also, the heat evolved
in sulfuric acid production is typically used to provide energy for

the remainder of the complex. Therefore this arrangement will be assumed for this paper, with the sulfur or sulfur source being imported to the fertilizer complex.

World sulfur production by form is tabulated below for 1970-2 (2)

	1970	1971	1972
Total, 1000 tons	41,777	42,561	45,353
Percent of total as			
Brimstone	55	56	60
Pyrites	28	27	23
Other	17	17	17

Total production has increased from 41.8 to 45.4 million tons. The proportion of sulfur supplied as brimstone has increased from 55 to 60% during this time, and the proportion supplied by pyrites has declined from 28 to 23%. Brimstone is now derived almost entirely from either Frasch mining or sulfur recovery operations--especially from sour and refinery gases.

The U.S. is, by far, the world's largest producer of Frasch sulfur. However, Frasch sulfur accounted for 70% of the total U.S. sulfur production in 1973 as compared with 77% in 1968. The recent world increases in brimstone production are due primarily to increases in recovered sulfur--particularly from Canada.

In 1960, Western World recovered sulfur accounted for only 26% of total brimstone output; by 1970 output of recovered sulfur has increased to the point that it exceeded Frasch sulfur for the first time. The petroleum industry is by far the largest source of recovered sulfur--supplying about 97% of that recovered in the Western World. In 1970 about 80% of the recovered sulfur was derived from natural gas facilities and about 16% from refineries processing oil. The world trend to increasing use of recovered sulfur is expected to continue (3).

In 1972 about 21% of the world's total sulfur production (all forms) was supplied as brimstone from the U.S., and 15% as brimstone from Canada. Poland, the third largest brimstone producer, supplied brimstone equal to 7% of 1972 world sulfur consumption.

Only about 17% of the world sulfur consumption was supplied in forms other than brimstone or pyrites. The main sources of sulfur in this category were metallurgical operations such as the roasting of copper and zinc concentrates, giving sulfur as a byproduct.

There are, therefore, three major sources of sulfur that might be utilized in phosphate fertilizer production--brimstone by Frasch mining, recovered brimstone from natural gas and pyrites. The energy associated with obtaining sulfur from these sources merits consideration as a part of the total energy requirement for alternative means of processing phosphate fertilizers.

The main external energy input for production of Frasch sulfur is the heating of the mine water. This heat requirement is reported to vary widely (perhaps tenfold) with mining conditions at different locations, averaging about 9 million Btu's per ton of sulfur.

For recovery of sulfur from sour natural gas and refinery gases, the processes are reported to be almost self-sufficient in energy. External energy of only about 0.3 million Btu's per ton of sulfur is normally supplied.

Energy consumption for production of sulfur from the desulfurization of oil is comparatively high. Approximately 30 million Btu's per ton of sulfur is required to decrease the sulfur content of a crude oil from 4% to 1% sulfur. Most of this energy input is associated with using some of the process oil for hydrogen production.

When pyrites are used as the source of sulfuric acid, the normal practice is to ship the pyrites to the fertilizer complex and to produce sulfuric acid directly by roasting the sulfide ore. The main energy consumption outside the fertilizer complex would be for mining, benefi-ciating, and transporting the concentrate. Energy for transport of pyrites is likely to be more significant in the total energy picture than transport of elemental sulfur because of the larger tonnages of material involved. It is difficult to determine a value for the energy required to mine and beneficiate the pyrites because of the variability of local conditions, mining and processing variations, and involvement with coproducts. A total of 0.5 million Btu's per ton of sulfur was estimated for the mining and preparation of the pyrites for feed into the sulfuric acid plant.

PHOSPHORIC ACID

Since there is an increasing trend toward production of ammonium phosphates and triple superphosphate (TSP), production of the phosphoric acid intermediate is a key item in determining the energy needs for phosphate fertilizers. Figure 3 illustrates the increasing trend to the use of phosphoric acid to supply the P_2O_5 in phosphatic fertilizers in the U.S. The percent of total fertilizer P_2O_5 from phosphoric acid increased from 45% in 1962 to 78% in 1972 and is projected to increase to 87% by 1980 (4). The world trend toward increasing use of phosphoric

acid as pictured in Figure 4 is similar to the U.S. trend. Wet-process
acid capacity was 50% of the world P_2O_5 supply in 1967, 58% in 1972,
and is projected to increase to about 68% of supply by 1977 (5). It is
apparent that the energy consumed in producing phosphoric acid will
be a dominant factor in the energy requirement for phosphatic fertilizers.
(Figures 3 and 4)

There are two processing routes by which phosphoric acid for fertilizer
use is produced--the wet process and the furnace process. Because of
the more favorable economics, almost all the acid now used in fertilizers
is derived from the wet process. This trend is expected to continue.
The furnace process gives an acid of higher purity than the wet process,
but high-purity phosphoric acid is not required for fertilizer production.

The furnace process is pictured on Figure 5. Phosphate rock, carbon and
silica are prepared and charged to an electric furnace. Sufficient
electrical energy is supplied to attain a temperature of over 2500°F.
The carbon acts as a reducing agent, and the silica ties up the calcium
in the phosphate rock. Elemental phosphorus is formed as a gas which
is condensed and then burned and hydrated to produce the phosphoric
acid. The main energy input is the electrical energy for the high
temperature furnace operation. (Figure 5)

Figure 6 pictures the wet process for making phosphoric acid. Sulfuric
acid is reacted with phosphate rock to produce phosphoric acid and
precipitate calcium sulfate which is removed by filtration. For the
dihydrate process the phosphoric acid from the filtration step is
usually concentrated from about 30% P_2O_5 to about 54% by evaporation.
With the hemihydrate process, the filter acid concentration is higher
(40-50% P_2O_5) and less evaporation is required. The dihydrate process
is much more prevalent than the hemihydrate process. The main energy
factor for the wet-process acid system is producing the sulfur for
sulfuric acid. (Figure 6)

The energy required to produce phosphoric acid by the furnace process
is about 27 million Btu's per ton P_2O_5. A breakdown of these energy
inputs is given below.

Processing step	Million Btu/ton P_2O_5
Mining and preparation of feeds	5
Production of phosphorus	22
Production of acid	0.1
Total	27.1

Energy consumed in mining and beneficiation of phosphate rock and in production of wet-process phosphoric acid by the dihydrate process is tabulated below.

	Energy consumed, million Btu/ton P_2O_5
Sulfuric acid preparation (exclusive of S processing)	0.1
Phosphate rock preparation	
Mining	0.4
Beneficiation	0.2
Drying	1.1
Rock grinding and acid preparation[a]	0.7
Total	2.5[b]

[a] Assumes steam for acid concentration is supplied by heat from burning sulfur.

