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United Nations Industrial
Development Organization

UNIDO/ITD/7
9 April 1969
ENGLISH

00979

INTERIM REPORT OF THE UNIDO FERTILIZER MISSION TO INDONESIA *

(Under SIS ID/OA 220 INDO (8))

From 15 October to 15 November 1968

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* This interim report has been prepared for the use of UNIDO and the Government of Indonesia. It has been cleared by them. The views and opinions expressed in this report are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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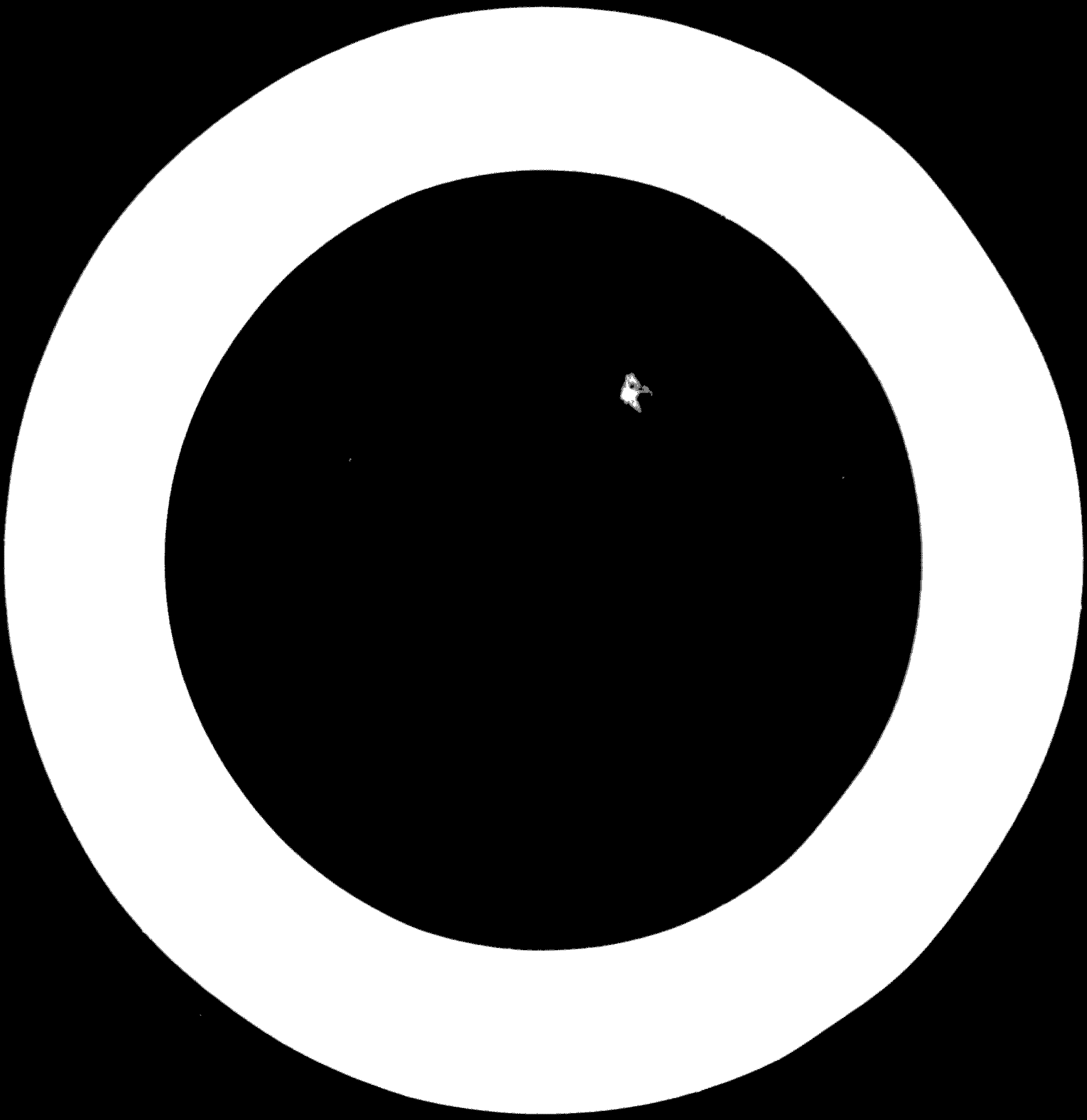

[illegible] REPORT

THREE FERTILIZER PROJECTS IN
INDONESIA
([illegible])

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I. INTRODUCTION

1. During the International Symposium on Industrial Development held in Athens during November-December 1967 contacts were established between the Indonesian Government Delegates and UNIDO. During the discussions an interest was expressed that UNIDO undertake a fertilizer mission to Indonesia to study certain specific problems related to the industry. Subsequently an official request was received through the Resident Representative and the terms of reference were as follows:

The fertilizer mission should study and make recommendations for the Government to take action and also for future UNIDO assistance on

1. the Tjilatjap phosphate plant in south central Java,
2. the Wanaradja sulphur plant in west Java, and
3. the Gresik ammonia plant at Surabaja in east Java.

To undertake the above, UNIDO organized an expert mission under the Special Industrial Services (SIS) consisting of Mr. M.C. Verghese, leader (nitrogen expert), Mr. F.T. Nielsson (expert on phosphates), and Prof. R. Kiyoura (sulphur expert). The first two members of the mission were briefed by the Industries Division of ECAFE on the 18th and 19th October and the visit to Indonesia was carried out between 19 October and 12 November 1968.

2. The mission was greatly assisted by the valuable guidance of the Resident Representative in Djakarta, Mr. Aly Ahmed Gritly, and the Deputy Resident Representative, Mr. Gvido Grisogono. The mission was received by the Director General of Chemical Industries, Col. Eng. Agus Sujono, and the Deputy Director General, Eng. Anwar Ibrahim. After discussing the overall aspects of the mission an itinerary was drawn up and three counterparts were assigned:

Ir. Nico Kansil (leader and nitrogen expert)
Ir. Supratignjo (Tjilatjap plant manager and phosphate expert)
Ir. Sjafri Saarin (sulphur expert)

The mission is extremely thankful to the above officials for assisting and guiding them in carrying out the mission successfully. A detailed list of the officials with whom the mission had discussions is given in Appendix 4.

II. BACKGROUND INFORMATION ON THE FERTILIZER INDUSTRY IN INDONESIA

A. The requirements of fertilizers in Indonesia (NPK) have been estimated by different authorities as follows:

1. Mr. J. Mahan and Mr. J. Maes, both FAO experts, have estimated that requirements of fertilizer in Indonesia in the form of basic elements are as follows:

N	749,941 tons
P_2O_5	710,742 tons
K_2O	318,467 tons

It should be noted that these are only requirements.

2. Prof. Go Ban Hong of the Department of Agriculture, estimates as follows:

For 1970 -	N	225,000 tons
	P_2O_5	183,000 tons
	K_2O	58,000 tons
For 1975 -	N	480,000 tons
	P_2O_5	457,000 tons
	K_2O	230,000 tons

3. The Department of Agriculture, going by trends as existing in 1963 and 1964 and disregarding the reduction in consumption in 1965 and 1966, estimates the following consumption of nitrogen, expressed in metric tons:

Wet Season Dry Season	1968/'69 1969	1969/'70 1970	1970/'71 1971	1971/'72 1972
Paddy	101,200	108,100	124,300	140,400
Non-Paddy *	36,800	39,100	41,400	46,000
Estates	40,340	44,890	46,330	47,970
Total	178,340	192,090	212,030	234,370

*Exclusive of nitrogen in compound fertilizers which are imported for special reasons.

4. Using a different approach, namely multiplying total area of fertilized paddy land by nitrogen application per hectare, the nitrogen consumption in 1969 and 1970 is expressed in metric tons as follows:

Wet Season	1968/'69	1969/'70
Dry Season	1969	1970
Java	124,636	168,983
Sumatra	18,905	27,430
Rest of Indonesia	10,769	16,420
Total	154,310	212,833

To this must be added consumption on non-paddy land and by the Estates estimated at 90,000 tons per annum.

5. Messrs. John Van der Valk and Associates recently estimated that with the production from the existing Pusri I, namely 48,500 tons per year, and the Petrokemia plant at Gresik now under construction producing 59,500 tons of nitrogen per year by 1973, the above two totalling a figure of 108,000 tons, a possible production by 1973 from the expansion of Pusri (Pusri II) with 600 metric tons of ammonia per day and producing 115,000 tons per year of N, the total availability in 1973 will be 223,000 tons of nitrogen. From the above it can be seen that this indigenous production will not be sufficient to meet the projected nitrogen consumption in 1973 of about 300,000 tons per year. Van der Valk came to a different conclusion than the above.

B. Existing units.

1. There is an ammonia and urea plant in Palembang (Pusri I) producing 100,000 metric tons of urea per year using natural gas as raw material.

2. The Petrokemia at Gresik, which is under construction, is expected to produce by 1970, 45,000 tons of urea per year and 150,000 tons of ammonium sulphate, using indigenous fuel oil and imported sulphur.

3. The phosphate project at Tjilatjap, obtained with bilateral aid from the USSR, is designed to produce 100,000 tons of simple superphosphate per year, using imported phosphate rock and imported or domestic sulphur. This plant is 30 % erected but construction has been at a stand still since 1966.

4. The Wanaradja sulphur plant is producing 3 tons of sulphur per day from volcanic sulphur muds.

C. The World Bank and IFC have been involved in the Indonesian fertilizer sector in various ways as follows:

1. In co-operation with USAID, IFC wrote the terms of reference for a study of the feasibility of expanding the Pusri fertilizer plant in Sumatra. USAID has engaged a consultant, John Van der Valk and Associates, who are presently in Indonesia completing this study.

2. IFC has also completed a study on natural gas reserves in Indonesia and furnished a report by IFC consultants, J.C. Sproule and Associates Ltd., to the Government of Indonesia.

3. At the request of the Government of Indonesia, the World Bank Group has undertaken to do a National Fertilizer Study for Indonesia covering all aspects of this sector of the Indonesian economy.

The present UNIDO fertilizer mission therefore did not visit Pusri but concentrated on the Tjilatjap phosphate project, the Wanaradja plant, and the Gresik ammonia plant.

III. TENTATIVE CONCLUSIONS AND RECOMMENDATIONS

1. Since in the Tjilatjap phosphate project 92 % of the equipment has been delivered and 30 % of the plant has been erected, and a total of about US$ 8 million has been invested, the mission very strongly recommends the Government of Indonesia to take immediate action to complete this project either by continuation of the bilateral assistance or, failing this, through other assistance. This plant can use the sulphur from Wanaradja when it is developed and can use imported rock phosphate to start with. This plant can produce triple superphosphate at a later stage utilizing imported phosphoric acid, which is being supplied in ocean going ships to India from Mexico. The plant can also use excess ammonia from Gresik to make ammoniated phosphate and produce a $N-P_2O_5-K_2O$ of 5- 20- 0

2. We recommend assistance from UNIDO in the form of an expert on phosphatic fertilizer production for one year to assist this project in its speedy completion and start-up. A draft Job
..... Description is attached (Appendix 10).

3. We recommend that UNDP and UNIDO assist the Indonesian Government in putting up a pilot plant at Wanaradja to develop a process to economically recover sulphur.

Ultimately sulphur needed both by the Tjilatjap and Gresik plants (50,000 tons per annum) should be produced in a commercial plant based on the pilot plant results. The pilot plant will use the sulphur muds from the Telaga Bodas crater. A draft
..... Special Fund request is attached to our report. This pilot project will establish the most economic and suitable process for the commercial unit. (App. 11)

4. For the Gresik fertilizer project, in order to assist in suitably disposing of the 6,000 tons of excess ammonia per year, which is most vital to the economic running of this plant, we suggest a Special Fund project for the direct application of ammonia for paddy and sugar can estates close to the Gresik plant.
..... A draft request for this project is attached to our report. (App.12)

5. The Gresik fertilizer plant has facility for making their product mix flexible, namely, they can produce within certain limits more urea and less ammonium sulphate, or less urea and more ammonium sulphate. The requirements of the market have still not been fully assessed. We recommend that UNIDO assist this project with a marketing expert to assist the plant with carrying out a market survey and to assist in determining the proper
..... product mix. A draft Job Description is attached to our report. (App. 14)

IV. TJILATJAP PHOSPHATE PLANT, SOUTH CENTRAL JAVA

The plant is located 3.5 km east of the city of Tjilatjap and 100 metres southeast of the village of Karangtalung. It was sold by Technopromexport, Moscow under a bilateral agreement between the Government of the USSR and the Government of Indonesia. Part of the contract involved a geological survey by Russian experts of the phosphate and sulphur deposits of Indonesia which was carried out in 1961-1963. Construction of the plant was begun in 1961 and terminated in 1965 with the cessation of Russian aid agreements. Ninety two per cent of the equipment was delivered and thirty per cent of the plant was erected when the project was stopped. Currently there are 420 persons on the plant payroll with 191 employed and the remainder on uncertain leave. The repair shop is operational as a small industry utilising the foundry and the carpenter shop for industrial contracts.

The initial contracts were for US$ 9,380,500 of Russian Letters of Credit (L/C) and US$ 2,117,000 of Czechoslovakian L/C for a total of US$ 11,497,500. Part of the Russian L/C have not been used. None of the Czechoslovakian L/C have been opened, so the current L/C investment in the plant is US$ 8,115,000. The figure is necessarily approximate due to variations in the exchange rate of the local currency, the Rupiah.

The housing for expatriate personnel, some 40 dwellings, is complete, some of it now being occupied by local project personnel.

The equipment material storage and repair maintenance shop are essentially complete.

A 2 x 6000 Kw powerplant is part of the project. One boiler is essentially complete, the other is about 30 % finished. The plant power requirements will be 3500 Kw during operation. The power system is tied into the Tjilatjap system which uses 1000 Kw. At present the power for the project and for the housing development is supplied by portable diesel generators.

The sulphuric acid plant is about 60 % complete with buildings, sulphur melter, blowers, converter shell, SO_3 cooler and acid coolers in place.

The phosphate operation is the least advanced with only the steel structure for the building in place.

Except for storage tank sections, equipment is either erected or in crates under cover. The erected equipment is painted and in excellent shape.

Surprisingly, the erected equipment appears to have been put up yesterday instead of three years ago. The project manager is trying his best to keep erected equipment in good shape, e.g. he keeps the piping filled with rain water to minimize corrosion. How long this newly-erected look will continue is questionable in view of the climatic conditions in the area.

One of the questions that was explored at great length was that "farmers do not want to use single superphosphate and prefer triple superphosphate".

Investigation reveals that the single superphosphate in 1962 was powdered material that apparently set up into hard lumps while in transit overseas and kept getting progressively harder in storage in Indonesia. It is understandable that such a product would be deemed unsatisfactory. On the other hand, the triple superphosphate being imported is granular and remains free flowing over a long period of time.

One of the most important points regarding the Tjilatjap phosphate plant is that it has a granulation section and that the product will be granular and free flowing. For this reason, we believe that the farmer will accept granular single superphosphate as readily as granular triple superphosphate, especially if the price of the product is favourable.

..... In Appendices 3 & 4 we show production costs for the manufacture of granular single superphosphate. These costs indicate that with imported rock phosphate and imported sulphur, the production cost will be US$ [illegible] per ton of P_2O_5, if the raw materials are trans-shipped via Singapore and US$ 138.0 per ton if the raw materials are shipped directly to Tjilatjap. This compares with a C.I.F. imported price in 1962 for powdered single superphosphate of US$ 175.0 per ton P_2O_5, and the 1967 C.I.F. imported price of granular triple superphosphate of US$ 174.0 per ton of P_2O_5.

The harbour of Tjilatjap is excellent, but there are about 30 wrecked ships in the harbour so that ingress is difficult and large ships cannot enter. Clearing of the harbour is underway and should be complete in 1970. The superphosphate plant cannot be finished before 1970. Therefore, about the time the plant is finished, the harbour would be cleared and direct shipments could arrive. As a result, we believe a production cost of US$ 138.0 per ton of P_2O_5 is a realistic cost F.O.B. plant in bags for granular single superphosphate at Tjilatjap.

A problem with new plants in Indonesia is that they must be self-sufficient according to Government standards. This means they must provide housing for workers and supervisors, have their own source of electric power, their own sewerage facilities and their own source of water. As a result, the total plant cost is fantastic as compared to a battery limits plant in a developed country.

It appears as if a final cost of US$ 11,656,000 may be a realistic figure for the total plant investment. One and one-half million Dollars can be assigned to the sulphuric acid plant because this is a self contained facility. Sulphuric acid costs on this basis are shown in Appendix 5. However,
..... we do not know how to allocate the probable revenues from the power plant or the probable income from the housing facilities. Therefore, the remaining US$ 10,156,000 of capital has been assigned to the superphosphate operation. Such a figure puts a tremendous depreciation burden on the cost of production because normally a granular superphosphate plant could be erected for well under one million Dollars, in which case the production cost of granular single superphosphate under Indonesian conditions would be US$ 127.0 per ton of P_2O_5.

Also, if the superphosphate operation were isolated, a 20 year depreciation period could be assumed. However, when one considers the large number of permanent concrete buildings, sewers and water treatment facilities, a 40 year depreciation period for the project, exclusive of the acid plant, appears reasonable.

The important thing to remember regarding the Tjilatjap phosphate operation is that because it has a granulation section, infinite variations in plant food manufacture are possible.

Once the plant is finished, an additional investment of about US$ 30,000 makes possible the production of granular ammoniated superphosphate of a 5-20-0 grade. The addition of urea to the superphosphate feed plus ammoniation could result in an 18-12-0 grade of granular mixed fertilizer, or in any other desired grade with an additional investment of about US$ 10,000.

Another important factor is that the plant equipment can be used to produce a wide variety of phosphates ranging from 20 % P_2O_5 to 46 % P_2O_5, all in granular form, by using sulphuric acid, phosphoric acid, or a combination of the two acids as
..... described in Appendix 8.

The trade journals have had artiĉles indicating that the Government of India has signed a contract with a Mexican producer to obtain wet-process phosphoric acid, C.I.F. India, at US$ 125.0 per ton of P_2O_5. We can assume that a ship could discharge most of its acid cargo in India and discharge the remainder at Tjilatjap for an additional US$ 5.0 per ton P_2O_5, or a cost at the plant of US$ 130.0 per ton P_2O_5.

To utilize imported phosphoric acid would require about US$ 50,000 additional investment for storage tanks, piping and meters. With US$ 130.0 per ton P_2O_5 acid and directly shipped phosphate rock, triple superphosphate could be produced
..... at Tjilatjap for a cost of US$ 130.0 per ton of P_2O_5 (App. 7). This compares with the 1967 import C.I.F. price of US$ 172.0 per ton P_2O_5.

Therefore, we recommend that the phosphate plant at Tjilatjap be finished as quickly as possible, even at the expense of a delay in the Pusri II expansion.

Estimates indicate that the capital needed to finish the project will be:

For construction:	US$ 2,117,000	
For equipment:	US$ 1,423,385	
TOTAL	US$ 3,540,385	at a D.P. rate of Rp 360 = US$ 1

We recommend also that the UNDP provide the services of one phosphate fertilizer expert for one year under the Technical Assistance programme to

1. Assist the Government in working out details for ammoniating phosphate using excess ammonia available from Gresik.

2. Study the feasibility of importing phosphoric acid to make double or triple superphosphate.

3. Advise and assist in the speedy completion of the project and its economic start-up.
   Project Data Sheets and Job Descriptions are attached
   ..... for Government approval (App. 9 & 10)

Although phosphate deposits are widely scattered throughout Java, the deposits are small and not sufficient to sustain an acidulation operation for superphosphates (e.g. in Kagen Grobogan there are 12,000 tons of phosphate scattered among 14 districts). The few known large deposits have been exploited so that they are no longer economic.

V. WANARADJA SULPHUR PLANT - WEST JAVA

The situation is different regarding sulphur.

The Russian survey team, mentioned previously, consisted of 29 persons including 11 geologists. Although their data indicate about 1.5 million metric tons of sulphur reserves throughout 10 districts in Indonesia, the deposits of real interest are at Telaga Bodas, Kawah Putih and Telaga Torus. Data regarding these deposits are shown in the following tabulation:

Location	Distance from Wanaradja, km	Type of Deposit	Economic Sulphur reserves, metric tons S
Telaga Bodas	14	Muddy clay	846,771
Kawah Putih	137	Muddy clay	132,008
Telaga Terus	132	Lump ore	49,463

A factory used to exist at Kawah Putih and 133,400 tons of sulphur were shipped from there in the period 1925 - 1941. In 1944 the sulphur factory was destroyed. The reserves were deemed insufficient for rebuilding the factory.

There is a small factory at Wanaradja built initially to process Telaga Bodas clay. It used to produce 24 tons per day of sulphur before the Japanese invasion, but after the war, partial rehabilitation has resulted in a factory that is producing 3 tons of sulphur per day.

Telaga Bodas is the crater of an inactive volcano. The crater has a lake containing 2,016,000 cubic metres of a muddy clay-sulphur mixture ranging in sulphur content from a low of 14.1 % to a high of 70 %. Out of a total sulphur content of 912,000 tons, it is estimated that there are 847,000 tons of economic reserves with an average sulphur content of 28 % S or better. The economic reserves include about 617,000 tons with an average sulphur content of 55 % or better.

When the factory operated before the war, the clay was transported as a slurry through 14 km of pipe from the lake to the factory. Part of the pipe line was rubber, part ceramic, and part an open wooden flume. Now only the ceramic underground portion is in existence and could become part of a new pipe line system.

Now the mud is brought to the factory from the crater by trucks. At the factory the mud is washed and treated in two stages in steam autoclaves. The first stage encourages the growth of the sulphur particles which are found in the original ore as minus 325 mesh particles.

In the second stage the clay is steamed long enough to melt the sulphur and separate it from the clay particles which also are of a minus 325 mesh size. The melted sulphur is cast into blocks and shipped out in bags.

Only about 40 % of the sulphur in the clay is being recovered.

At the same time the factory is processing some lump ores (65 % - 70 % S) from deposits at Papandajan (90 km) and Tangkuban (150 km) in a single stage melting autoclave step. However, the latter two deposits have a total reserve of only 16,000 tons of sulphur.

It has been suggested that the Telaga Bodas clay could be burned directly at the site in a plant to yield sulphuric acid. However, the water content of the clay, and the fine particle size of the sulphur interspersed within the fine particles of clay make a combustion process infeasible. At the same time, a recovery of only 40 % of the sulphur from the clay is an economic tragedy which Indonesia can ill afford.

It is recommended that the UNDP provide a Special Fund project for a technical pilot plant. This pilot plant would study the best means of upgrading the ore through flotation or other means, and of recovering the sulphur from the ore using various types of autoclaves. It is believed that a process can be developed which will recover over 90 % of the sulphur present in the ore. If we assume that 80 % of the economic reserves can be removed from the crater, then the overall sulphur recovery from the crater would be .90 x .80 or 72 % of 847,000 or over 600,000 tons of sulphur of 99+ % purity.

The phosphate plant at Tjilatjap will require about 43 tons per day of sulphur, while the Gresik plant will require about 110 tons per day of sulphur, for a total requirement of 50,000 tons per annum. At this rate, the Telaga Bodas deposit would last about twelve years, or long enough to justify the 5 million Dollar investment required for a 160 tons of sulphur per day operation.

If we assume the lower price for sulphur of US$ 54.60 per ton C.I.F. Indonesia, and subtract US$ 9.0 per ton for amortization and interest charges, then we have a foreign exchange saving of US$ 45.60 per ton or US$ 2,280,000 saving in foreign exchange per year with a new sulphur operation at Wanaradja.

However, before anyone will invest in such an operation, there must be engineering data available for designing a large scale plant. The present operation with its 40 % recovery system cannot supply such data.

For that reason it is necessary to build the pilot plant mentioned earlier.

A Government request for such a project is attached. (App.11)

VI. GRESIK AMMONIA PLANT, (SURABAJA), EAST JAVA

The Petrokemia plant is about 30 % complete and 95 % of the equipment is at the site. About 1700 workers are busily engaged in bringing the project to completion. It is expected that the plant will be commissioned early in 1969.

The plant is designed to produce 200 tons per day, ammonia (70,000 tons per annum) of which 6,000 tons are for sale with the balance to be converted into urea and ammonium sulphate.

The plant is based on the partial oxidation of fuel oil and so has a liquid air plant in connection. In addition there is a 350 ton per day sulphuric acid plant on the site.

A 200 ton per day plant using partial oxidation of fuel oil is not a low cost producer at below design capacity, so every effort must be realized to maintain full capacity, and to find a market for the excess ammonia.

The tentative product mix will be:

Ammonia	6,000	tons	per annum
Urea	45,000	"	" "
Ammonium Sulphate	150,000	"	" "

Our recommendation regarding Gresik is that it be brought to completion as rapidly as possible under the original design conditions to yield the tentative product mix listed above, using imported sulphur initially for the production of sulphuric acid.

We suggest two alternatives for ready disposal of the 6,000 tons per annum of excess capacity.

1. The plant has acquired 140 high pressure cylinders capable of holding about one ton of liquid ammonia at atmospheric temperatures. These vessels could be used to transport 20 tons of ammonia per day to the phosphate plant at Tjilatjap for producing ammoniated superphosphate of about a 5-20-0 grade.

2. The excess ammonia could be used as a direct application fertilizer on estate crops and for irrigated paddy. Since this would be a novel use of ammonia in Indonesia (55 % of the ammonia in the United States is applied directly to the soil), some preliminary field testing is needed. We recommend that the UNDP provide a Special Fund project to determine the feasibility of direct application of ammonia under the agricultural conditions prevailing in Indonesia. A Government request for such a project is attached. (App. 12)

.....

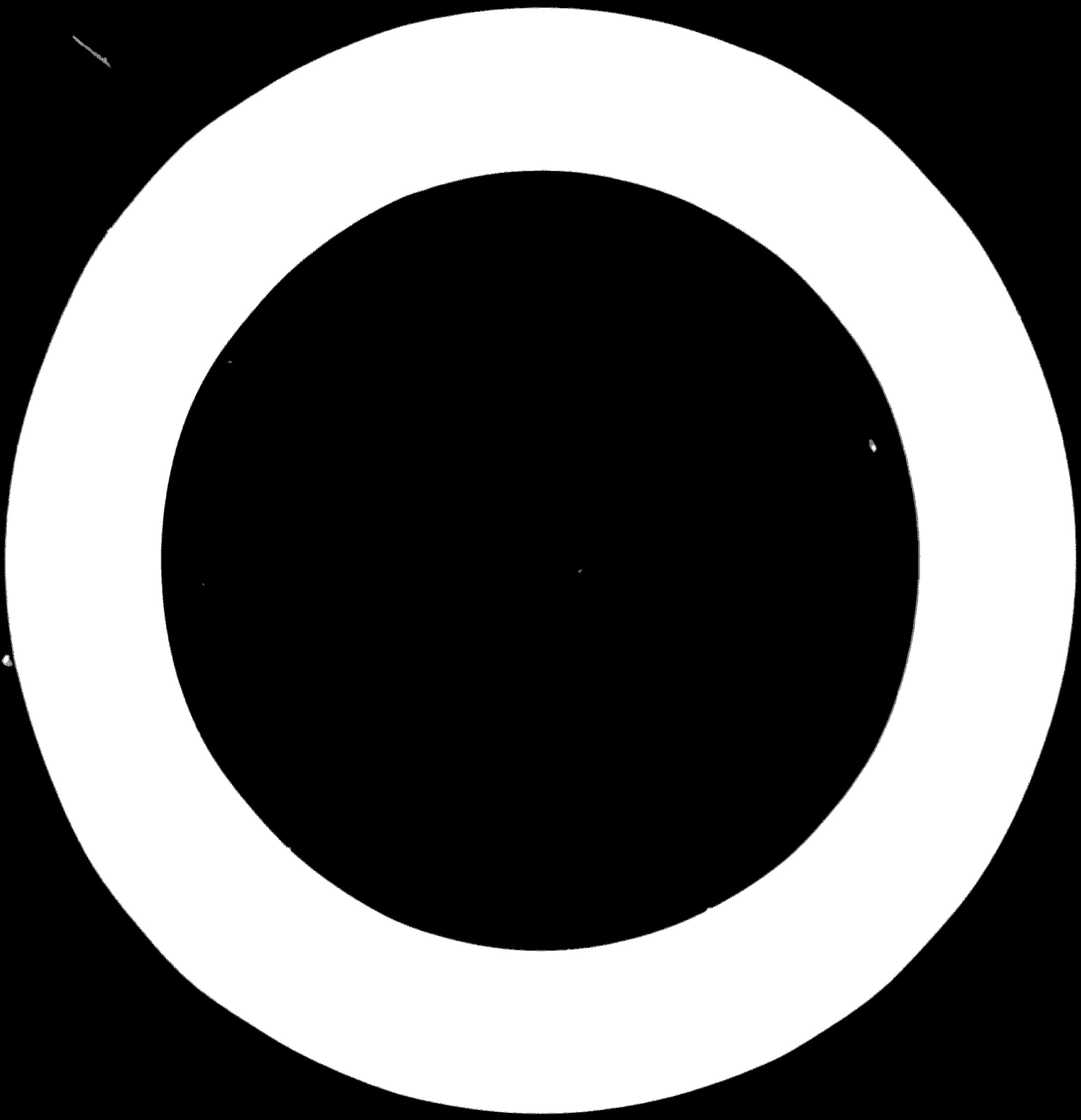
Although the tentative product mix shows 45,000 tons urea and 150,000 tons ammonium sulphate per annum, the proportions can be varied as dictated by market conditions. However, once the warehouses are full of a certain product mix, it is too late to determine whether the farmers' preference is for the same ratio of products as that found in the warehouses. Therefore it is necessary that a market study be made immediately to determine just what ratio of urea and ammonium sulphate is needed to satisfy consumer demand so the plant can operate at full capacity. We recommend that the UNDP provide a marketing expert under the SIS programme to assist plant management in determining the most profitable product mix for operations.