[b] Does not include energy for S processing.

The total external energy consumption for merchant-grade wet-process acid production is obtained by adding the energy required for processing the sulfur (see page 4) to the total for the other processing steps as outlined above.

The total energy consumed per ton of P_2O_5 in producing the wet-process acid with each of the three major sulfur sources is tabulated below.

Sulfur source	Total external processing energy required for merchant-grade acid (54% P_2O_5) production, million Btu/ton P_2O_5
Frasch	10.6
Pyrites	3.0
Recovered (from sour or refinery gases)	2.8

Depending on the sulfur source, the total external energy consumed in processing for the wet process is 3 to 11 million Btu's per ton of P_2O_5 as compared with about 27 million for the furnace process. There is not much difference in the total quantity of feed materials required for the two processes, with phosphate rock common to both and supplemental carbon and silica required for the furnace process versus sulfur

or pyritesfor the wet process. If it is desirable to transport the phosphorus or phosphoric acid as an intermediate, shipment of elemental phosphorus instead of merchant-grade acid (54% P_2O_5) would result in some energy savings. On a P_2O_5 basis, shipment of 1 ton of phosphorus would be equivalent to about 4 tons of merchant-grade acid. A shipping distance of about 8000 miles by water or rail would be required for elemental phosphorus to recover the processing energy advantage of merchant-grade wet-process acid produced from Frasch sulfur.

Since the energy consumed in producing wet-process acid is much less than for furnace acid and energy saved in shipping phosphorus is not likely to make up this processing energy difference, the remainder of this paper will be primarily concerned with the wet process.

PROCESSING PHOSPHORIC ACID INTO GRANULAR PRODUCTS

As shown in the previous section of this paper, the main granular phosphate products are ammonium phosphates and TSP. The future trend is to higher proportions of these two materials and lesser proportions of single superphosphate and basic slag. Therefore, ammonium phosphates and TSP are the only currently marketed granular materials studied for this paper.

The most important ammonium phosphate product is granular diammonium phosphate (DAP) of 18-46-0 grade. This product represents about 80 to 90% of the straight granular ammonium phosphate produced in the U.S., but a lesser proportion in the remainder of the world. Below is a summary of the energy consumed in producing granular DAP by the usual procedure, which involves ammoniation and granulation of the wet-process acid, followed by drying of the product.

	Energy required,[a] million Btu/ton product P_2O_5		
Phosphoric acid preparation	3[b]	or	11[c]
Ammoniation and granulation	1.3		
Drying	1.0		
Total	5[b]	or	13[c]

[a] Does not include energy consumed in producing the ammonia. If ammonia production energy is included, an additional 44 million Btu's per ton N should be added.

[b] Based on pyrites or sulfur recovered from sour or refinery gas.

[c] Based on Frasch sulfur.

Excluding the energy required to produce the ammonia, about 5 to 13 million Btu's is required per ton of product P_2O_5 in DAP, depending on the source of sulfur used to make the wet acid. The heat of reaction is utilized to evaporate about 80 to 90% of the water in the wet-process acid so that the fuel for drying accounts for only a minor proportion of the energy requirement for water evaporation (6). The processing energy required for other ammonium phosphate products (exclusive of ammonia production), such as monoammonium phosphate, would likely be about the same as for DAP on a P_2O_5 basis.

The tabulation below shows the energy required per ton of P_2O_5 to produce TSP of about 0-46-0 grade.

Processing step	Energy required, million Btu/ton product P_2O_5		
Rock preparation [a]		0.5	
Phosphoric acid preparation (54% P_2O_5)	2.1^b	or	7.7^c
Acidulation and granulation		0.1	
Drying		0.9	
Total	4^b	or	9^c

[a] The rock fed directly to the granulation system; equivalent to 30% of the total P_2O_5.

[b] Sulfur from pyrites or recovered from sour or refinery gas.

[c] Frasch sulfur.

In producing granular TSP, phosphate rock is finely ground and reacted continuously with wet-process acid in tanks so that about 70% of the P_2O_5 is supplied by the acid. A slurry flows from the reaction tanks to a granulator. The granulator product is dried. For TSP production about 4 to 9 million Btu's per ton of product P_2O_5 is required (depending on sulfur origin) for processing.

Since about 30% of the P_2O_5 in this product is derived directly from phosphate rock, the energy required per ton of product P_2O_5 in TSP is about 70% of that needed for granular DAP. However, some ammonia is fixed with the acid P_2O_5 in the DAP and this has not been taken into account in the above comparison. Ammonia has the lowest processing energy requirement of the common nitrogen fertilizers, and fixation of some of it with phosphoric acid is probably attractive from an overall plant nutrient versus energy viewpoint.

LIQUID PHOSPHATE FERTILIZERS

Almost all of the phosphate applied as liquids is in the form of liquid mixtures derived from phosphoric acid. Liquid mixtures supply a minor portion of the fertilizer P_2O_5 in the U.S. and an even lesser proportion in the remainder of the world. However, in the U.S. and in some areas of Europe, use of liquid mixtures is growing at a comparatively high rate.

The consumption of liquid mixtures in the U.S. in 1972 was estimated to be about 3 to 4 million tons, with an average P_2O_5 content of about 15% (7). This gives about 0.5 million tons of P_2O_5 as liquid mixtures--roughly 10% of the total U.S. fertilizer P_2O_5 consumption. [In addition to liquid mixtures, an estimated 50,000 to 70,000 tons per year of P_2O_5 was directly applied as phosphoric acid (8).]

The technology of processing phosphoric acid into final liquid mixes varies with local market conditions, but usually involves ammoniation and then mixing with other soluble materials such as urea – ammonium nitrate solution and soluble potash. In general, this final compounding of liquids from phosphoric acid involves only the energy supplied for mixing and cooling operations--probably requiring a little less energy than is needed to process phosphoric acid into granular DAP or granular TSP. But two factors characteristic of the U.S. liquid industry are the use of superphosphoric acid instead of orthophosphoric acid and the calcination of the phosphate rock used to make the wet-process acid. The use of superphosphoric acid keeps some of the impurities in solution and increases the ammonium phosphate solubility, thereby improving product quality and increasing the grade. Calcination of the phosphate rock burns out the carbonaceous material, giving a clear liquid product rather than a black one. (Rock calcination is often carried out for reasons other than for production of clear products).

The energy charge for production of the superphosphoric acid is about 2 to 2.5 million Btu's per ton of P_2O_5. The energy required for rock calcination varies widely in accordance with the composition of the phosphate rock--for phosphate from central Florida, about 3 million Btu's per ton P_2O_5 is required. For some sources of rock, combustion of the organics in the rock can supply almost all of the heat requirement (9).