..... A Project Data Sheet (App. 13) and Job Description (App. 14) for the SIS programme is attached for Government approval.

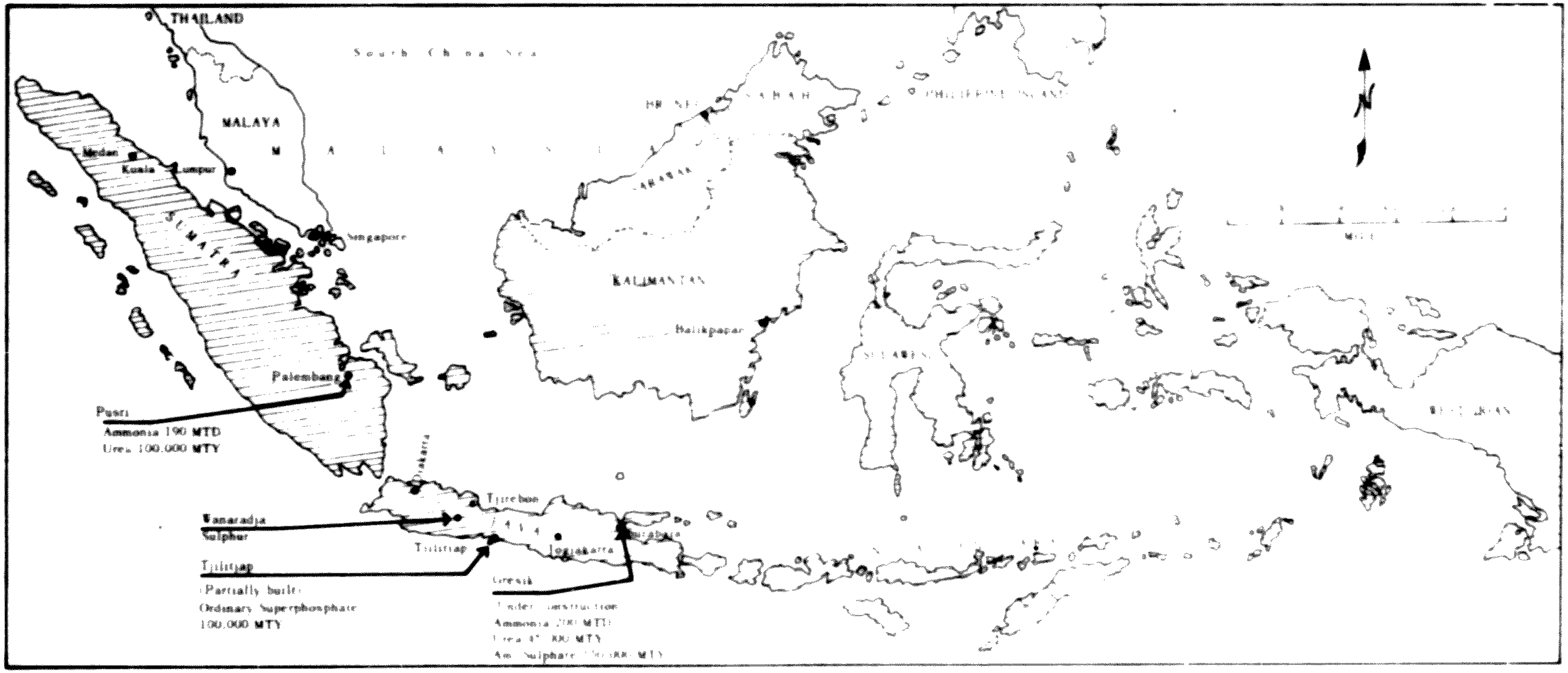
.-.-.-.-.-.-.

In conclusion, we repeat our recommendations:

1. Finish the Tjilatjap phosphate plant as planned.
2. Finish the Gresik ammonia, urea, ammonium sulphate plant as planned.
3. Request UNDP assistance for:
    (a) A technical pilot plant for sulphur recovery at Wanaradja.
    (b) A pilot project to study the application of anhydrous ammonia directly to the soil, so as to utilize the excess ammonia capacity at Gresik.
    (c) Technical assistance to aid in the start-up of the plant at Tjilatjap as well as aid in the study of ammoniation, and the manufacture of triple or double superphosphate there.
    (d) Marketing assistance for determining the best product mix at Gresik.



INDONESIA

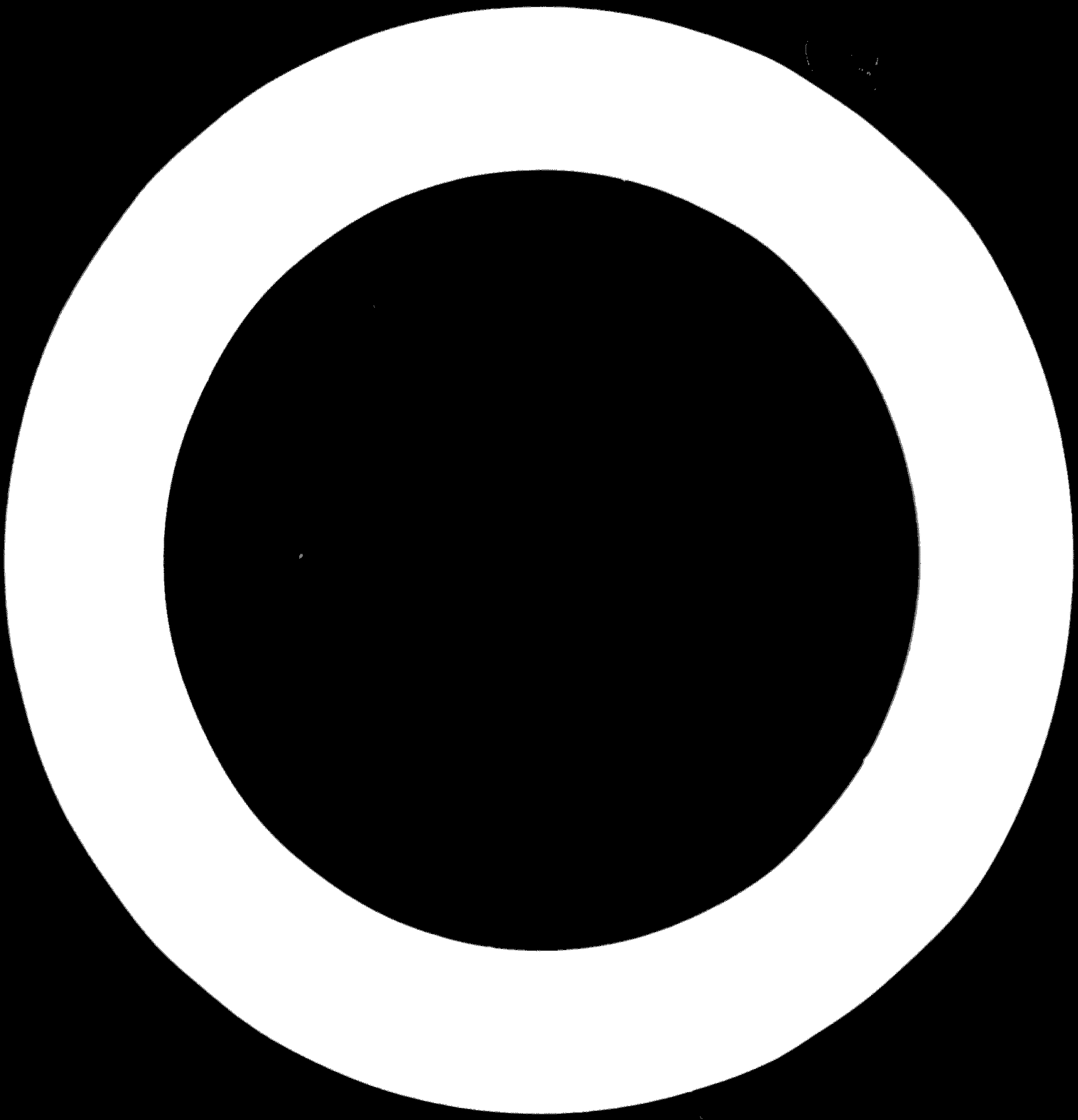


Pusri
Ammonia 190 MTD
Urea 100,000 MTY

Wanaradja
Sulphur

Tjilatjap
(Partially built)
Ordinary Superphosphate
100,000 MTY

Gresik
(Under construction)
Ammonia [illegible] MTD
Urea [illegible] MTY
Am. Sulphate [illegible] MTY

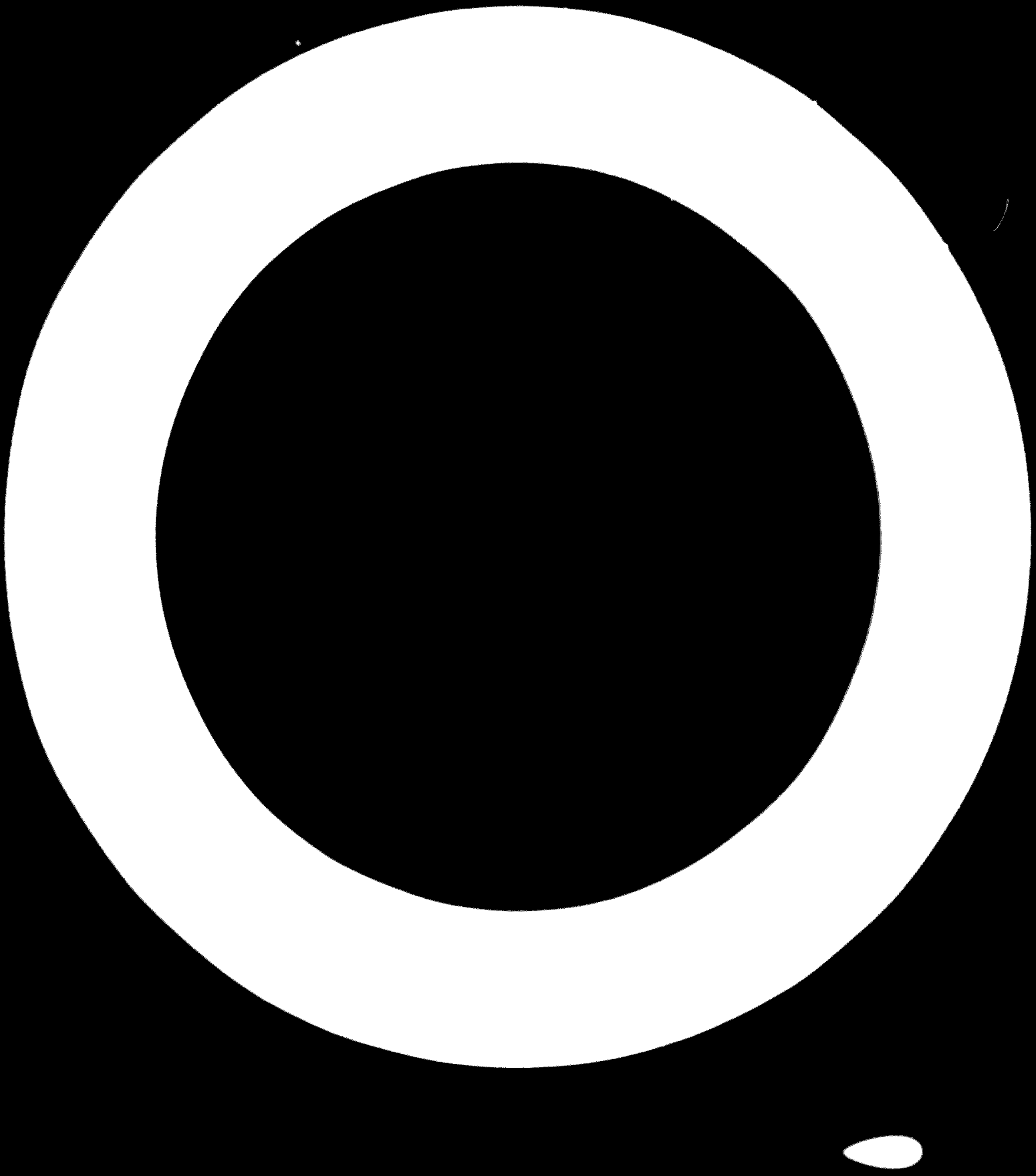


Appendix [illegible]

ITINERARY [illegible] MISSION [illegible]

Mission consisted of: 1. Mr. [illegible] Verghese
2. Mr. [illegible] Nielsson
3. Prof. Dr. Kiyura

24-10-1968	Thursday	– [illegible]
25-10-1968	Friday	– Meeting with counterpart [illegible] [illegible] of the mission.
26-10-1968	Saturday	– Courtesy visit to the Director General for Chemical Industries. – Meeting with counterpart Ir. [illegible]
27-10-1968	Sunday	– [illegible] in the afternoon.
28-10-1968	Monday	– Wonokromo
29-10-1968	Tuesday	– Wonokromo – Mission group leaves for Tjilatjap in the afternoon. – Sulphur expert Prof. Dr. Kiyura and counterpart Ir. Sjafri [illegible] stay at Wonokromo until [illegible]
30-10-1968	Wednesday	– Tjilatjap
31-10-1968	Thursday	– Tjilatjap – Mission group leaves for Gresik in the afternoon. – Phosphate expert Mr. Nielsson and counterpart Ir. Supr[illegible] to stay at Tjilatjap until [illegible] Nov. [illegible]
1-11-1968	Friday	– Gresik
2-11-1968	Saturday	– Gresik – Nitrogen expert Mr. Verghese and project officer Ir. [illegible] to stay at Gresik until 3 Nov. 1968
4/5-11-1968	Mond./Tuesd.	– Preparation of interim report for the Director General in Djakarta.
6-11-1968	Wednesday	– Mr. Verghese leaves Djakarta.
12-11-1968	Tuesday	– Mr. Nielsson & Prof. Kiyura leave Djakarta.



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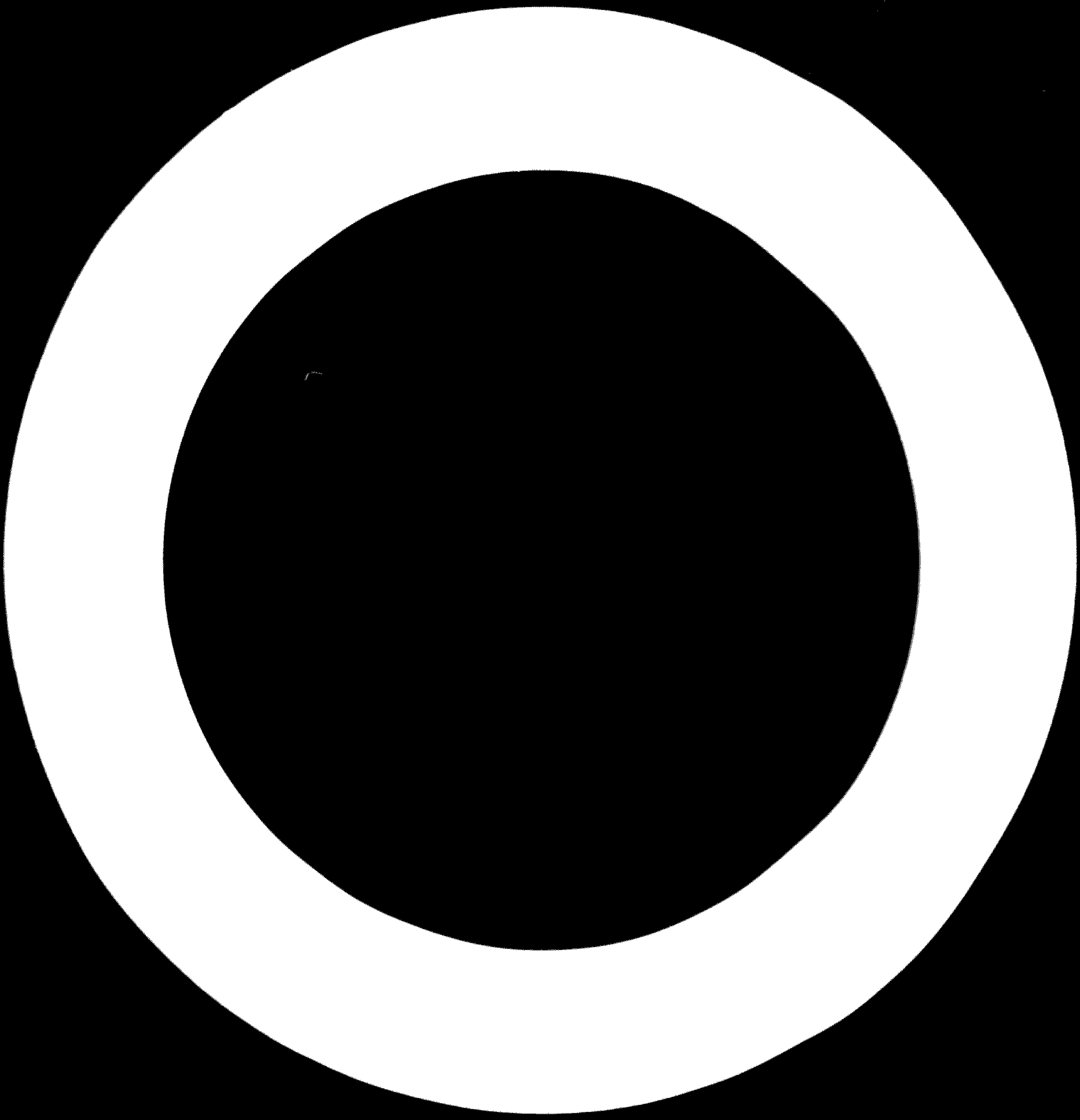


Appendix [illegible]

PERSONS INTERVIEWED IN [illegible]

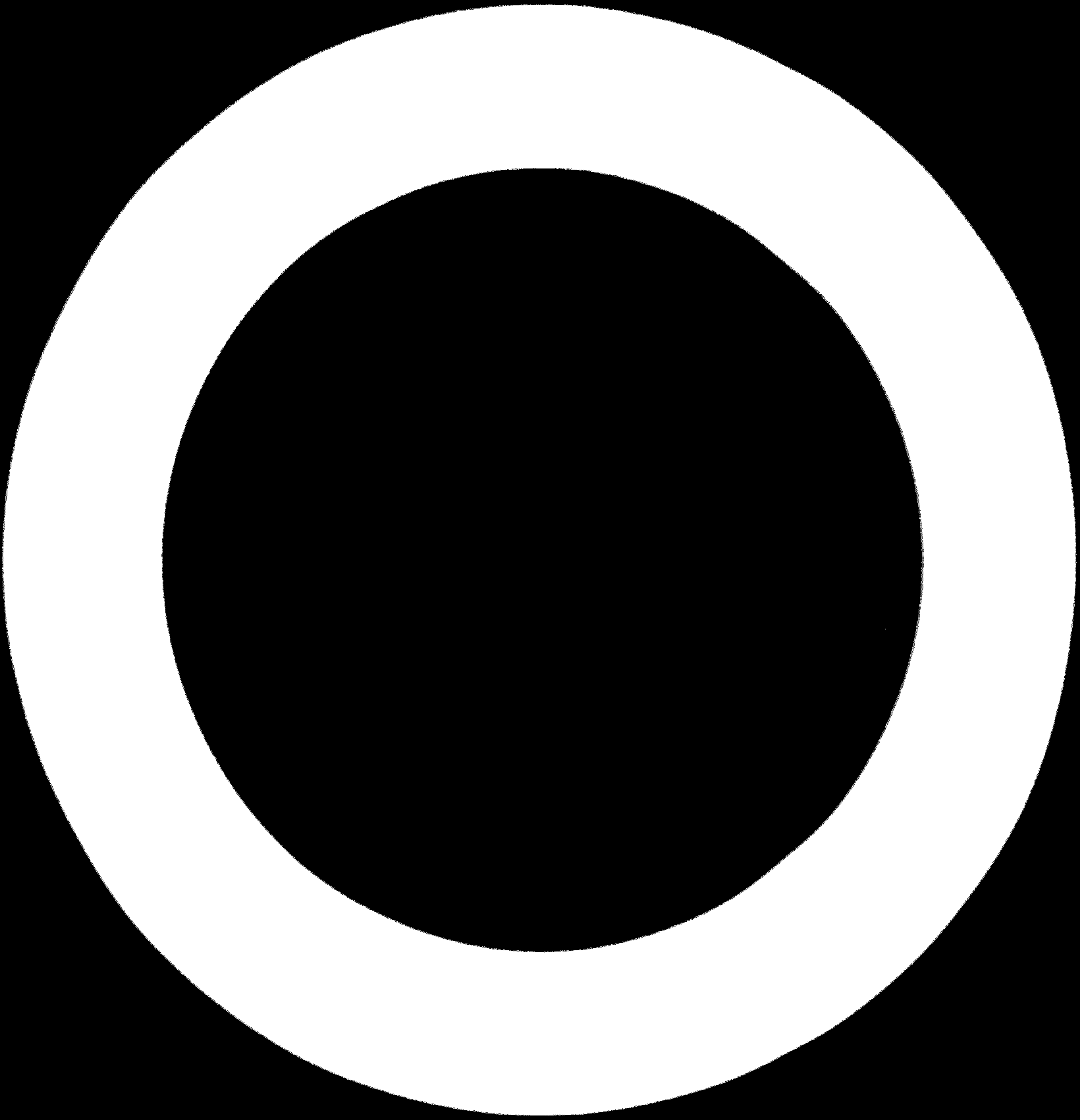
Unless otherwise noted, [illegible] Djakarta, Indonesia

Mr. A.G. Menon	Director, [illegible], Bangkok, Thailand
Mr. [illegible].Y. Li	[illegible]
Mr. [illegible]	" " " "
Mr. Achmed Slamet	" " "
Mr. Aly Gritly	Resident Representative, UNDP
Mr. Gvido Grisogono	Deputy Resident Representative, UNDP
Col. Ir. Agus Sujono	Director [illegible] Dept. of Chemical Industries
Ir. Anwar Ibrahim	Deputy Director [illegible] " " " "

Mission Counterparts:

1. Ir. [illegible] Kamil, L[illegible] & Nitrogen Expert, Dept. of Chemical Industries
2. Ir. Supratikno, Tjilatjap [illegible] Expert
3. Ir. Sjafri Sa[illegible], Sulphur Expert, Department of Chemical Industries

Dr. Ing. Purnomo Sidi	National Bureau of [illegible] Development [illegible]
Ir. Abdul Rasjid	[illegible]
Wagimin Siswo[illegible]	Port Commander, Tjilatjap
En. I.Simandjuntak	Government Representative, [illegible] Gresik (Surabaya)
Ir. Suratman	" " " "
Mr. O.G. Woodside	Consultant " " " "
Alwyn Y. Young	Technical Assistance Expert, UNIDO/UNDP
Ir. A.R. Soehoed	Member Foreign Investment Board
Mr. Rusli Jahja	Director of Marketing, Head of Logistics Division, Department of Agriculture
Mr. Soedharjo Rawidjo	Acting Director, Directorate General of Agriculture
Dr. D. Muljadi	Agronomist, Soil Research Institute, Bogor
Prof. Dr. Go Ban Hong	Director, Central Research Agriculture Institute, Bogor
Dr. M. Partosoedarso	Director, Research Institute for Estate Crops, Bogor
Mr. H.L. Beemer	Private Investment & Industry Officer, U.S. Agency for International Development (AID)
Mr. T.W. McCarty	Programme Officer, AID
Mr. E. Cook	Extension Training Adviser, Agriculture, AID
Mr. S.M. Sulaiman	International Bank for Reconstruction and Development
Dr. Ing. M. Harsono	Institute of Industrial Research and Training, Ministry of Industry
Mr. Soerjo Sediono	Vice Chairman, Office of Foreign Investment Board, and Head, Research Institute for Industrial Development.



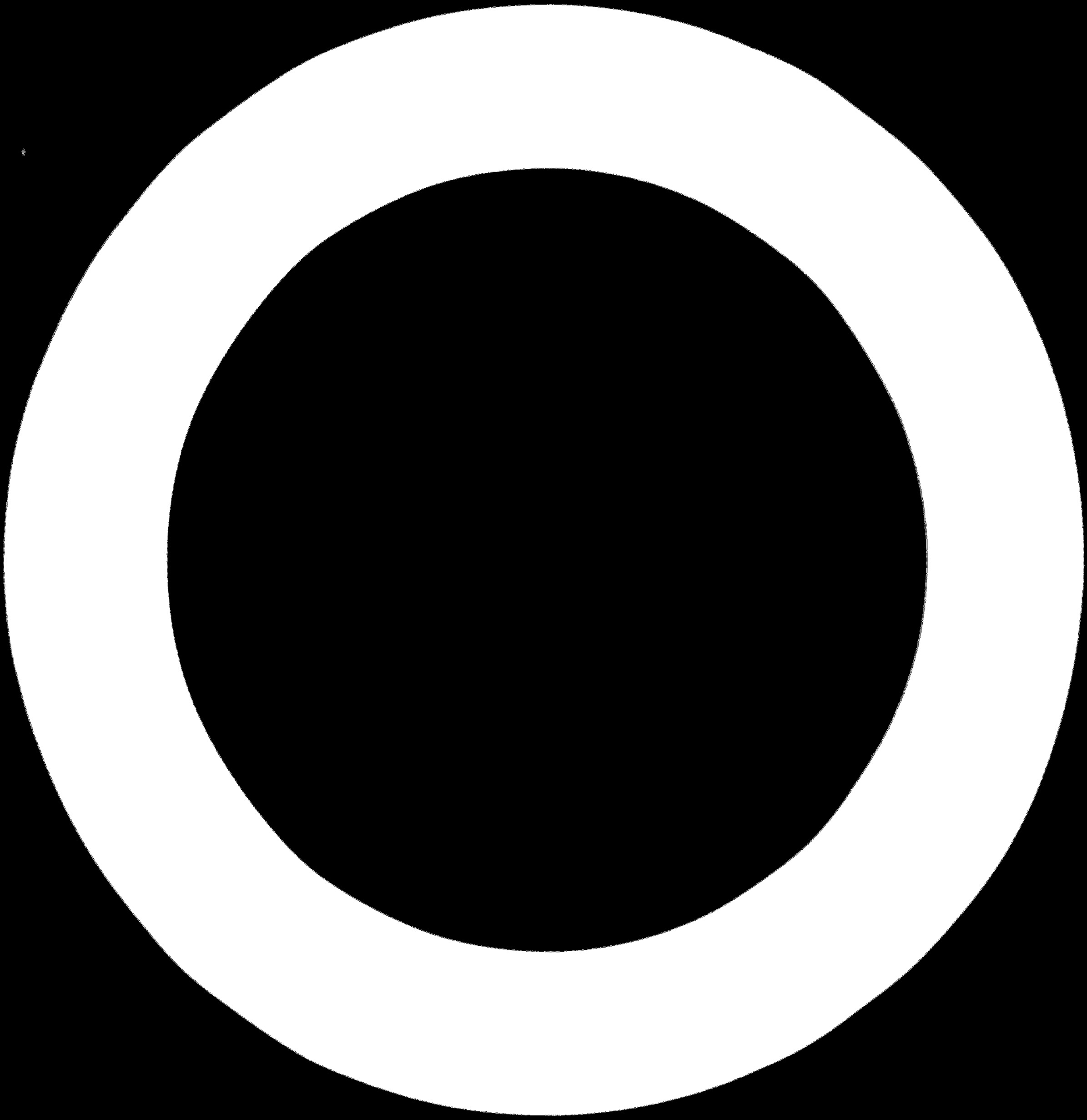
DELIVERY COSTS US$/metric ton

	via Singapore	Direct
Sulphur F.O.B. America	US$ 45.00	US$ 45.00
Freight & Insurance	13.00	9.60
C.I.F. Tjilatjap	58.00	54.60
Unloading & Freight	1.90	1.00
Del. Plant	59.90	55.60
74/75 % BPL 34.42 % P_2O_5		
Rock phosphate F.O.B. Tampa	10.15	10.15
Freight & Insurance	13.90	4.60
C.I.F. Tjilatjap	24.05	14.75
Unloading & Freight	1.00	1.00
Del. Plant	25.05	15.75
per kg rock	0.02505	0.01575
per kg P_2O_5	0.0728	[illegible]

Assume a US$ 11,656,000 plant with US$ 1,500,000 allocated to sulphuric acid at 15 years depreciation, and US$ 10,156,000 allocated to superphosphate at 40 years depreciation because of the large proportion of buildings involved.

Sulphuric acid – 36,000 tons per year, 100 %, US$ 1,500,000 capital

		Sulphur via Singapore		Sulphur Direct
Sulphur 0.333xUS$ 59.90	US$	19.95	0.333x$55.60	$ 18.50
Utilities (steam to power plant offsets power)		0.00		0.00
Repair labour 0.3 % of 1.5 m. capital		0.13		0.13
Repair material 4 % of 1.5 m. capital		1.67		1.67
Operating labour		0.08		0.08
Laboratory & Supplies		0.06		0.06
Depreciation, 6.7 % of capital		2.89		2.89
Overhead 40 % of labour		0.01		0.01
Production cost/metric ton	US$	24.79	US$	23.34
Production cost/kg 100 % H_2SO_4		0.02479		0.02334

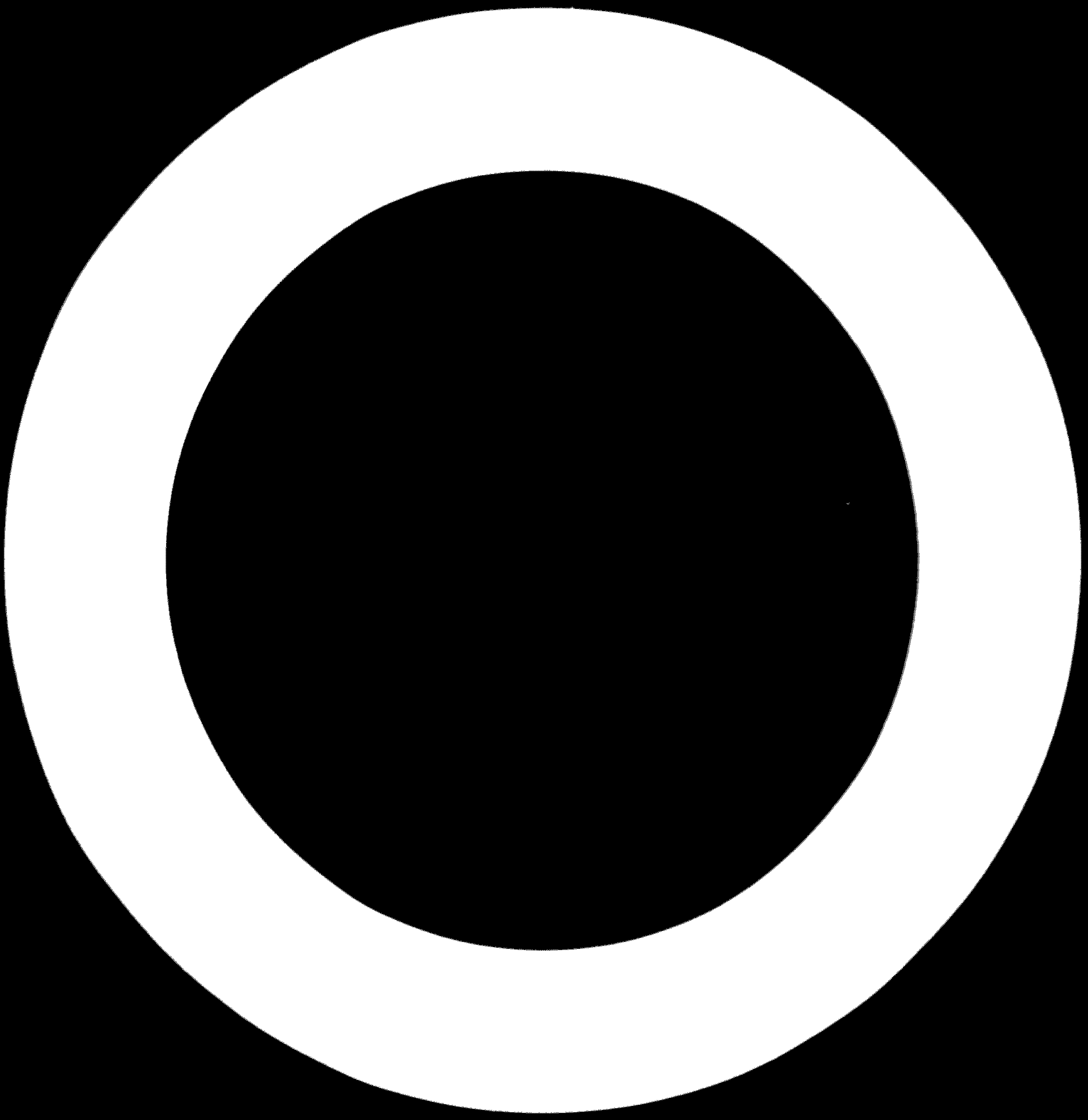


GRANULAR SINGLE SUPERPHOSPHATE; 20 % CITRATE SOLUBLE P_2O_5, 16 % WATER SOLUBLE P_2O_5 - 100,000 tons/year, US$ 10,156,000 capital

Acidulation: 1.79 kg H_2SO_4/kg Cit. Sol. P_2O_5

2.96 kg Rock/kg Cit. Sol. P_2O_5

		Rock & Sulphur via Singapore			Rock & Sulphur direct
H_2SO_4 1.79x0.02479x20	=	US$ 8.86	1.79x0.0234x20	=	8.38
Rock 2.96x0.02505x20	=	14.86	2.96x0.02075x20	=	12.30
Utilities	=	0.15		=	0.15
Repair labour	=	0.11		=	0.11
Repair material	=	0.53		=	0.53
Operating labour	=	0.24		=	0.24
Laboratory & Supplies	=	0.06		=	0.06
Depreciation, 2.5 % of capital	=	2.54		=	2.54
Overhead, 40 % of labour	=	0.14		=	0.14
Bags, 25 kg	=	3.00		=	3.00
Production Cost per metric ton F.O.B. plant		US$ 30.49			US$ 27.45
Cost per ton P_2O_5:		US$ 152.00			US$ 137.00
If capital were US$ 1,000,000 production cost per ton P_2O_5, at 5 % depreciation, would be:		US$ 142.00			US$ 127.00
1962 import price CIF for **powdered** single super was		US$ 35.00 per ton	or		US$ 175.00 per ton P_2O_5



TRIPLE SUPERPHOSPHATE

India is planning contracts [illegible] wet process acid, C.I.F. India at US$ 125.00 per metric ton P_2O_5. We can assume that partial cargoes would be discharged at Chittagong for an additional US$ 5.00 per ton P_2O_5 for a landed cost of US$ 130.00 per metric ton P_2O_5.

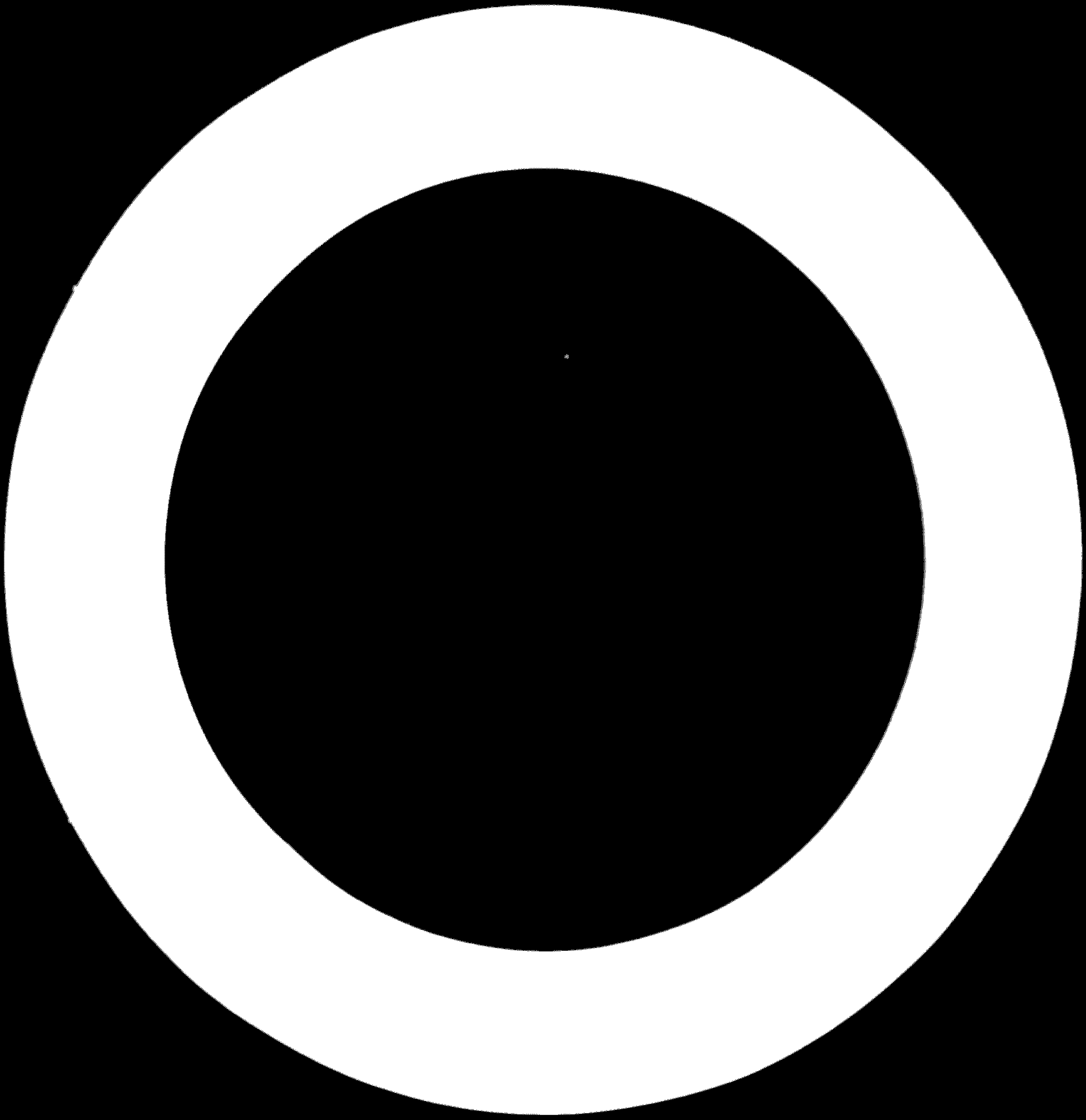
Formulation: 0.740 kg acid P_2O_5 per kg. Cit. Sol. P_2O_5

.303 kg rock P_2O_5 per kg Cit. Sol. P_2O_5

Cost of acid, 0.740x0.130	=	US$ 0.0962
Cost of rock, direct, from App. 5, .303x0.0665	=	.0201
Raw material cost per kg P_2O_5	=	US$ 0.1163
Raw material cost per ton product, 46% P_2O_5	=	53.00
Manufacturing cost, incl. bags, from App. 6	=	6.77
Production cost F.O.B. plant per ton	=	US$ 59.77
<u>Cost per ton</u> P_2O_5	=	130.00

1967 import price for triple super,
C.I.F., was US$ 79.20 per metric ton 46% P_2O_5 product

or US$ 172.00 per ton P_2O_5



Pilot Plant Data for Producing High Grade Superphosphates

I&EC—March 1953

Because the production of phosphoric acid by the wet process may be increased significantly to permit the recovery of uranium salts as a by-product from phosphate rock, there is considerable interest in the feasibility of using wet-process acid for the production of enriched and concentrated superphosphates in existing ordinary superphosphate equipment. This paper describes small scale and pilot plant studies of the acidulation of phosphate rock with mixtures of sulfuric and wet-process phosphoric acid and with wet-process acid alone.

Information was obtained in the pilot plant on the mixing, denning, and curing characteristics of enriched and concentrated superphosphates, and operating conditions that should be satisfactory for use of mixed acid in several types of ordinary superphosphate equipment were identified. The phosphorus pentoxide contents of the enriched and concentrated superphosphates were as available as those in ordinary superphosphate, and the products were as amenable to handling in bags and to ammoniation as is ordinary superphosphate.

The superphosphates produced with mixed acid or phosphoric acid are of high grade and can be used in the production of high analysis fertilizers for which there is a growing demand.

ENRICHED AND CONCENTRATED SUPERPHOSPHATES

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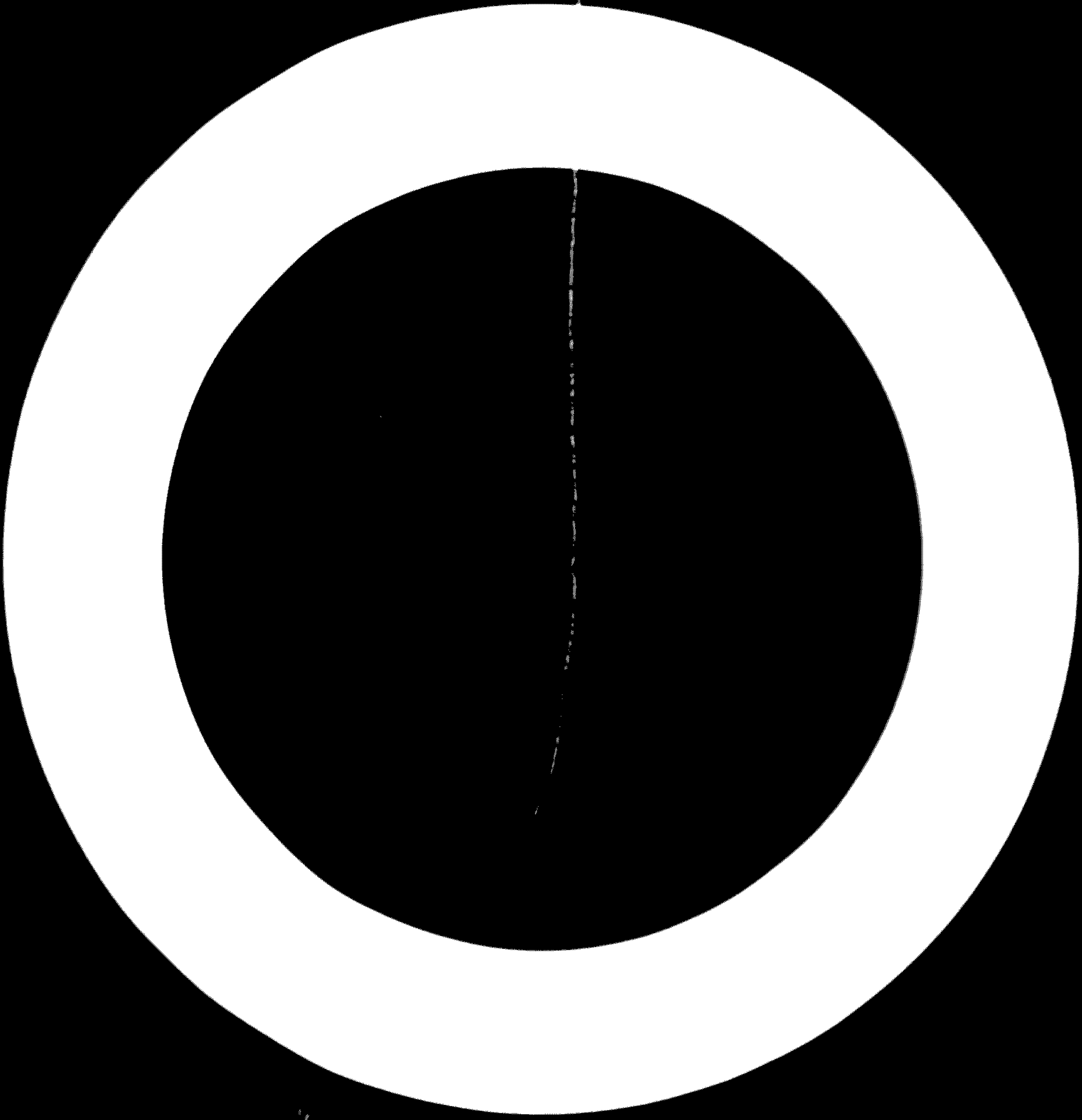
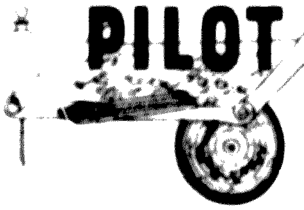
Tennessee Valley Authority, Wilson Dam, Ala.; U. S. Department of Agriculture, Beltsville, Md.

Reprinted from INDUSTRIAL AND ENGINEERING CHEMISTRY, Vol. 45, Page 681, March 1953



PILOT PLANTS



Enriched and Concentrated Superphosphates

L. D. YATES AND F. T. NIELSSON
Tennessee Valley Authority, Wilson Dam, Ala.
AND
E. J. FOX AND R. M. MAGNESS
U. S. Department of Agriculture, Beltsville, Md.

CONCENTRATED superphosphate is the usual product of acidulation of phosphate rock with phosphoric acid, variously known as double, triple, or treble superphosphate. Enriched superphosphate may be a mixture of ordinary and concentrated superphosphates or the product of acidulation of phosphate rock with a mixture of phosphoric and sulfuric acids. Because of the increasing demand for high analysis fertilizers, enriched and concentrated superphosphates appear to be increasingly attractive to producers of ordinary superphosphate. This fact was evidenced by the large attendance of industry representatives at demonstration tests of the production of enriched and concentrated superphosphates in ordinary superphosphate equipment held at Hattiesburg, Miss., last spring (*12*). Heretofore, interest on the part of superphosphate manufacturers has been largely academic inasmuch as phosphoric acid has not been generally available at prices attractive to them. This picture, however, may be subject to change in the near future as the Atomic Energy Commission has become interested in increasing the production of wet-process phosphoric acid in order to recover uranium salts as a by-product from phosphate rock ([illegible]). Consequently, the AEC is encouraging the expansion of present facilities and construction of new ones to make wet-process phosphoric acid. Some of this increased production of phosphoric acid may be available for use in existing ordinary superphosphate plants to produce enriched and concentrated superphosphates.

In 1926 a patent on the production of enriched superphosphate was issued to Larison (*10*); the equipment and details of the process were not specified. The results of laboratory experiments with mixtures of phosphoric and sulfuric acids are summarized by Bridger (*2*). A recent paper by Fox and Hill (*4*) presented a theoretical analysis of the problems that would be encountered in the production of enriched superphosphate. However, only very limited information is available on the techniques of production of enriched and concentrated superphosphates in equipment used in the manufacture of ordinary superphosphate (*12*). Therefore, the Atomic Energy Commission suggested that consideration be given to procuring the technical information required to carry out these operations effectively. To obtain this information, the U. S. Department of Agriculture and the Tennessee Valley Authority undertook a joint experimental program. USDA carried out small scale tests, and TVA did the pilot plant work. It is recognized that the equipment in ordinary superphosphate plants varies considerably (*7*). Some plants have batch-mechanical dens, some have box-type dens (batch), and others have continuous dens. Some plants have continuous mixers, but in most plants batch-type pan mixers are used. Because of the variation in equipment, precise answers to all the questions that might arise in the production of enriched and concentrated superphosphates in every plant could not be obtained in any experimental program of reasonable scope, and some experimenting would have to be done in the conversion of any plant.

The objective of the work reported here was to reduce to a minimum the volume of plant scale research necessary to any such transition. The small scale tests were designed to supply information on rock phosphate conversion to available forms under standard conditions and to relate these results to the physical condition of the charge, time of setting, and reaction temperatures and to relate batch temperature and consistency to the concentration, composition, and temperature of the acidulant. The pilot plant experiments were intended primarily to determine the mixing, denning, and curing characteristics of full-size batches of suitable mixed-acid superphosphates in order to provide data for guidance in the selection of appropriate conditions for their manufacture. The possibilities of one type of continuous den in mixed-acid treatment may be inferred from the published results of recent factory-scale experiments (*12*). Because enriched and concentrated superphosphates may be expected to be used mainly in mixed fertilizers, the behavior of the pilot plant products on ammoniation was also studied. Since some of the more concentrated superphosphates are likely to be used for direct application to the soil, tests were made to determine their caking properties in bag storage and their drilling characteristics.

Acidulation — Mole Ratio of $\frac{P_2O_5 + SO_3}{CaO}$

Florida land-pebble phosphate was used in all the experiments. The compositions and screen analyses of the rocks are shown in Table I. Virgin 93% sulfuric acid was used in all tests. The phosphoric acids that were used had been made by the wet process; their compositions are given in Table II.

In the rock-acid reactions, 1 mole of sulfur dioxide or phosphorus pentoxide is equivalent to 1 mole of calcium oxide. The acidulating values of the phosphoric acids were determined by titration with sodium hydroxide to the methyl orange end point, which titrates the first hydrogen ion of pure phosphoric acid. In

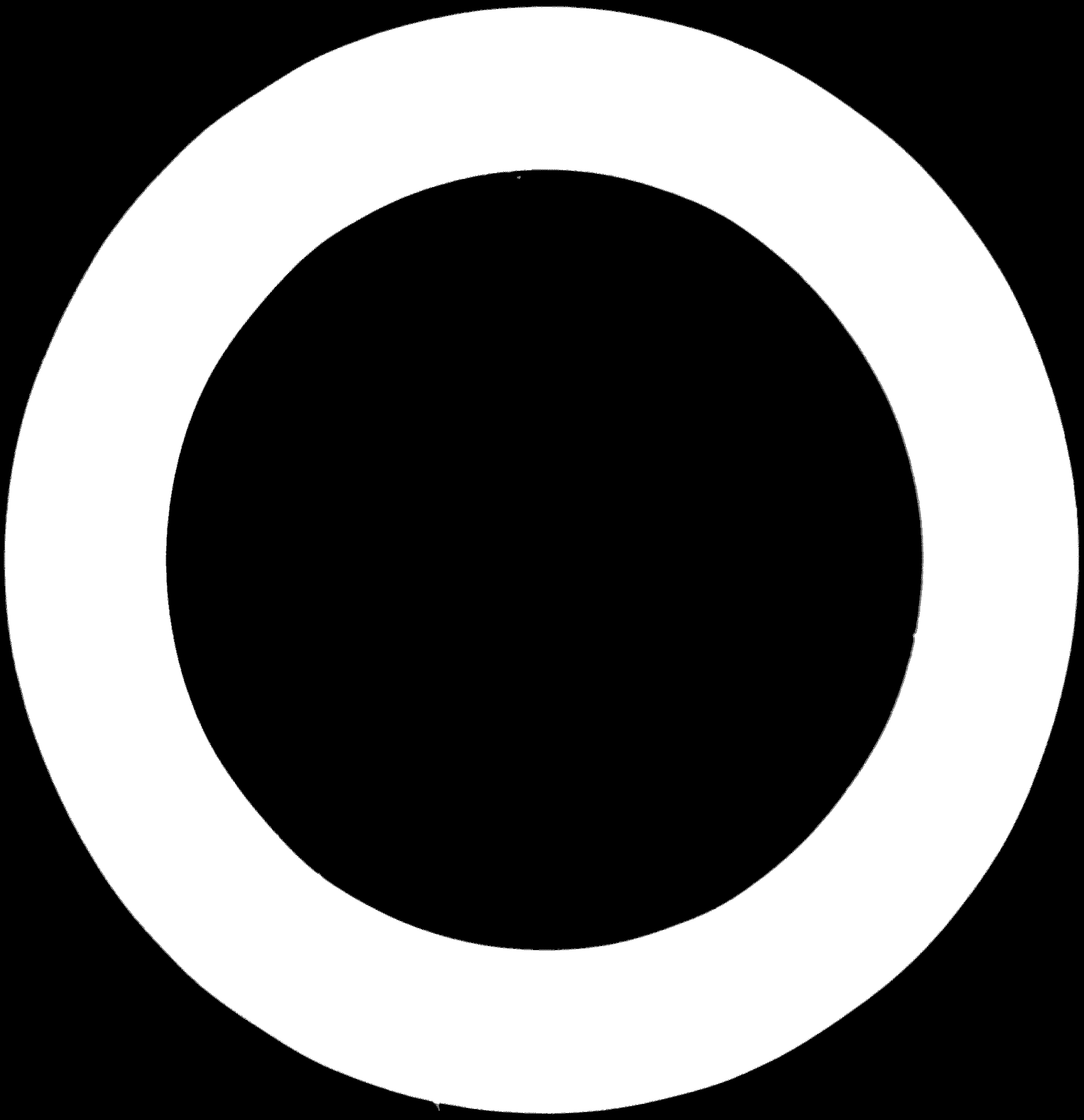


Table I. Compositions and Screen Analyses of Phosphates

Scale of Work	Composition, %ᵃ P_2O_5	CaO	F	Fe_2O_3	Al_2O_3	CO_2	SO_3	Ignition loss	Moisture
Small scale	32.2	47.3	3.37	1.25	1.22	2.9	1.2	4.6	0.7
Pilot plant	34.7	49.5	3.6	1.3	1.2	2.8	0.3	4.6	0.6

	Screen Analyses: Wet Cumulative % through Indicated Sieve Size (U. S.) 60	100	150	200	250	325
Small scale	98.4	87.5	78.2	57.1	48.7	36.7
Pilot plant	95.4	88.2		71.0		49.9

ᵃ Air-dry basis.

preparing mixed acid, sulfuric acid was replaced with an equivalent amount of wet-process phosphoric acid on the basis of 2 moles of titratable phosphoric acid per mole of sulfuric acid. Since the wet-process phosphoric acids contained appreciable amounts of iron and aluminum phosphates as well as other impurities, the total phosphorus pentoxide in the acid in some cases exceeded the phosphorus pentoxide equivalent of the titratable acid by an appreciable amount (Table II).

Table II. Compositions of Phosphoric Acids

	Composition, % H_3PO_4ᵃ	P_2O_5	CaO	F	Fe_2O_3	Al_2O_3	SO_3	H_2Oᵇ
Small scale test	74.5	58.6	0.23	0.6	1.2	0.8	0.7	
Pilot plant tests								
Aᶜ	65.4	50.6	0.3	0.5	1.1	0.9	0.7	27.5
Bᵈ	75.3	57.6	0.1	0.5	1.1	0.7	0.9	19.0
Cᵉ	74.3	53.1	0.3	1.3	2.5	1.6	2.8	19.4

ᵃ Acidity determined by titration with standard NaOH to methyl orange end point.
ᵇ Determined by Karl Fischer method as described by Zerban and Sattler (9); this procedure was tested for phosphoric acid.
ᶜ Used in tests of production of enriched superphosphate.
ᵈ Prepared by concentrating acid A; used in tests of production of concentrated superphosphate.
ᵉ Used in tests of production of concentrated superphosphate.