It was not possible to get an accurate estimate of the proportion of P_2O_5 used in liquids that is derived from superphosphoric acid or from calcined rock. Thus, the total energy requirement for rock calcination plus superphosphoric acid production, the combination of which is required for "premium" quality liquids, can be as much as 5 to 6 million Btu's per ton of P_2O_5. Fluid products based on calcined rock and superphosphoric acid would require about twice as much energy per unit of P_2O_5 as granular TSP.

ENERGY FOR TRANSPORT OF FEEDS AND PRODUCTS

Transport of products and intermediates

Both of the major phosphate fertilizer products (TSP and DAP) contain about 46% P_2O_5. Therefore, movement of either of these products by rail or water would require about 1600 Btu's per ton P_2O_5 per mile and truck movement about 5700 Btu's per ton P_2O_5 per mile. DAP would have to be transported as far as about 8000 miles by rail or water or 2000 miles by truck for the energy of transport to be equal to the energy consumed in production. Therefore, energy consumed in product transport is not likely to be substantial except where long-distance international transport is involved.

International trade of phosphoric acid intermediate has become commonplace in the past few years. Recently, there has been increased interest in shipment of superphosphoric acid (68-70% P_2O_5) instead of merchant-grade acid to save on freight and handling costs. Shipment of a 70% P_2O_5 versus 54% P_2O_5 acid would decrease the tonnage by about 23%. Water transport of super acid would save about 300 Btu's per ton P_2O_5 per mile as compared with merchant acid. Therefore, the super acid would have to be transported about 7000 miles (one-way distance) to recover the energy required to concentrate the merchant-grade acid to super acid. (The shipping distance from Jacksonville, Florida, to the Russian Black Sea Coast is about 6000 miles; Tampa to Rotterdam is about 5000 miles).

Transport of Raw Materials

To produce a ton of P_2O_5 as wet-process acid, a minimum of about 4 tons of raw materials ($>$ 3 tons of rock and $<$ 1 ton of sulfur) is required. When phosphate rock is transported long distances in international trade, such as from Florida to Japan or Europe, the energy associated with its movement may be quite substantial. For example, a 2000-mile shipment of phosphate rock would consume about as much energy as would be required to process the P_2O_5 into wet-process acid by using pyrites or sour-gas sulfur (3 million Btu's).

In the U.S. where the usual practice has been to locate the phosphoric acid and phosphate granulation units close to the sources of phosphate rock and sulfur (Florida and Louisiana Gulf Coast), the energy for transport of raw materials is not very significant in comparison with that of processing.

POTENTIAL IMPACT OF NEW TECHNOLOGY ON ENERGY REQUIREMENTS FOR PROCESSING PHOSPHATES

No radically new phosphate products or processes are visualized in the foreseeable future (5-10 yr) in the chemical fertilizer industry. As indicated in previous sections, there will be an increasing trend to production of wet-process acid and finished products made from it. Therefore, it is in these areas of processing that potential effects of new or improved technology on energy required for phosphate processing were evaluated.

Sulfur

U.S. Situation : Since the energy associated with sulfur production
has a major effect on the total energy consumed in producing phosphate
fertilizers, future trends in sulfur production should be considered.

The following tabulation gives the U.S. consumption and production
of sulfur in all forms in 1972 from data by Gittinger (10).

Consumption (000's)		Production (000's)			
		Brimstone			All
Total	Fertilizer	Total	Frasch	Recovered	other
9.8	5.2 (4.2 for phosphoric acid)	10.5	7.3	1.8	1.4

Of the total sulfur consumption of about 9.8 million tons, fertilizers
accounted for about 5.2 million tons, about 55% of the total. Phosphoric
acid production alone was reported to account for about 4.2 million
tons of sulfur, or over 80% of the total sulfur consumed in fertilizers.

Total sulfur production in 1972 was about 10.5 million tons, of which
about 70% was Frasch sulfur and about 18% was recovered sulfur, mostly
from sour gas. Thus, Frasch sulfur production far exceeded equivalent
sulfur utilization in fertilizers. Most of the sulfur used to produce
fertilizers in the U.S. is derived from the Frasch process. However, as
indicated in an earlier section, Frasch sulfur is declining in impor-
tance.

Figure 7 (11) gives a projection of the U.S. sulfur supply-demand
situation from 1970 to 2010 made with data from Slack (12). The top
curve is estimated sulfur consumption in the U.S. Consumption increases
from about 12 million tons in 1975 to about 32 million by 2010. The
next curve (second from top) gives the projected sulfur supply exclusive
of stack emission sources. Sulfur availability begins to change from a
surplus into a deficit situation about 1974. Difficulties in obtaining
natural gas are already hurting Frasch sulfur production, and future
gas shortages could make this supply-demand imbalance even greater than
shown here. The indicated difference between supply and demand is about
7.5 million tons in 2000 and 10 million in 2010. (Figure 7)

The next curve gives sulfur consumed in fertilizers--projected to
increase from the present 5 million tons to about 13 million tons by
2010. The bottom curve is the estimated sulfur available from emission
reduction sources. This is based on the amount of abatement required
just to keep emissions at the 1970 level. Total emissions will be much
larger. (In these data, stack gas cleaning is the main source of S from
emission reduction sources; sulfur recovered from sour gas, refinery

operation, or oil desulfurization is not included in these emission sources). The sulfur available from emission reduction is estimated to increase from about 1 million tons in 1975 to about 10 million by 2000 and to about 18 million by 2010. Part of this sulfur from abatement will likely be used to at least make up the difference between the supply from nonabatement sources and consumption. (The abatement sulfur that cannot be marketed will probably be disposed of in "throw-away" processes). At about the year 2000, potential sulfur from emission sources would about equal sulfur demand for fertilizers and would substantially exceed fertilizer sulfur demand by 2010.

World Situation : Coleman estimated the world sulfur requirement for phosphatic fertilizers in 1976-7 as about 22 million tons and total sulfur requirements for all sources as about 52 million tons (13). White estimated that worldwide sulfur emissions from man-generated sources were about 70 million tons in 1969 (14). This number will increase with time. Therefore, emission sulfur alone apparently substantially exceeds world sulfur consumption.

Although it is impossible to predict the future effect of recovered sulfur on the energy consumption of the world phosphate fertilizer industry, it does appear that the effect will likely become of major and increasing importance. The quantity of this recovered sulfur from stack emission sources used in fertilizers will depend on the relative economics. Sulfur abatement processes will undoubtedly consume a large amount of energy—an amount that cannot even be now defined because the technology is mostly undeveloped. However, if the sulfur must be recovered to meet pollution regulations, then the energy for its recovery cannot be attributed entirely to fertilizers. In fact, in some situations production of fertilizer may become a means for simply disposing of recovered sulfur. Whenever recovered sulfur is available, supplemental energy requirements to produce phosphate fertilizers from it will be comparatively low—perhaps less than 3 million Btu's per ton of P_2O_5 in wet-process acid.