In the small scale tests the amount of acid used was equal to 57.5 pounds of sulfuric acid per 100 pounds of rock. The degree of acidulation was 0.965, expressed according to Equation 1

$$\text{Acidulation} = \frac{\text{Moles } P_2O_5 \text{ from rock} + \text{Moles } H_2SO_4 \text{ equivalent to titer of wet-process } H_3PO_4 + \text{Moles } SO_3 \text{ from sulfuric acid}}{\text{Moles CaO from rock}} \qquad (1)$$

This equation also was used for expressing acidulation in the pilot plant work. For the purpose of simplification the ratio shown on the right side of Equation 1 is referred to in the text and in the tables as the $\frac{P_2O_5 + SO_3}{CaO}$ mole ratio.

Acid mixtures are described in terms of percentages of sulfuric acid replaced with phosphoric acid. Since 2 moles of the latter is required to replace 1 mole of sulfuric acid and the molecular weights of these acids are sensibly the same, it is evident that their combined weights may be expressed as

$$Wa = S(1 + x)$$

where

Wa = combined weight of H_2SO_4 and H_3PO_4
S = parts of H_2SO_4/100 parts of rock, by weight
x = fraction of H_2SO_4 replaced with H_3PO_4

Thus, with ordinary superphosphate $x = 0$ and $Wa = S$, and with concentrated superphosphate $x = 1$ and $Wa = 2S$—that is, the weight of phosphoric acid required is twice the weight of sulfuric acid. Consequently, the weight of the charge per unit weight of rock as well as the percentage of phosphorus pentoxide in the product increased with the percentage replacement.

The total weight of the acidulant, Ws, is obtained by dividing the acid weight, Wa, by the combined acid concentration. Assuming water as the third component of the acidulant, the acid concentration and its composition may be defined in terms of per cent water and per cent replacement as given in Tables III through VI.

Phosphate rock conversion to available forms was calculated by difference between the estimated phosphorus pentoxide contributed by the rock and the citrate-insoluble phosphorus pentoxide found by analyses of the product. In small scale tests calculations were based on the make-up of the acidulates; complete analyses were not obtained. In pilot plant products the calculations were based on the chemical analyses of the products for CaO, P_2O_5, and SO_3.

Small Scale Experiments Covered Wide Range of Acidulants and Operating Conditions

The change-can type mixer (6) used in the small scale tests was equipped with stainless steel blades and cans 14 inches in diameter by 12 inches deep. The off-center stirrer assembly attached to a hood-type cover, revolved at 90 r.p.m. in opposite direction to the can rotated at 45 r.p.m. Evolved gases were exhausted through a 3-inch diameter telescoping vent pipe attached to the cover, which could be raised and lowered by a rack and pinion gear. A drag stick, operating against spring tension, with pointer moving across a calibrated scale to measure the consistency of the charge, and a thermocouple well were inserted through and attached to the cover, which also had a 3-inch diameter opening through which the acid was added. The junction of the iron-constantan thermocouple was silver-soldered to a thin stainless steel tip electrically and thermally insulated from the stainless steel well by a stout hard rubber shield. This highly sensitive couple junction was positioned about 2 inches away from the side and 1½ inches above the bottom of the can.

A 12-pound charge of phosphate rock was weighed in the can, the latter placed on the mixer, and the cover lowered. The requisite amount of preheated acid was then poured rapidly onto the rock while the mixture was being stirred. Time measurements started when all the acid had been added. Systematic observations on the consistency and temperature of the charge were recorded, and the course of the reaction in terms of acid consumed was followed by the titration of residual free acid in weighed grab samples, usually taken at 10-minute intervals during the first 30 minutes. In one series of experiments, mixing was continued until the mixture thickened; in another the mixing was limited to 2 minutes or less, depending on the rate of set. Temperature measurements were continued for 30 minutes or until the temperature generated by the heat of reaction reached a maximum and started to decline. The cover of the mixing machine then was raised, and the adhering material was scraped from the mixing blades and other parts of the equipment. The can with its charge then was covered and transferred to an electrically heated oven maintained at 155°, 175°, or 185° F., usually the latter, for curing overnight. About 24 hours later the charge was reweighed and sampled by cutting a core from top to bottom of the charge about midway between its center and circumference. In a few instances the product was too crumbly to permit a solid core being taken, in which case reasonable precautions were observed to secure portions of the sample from various parts of the charge. These samples were ground, screened, well mixed by rolling on paper, and analyzed immediately. Other pertinent details of the procedure are noted in the presentation and discussion of the results given in Table III and shown in Figure 1.

Acid consumption by reaction with the rock during the first 20 minutes in mixtures made with 75, 70, and 65% acid solutions (approximately 25, 30, and 35% water, respectively) is plotted against acidulant composition in Figure 1, in which the curves for initial acid temperatures of 104°, 140°, and 176° F. for each of the three acid concentrations are shown. The acid consumption during the 20- and 30-minute periods did not greatly exceed the

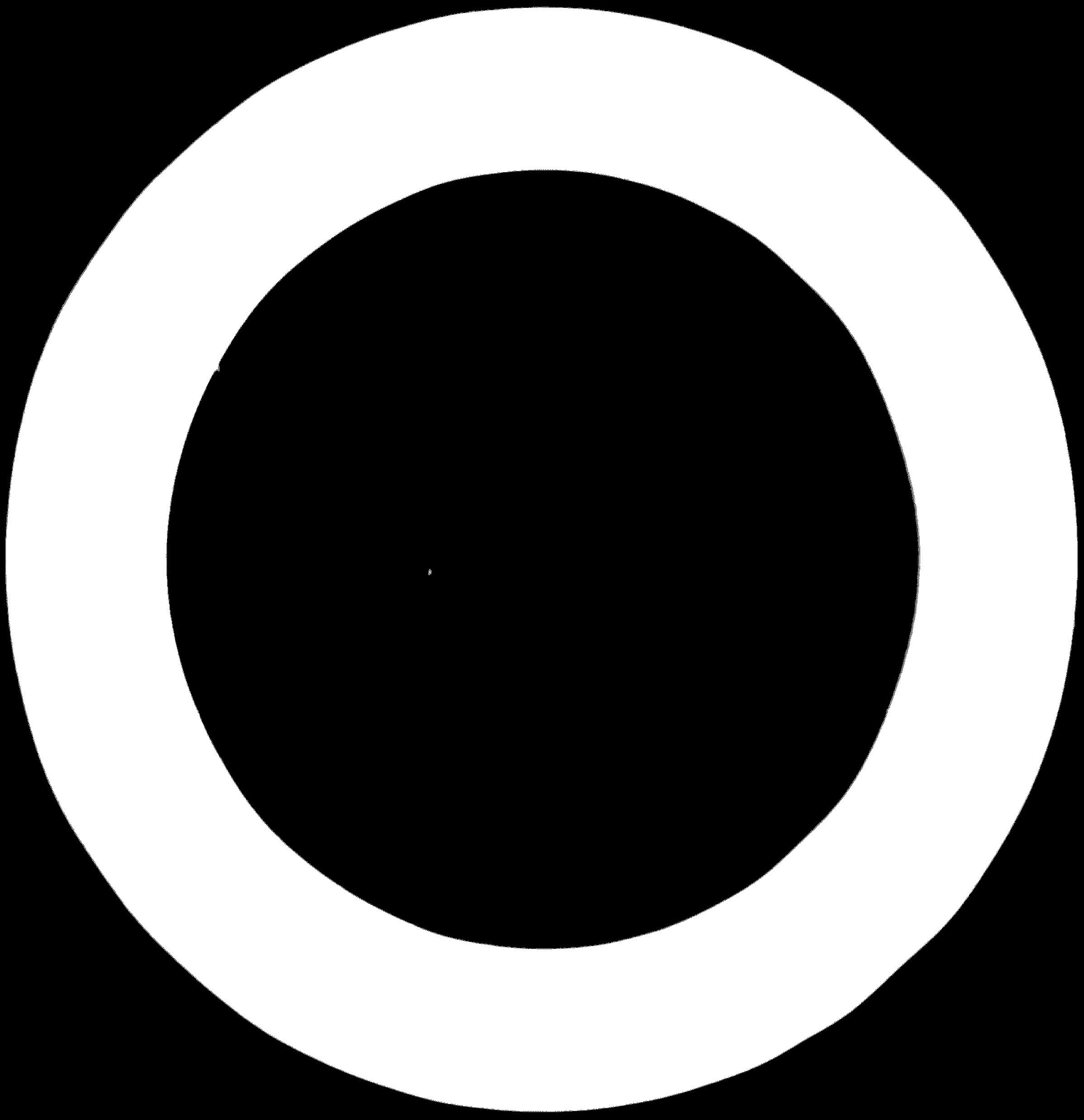


Table III. Character of Acidulates and Quick-Cured Superphosphate Prepared in 20- to 30-Pound Lots

Acidulant		Mixing Time, Min.	Batch Temperature, °F, at End of					Condition of Product at End of		Weight of Charge, Lb.	Weight Loss during Mixing and Curing^d, 24 Hr., %	P_2O_5 in Day-Old Product, %	Conversion of Rock (24 hr.)^e, %
H_2O content, %	Temp., °F		1 min.	2 min.	[illegible]	[illegible]	Min.^a	20 min.^b	24 hr.^c				
0% Replacement													
25	104	1	234	[illegible]	[illegible]	[illegible]		B	[illegible]	21	[illegible]	[illegible]	[illegible]
	140	2	[illegible]	240	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	20.2	[illegible]
	176	1	[illegible]	[illegible]	244	[illegible]		A	[illegible]		[illegible]	[illegible]	[illegible]
30	104	1	[illegible]	214	[illegible]	226	4	A		[illegible]	[illegible]	[illegible]	[illegible]
	140	2	214	218	[illegible]	[illegible]	[illegible]	A	[illegible]			[illegible]	[illegible]
	176	2	221	226	223	226	[illegible]	A				[illegible]	[illegible]
35	104	[illegible]	149	169	[illegible]	[illegible]	10	A			[illegible]	[illegible]	[illegible]
	140	[illegible]	180	198	205	205	3	A				[illegible]	[illegible]
	176	1	[illegible]	214	[illegible]	214	2	A			[illegible]	[illegible]	[illegible]
16.7% Replacement													
25	104	2	168	[illegible]	203	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
	140	2	196	[illegible]	[illegible]	[illegible]	[illegible]	B			[illegible]	[illegible]	[illegible]
	176	2	223	228	242	232	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
30	104	2	[illegible]	154	[illegible]	208	7	B		[illegible]	[illegible]	[illegible]	[illegible]
	140	2	183	[illegible]	207	217	8	[illegible]			[illegible]	[illegible]	[illegible]
	176	2	212	225	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
35	104	2	[illegible]	[illegible]	[illegible]	[illegible]	40	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
	140	2	176	180	[illegible]	198	10	B			[illegible]	[illegible]	[illegible]
	176	2	194	190	200	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]
33.3% Replacement													
25	140	2	180	[illegible]	194	[illegible]	[illegible]	[illegible]					
	140	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
	176	2	200	[illegible]	[illegible]	234	[illegible]	B					
	176	[illegible]	[illegible]	[illegible]	204	[illegible]	2	[illegible]	[illegible]				
30	140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
	140	30	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	[illegible]				
	176	2	190	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]
	176	10	181	[illegible]	[illegible]	194	[illegible]	[illegible]	[illegible]				
35	140	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
	140	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
	176	2	[illegible]	183	[illegible]	206	20				[illegible]	[illegible]	
	176	[illegible]	184	187	[illegible]	207	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
83.3% Replacement													
25	104	2	[illegible]	[illegible]	[illegible]	183	40^h	B		[illegible]		[illegible]	[illegible]
	140	[illegible]	[illegible]	[illegible]	[illegible]	198	20	A				[illegible]	[illegible]
	176	10	[illegible]	[illegible]	[illegible]	[illegible]		B			[illegible]	[illegible]	[illegible]
30	104	1	[illegible]	[illegible]	[illegible]	[illegible]	20	B		[illegible]	[illegible]	[illegible]	[illegible]
	140	3	144	150	[illegible]	163	[illegible]	B			[illegible]	44	[illegible]
	176	[illegible]	183	[illegible]	187	194	20	A			[illegible]	[illegible]	[illegible]
35	104	[illegible]	97	107	120	138	20	B			[illegible]	[illegible]	[illegible]
	140	2	140	141	153	162	20	B	[illegible]	44	[illegible]	[illegible]	[illegible]
	176	1	[illegible]	[illegible]	[illegible]	187	[illegible]	A			[illegible]	[illegible]	[illegible]
100% Replacement													
25	104	2	[illegible]	138	[illegible]	180	40^h	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	140	[illegible]	[illegible]	[illegible]	171	180	[illegible]	A			[illegible]	[illegible]	[illegible]
	176	[illegible]	[illegible]					B	[illegible]			[illegible]	[illegible]
30	104	[illegible]	[illegible]					B	[illegible]		[illegible]	[illegible]	[illegible]
	140	[illegible]	[illegible]	147	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
	176	1	[illegible]	[illegible]	180	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
35	104	[illegible]	[illegible]	[illegible]	120	[illegible]	[illegible]	B	[illegible]		[illegible]	[illegible]	[illegible]
	140	1	[illegible]	124	142	[illegible]	[illegible]	B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	176	1	[illegible]	[illegible]	[illegible]	183	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]

[a] Time at which highest observed temperature was attained.

[b] Character of acidulate. A = soft and crumbly; B = damp [illegible] sticky [illegible] sticky solid to thick paste with noticeable tendency to flow; D = readily flowing paste; E = lumpy. [illegible] for example [illegible] in consistency [illegible] material [illegible] condition.

[c] Character of product. 1 = dry and easily crumbled, capable of being removed with hand scoop; 2 = [illegible] damp [illegible] shovable; 4 = porous and hard; 5 = dense and hard; 6 = poorly mixed as evidenced by dry rock in bottom of container or by [illegible].

[d] Result calculated from weights of ingredients and product.

[e] Result calculated from analyses of [illegible] cured product; figures in parentheses determined on products obtained by [illegible].

[f] Oven temperature was 155° F.

[g] Oven temperature was 175° F.

[h] Temperature still rising.

consumption observed during the first 10 minutes so that the results for the 20-minute period will serve to illustrate the results for all three.

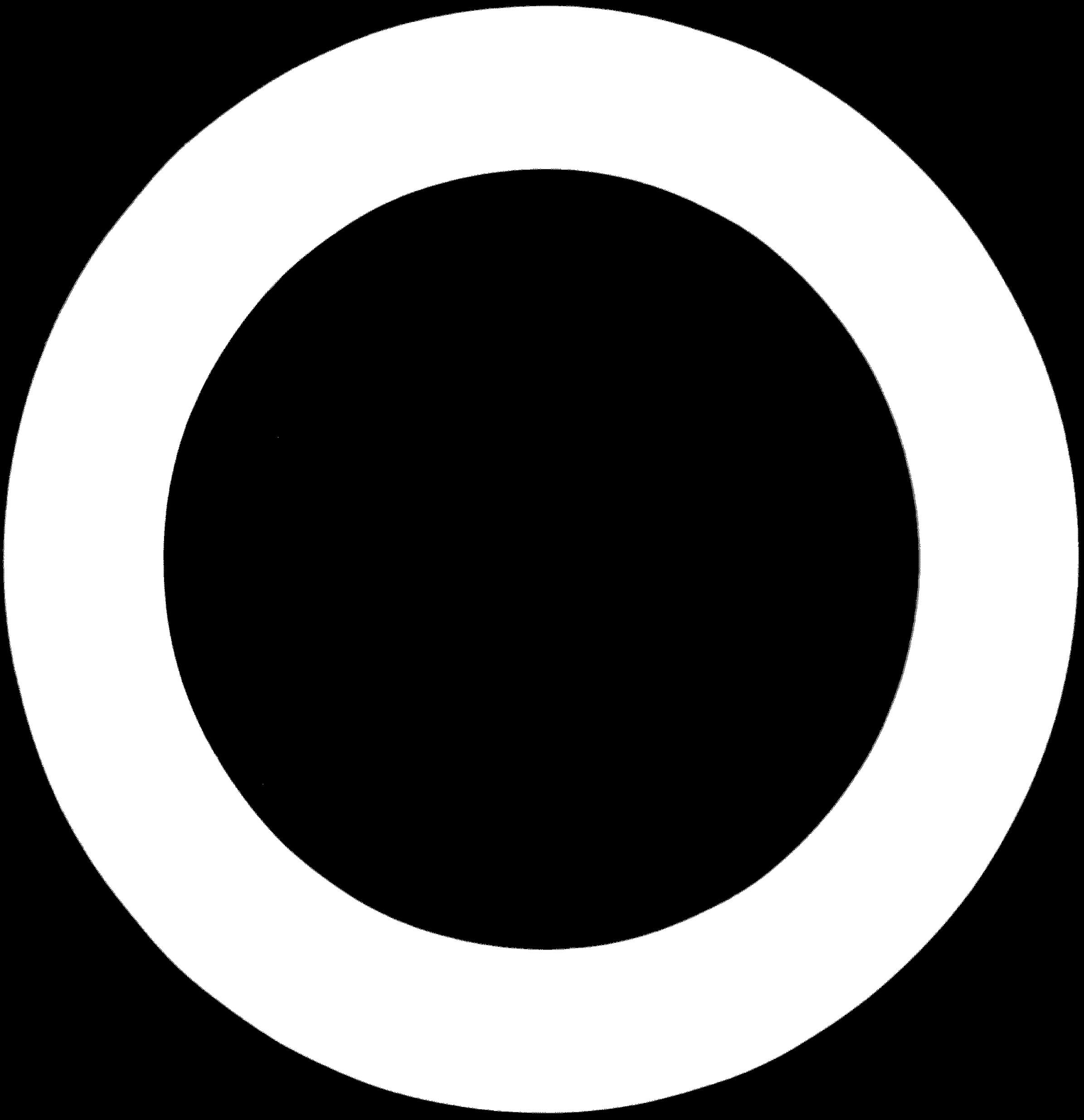
With sulfuric acid (0% replacement) the effects of varying the acid concentration and the initial acid temperature were relatively small because the heat of reaction in all cases raised the batch temperature to, or near to the boiling point of the solution where large heat losses by evaporation tended to level off the reaction temperature. With increasing replacement of sulfuric acid the effects of acid concentration and temperature increased, as is indicated by the spread of the curves at 50% replacement. With an initial acid temperature of 104° F., acid consumption at all three concentrations decreased from about 67% at 0% replacement to about 25% at 50% replacement, then increased again at higher replacement to about 40% of the total acid.

Progressive increases in acid consumption with increasing replacement over the range 0 to 50% were caused by raising the temperature of the acid. Because of the rapid set of mixtures made with 75% acid at 83.3 and 100% replacement, proper mixing was not obtained and acid consumption was not determined.

The chemical behavior of the acidulates as shown in Figure 1 is reflected in the temperature data and physical characteristics presented in Table III. The decrease in acid consumption with increasing replacement of sulfuric with phosphoric acid (Figure 1) is accompanied by a corresponding decrease in batch temperature (columns 4 to 7, Table III) and a prolongation of the period of fluidity as indicated by the mixing time (column 3). Limiting the agitation to 2 minutes or less generally resulted in higher batch temperature due to diminished heat losses occasioned by the agitation of the charge. A corresponding delay in the attainment of the maximal batch temperature also occurred, as is shown by the results for 33.3% replacement. On the other hand, pronounced segregation of the solid and liquid phases was noted in several instances where agitation was stopped before the mixture stiffened.

The physical characteristics of the oven-cured products present a pattern analogous to that of the acidulates at the end of 20 minutes (columns 8 and 9, Table III). High temperature and water content improved the tractability of the products of the mixed acidulants, especially those derived from the sticky pastes at 33.3% replacement.

Rock phosphate conversion to available forms at the end of 24 hours (column 13, Table III) under the stipulated conditions of curing did not show consistent dependence on any of the studied



factors. Such variations as did occur appear to be more closely associated with the lack of uniformity of mixing due to differences in the setting rates than to any of the controlled variables of acid temperature, composition, or concentration. However, when all the tests are considered together, the trend is toward higher conversion with 65% acid at 140° F. With respect to effect of temperature of the acid, these results agree with those obtained in the pilot plant. However, the concentration of the acid had little effect on conversion of rock phosphorus pentoxide in products that had been cured for 14 days or more.

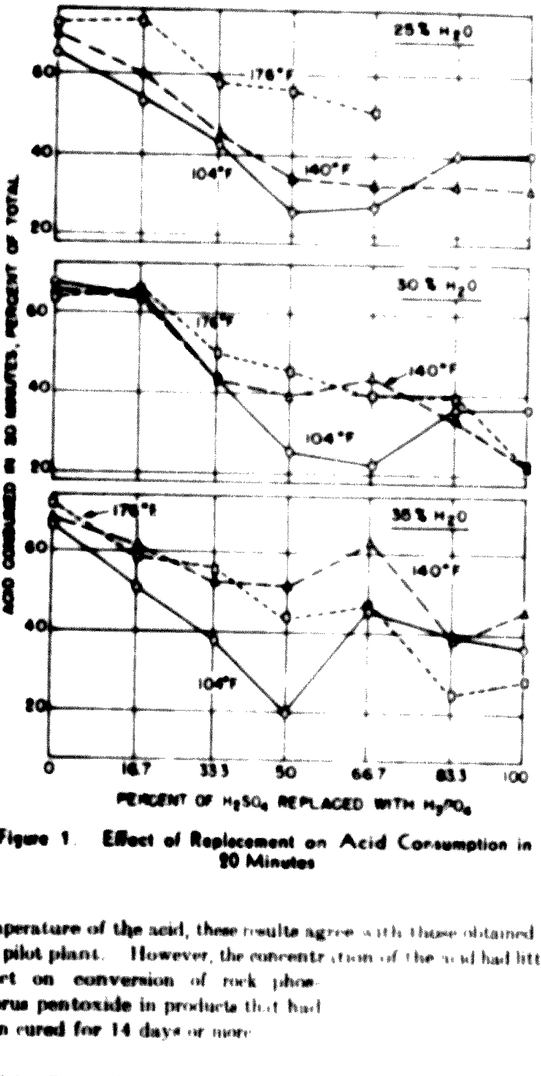


Figure 1. Effect of Replacement on Acid Consumption in 20 Minutes

In Pilot Plant Tests, Acidulation Averaged 0.97 (60 Lb. H_2SO_4/100 Lb. Phosphate Rock)

The pilot plant tests were made with 0, 20, 33, and 100% replacement acid at 110°, 130°, and 150° F.; 20% replacement corresponds to a 1:2 weight ratio of phosphoric to sulfuric acid and 33% replacement to a 1:1 weight ratio. The water contents of the acids were varied from 18 to 32%. The ordinary superphosphates (0% replacement) were made with 70% sulfuric acid at 130° F. and were carried through the tests as standards for comparison. The desired acidulation for all tests was 0.97, which is equivalent to the use of 60 pounds of sulfuric acid per 100 pounds of the phosphate rock in the production of ordinary superphosphate. However, acidulation as determined from analyses of samples of the superphosphates varied from 0.93 to 1.01, equivalent to 57 to 61.5 pounds of sulfuric acid per 100 pounds of phosphate rock. Where possible, comparisons were made in a narrower range of acidulations.

Figures 2 and 3 show the equipment used in the pilot plant tests. Mixing was carried out in a 1-ton Model F Stedman mixer. A sheet-metal jacket containing steam coils was placed around the pan so that it could be preheated to the equilibrium temperature that was obtained when several batches of ordinary superphosphate were made in it consecutively. In this way a single batch of superphosphate could be made without its being cooled unduly by the pan. Thermocouples were provided for measuring the temperature of the metal of the pan and of the superphosphate in it. The acid storage and mixing tanks were equipped with agitators, and the mixing tank and acid feed tank contained coils for steam or water to permit adjustment of acid temperature. Phosphate rock was fed to the mixer through a weigh hopper mounted above the mixer.

The superphosphate fell from the mixer through a 12-inch pipe and into a horizontal, wooden cylindrical den (44 inches inside diameter by 37 inches inside length) that could be rotated. The side walls of the den were 4 inches thick, and the back end had two walls with an air space between. These walls served to insulate the den effectively. A heavy wooden door at the front of the den could be opened or closed quickly. The temperature of the material in the den was obtained through use of a thermocouple that could be inserted into the den through the back wall.

The superphosphates were cut from the den with a blade that extended from the center of the den to one of its edges. The blade was attached to a hydraulically operated piston. As the den was rotated, the blade was advanced into the den so that it removed a ½-inch layer of superphosphate. As it was cut from the den, the superphosphate crumbled and fell onto the lower end of an Ace portable conveyor, by means of which it was elevated and dumped into heated open-top curing bins. The bins, which were 18½ inches by 18½ inches by 10 feet deep and were constructed of wood and lined with asphalt-impregnated paper, had a capacity of 1600 pounds of superphosphate. The superphosphates were held in the bins at about 130° F. to simulate curing in large piles.

When either ordinary or an enriched superphosphate was being made, the mixing procedure was as follows. The flow of phosphate rock to the pan was started a few seconds before the flow of acid

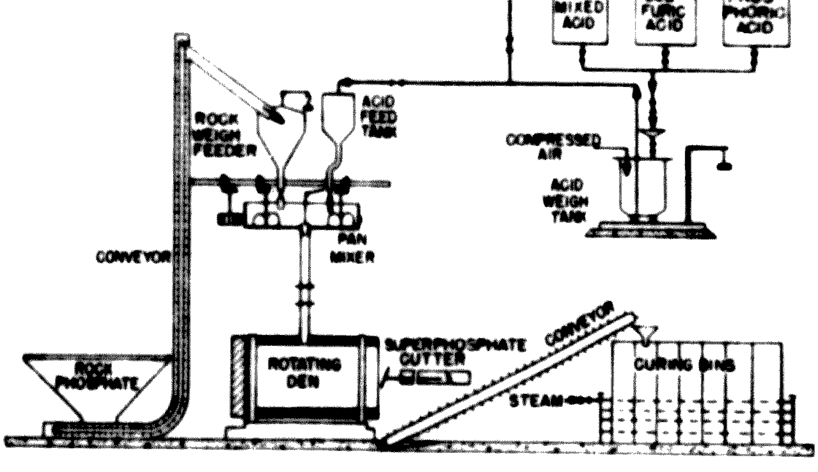
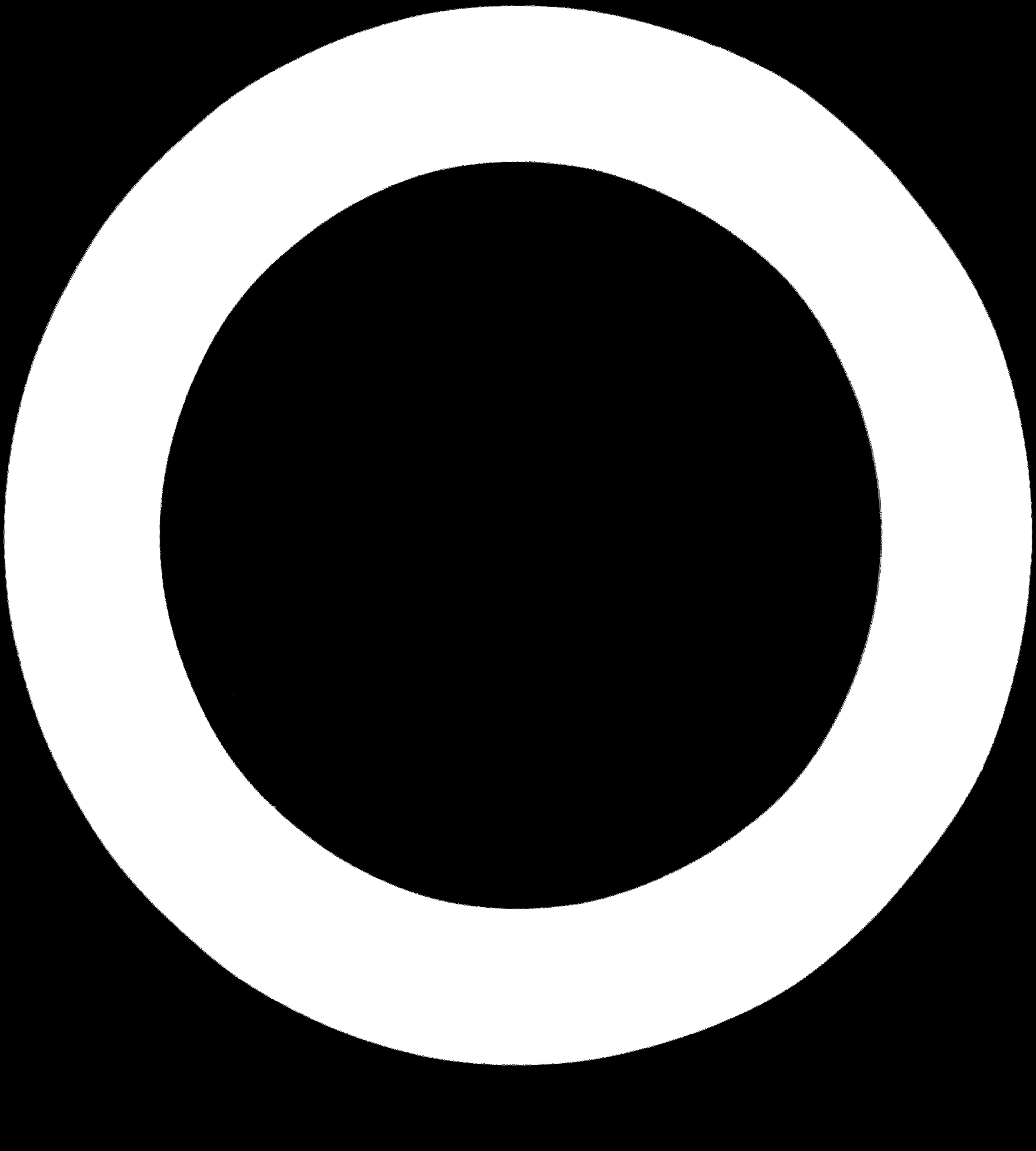


Figure 2. Flow Sheet



mixing was continued for about 20 seconds after maximum bloat had occurred, after which the pan was discharged. Charging, mixing, and discharging required about 2 minutes.