Phosphoric Acid

The normal practice has been to dry phosphate rock used to produce wet-process acid before feeding it to grinding mill. Recently, Houghtaling revealed plans for wet feeding and grinding of phosphate rock had been included in the design of several large wet-process acid units now being constructed (15). Fuel savings due to avoiding the drying step were reported to be about 1.1 million Btu's per ton P_2O_5.

The dihydrate process has been generally preferred for production of wet-process acid. All of the plants in the U.S. and most of the European units utilize the dihydrate-type system. The hemihydrate/ dihydrate process has been utilized in several plants in Japan for a number of years. In 1970, a plant employing the hemihydrate process was put in operation in the Netherlands. Other plants in Europe using the hemihydrate/dihydrate process have been announced.

The hemihydrate process is reported to produce acid containing 50 to 54% P_2O_5 directly, avoiding the acid concentration step. With the hemihydrate system, steam savings are reported equivalent to be about 3 million Btu's per ton P_2O_5 as compared with the conventional dihydrate system (16). To take advantage of the energy savings potential of the hemihydrate process in a complex where sulfuric acid is also produced from brimstone or pyrites, the steam generated at the sulfuric acid unit would need to be used in other areas of the complex or else used to produce electric power.

Granulation

A melt-type granulation process for production of ammonium phosphates without any drying step has been developed and used on plant scale. In this granulation system, the heat of ammoniation is utilized efficiently to evaporate all the water in merchant-grade wet-process acid (52-54% P_2O_5) so that no drying of the product is required (17). The energy savings for this process is about 1 million Btu's per ton P_2O_5 in comparison with the usual ammonium phosphate processes now in use.

RELATIONSHIP OF ENERGY FOR FERTILIZER PROCESSING TO OTHER AGRICULTURAL INPUTS

Data from White indicate that the external energy consumed in production of ammonia (based on natural gas feed) is about 44 million Btu's per ton N and, for potassium chloride, about 4 to 5 million Btu's per ton K_2O (18). Therefore, processing of phosphate fertilizer consumes much less energy than nitrogen and requires in the range of one to two times as much energy as potash (depending primarily on the sulfur source for processing the phosphate).

Heichel estimated that U.S. agriculture took only 3.5% of the U.S. energy consumption in 1973 (19). Of the total energy used in the U.S. agriculture, he estimated that about 23% went for fertilizer. A recent study by Pimentel detailing the total energy required to produce corn in the U.S. in 1970 indicated that the phosphate fertilizer used represented less than 2% of the total energy consumption in the production and marketing of the crop (20).

The above data indicate that the energy used to produce phosphate fertilizer is quite small in relationship to total energy consumption for a "high-energy" type economy. The proportion of energy used for phosphate fertilizer production in less energy intensive economies would probably represent a greater proportion of the total energy requirements.

SUMMARY

The major factor in total energy consumption in production of phosphate fertilizers is the energy required to produce phosphoric acid. Phosphoric acid is expected to be used in production of over 70% of the world's fertilizer P_2O_5 by 1977. Phosphoric acid production by the wet process consumes less than half the energy needed for the furnace process.

The external energy requirements for wet-process acid production are highly dependent on the source of the sulfur used to make the sulfuric acid. With Frasch sulfur, about 11 million Btu's per ton wet acid P_2O_5 is required. For pyrites or sulfur recovered from sour or refinery gas, only about 3 million Btu's per ton P_2O_5 is consumed.

Conversion of the wet-process acid to granular ammonium phosphate (18-46-0) requires about an additional 2 million Btu's per ton P_2O_5 above that needed to make the acid. Granular TSP takes about 30% less energy to produce per unit of P_2O_5 than granular ammonium phosphate. Premium quality liquid mixtures, based on superphosphoric acid and calcined phosphate rock, require about twice as much energy as TSP.

The energy consumed in transport of products and feed materials by rail or water is usually not large in proportion to the energy for production except when international shipment is involved. For example, water shipment of 1 ton of P_2O_5 as TSP 1000 miles would only consume about 1.5 million Btu's.

The energy consumed in producing phosphate fertilizers represents only a small proportion of the total energy input for agriculture. A ton of P_2O_5 as TSP requires less than 25% of the energy needed to produce a ton of N in ammonia from natural gas. A study detailing the energy consumed in production of corn in the U.S. indicated that the phosphate fertilizer used represented only about 2% of the total energy used in producing and marketing crop.

No radical changes in phosphate processing technology that would affect energy needs are visualized in the foreseeable future. Some decreases in energy needs for phosphate processing can result from (1) wet grinding and wet feeding of phosphate rock to the wet acid system, (2) changing to the hemihydrate wet acid process from the dihydrate process (decreasing acid concentration requirements), and (3) using the melt-type ammonium phosphate granulation process (avoiding drying).

The origin of future sources of sulfur will likely have a major impact on the energy consumed in phosphate processing. The proportion of sulfur supplied from recovery and emission sources is expected to increase, with use of stack gas sulfur probably becoming prominent in the 1980's. Recovery of stack gas sulfur will likely require much energy, but at least part of this energy loss can be attributed to pollution control.