This mixing procedure was not satisfactory for making concentrated superphosphate; when it was used, the concentrated superphosphate in the den contained many lumps of partially reacted phosphate. It was found that by adding all the rock and about half of the acid simultaneously, followed in a few seconds by the addition of the remainder of the acid, a well-mixed acidulate could be produced. The concentrated superphosphates set more rapidly than those of other types and when type B phosphoric acid (Table II) was used and the water content of the acid was in the lower part of the range investigated, the allowable mixing time was only about 45 seconds. When type C acid, which contained more impurities than type B, was used, the superphosphate remained fluid and could be retained in the pan for about 90 seconds. In making concentrated superphosphate, it appeared that best mixing was obtained when the temperature of the acid was 150° F.

Batch Temperature Decreased with Increase in Replacement

Figure 4 shows time-temperature curves for superphosphates in the mixer and in the den. The temperature of the mixed acid used in the tests was 130° F. except that 150° F. phosphoric acid was used for the concentrated superphosphate. The water contents of the acids were in the range 27.4 to 32.2%. The break in each curve represents the transfer of the superphosphate from the mixer to the den. The first readings for the den temperatures were low because of the time required for the thermocouple to reach the temperature of the superphosphate.

The curves show, as do the results of the small scale tests (Table III), that as the replacement of sulfuric acid with phosphoric acid was increased the maximum temperature attained by the superphosphate decreased and the rate of temperature rise also decreased. These observations are in agreement with predicted temperature response to sulfuric acid replacement (4). The higher acidulant temperature (150° F.) used in the case of 100% replacement is partly responsible for the position of this curve relative to the one for 33.3% replacement.

Other tests showed that when replacement was held constant decreasing the water content of the acid increased the maximum temperature.

Minimum Time in Den and Rate of Hardening Established Denning Characteristics

The study of denning characteristics involved the determination of (1) minimum denning time, which was defined as the length of time that the superphosphate had to be retained in the den to avoid slumping and to ensure satisfactory disintegration into free-flowing crumbs, and (2) the rate of hardening of the superphosphate after minimum denning time had been reached. Consideration was given to the various types and sizes of dens in use and to the length of time that ordinary superphosphate usually is retained in these dens. In continuous dens of the Broadfield or Sackett types all the superphosphate remains in the den for the same relatively short periods. In batch dens the retention time of each succeeding mixer batch decreases and the

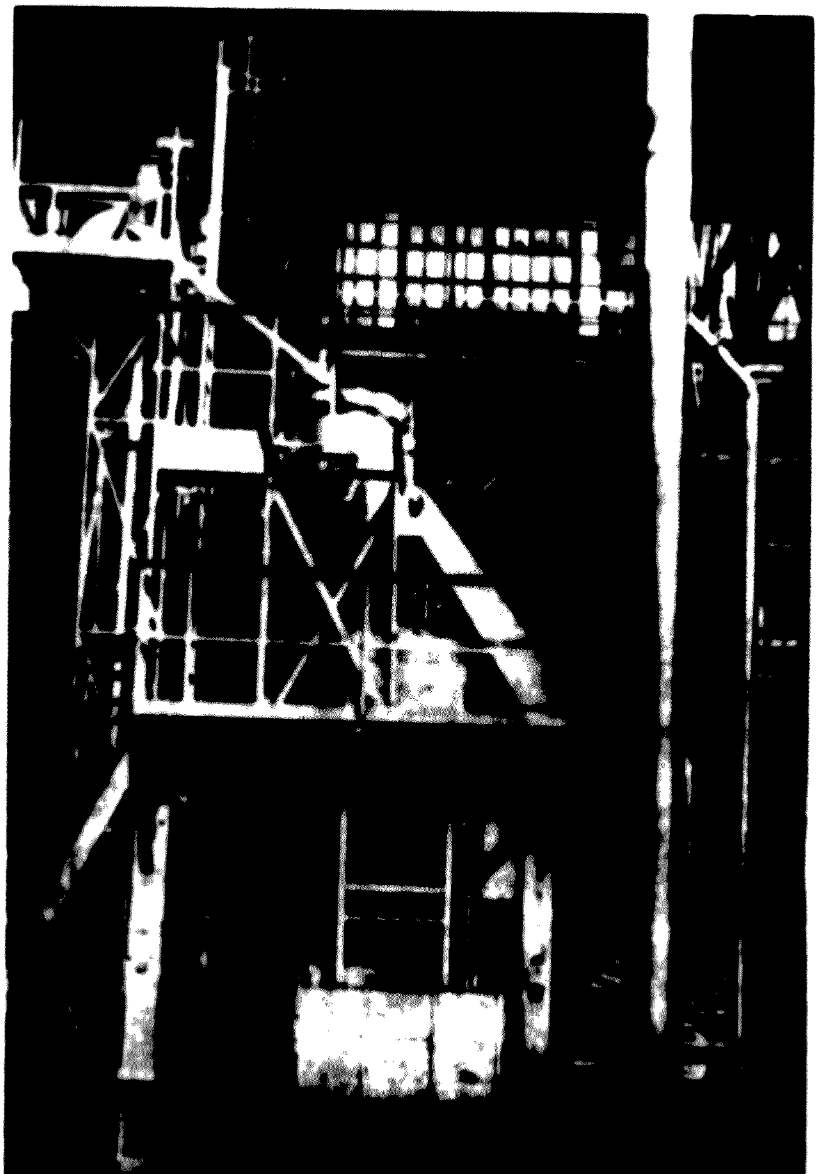


Figure 3. Pilot Plant

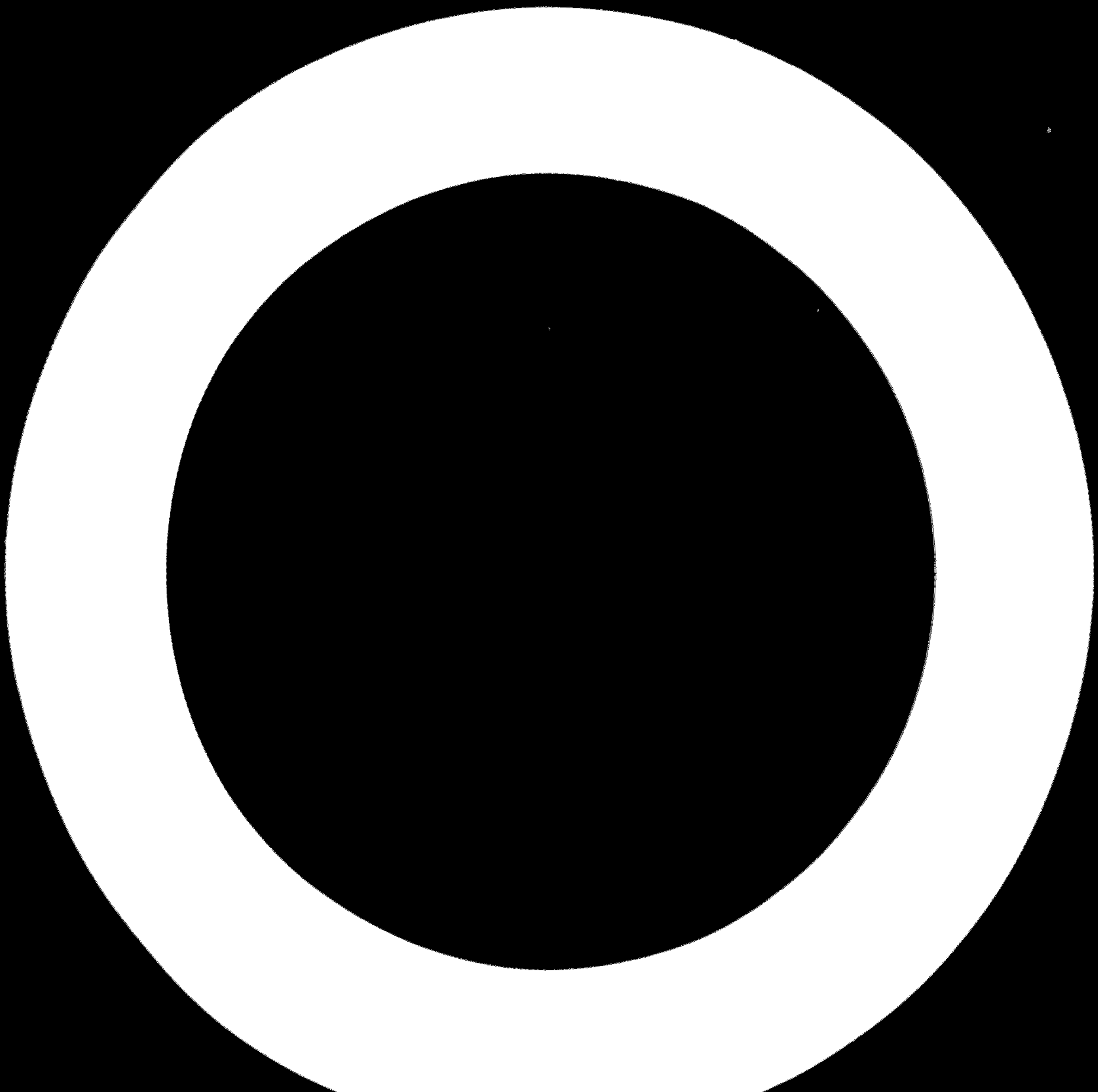


Table IV. Denning Characteristics of Superphosphates

Acidulant Water content, %	Acidulant Temp., °F	Acidulation[a] $\frac{CaO}{P_2O_5 + SO_3}$ Mole Ratio in Superphosphate	Denning Characteristics: First cut, Minimum denning time, min.	First cut, Cutter motor load[b], amp.	Second cut, Time, min.	Second cut, Cutter motor load[b], amp.	Third cut, Time, min.	Third cut, Cutter motor load[b], amp.	Fourth cut, Time, min.	Fourth cut, Cutter motor load[b], amp.
0% Replacement										
30	130	0.94	28	0.1	43	0.2	71	0.3		
30	130	0.94	18	0.2	33	0.1	63	0.3		
30	130	0.94	30	0.2	210	0.2	290	0.4		
30	130	0.96	28	0.2	43	0.2	73	0.2		
30	130	0.96	18	0.1	33	0.2	63	0.2		
30	130	0.97	18	0.1	33	0.2	63	0.3		
30	130	0.97	14	0.1	29	0.2	74	0.3		
30	130	0.98	25	0.1	34	0.[illegible]	74	0.2	90	[illegible]
20% Replacement[c]										
19.3	110	0.98	28	0.1	43	0.3	73			
19.3	130	0.96	33	0.2	48	0.2	78	0.8		
19.3	150	0.97	38	[illegible]	53	[illegible]	78	[illegible]		
22.3	130	1.01	33	[illegible]	48	[illegible]	83	0.6		
25.3	110	0.98	43	0.1	48	[illegible]	108	0.3		
25.3	130	0.96	38	[illegible]	58	[illegible]	98	0.2	290	4
25.3	150	0.96	13	[illegible]	53	[illegible]	84	[illegible]		
30.4	110	0.95	29	[illegible]	28	[illegible]	78	[illegible]		
30.4	110	0.96	40	[illegible]	44	[illegible]	74	[illegible]		
30.4	130	0.96	38	[illegible]	210	[illegible]	[illegible]	[illegible]		
30.4	150	0.95	24	0.2	53	[illegible]	84	[illegible]		
31.4	130	0.98	28	0.1	39	[illegible]	64			
31.4	130	0.98	30	0.2	43	[illegible]	71			
31.4	130	1.00	34	0	33	[illegible]	67			
31.4	130	1.01	35	[illegible]	49	[illegible]				
32.8	110	[illegible]	33	[illegible]	45	[illegible]	60	[illegible]	180	
					218	[illegible]	[illegible]	[illegible]		
33% Replacement[c]										
19.2	110	0.96	37	[illegible]	50	[illegible]	90			
21.0	110	0.98	19	[illegible]	54	[illegible]	84			
21.0	130	0.98	24	[illegible]	35	[illegible]	64			
21.0	130	0.98	[illegible]	0.2	60	[illegible]	70	0.4		
21.0	130	0.99	30	0.2	[illegible]	[illegible]	[illegible]	[illegible]		
21.0	130	0.99	24	0.2	69	[illegible]	6	0.4		
21.0	130	0.98	28	0.2	48	[illegible]	64	0.4		
22.5	110	1.00	90	0.1	65	[illegible]	78	[illegible]		
22.5	130	0.94	46	0.1	61	0.2	67	0.4		
22.5	150	0.95	36	0.2	4[illegible]	[illegible]	61	0.4		
27.6	130	0.97	40	[illegible]	270	0.2	7[illegible]			
29.2	150	0.93	118	[illegible]	133	0.2	290	4		
30.2	130	0.97	105	[illegible]	300	0.2	163	0.[illegible]		
30.2	130	0.99	96	[illegible]	180	0.2	340	0.5	1020	0.5
32.2	130	0.97	139	0.2	340	[illegible]	300	0.4	1140	4
							290	0.4		
100% Replacement										
18.1[e]	130	0.98	25	0.2	52	0.3	115	0.4		
18.3[e]	130	1.00	16	0.1	41	[illegible]	94	0.1	1320	1.6
20.1[f]	130	0.93	9	0.2	24	[illegible]	84	0.5	1080	0.5
22.1[e]	130	0.96	12	0.1	62	[illegible]	22	0.2		
25.2[f]	130	0.98	6	0.2	21	0.2	64	0.2		
27.4[e]	130	0.98	31	0.2	61	0.2	2[illegible]	0.3	1[illegible]8	0.8

[a] Calculated from analyses of sample removed from den.
[b] Difference in current with cutter turning in superphosphate and in air.
[c] Prepared using type A phosphoric acid (Table II).
[d] Stalled; current load greater than 2.5 amperes.
[e] Prepared using type C phosphoric acid (Table II).
[f] Prepared using type B phosphoric acid (Table II).

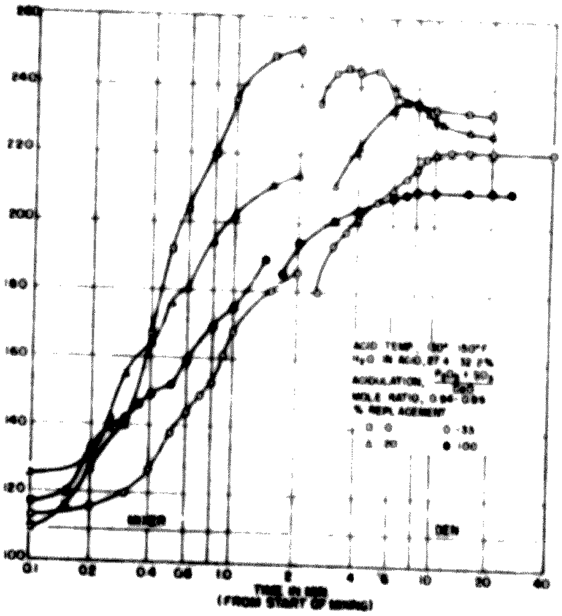
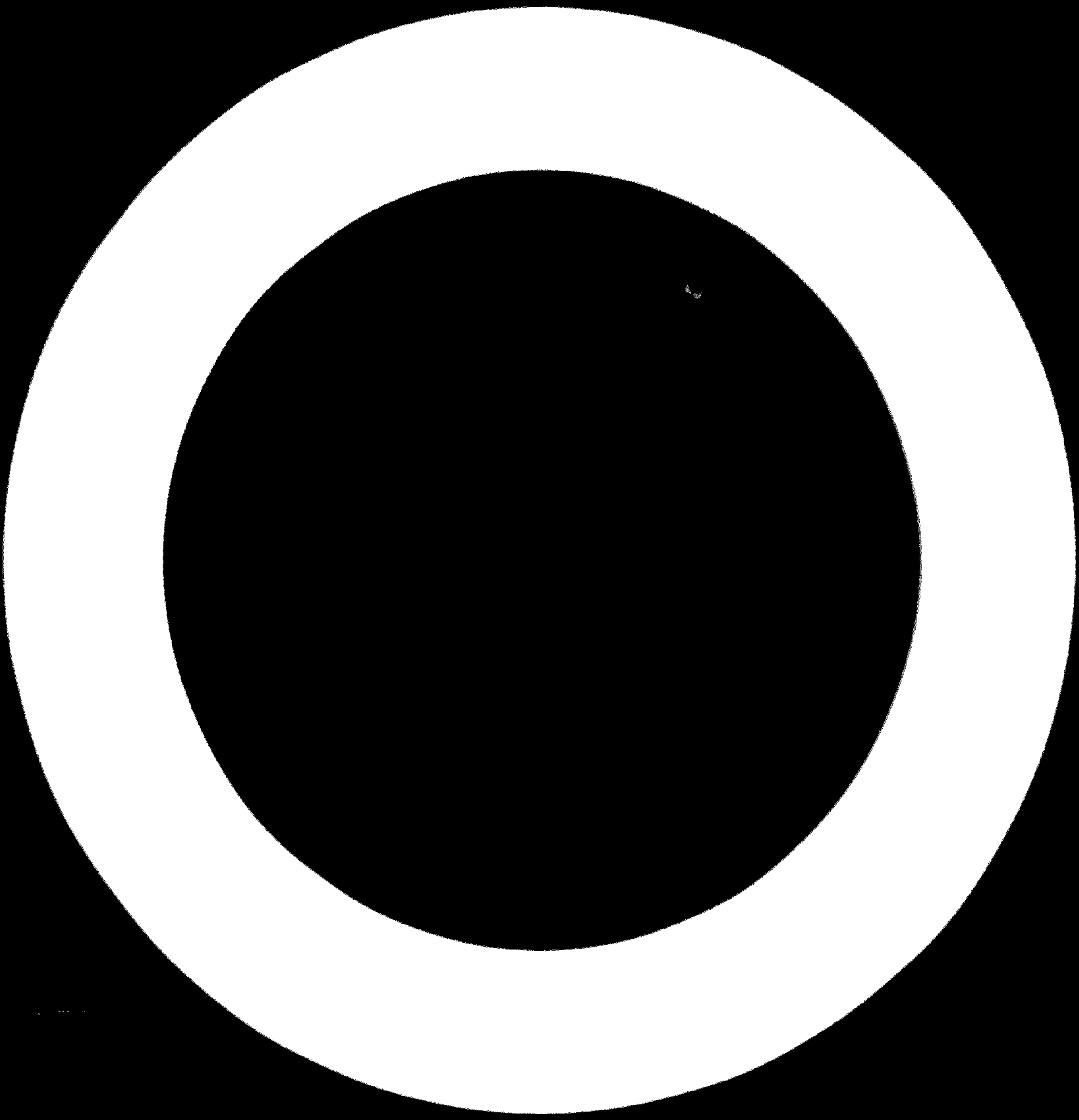


Figure 4. Effects of Proportion of Phosphoric Acid on Mixer and Den Temperatures

minimum denning time as determined in this work would apply most closely to the last batch to enter the den. It is recognized that mixing of batches in a den takes place to some extent, but the effect of this factor was not determined.

Some of the superphosphates became extremely hard a short time after they had reached a condition suitable for disintegration, and it appeared doubtful that they could be removed satisfactorily from the den by use of conventional excavating equipment. It was considered that a superphosphate might be removed from a den of a given type satisfactorily if it were not appreciably harder than ordinary superphosphate at the normal time of excavation for the den.

The minimum denning time and the rate of hardening were determined through use of the double wing cutter shown in Figure 5. This cutter was rotated at 45 r.p.m. by a small electric motor which was connected to the cutter through a speed reducer. It could be attached to the large cutter mentioned previously and advanced by the hydraulic cylinder. Through use of the double-wing cutter, a hole 10 inches in diameter and about 12 inches deep could be bored into the superphosphate in the den. The rate at which this cutter was advanced was such that each blade continuously shaved off a layer of superphosphate 1/8 inch thick. The current drawn by the cutter motor while a cut was being made was recorded. The difference in current required to turn the cutter in the air and to cut the superphosphate was taken as a measure of the hardness of the superphosphate.



In testing a batch of superphosphate, the door of the den was kept closed except when cutting was in progress. The earliest time at which the superphosphate would not slump and a satisfactory cut could be made with the double-wing cutter was called the minimum denning time. Other cuts were made later to determine the rate of hardening; the time between cuts varied with the type of superphosphate being tested. Results of the tests are shown in Table IV.

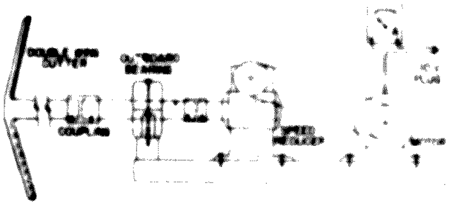


Figure 5. Double-Wing Cutter Assembly

For ordinary superphosphate the minimum denning time varied from 18 to 30 minutes and averaged 22 minutes. Figure 6 shows a smoothed curve for hardness, as measured by cutter-motor load, versus denning time for ordinary superphosphate made at acidulations in the range 0.94 to 0.98. Increasing the acidulation in this range had no uniform effect on minimum denning time or on rate of hardening.

Results Indicate Satisfactory Operation for Enriched and Concentrated Superphosphates in Most Standard Dens

20% Replacement. For enriched superphosphate made with acid in which replacement was 20% (Table IV), the minimum denning time did not vary uniformly with acidulation or with the temperature or water content of the acid; it ranged from 11 to 43 minutes and averaged 31 minutes, which is not very different from the average for ordinary superphosphate. The rate at which the superphosphate hardened in the den was not appreciably affected by acid temperature. Figure 7 shows the effect of time in the den on hardness for enriched superphosphates made with acids with different water contents. The curve for ordinary superphosphate is shown for comparison. Smoothed curves are shown. As the water content of the acid increased, the rate of hardening in the den decreased. When the water content of the acid was less than about 25%, the enriched superphosphate hardened more rapidly than ordinary superphosphate. When the acid contained more than about 25% water, the rate of hardening was less rapid than that of ordinary superphosphate.

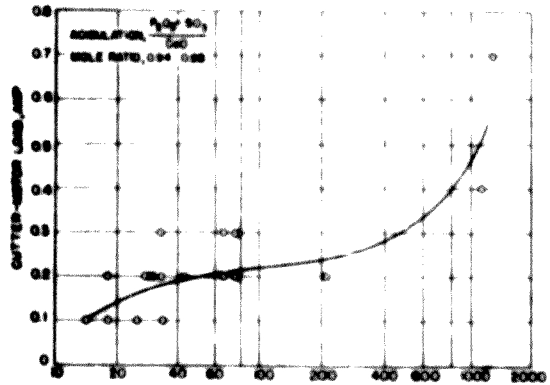


Figure 6. Effect of Time in Den on Hardness of Ordinary Superphosphate

0% Replacement

The data indicate that for a continuous den in which the superphosphate is retained for only about 30 minutes the water content of the acid could be as low as 19%. Acid of this water content probably would not be satisfactory for use with a batch-mechanical den in which the denning time is 1.5 to 2 hours because at the end of such a long period the superphosphate would be appreciably harder than ordinary superphosphate for which the excavating equipment is designed. With such a batch-mechanical den the data indicate the use of acid containing 22 to 25% water. Similarly, for use with box dens in which the superphosphate would be retained for even longer periods of time, acid containing 25 to 30% water is indicated.

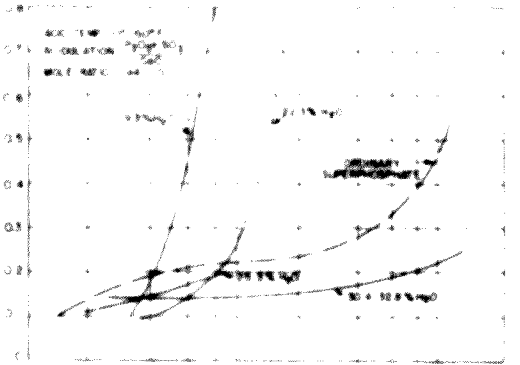


Figure 7. Effect of Time in Den on Hardness of 20% Replacement Superphosphate

33% Replacement. For enriched superphosphate in which replacement was 33%, the minimum denning time increased with water content of the acid (Figure 8). With acids containing from 21 to 22% water, minimum denning times were longer when the acid temperature was 110° F. than when it was 130° or 150° F., and an increase in acid temperature increased the rate of hardening. Figure 9 shows the effect that time in the den exerts on hardness of the enriched superphosphates made with acids of several water contents at 130° F. When made with acids containing 19 to 22% water, the superphosphates hardened more rapidly than ordinary superphosphate. When made with acids containing 30 to 32% water, the superphosphates hardened at about the same or at a lower rate than ordinary superphosphate. In a test with acid containing 27.6% water the enriched superphosphate was no harder than ordinary superphosphate after 270 minutes in the den.

In the production of enriched superphosphate with acid in which replacement is 33%, acid containing 19 to 20% water probably would be satisfactory for use with a continuous den, and one containing 30% water probably would be satisfactory for use with a box den in which the superphosphate is retained overnight. It appears that acid containing about 22% water would be best for use with a batch-mechanical den, but the period between the minimum denning time and the time at which the superphosphate becomes appreciably harder than ordinary superphosphate would be short, and shorter than usual denning cycles probably would have to be used. A small change in water content of the acid in this range made a big difference in the denning characteristics of the superphosphate. Therefore, close control of water content would be necessary.

No tests were made of the effect of purity of phosphoric acid on the denning characteristics of enriched superphosphates.

Concentrated Superphosphate. The data for concentrated superphosphate (Table IV) show that when type B phosphoric acid was used the minimum denning time was shorter than when the more impure acid, type C, was used.