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FUEL OIL

INTERNAL ENERGY TRANSFORMATIONS

ELECTRICITY

ANY OTHER EXTERNAL ENERGY INPUTS

<u>FERTILIZER</u> <u>COMPLEX</u>

BOUNDARY USED IN ENERGY COMPUTATION

NATURAL GAS
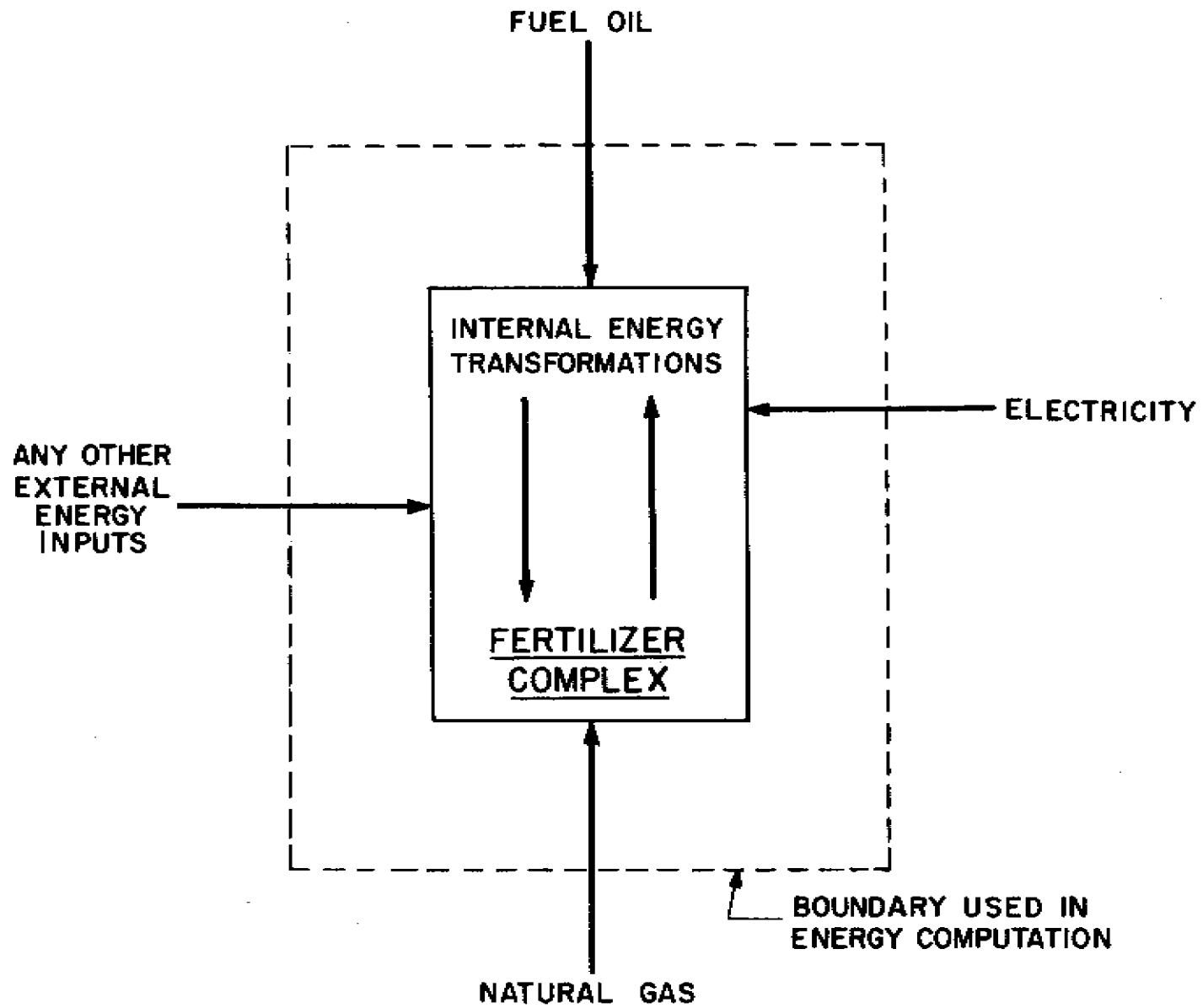
Fig. 1: Basis Used in Energy Computations
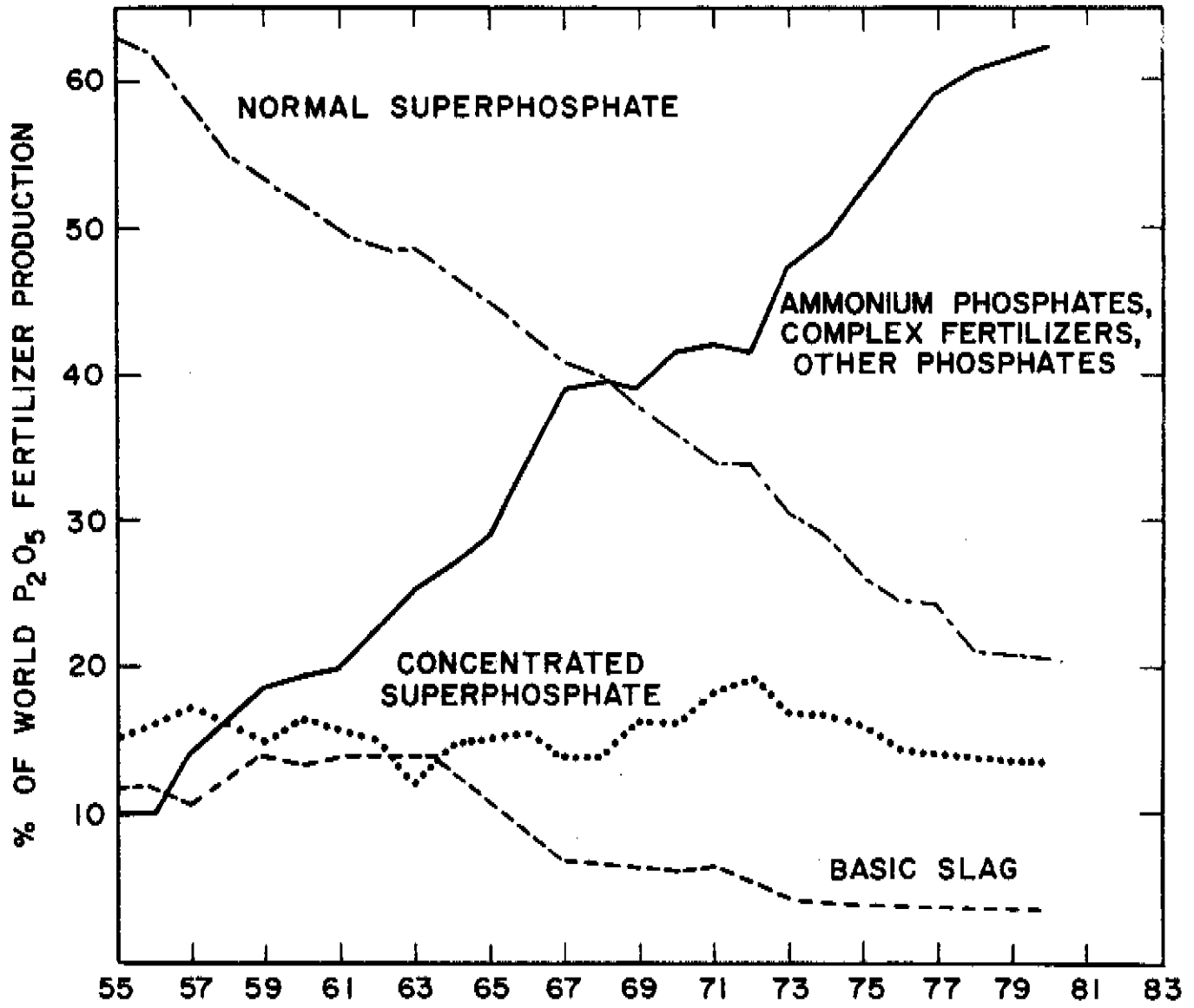
Fig. 2: World Trends in Types of Phosphatic Fertilizer Materials