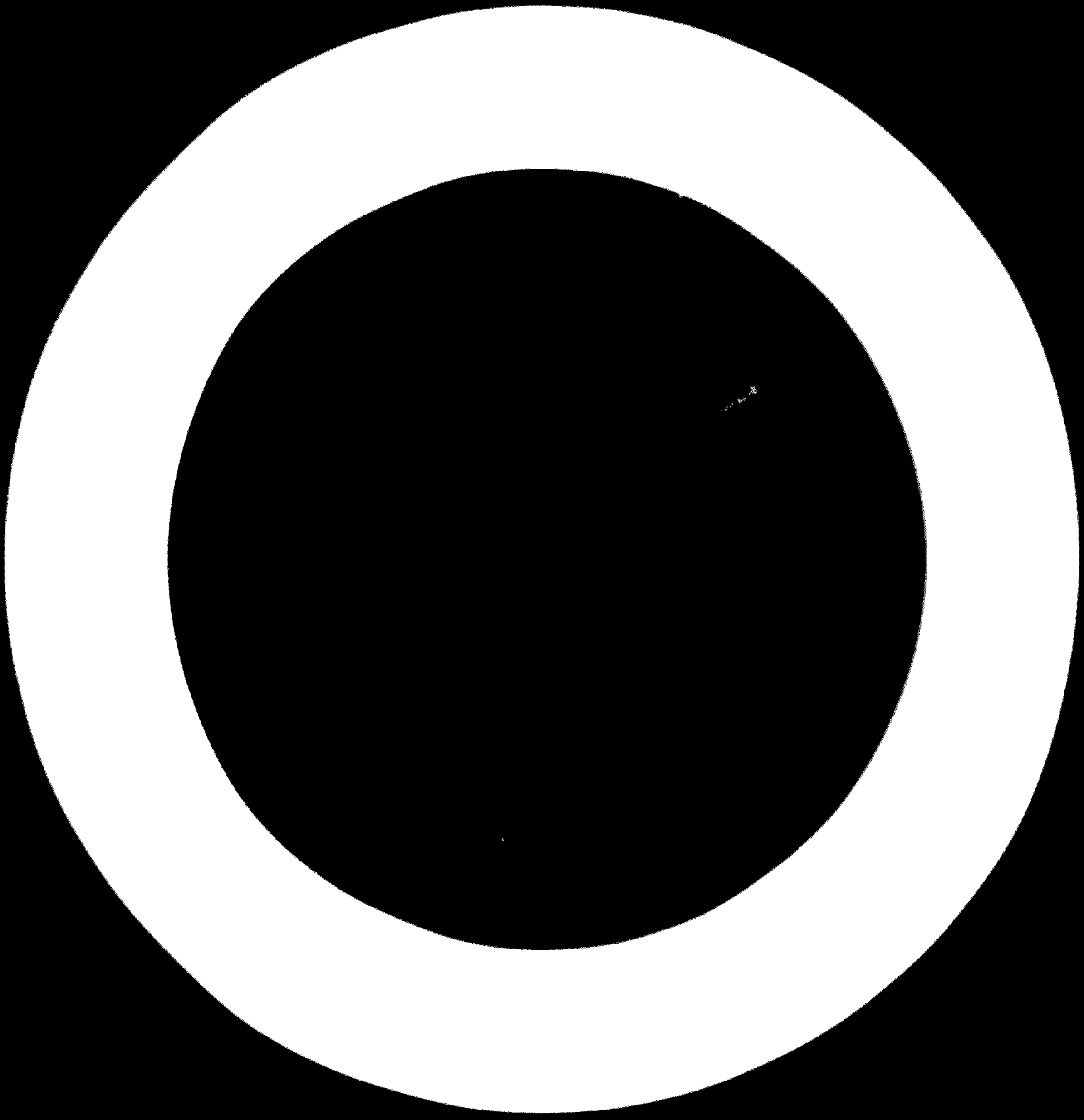


Table V. Composition of Cured Superphosphates

Acidulation, $(P_2O_5 + SO_3)$/CaO Mole Ratio	Water Content of Acid, %	Days in Storage	Composition[a], % P₂O₅ Total	Available	Water soluble	Free acid	H_2O[b]
0% Replacement							
0.97	30	14	20.5	19.7	17.7	1.3	7.2
0.97	30	30	20.7	20.1	18.7	2.7	5.6
20% Replacement[c]							
1.01	22.3	14	30.2	29.7	25.0	.8	4.0
0.99	31.4	14	27.8	27.2	25.0	4.1	8.0
0.96	31.4	30	28.2	27.9	25.4	3.5	5.6
33% Replacement[c]							
0.99	21	14	34.6	33.8	30.0	1.8	1.9
0.97	32.2	14	32.3	31.7	28.1		4.8
100% Replacement[d]							
0.98	18.3	14	49.1	48.5	44.7	2.2	4.4
0.98	27.4	14	47.8	47.1	40.8	3.7	4.0
0.97	27.4	30	48.1	47.8	41.3	4.1	3.[illegible]

[a] Samples from curing bins.
[b] Determined by drying by A.O.A.C. method in vacuum desiccator over magnesium perchlorate.
[c] Prepared using type A phosphoric acid (Table II).
[d] Prepared using type C phosphoric acid (Table II).

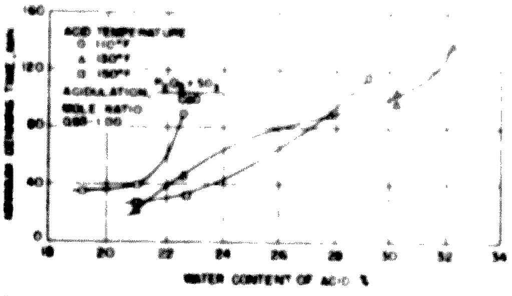


Figure 8. Effect of Water Content of Acid on Minimum Denning Time of 33% Replacement Superphosphate

However, for both types of acids and in the entire range of water contents studied, 18 to 27%, the minimum denning time did not exceed 32 minutes, which was about the same as for ordinary superphosphate. The solid curve of Figure 10 correlates denning time and hardness of concentrated superphosphates that were made with acid of type C containing 18.1 to 27.4% water and for one made with acid of type B containing 25.2%. This curve practically coincides with that for ordinary superphosphate; this indicates that any of these concentrated superphosphates probably could be handled in any kind of ordinary superphosphate den. The dotted curve is for concentrated superphosphate made using acid of type B containing 20.1% water. This superphosphate hardened more quickly than ordinary superphosphate. It appears that increasing the purity of the acid increases rate of hardening.

For the range of acid purity that might be encountered in commercial practice, the data on curing and denning characteristics indicate the use of acid containing from 25 to 27% water in the production of concentrated superphosphate in equipment commonly used in producing ordinary superphosphate.

Cured Products Had High P_2O_5 Availability

Only products made with acid at [illegible] F. were given the curing time because analyses of samples made with [illegible] hot acid and quick-cured at 150° F. had indicated that conversions of rock phosphorus pentoxide were about equal when the temperature of the acid was 100° or 150° F. and that conversion was lower when the acid was at [illegible] F. The same general trend was noted in the small-scale tests (Table III). Some of the concentrated superphosphates that had been made with acid at 150° F. to secure better mixing in the pan were cured in the den.

Figure 11 shows conversions of phosphorus pentoxide [illegible] abilities in superphosphates removed from the curing bins after storage for various periods [illegible]. These superphosphates had been made with acids in which the replacement was 0, 20, [illegible]

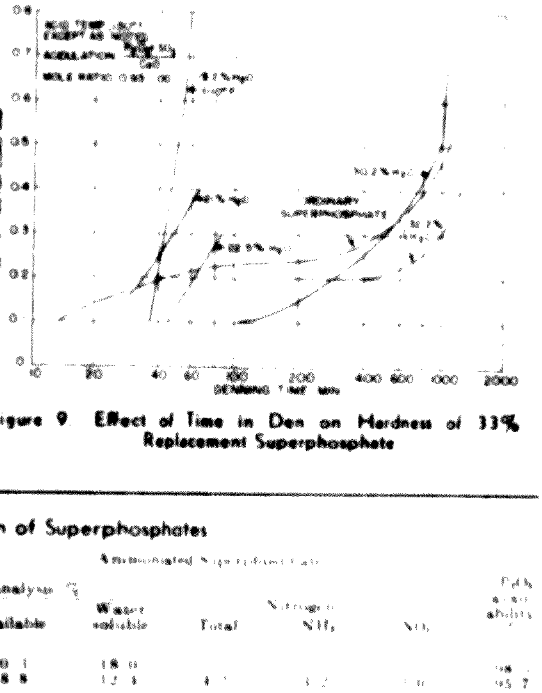
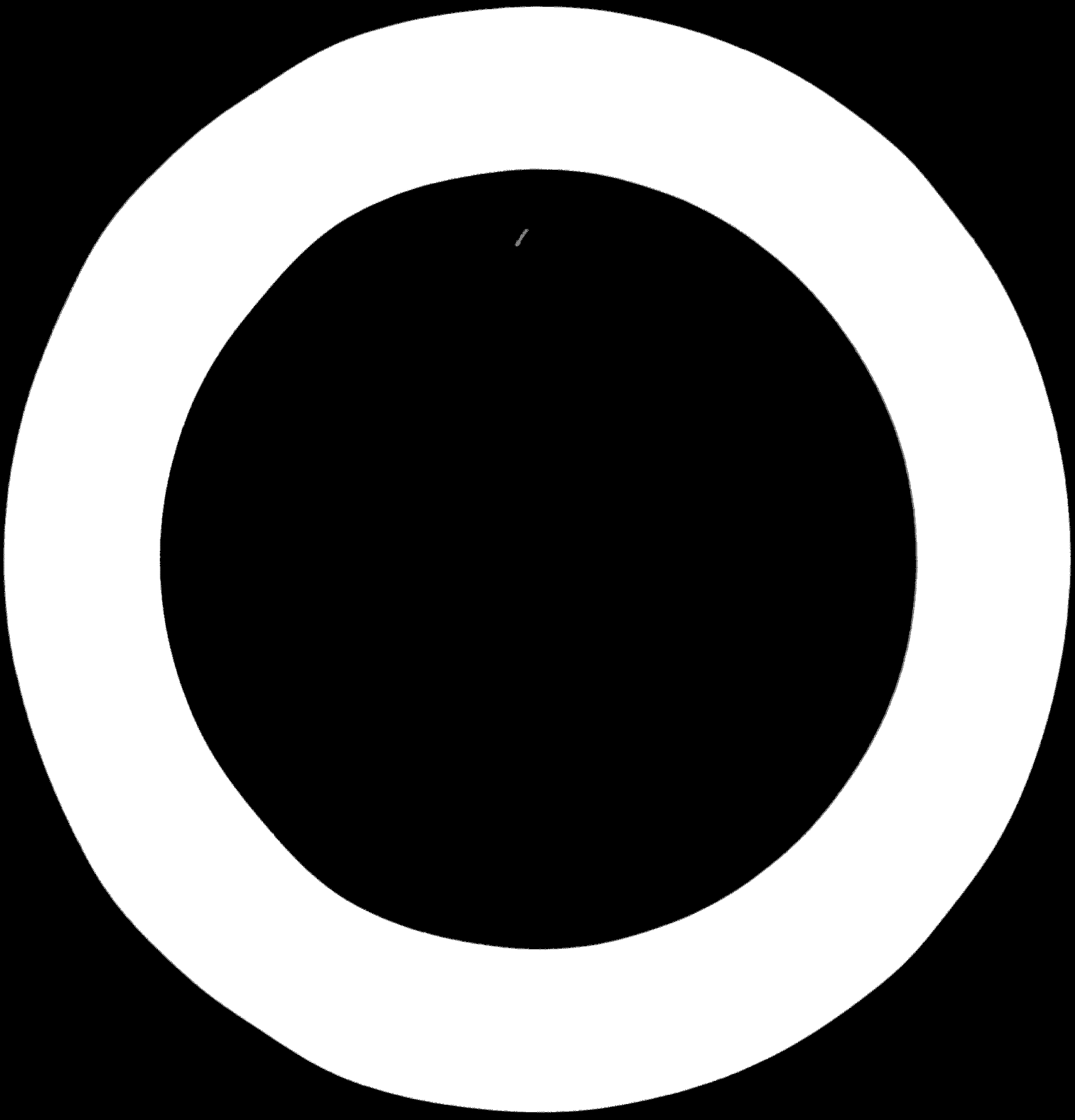


Figure 9. Effect of Time in Den on Hardness of 33% Replacement Superphosphate

Table VI. Results of Ammoniation of Superphosphates

Superphosphate: Water content of acid, %	Superphosphate: Acidulation, $(P_2O_5 + SO_3)$/CaO mole ratio	Curing, days	Description of Sample	Ammoniation, Lb. Neut. NH_3/Unit P_2O_5 in Feed	Ammoniated Superphosphate: P_2O_5 analysis, %: Total	Available	Water soluble	Nitrogen: Total	NH_3	NO_3	P_2O_5 availability, %
0% Replacement											
30	0.98	14	Feed		20.6	20.1	18.0				98.[illegible]
			Product	2.72	19.6	18.8	12.4	4.[illegible]	3.2	[illegible]	95.7
20% Replacement[a]											
22	1.01	14	Feed		30.[illegible]	30.3	25.1				98.7
			Product	2.68	27.8	27.2	15.7	6.0	4.[illegible]	[illegible]	97.8
31.1	0.98	14	Feed[b]		26.7	26.3	24.3				98.5
			Product	2.90	23.4	22.1	13.4	5.4	4.1	1.1	94.5
33% Replacement[a]											
21	0.99	15	Feed		35.0	34.3	30.5				98.0
			Product	3.06	29.9	29.0	15.0	7.[illegible]	5.6	1.7	97.1
32.3	0.97	14	Feed		32.3	31.7	28.1				98.1
			Product	2.65	28.1	26.1	14.3	6.2	4.6	1.6	92.9
100% Replacement[c]											
18	0.98	21	Feed		48.4	47.8	44.4				98.8
			Product	2.55	42.4	40.8	23.2	8.2	6.3	1.9	96.1
27.4	0.97	30	Feed		48.1	47.8	41.3				99.4
			Product	2.68	39.4	38.3	22.1	8.[illegible]	6.4	2.1	97.2

[a] Prepared using type A phosphoric acid (Table II).
[b] Product indicated 18% replacement.
[c] Prepared using type C phosphoric acid (Table II).



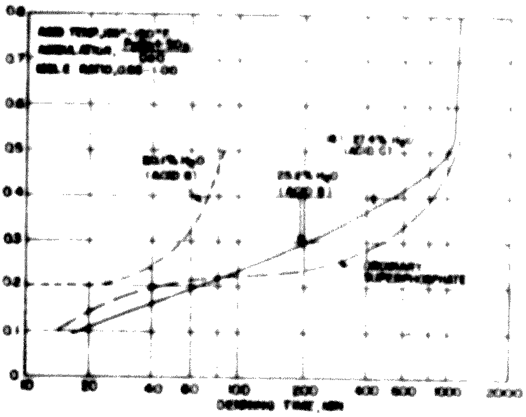


Figure 10. Effect of Denning Time on Hardness of Concentrated Superphosphate

100% Replacement

and 100% and the water contents were 20.0, 18.4, 21.1, and 27.4%, respectively. Type A phosphoric acid was used in making the enriched superphosphates and type C acid was used for the concentrated superphosphate.

After 14 or 30 days of curing, there was little difference in conversions of rock phosphorus pentoxide or availabilities of phosphorus pentoxide in the superphosphates. Conversion of rock phosphorus pentoxide in the concentrated superphosphate increased most rapidly with time of curing. Figure 12 shows the effects of water content of the acid on conversion in enriched and concentrated superphosphates. Conversion in the enriched superphosphates was increased about 1% when the water content of the acid was increased from about 20 to 30%. Conversions in concentrated superphosphates made with acids containing 18 or 27% water and cured 14 to 30 days were about equal. Somewhat lower conversions were obtained in the concentrated superphosphate made with acid that contained 21.1% water, but it appears that conversion in this material might have equaled that in the other concentrated superphosphates if curing had been continued for a longer time. After 21 days of curing, phosphorus pentoxide availability was 97.1% in this superphosphate, which was higher than that in the ordinary superphosphate that had been made at the same acidulation and cured for a like period.

Analyses of bin-cured superphosphates (Table V) show that the grade is affected by replacement, water content of acid, and curing time. The effects of replacement and water content are so pronounced that close control of acid composition would be required in commercial operation. It was noted that conversion and grade had increased slightly after disintegration and handling of the superphosphates in the pilot plant for ammoniation or bagging. However, such increases probably would not occur in a large plant because there would be less opportunity for the products to dry.

The data on fluorine evolution during mixing and curing are too few for presentation on a quantitative basis. However, they indicate that the proportion of fluorine evolved from the rock and acid decreased as replacement increased.

Curing in the bins was found to be comparable to curing in large piles. Nomographs published by Shoeld, Wright, and Sauchelli (*11*) show that ordinary superphosphate made under the condition of acid concentration and temperature, phosphate composition, and acidulation used as standard in the present work should contain 20.5% total phosphorus pentoxide and about 19.9% available phosphorus pentoxide after being cured in a plant pile for 30 days. The averages of total and available phosphorus pentoxide contents of three batches of the standard ordinary superphosphate cured for 30 days in the bins were 20.7 and 20.1%, respectively (Table V).

The data indicate that attaining high phosphorus pentoxide availability presents no problem with any of these superphosphates. Using acids with any water content in the range studied, the phosphorus pentoxide availabilities of all the superphosphates would be about the same after they had been cured. However, to produce a superphosphate of maximum grade and to ensure that a mixed fertilizer containing this superphosphate would be in the best condition, the water content of the acid should be as low as possible. The data indicate that the minimum water content that could be used varies with the denning characteristics of the superphosphate and the type of den used.

Products Showed No Caking after Storage for 6 Months

Superphosphates that had been cured for 30 days were bagged in five-ply paper bags having one asphalt-laminated ply and stored in piles twelve bags high. The superphosphates showed no caking after 6 months of storage. The enriched and concentrated superphosphates drilled as well as did the ordinary superphosphate through a John Blue No. 30 screw-type fertilizer drill after storage.

Ammoniation of the Superphosphates Resulted in Only Small Losses in P_2O_5 Availability

Some of the cured superphosphates were ammoniated to determine how they would respond to this treatment in the preparation of mixed fertilizers. Although, in the manufacture of mixed fertilizers, superphosphate usually is mixed with other fertilizer ingredients before being ammoniated, the superphosphates produced in the present work were ammoniated by themselves.

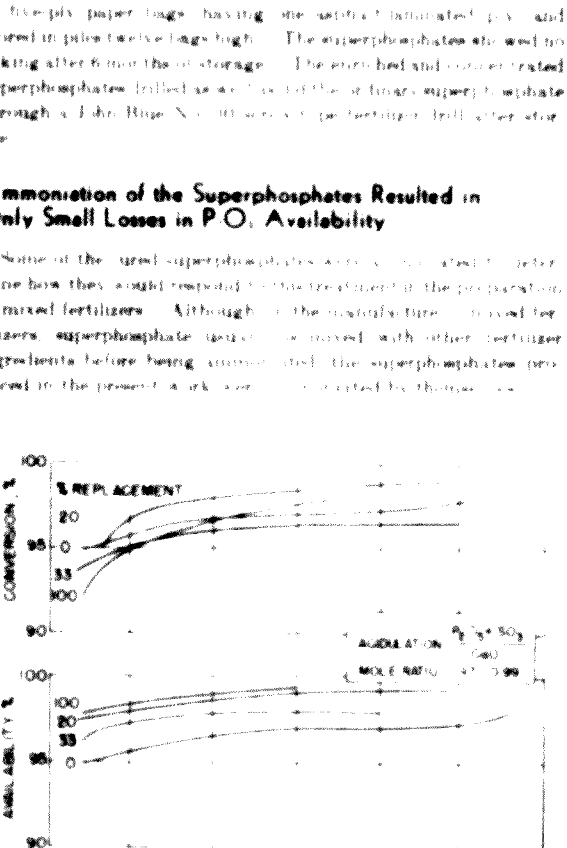


Figure 11. Effects of Proportion of Phosphoric Acid and of Curing on P_2O_5 Availability and Conversion

A 1-ton drum-type mixer was used in the ammoniation of 1000-pound batches of the cured superphosphates with ammoniating solution prepared in the laboratory to have the composition of Barrett No. III nitrogen solution (55.5% NH_4NO_3, 26% NH_3, and 18.5% H_2O). The average degree of ammoniation was 2.8 pounds of neutralizing ammonia per unit of available phosphorus pentoxide in the unammoniated superphosphate, which probably is lower than that used by some manufacturers but is in the upper part of the range recommended in the manual "Barrett Standard Nitrogen Solutions" (*1*). The average rate of addition of solution to the mixer was such that 26 pounds of neutralizing ammonia was added per minute. The superphosphates that were used had been made at acidulations of from 0.95 to 1.01 and had been cured for 14 to 30 days before being ammoniated.

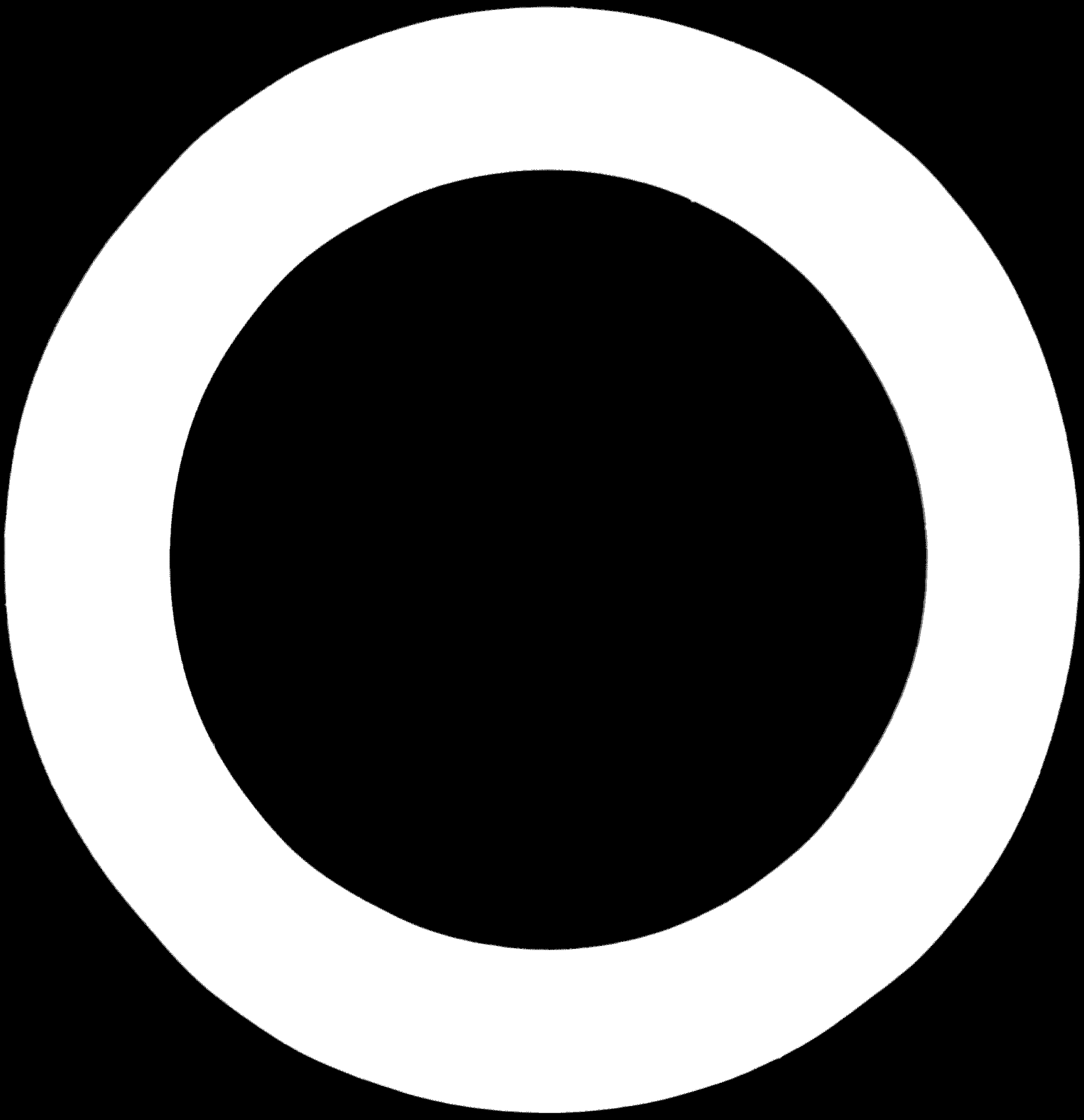


Table VI shows data and results from the ammoniation tests. Losses of ammonia were practically nil. In tests with ordinary superphosphate the average loss of phosphorus pentoxide availability was 2.8%. In the ammoniation of concentrated superphosphate that had been made with acid that contained 18 or 27% water, loss of phosphorus pentoxide availability was about 2.5%. In the ammoniation of the enriched superphosphates, loss of availability increased from about 1% to 4 to 5% as the water content of the acid used in preparing the superphosphate was increased from about 20 to 30%. Hecht *et al.* (*5*) and Jones and Rohner (*8*) have shown that increasing the moisture content of superphosphate or of mixtures containing superphosphate increased the loss of phosphorus pentoxide availability incurred on ammoniation.

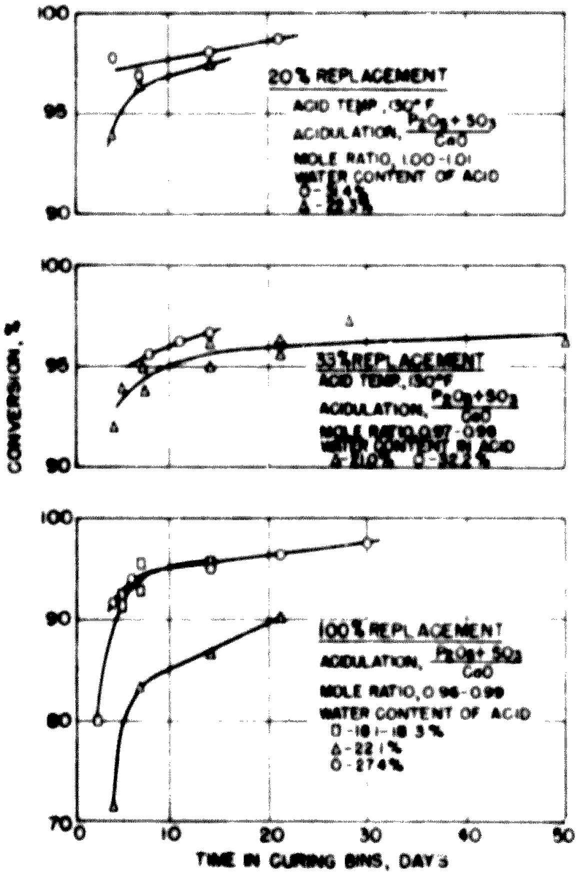


Figure 12. Effect of Curing Time and Water Content of Acid on Conversion of Rock P_2O_5

None of the losses of availability is considered serious. However, as shown by Keenen (*9*), the losses would be much smaller if the superphosphates were ammoniated in mixture with other materials or if the ammoniated superphosphate were mixed with other materials. Dry mixing the ammoniated 33% replacement superphosphate made with acid containing 32.3% water (Table VI) with enough ammonium sulfate and muriate of potash to produce a fertilizer of 11-11-11 grade increased phosphorus pentoxide availability from 92.9 to 95.7%, which, in effect, reduced the loss of availability from 5.2 to 2.4%. The behavior of the experimental superphosphates on being ammoniated appeared satisfactory.