6.10 TOTAL P_2O_5

5.33 PHOS ACID P_2O_5

4.38 TOTAL P_2O_5

3.42 PHOS ACID P_2O_5

87 %

2.53 TOTAL P_2O_5

1.12 PHOS ACID P_2O_5

78 %

45 %

1962

1972

1980

Fig. 3: Million Metric Tons of P_2O_5 Demand in U.S. and Proportion from Phosphoric Acid
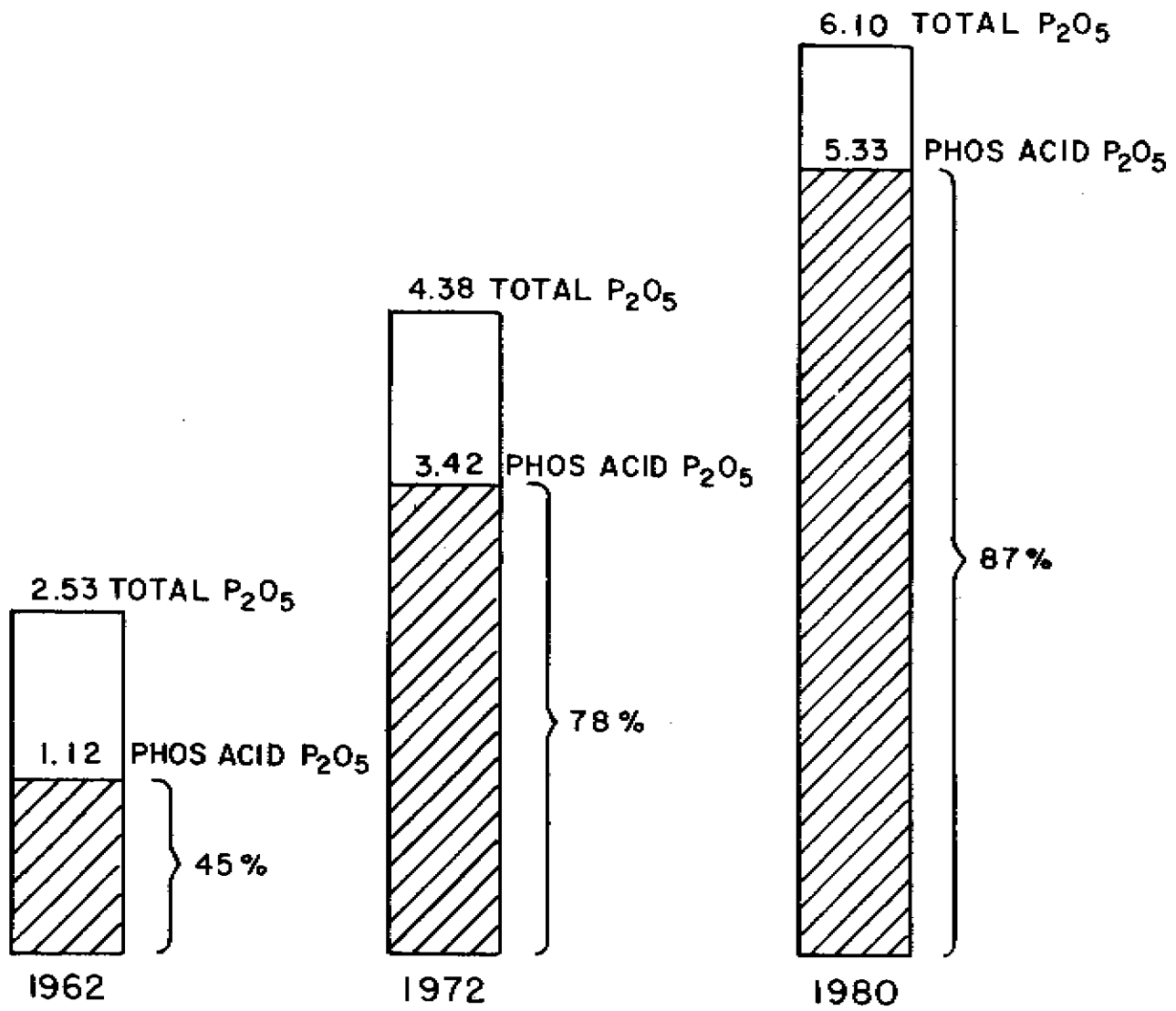
Fig. 4: Million Metric Tons of P_2O_5 Supply in World and Proportion from Wet—Process Acid
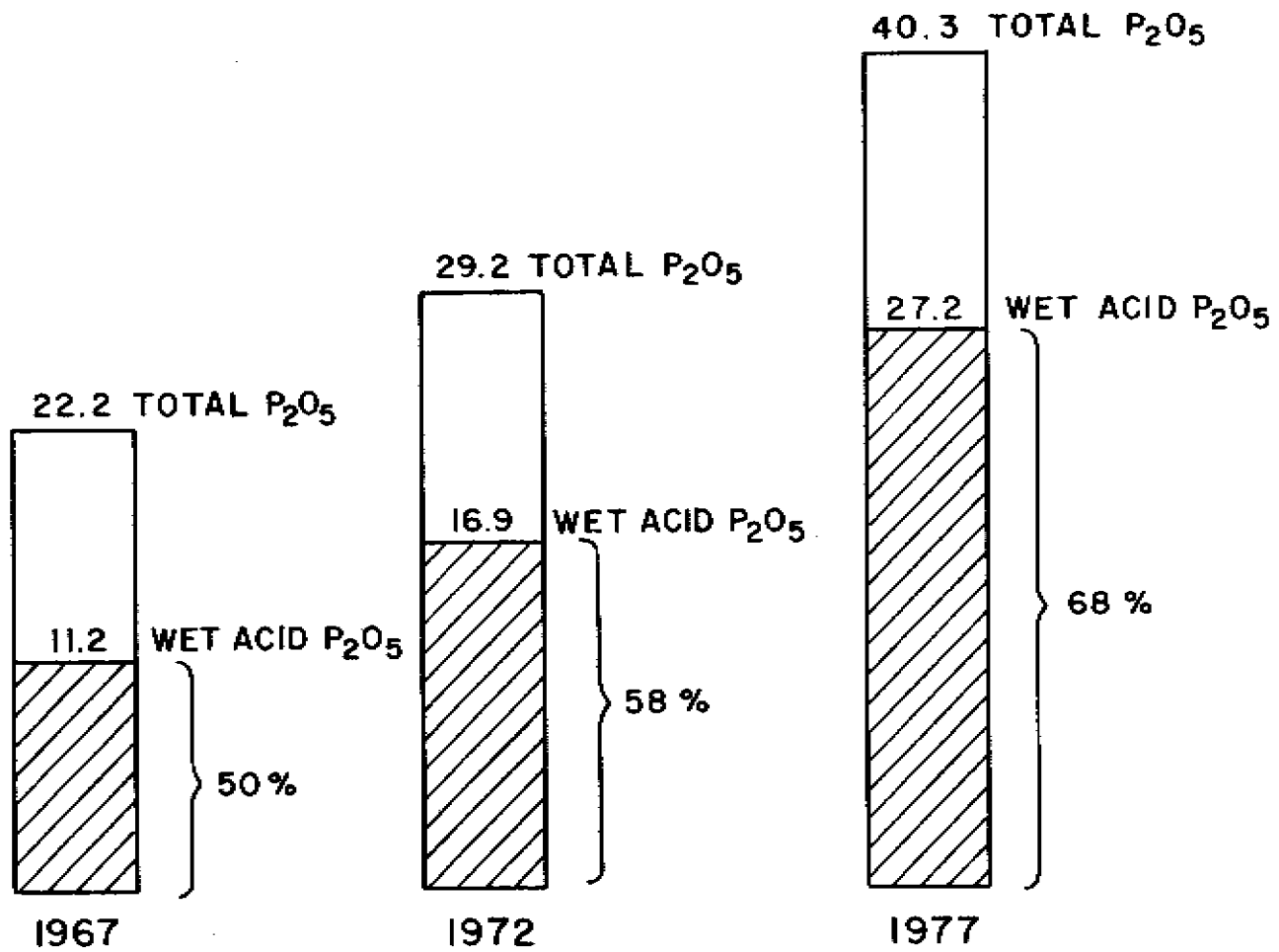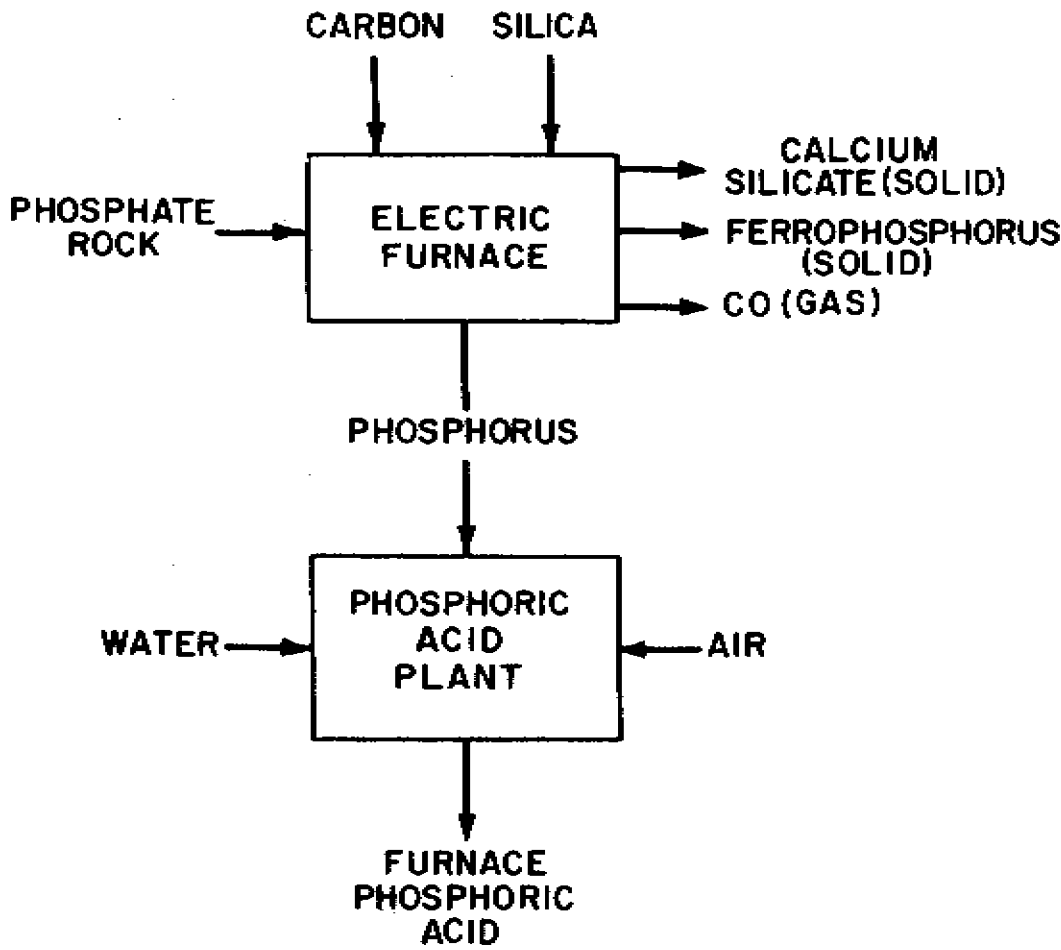
CARBON   SILICA