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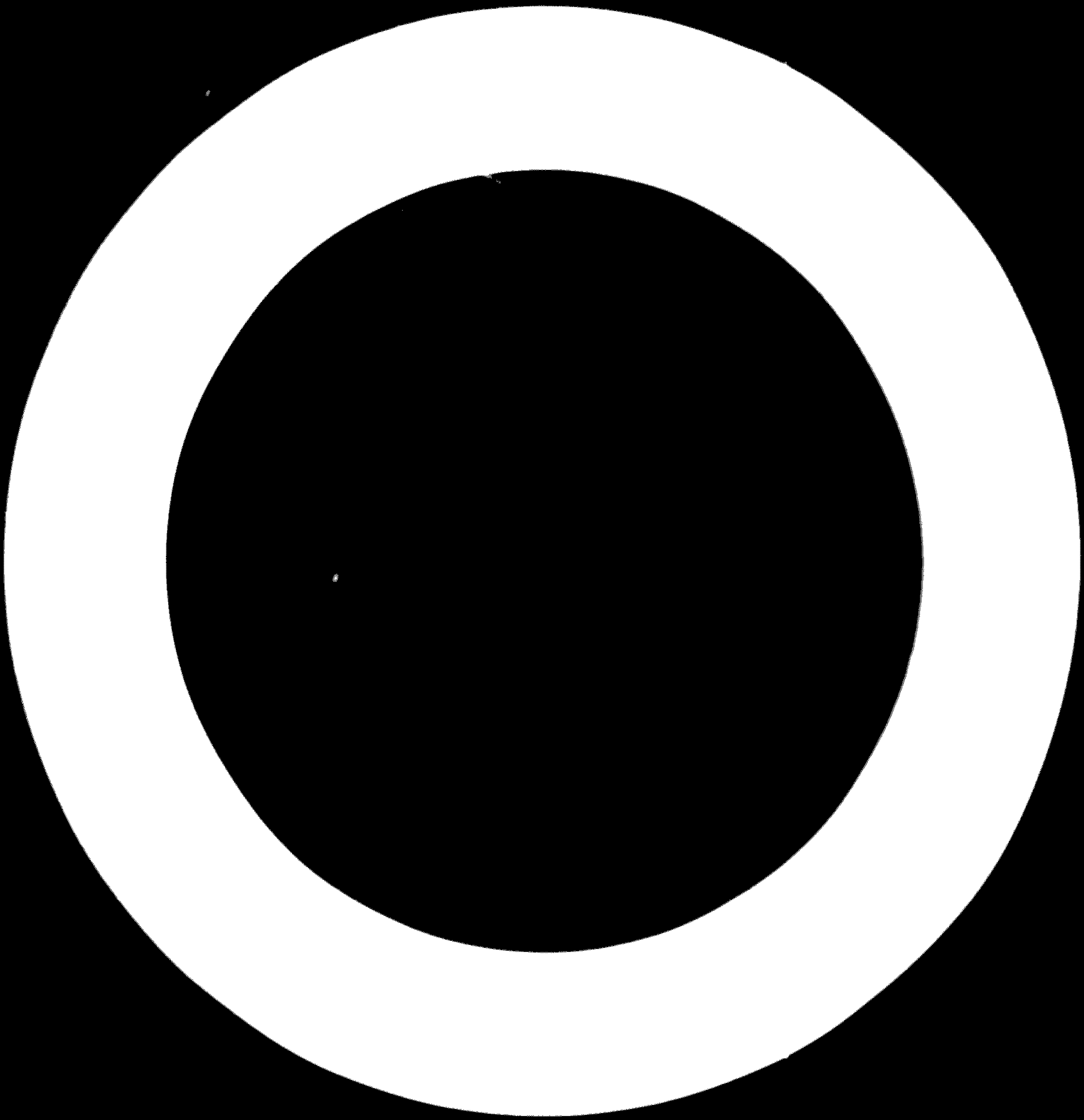


JOB DESCRIPTION

Post Title: A Chemical or Mechanical Engineer - Phosphate Fertilizer Production Expert.

Duration: One year.

Date required: January 1969

Duties: The expert will be assigned to work at the phosphate plant in [illegible].

He will also advise the plant project management during the final completion stages of the plant and provide assistance during the start-up of the sulphuric acid and superphosphate operations.

He should also make a feasibility study of the use of imported phosphoric acid in the production of double and triple superphosphate.

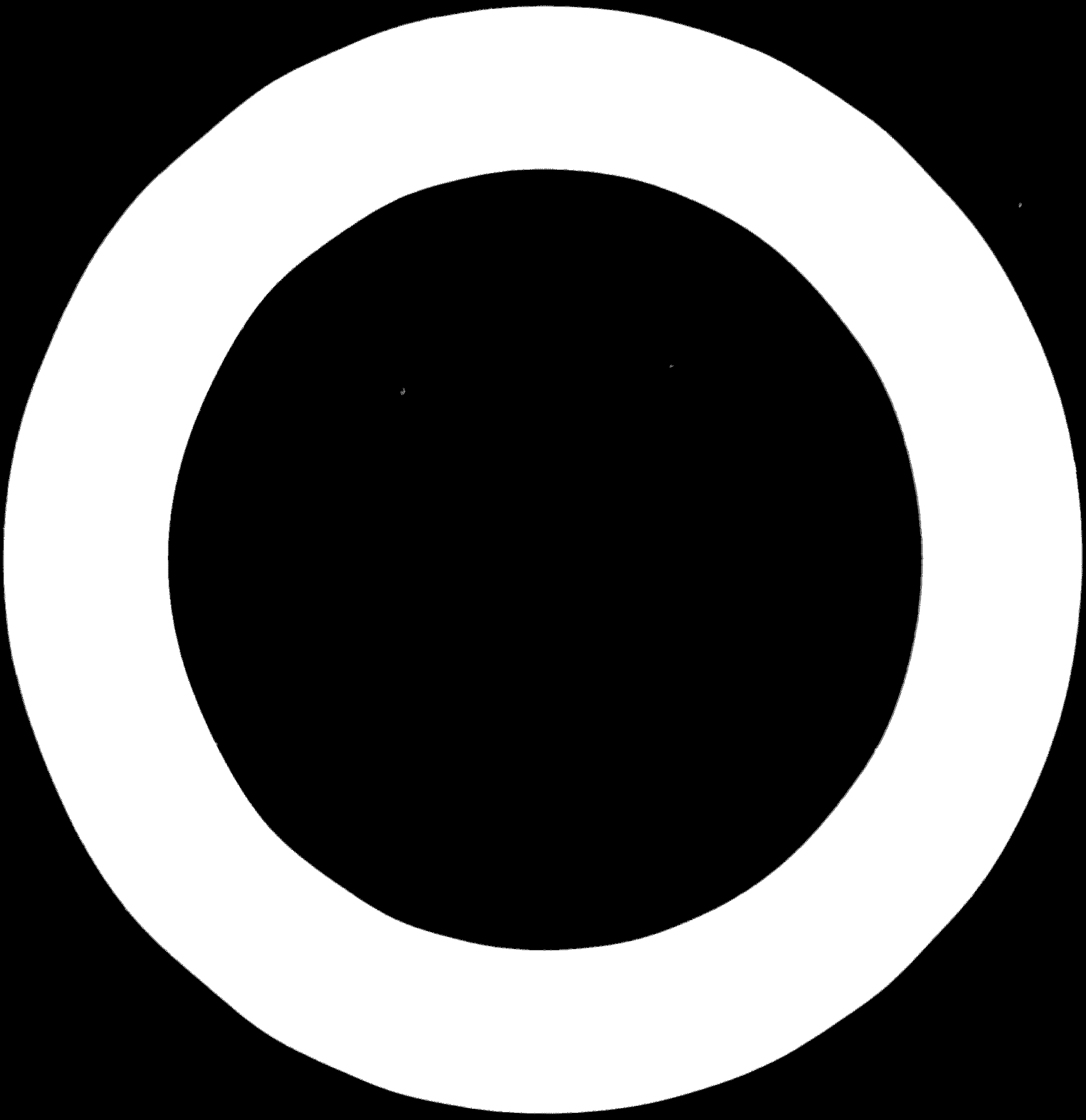
In addition, he will assist the Government in working out the details of using excess ammonia from the [illegible] plant in producing ammoniated superphosphate and other complex fertilizers at [illegible].

Qualifications: University Degree in Chemical Engineering, or Mechanical Engineering, and at least 5 years experience in the production of superphosphate and granular phosphate fertilizers.

Language: English

Background Information: The phosphate plant of [illegible] was started in 1960 under bilateral agreements and construction was stopped in 1965 when the agreements were terminated. 92 % of the equipment is on hand and the erection of the plant is about 30 % complete. It is expected that construction will be renewed in 1969 and that the plant will be finished in 1970.

The plant is designed to produce 100,000 tons per year of granular single superphosphate. The plant consists of 120 ton per day sulphuric acid plant, phosphate rock grinding facilities, superphosphate mixing and storage facilities

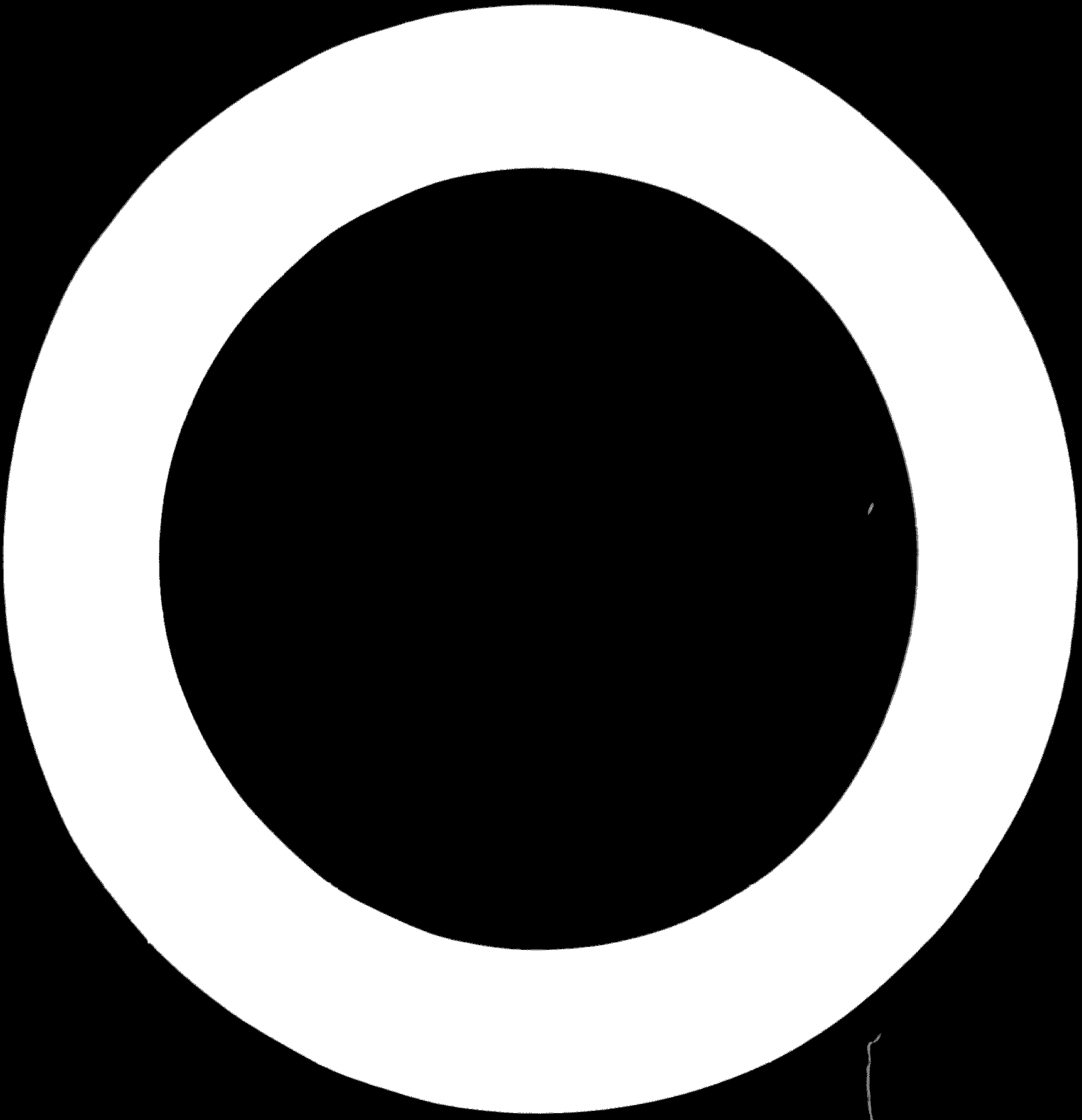


Background Information:

and transportation facilities. In addition a power plant, water and sewage works are part of the project. The plant will start up using imported [illegible] supplies.

The plant has enough equipment and space that with slight additional investment it will be possible the manufacture of superphosphate, the manufacture of complex fertilizers, and the production of double or triple superphosphate.

The ammonia plant at [illegible] will produce [illegible] tons per year excess ammonia above the needs for [illegible] ammonium sulphate. This excess ammonia must be utilized to insure economical operation of the [illegible] plant. A 100,000 ton per year superphosphate plant would require about [illegible] tons per year of ammonia in an ammoniation process.



[illegible]

[illegible]

[illegible]

[illegible]

Project Duration: [illegible]

Amount requested from the UNDP Special Fund: [illegible]

Proposed Government counterpart Contribution: [illegible]

Contribution towards local operating costs: [illegible]

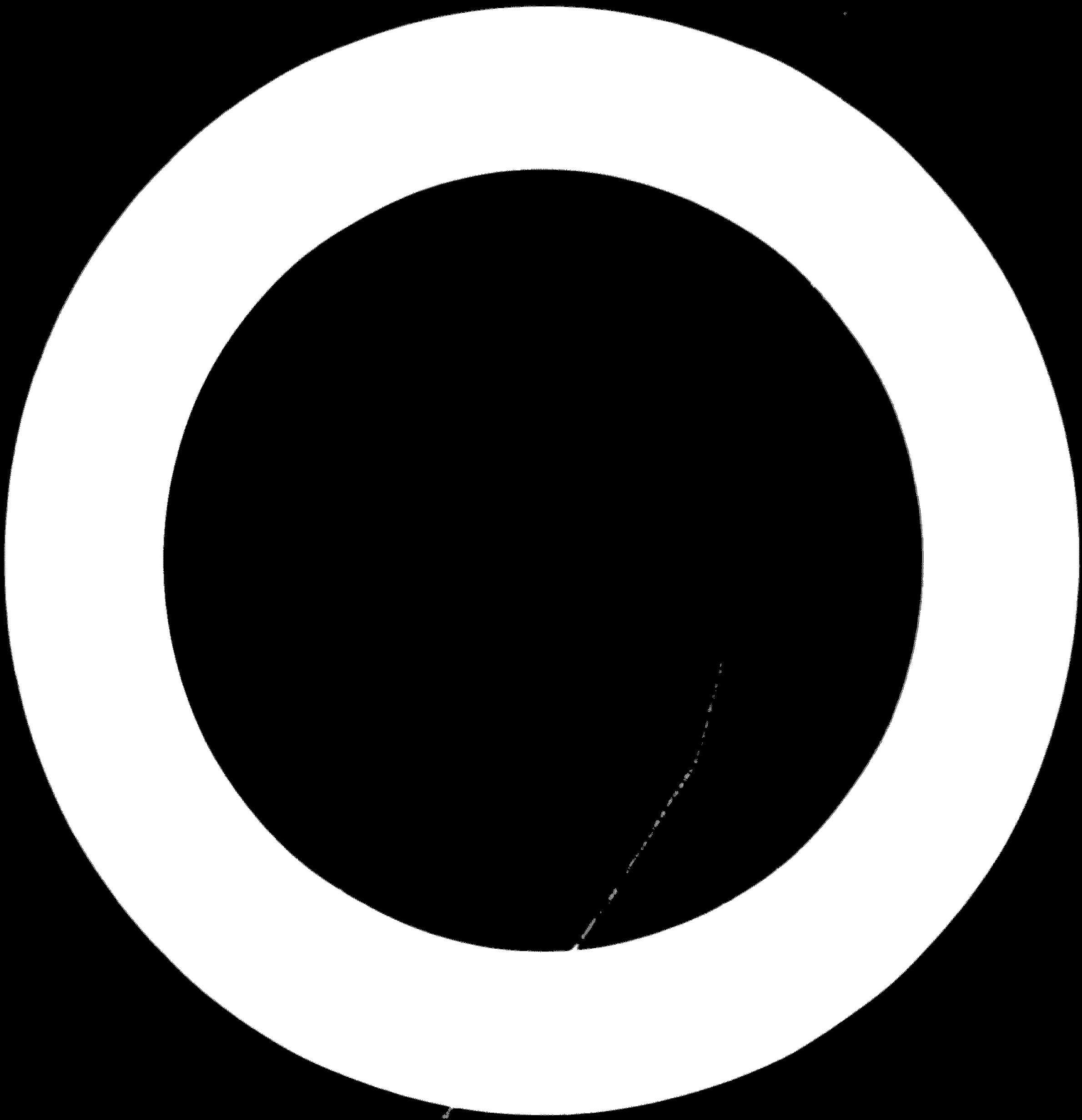
Proposed Government Co-operating Agency: Department of Chemical Industry

Participating and Executing Agency: United Nations Industrial Development Organization

I. Background

1. The Government of Indonesia attaches great importance to agricultural input industries. Indonesia's purchase of large quantities of rice (up to 1 million tons) in the world market and consequent heavy expenditure of scarce foreign exchange underlines the importance of increasing domestic rice and other food production. The central role of cash crops in Indonesia's exports highlights the need for higher yields and expanded output of these crops. To achieve this will require, among other things, the use of much greater quantities of fertilizers.

2. An ammonium sulphate facility being built at Gresik and a superphosphate plant under construction at Tjilatjap will go far in saving foreign exchange being used to import fertilizers. However, these facilities will start up using imported sulphur. The development of an indigenous sulphur industry will save US$ 2,250,000 yearly, in foreign exchange if a 160 ton per day facility to supply the needs of the Gresik and Tjilatjap plants is installed at Wanaradja to process the sulphur muds from the Tolaga Bodas crater. This crater has economic reserves of over 846,000 tons of sulphur at a distance of 14 km from an existing plant at Wanaradja.



3. However, the existing plant which manufactures [illegible] tons of sulphur in 24 hours recovers only [illegible] of the sulphur from the feed clay, and the process cannot be used to design a 100 ton per day facility.

4. A technical pilot plant is necessary to obtain design data for a large-scale plant. The Government of Indonesia is now requesting the assistance of the UNDP (Special Fund) in establishing this pilot plant.

5. The project has been evaluated with the aid of a consultant from the United Nations Industrial Development Organization.

II. The Project

6. The purpose of the project, the duration of which is two years, is to provide technical and economic data for the design of a large-scale facility which will manufacture 100 tons per day of 99+ % sulphur. The sulphur will supply sulphuric acid facilities being built in fertilizer plants at Gresik and Tjilatjap. The pilot plant will have a capacity of [illegible] tons of sulphur per 24 hour day.

7. The pilot plant is expected to provide data regarding:

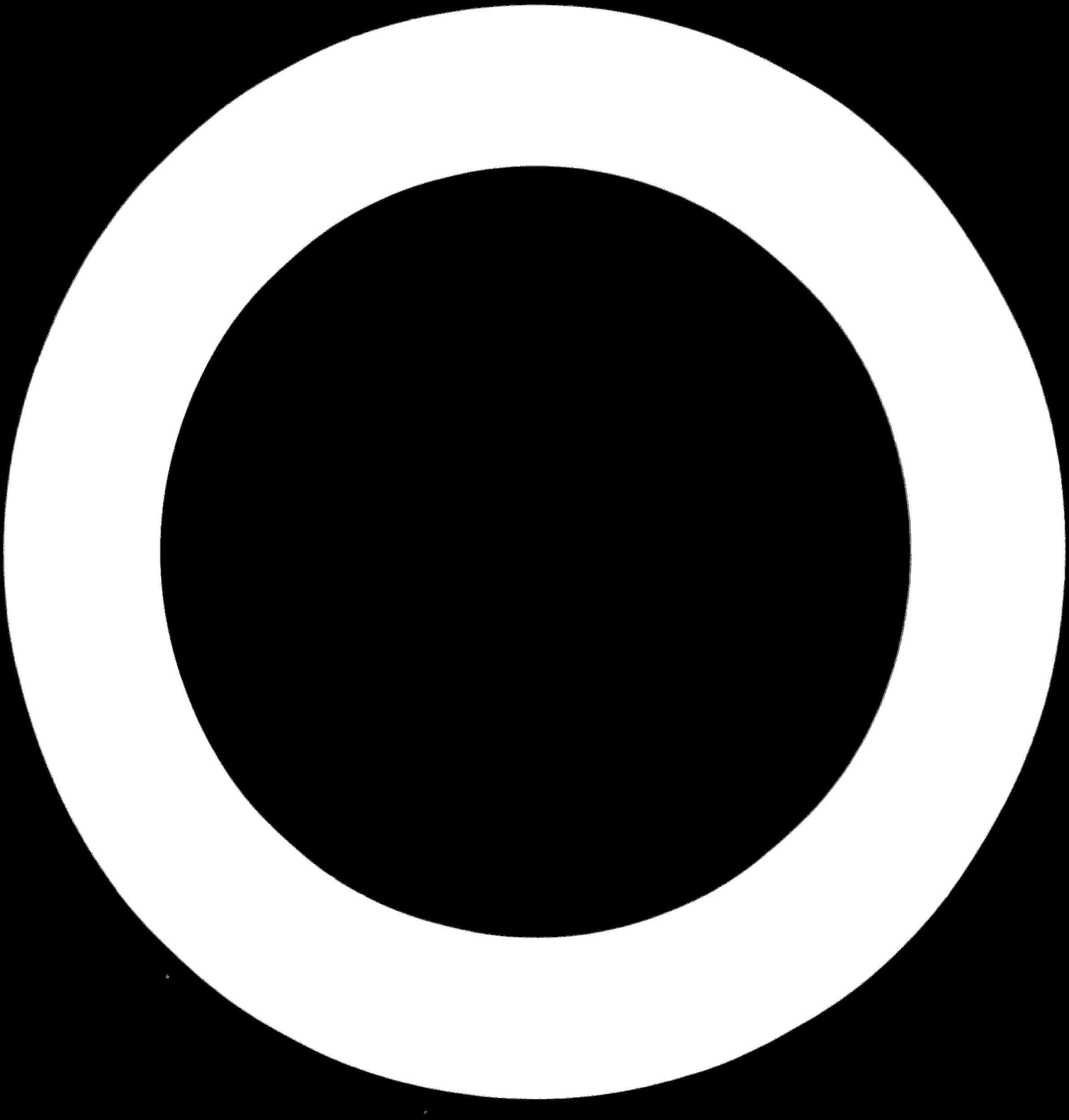
   (a) Means for concentrating the sulphur in the feed clay from a range of 20 % - 65 % S to a uniform feed containing about 75 % sulphur. This will involve studies using classifying, flotation and thickening equipment.

   (b) Means for separating the sulphur from the clay particles in the feed. This will involve studies with different kinds of autoclave arrangements.

   (c) Means for removing organic impurities from the melted sulphur. This will involve studies with various filtration aids.

   (d) Technical problems involved in direct combustion of the feed clay.

   (e) Means for transforming the melted sulphur into a solid suitable for shipment. This will involve a study of casting techniques.

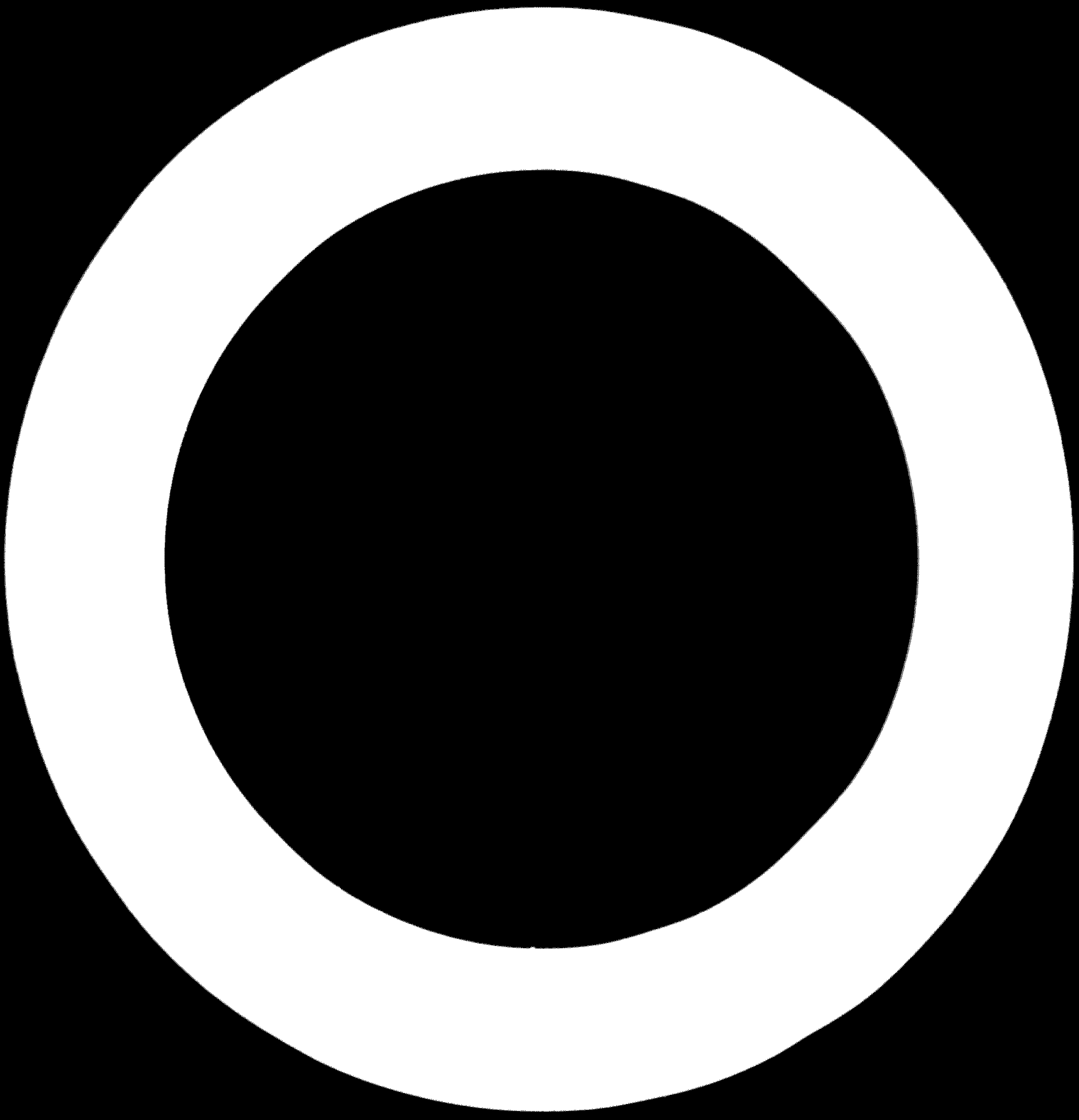


8. The UNDP (Special Fund) is requested to provide:

- the services of an internationally recruited expert as Project Manager for a total period of two man-years,
- the services of an internationally recruited expert with ore dressing experience for a total period of two man-years,
- pilot plant equipment,
- certain office equipment,
- costs of other necessary imported equipment,
- expenses for travel of experts outside the country

9. The Government proposes to provide:

- modernization of the guest house at Garut for experts living quarters,
- the services and salaries of national counterparts totalling 7½ man-years,
- secretaries, chauffeurs and maintenance staff,
- skilled and unskilled labour for the operation of the pilot plant,
- necessary civil engineering works connected with the erection of the pilot plant,
- for the haulage of all imported equipment from the point of delivery to the site and to provide skilled and unskilled labour and locally available auxiliary construction material required in the erection of the process equipment furnished by the United Nations Development Programme,
- use of the existing facilities at the Wanaradja sulphur plant where possible,
- meeting such operating costs for the running of the pilot plant as can be provided from local sources.