PHOSPHATE
ROCK → ELECTRIC FURNACE

→ CALCIUM SILICATE (SOLID)

→ FERROPHOSPHORUS (SOLID)

→ CO (GAS)

PHOSPHORUS

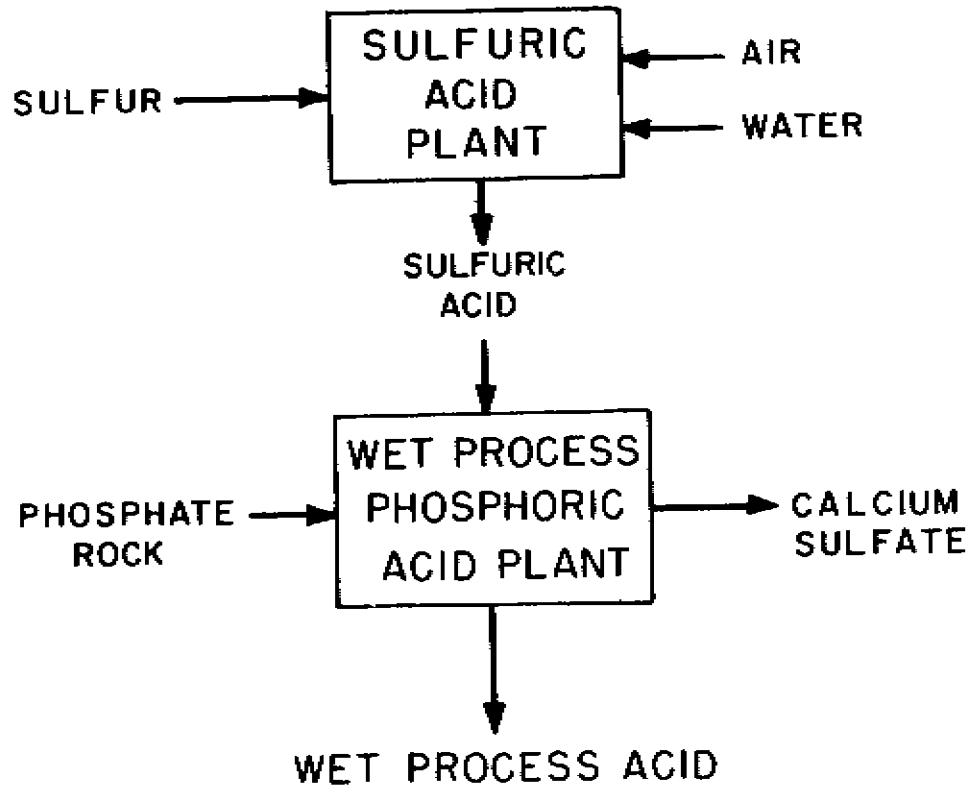WATER → PHOSPHORIC ACID PLANT ← AIR

FURNACE PHOSPHORIC ACID

Fig. 6: Flow Diagram for Phosphoric Acid Production by the Wet Process
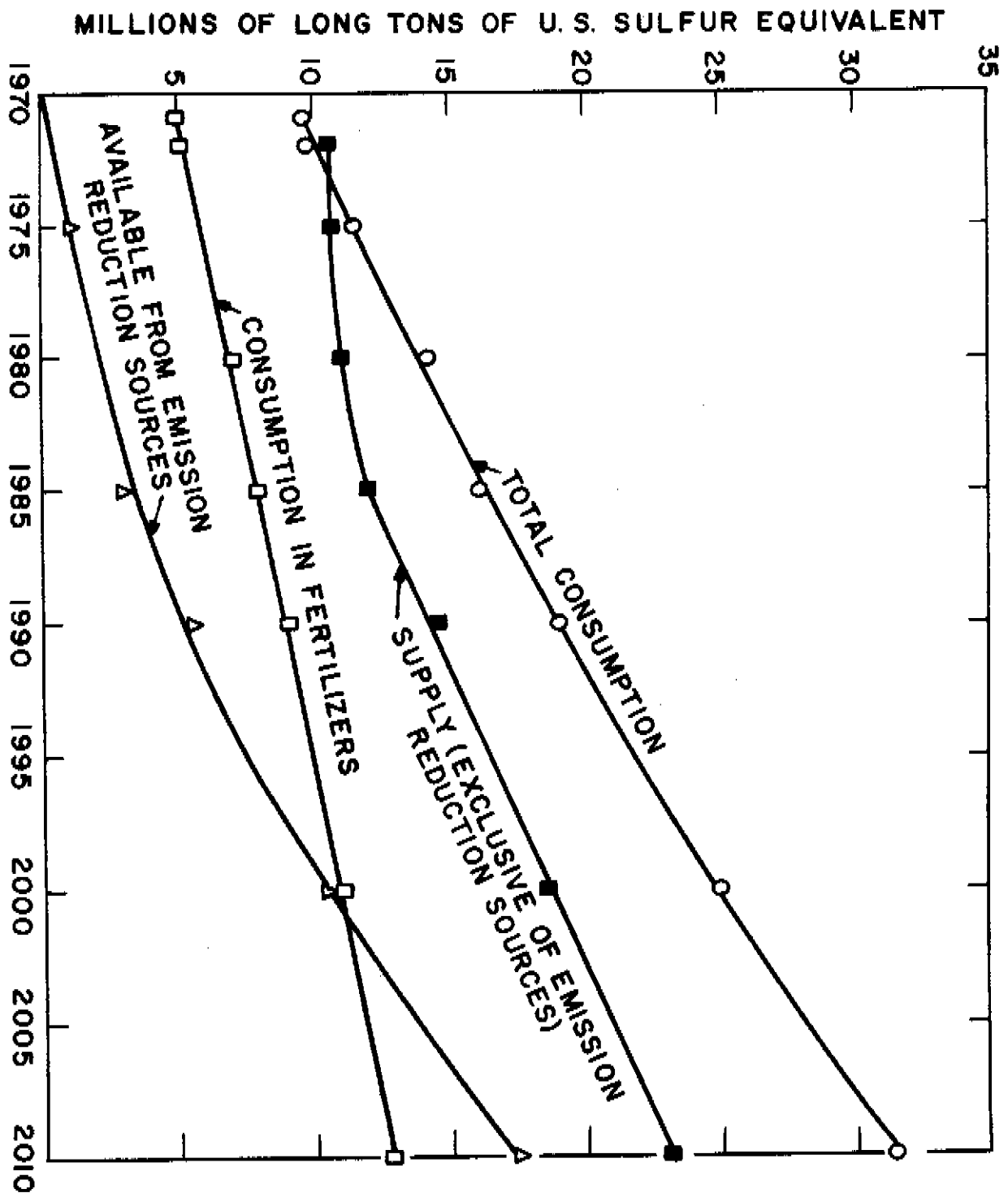
Fig. 7: U.S. Sulfur Supply—Demand Situation (All forms of sulfur)

DISCUSSION

The author read essentially the introduction and the summary
of his paper with some special references to phosphoric acid
(end of page 4 to beginning of page 5), and to the last part
of the paper (end of page 12, beginning of page 13).

M. DAVISTER (Société de Prayon, Belgium)

I would like to ask Mr. Davis a rather original question : when
speaking of energy consumption in the fertiliser industry and
particularly in the production of phosphoric acid, in estimates
presently made, should the possibility of energy production asso-
ciated with phosphoric acid manufacture not be taken into account?
And I see it that way. It is well known that some phosphate ores
contain substantial amounts of uranium. This uranium may be reco-
vered from phosphoric acid at a concentration of about 30 %. This
can be done by solvent estraction processes involving previous
purification of the acid but avoiding the cost of mining fairly
rare and scattered deep in the uranium ore. Then the recovery of
uranium from fairly unconcentrated phosphoric acid would save on
the uranium ore mining and, in addtion, would supply the nuclear
fuel with an energy capacity much in excess of that needed for
producing phosphoric acid.

M. DAVIS

It is certainly a valid observation - Recovery of uranium should
be considered in the future energy system for phosphate fertilisers.
There is quite a lot of interest in the U.S. at the present time
in recovery of uranium because the prices are increasing. I
understand there are probably two plants known in the U.S. that
are practising some uranium recovery.