III. Financial Data

A. Contribution of the United Nations Development Programme [illegible]

(a) Experts

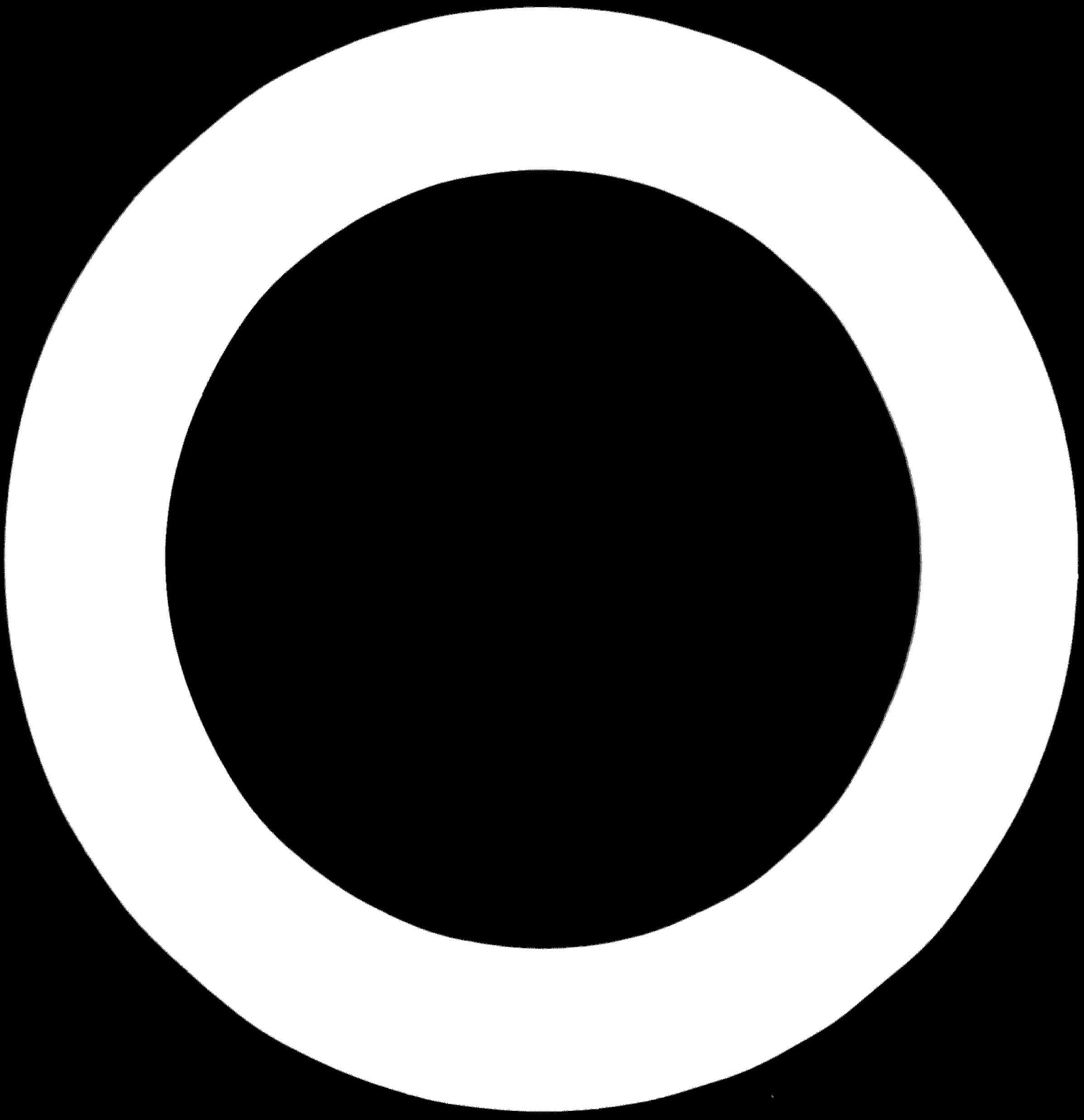
	Total man-months	Total US$	[illegible]	[illegible]
Project Manager	24	[illegible]	[illegible]	[illegible]
Ore beneficiation Engineer	24	[illegible]	[illegible]	[illegible]
	[illegible]			US$ 110,000

(b) Equipment

Imported office equipment	US$ [illegible]	
Jeep	[illegible]	
Trucks (2)	[illegible]	
Pilot plant		
1. Classifier	[illegible]	
2. Flotation cell	[illegible]	
3. Thickener	[illegible]	
4. Autoclave	[illegible]	
5. Filter and compressor	[illegible]	
6. Pump and piping	[illegible]	
7. Casting and others	5,000	
8. Instrumentation and laboratory equipment	20,000	
9. Chemical reagents	[illegible]	
Sub-total		US$ 160,000

(c) Miscellaneous

Documentation	US$ 5,000	
Travel expenses outside the country	5,000	
Contingency	30,000	
Sub-total		US$ 40,000
TOTAL amount requested from the UNDP (Special Fund)		US$ 310,000



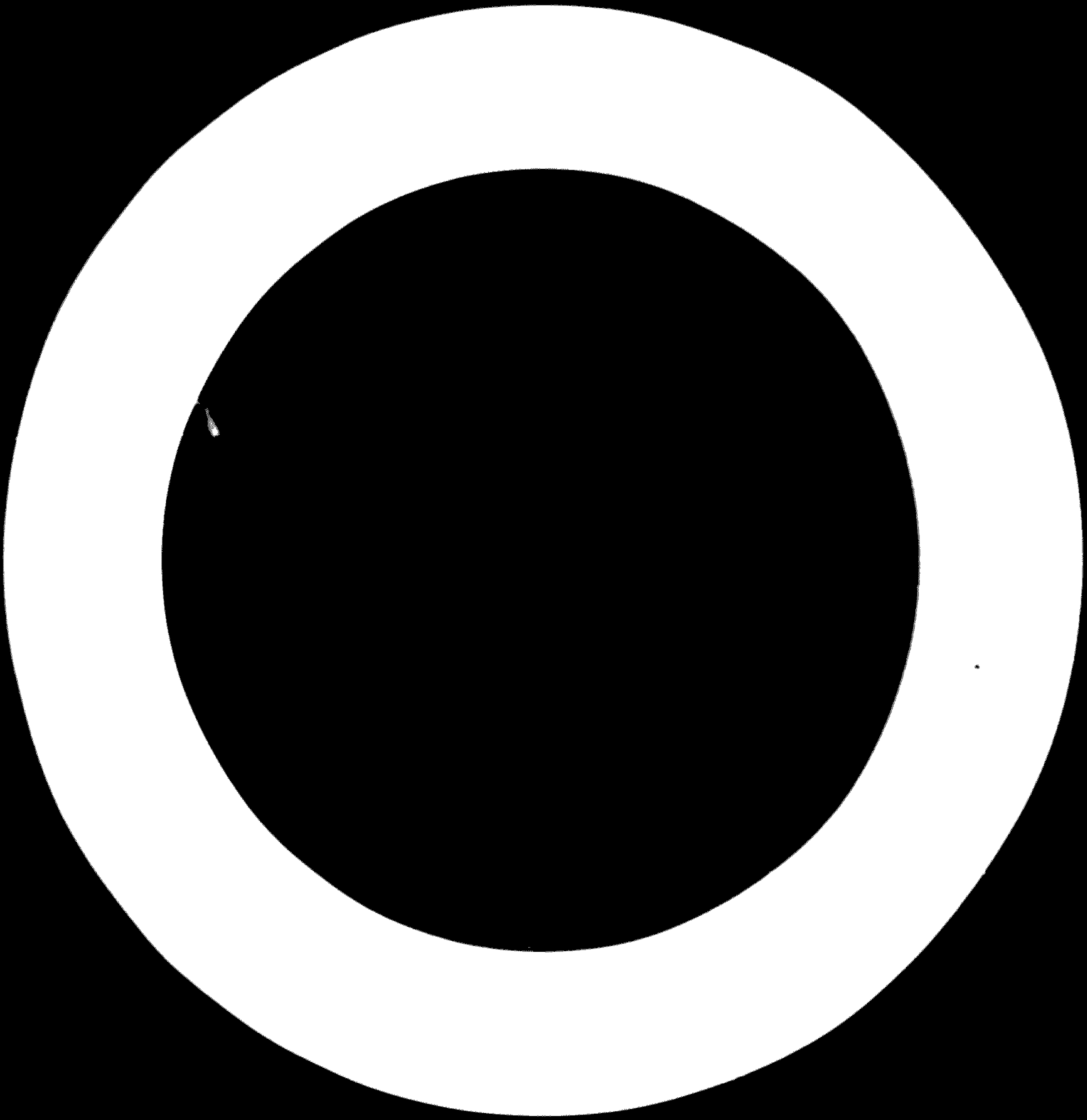
B. [illegible] Government Counterpart Contribution

Counterpart staff	Total man-months	Total US$	[illegible]	[illegible]
Project Manager	[illegible]	[illegible]	[illegible]	[illegible]
Mining Engineer	[illegible]	[illegible]	[illegible]	[illegible]
Chemical Engineer	[illegible]	[illegible]	[illegible]	[illegible]
Chemist	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]		US$	[illegible]

Other Salaries	US$ [illegible]	
Rental of office space [illegible]	[illegible]	
Office supplies	[illegible]	
Civil engineering	[illegible]	
Operating expenses	[illegible]	
Transportation	[illegible]	
Domestic travel	[illegible]	
Modernization of guest house	[illegible]	
		US$ 215,[illegible]
	TOTAL	US$ 2[illegible],1[illegible]

C. Local Operating Costs

The Government proposes to pay an amount estimated at US$ 16,500 as a cash contribution towards the local operating costs of the project.



[illegible]

[illegible]

[illegible]

[illegible]

Project Information: [illegible]

Amount requested from the UNDP (Special Fund) [illegible]

Proposed Government Counterpart Contribution [illegible]

Contribution of [illegible] [illegible]

Proposed Government Co-operating Agency: Department of [illegible] Industry

Participating and Executing Agency: United Nations Industrial Development Organization [illegible]

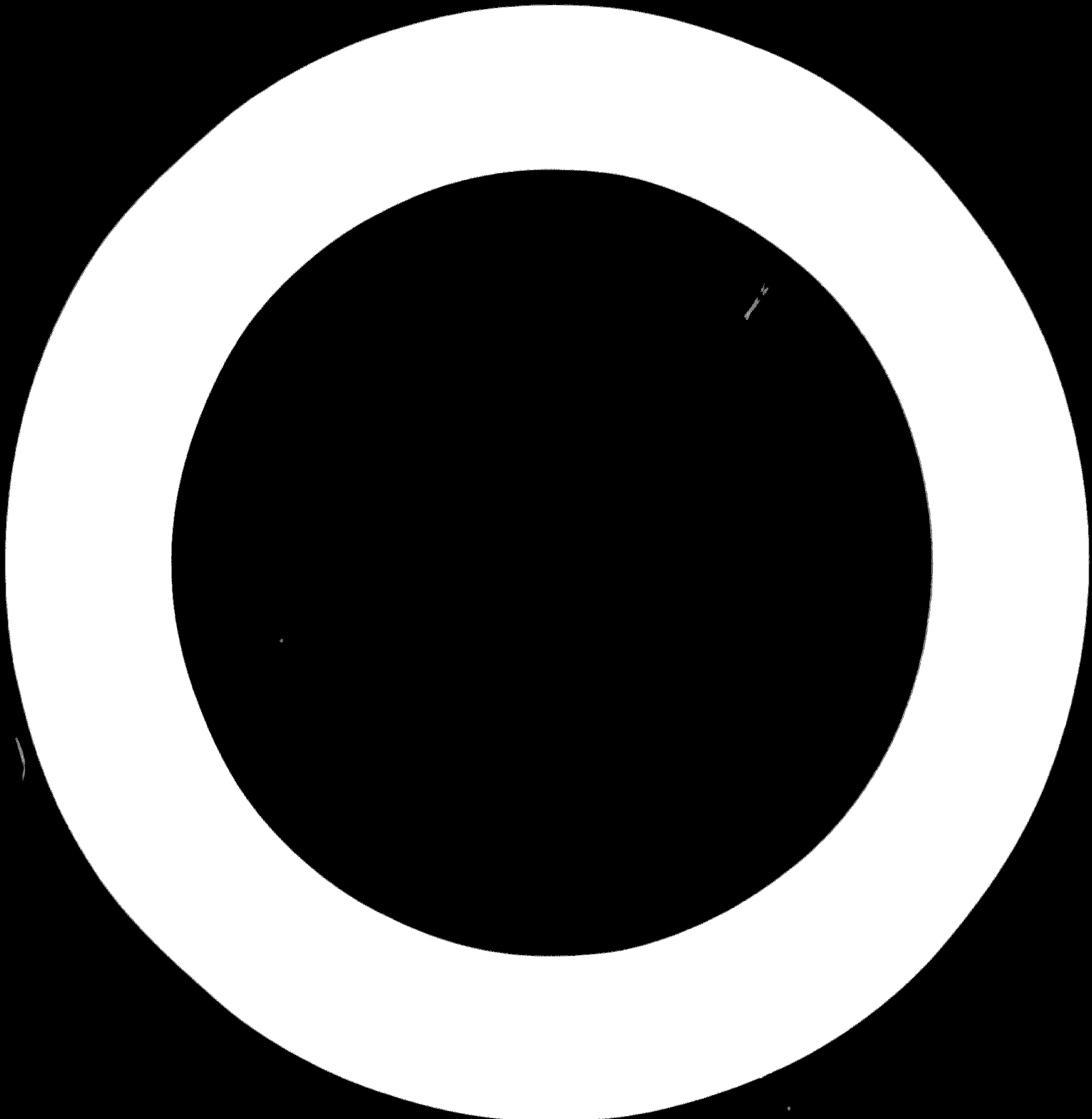
I. Background

1. Comprising over 3000 islands [illegible], Indonesia possesses a wide variety of climates and soils. Out of the country's total of 13.[illegible] million hectares in crops in 19[illegible], 55% were devoted to rice. Corn is the second most important crop, accounting for 23% of cropped area. Indonesia's food production occurs principally in Java, where almost three-fourths of the total population of some 11[illegible] million live. Expansion of agricultural production in Java can be attained only by higher yield per unit of land area, since virtually all the land suitable for crops is under cultivation. Fertilizer is one of the most important inputs to increase yields.

2. A government-owned enterprise at Palembang, Sumatra manufactures 100,000 tons of urea per annum.

3. Another government-owned enterprise at Gresik (Surabaya), manufacturing 70,000 tons ammonia per annum, will come on stream in early 1970 with the following tentative product mix:

Ammonia, [illegible],000 tons per annum
Urea, 45,000 " " "
Ammonium Sulphate, 150,000 " " "



4. The 200 ton per day plant is based on the partial oxidation of fuel oil. This plant was not [illegible] production at below design capacity, [illegible] every effort [illegible] realized to maintain capacity and to find [illegible] [illegible] [illegible].

5. One means of using the excess ammonia would be [illegible] as a direct application nitrogen material for rice [illegible] [illegible] with about 90% of the ammonia manufactured in the United States is applied directly to the soil, this would be a novel method in Indonesia. The possibilities for low cost nitrogen fertilizer are [illegible] [illegible] application of ammonia that the Government of Indonesia is requesting assistance in the establishment of a pilot project for this purpose.

II. <u>The Project</u>

6. The purpose of the project, the duration of which is three years, is to determine:

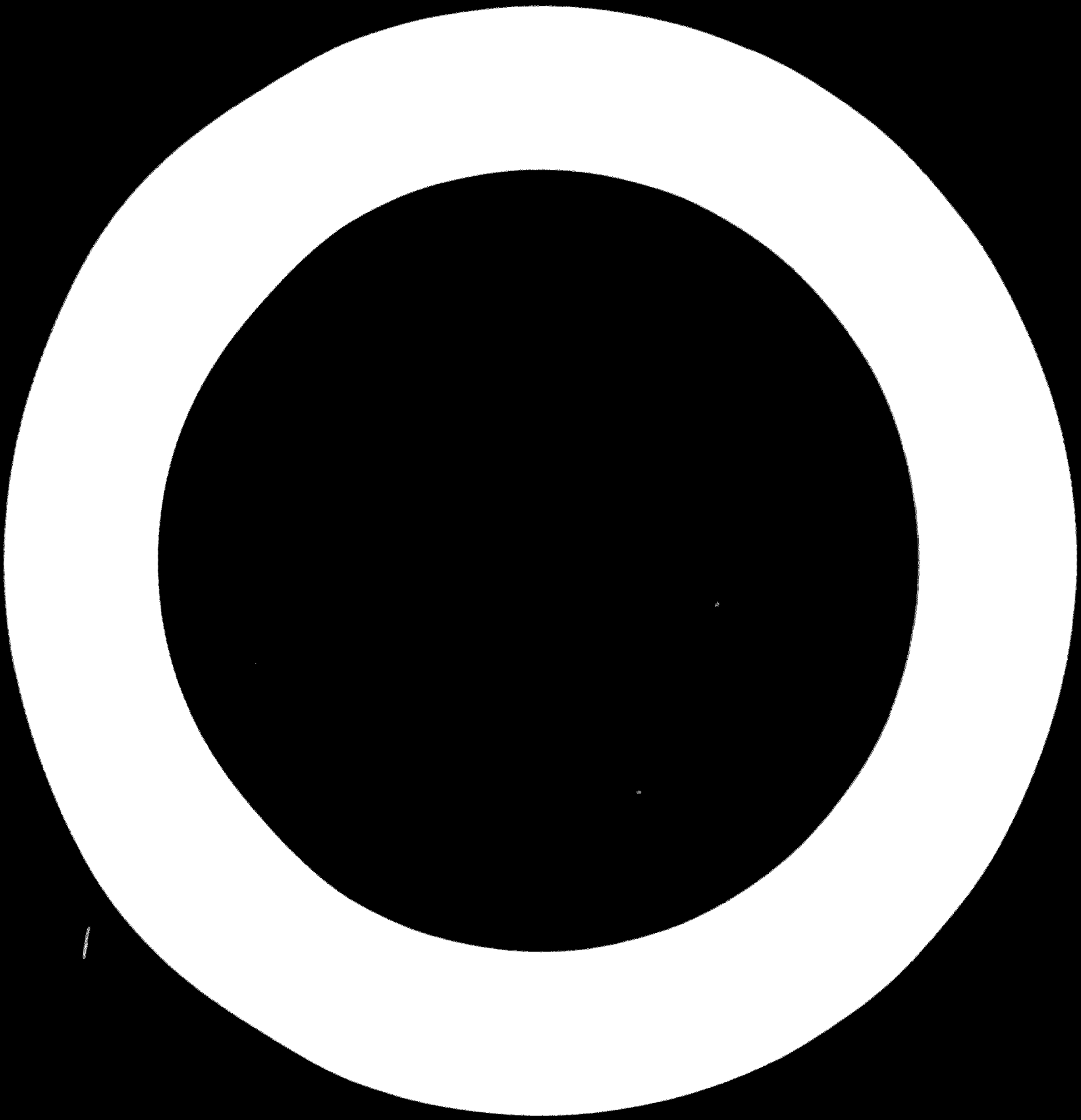
   1. The feasibility of applying ammonia directly to [illegible] [illegible] irrigated paddy under Indonesian conditions.

   2. The economics of using anhydrous or aqua ammonia as direct application fertilizers.

   3. The most feasible and economic means of transporting the product to the farm and of applying it to the land.

7. The UNDP (Special Fund) is requested to provide:

- the services of an internationally recruited expert as Project Manager for a total period of three man-years,
- the services of an internationally recruited expert with agricultural engineering experience for a total period of two man-years,
- process equipment for converting anhydrous ammonia into aqua ammonia,
- application tanks to inject ammonia into the soil as well as field storage tanks, and tank transport wagons,
- cost of other necessary imported equipment,
- certain office equipment,
- expenses for travel of experts outside the country.



d. The Government proposes to provide:

- the services of [illegible] totalling [illegible] man-years,
- secretaries, chauffeurs and [illegible] staff,
- skilled and unskilled labour for [illegible] equipment,
- necessary civil [illegible] the erection of field installations,
- for the [illegible] equipment from the point of delivery to the site and to provide skilled and unskilled labour and [illegible] auxiliary construction materials required for the erection of the equipment furnished by the United Nations Development Programme,
- such [illegible] of the project [illegible].

III. Financial Data

A. Contribution of the United Nations Development Programme

(a) Experts

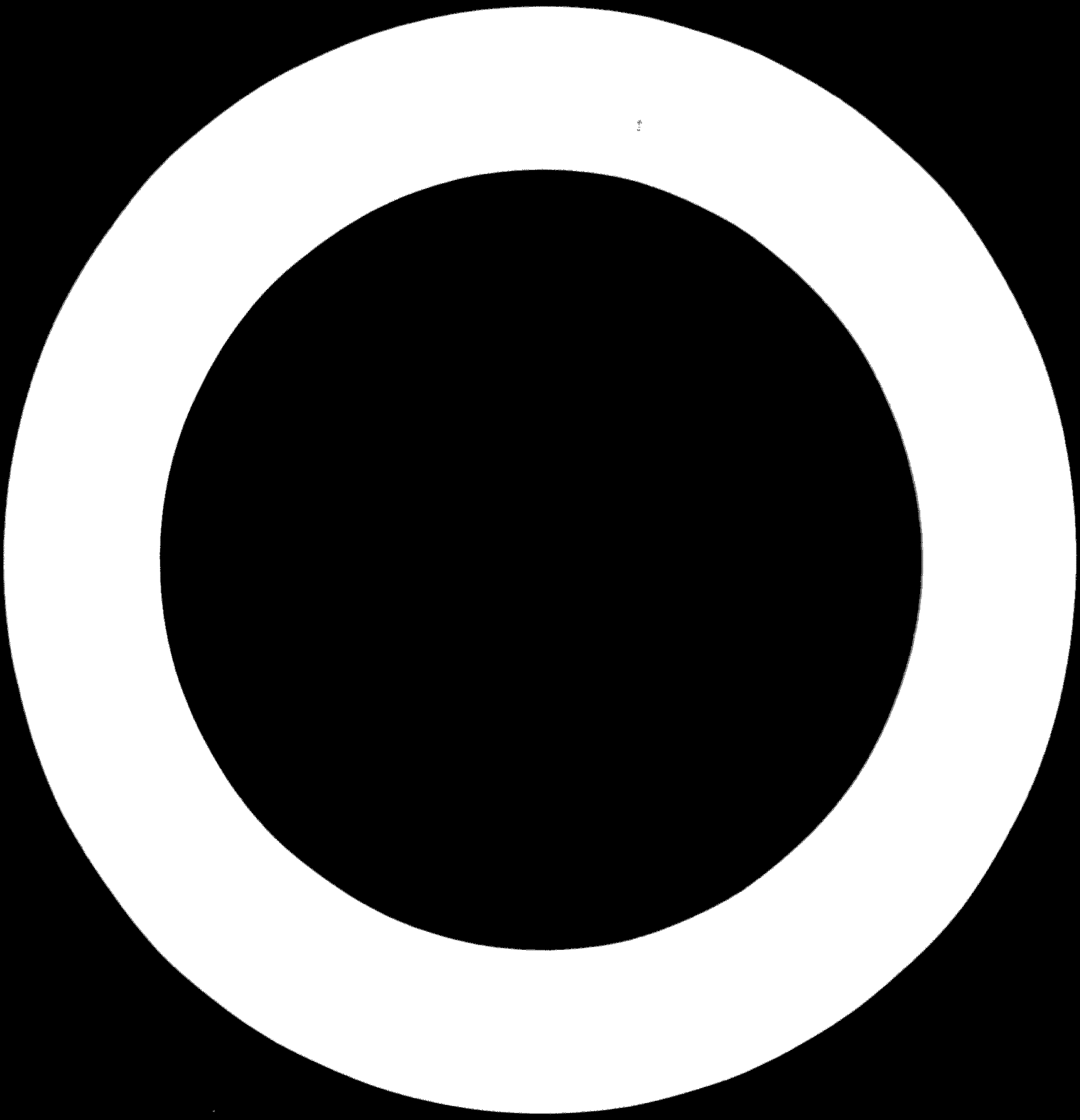
	Total man-month	Total US$	I	II	III
Project Manager	36	[illegible]	12	12	12
Agricultural Engineer	24	[illegible]	—	12	12
	60			US$	[illegible]

(b) Equipment

Imported office equipment	US$ [illegible]		
Jeep	5,000		
Tractor	5,000		
Trucks (2)	[illegible]		
Application tanks	[illegible]		
Ammonia converter (for pump)	[illegible]		
Tank transport wagon	[illegible]		
Field storage tanks	10,000		
Storage parts	5,000		
Maintenance equipment	10,000		
Sub-Total		US$	[illegible]

(c) Miscellaneous

Documentation	US$ 5,000		
Travel outside the country	5,000		
Contingency	30,000		
Sub-Total		US$	40,000
TOTAL amount requested from UNDP (Special Fund)		US$	320,000



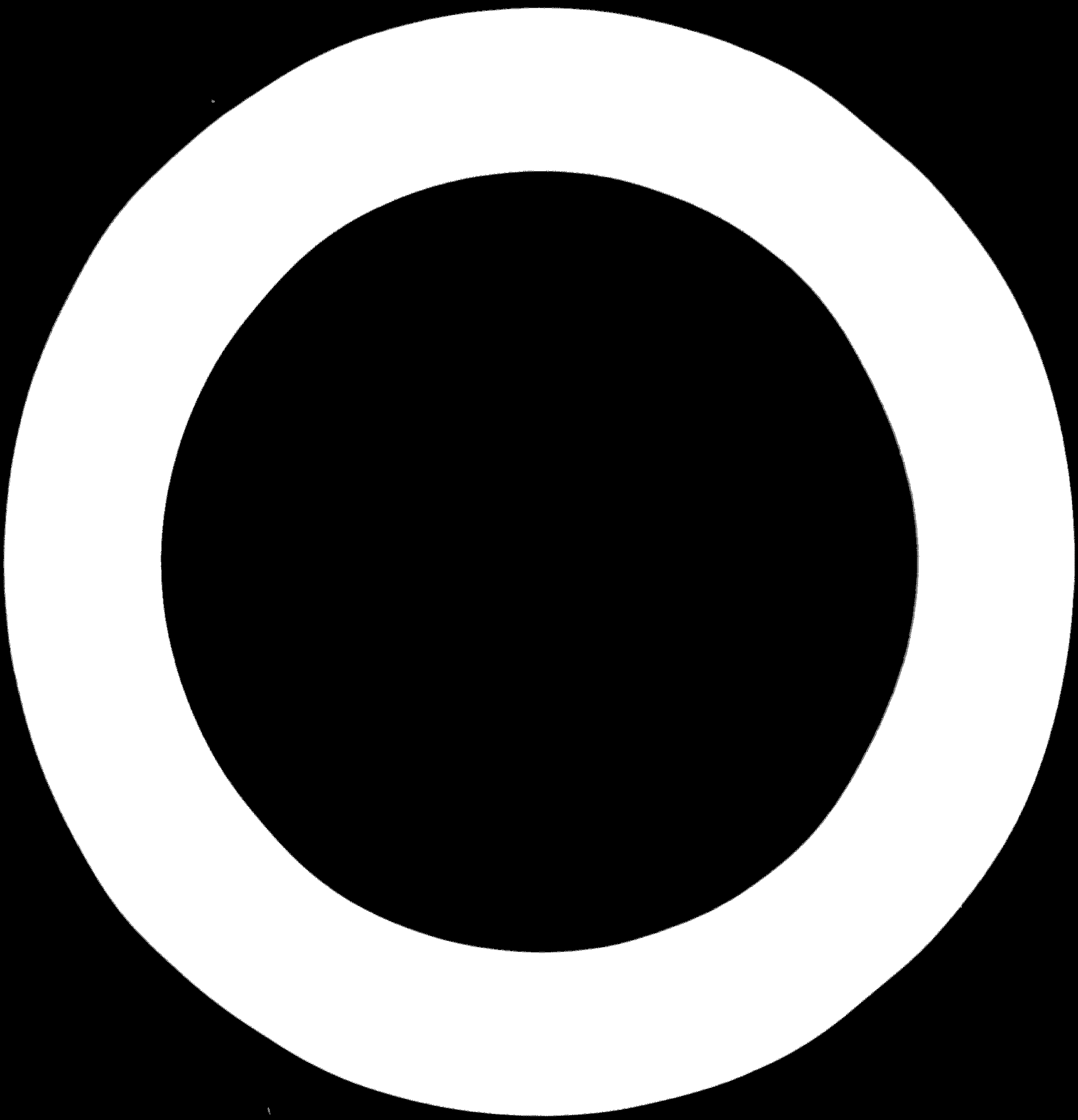
B. Proposed Government Counterpart Contribution

Counterpart staff	Total man-months	Total cost	Year I	Year II	Year III
Project Manager	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Agricultural Engineer	[illegible]	[illegible]	—	[illegible]	[illegible]
Agronomist	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chemist	[illegible]	[illegible]	—	[illegible]	—
	[illegible]				US$ [illegible]

Other [illegible]	[illegible]	
Rental office space [illegible]	[illegible]	
Office supplies	[illegible]	
Civil engineering	[illegible]	
Operating expenses	[illegible]	
Transportation	[illegible]	
Domestic travel	[illegible]	
Farm rental	[illegible]	
		US$ 172,000
	TOTAL	US$ [illegible]

C. Local Operating Costs

The Government proposes to pay an amount estimated at US$ 21,000 as a cash contribution toward the local operating costs of the project.



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

United Nations Development Programme

Special Industrial Services

[illegible]

1. **Reference No.:**	SIS/IND/ -
Country:	Indonesia
Project Title:	Short-term Technical Assistance to assist plant management in determining the proper production mix.
Date Formal Request received:	
Government Department submitting Request:	Department of Chemical Industry, through the Resident Representative
Specific Government Agency concerned with the Project:	Department of Chemical Industry

2. **Description of the Project:**

A marketing expert will be assigned to the Urea-Ammonium Sulphate Plant at Gresik to advise on the proportions of urea and ammonium sulphate that should be manufactured.

3. **Summary of major grounds for Request:**

This request is based on a UNIDO fertilizer team's mission that visited Indonesia in Oct.-Nov. 1968. The Government of Indonesia is keenly interested in maintaining the output of the Gresik plant at its maximum.

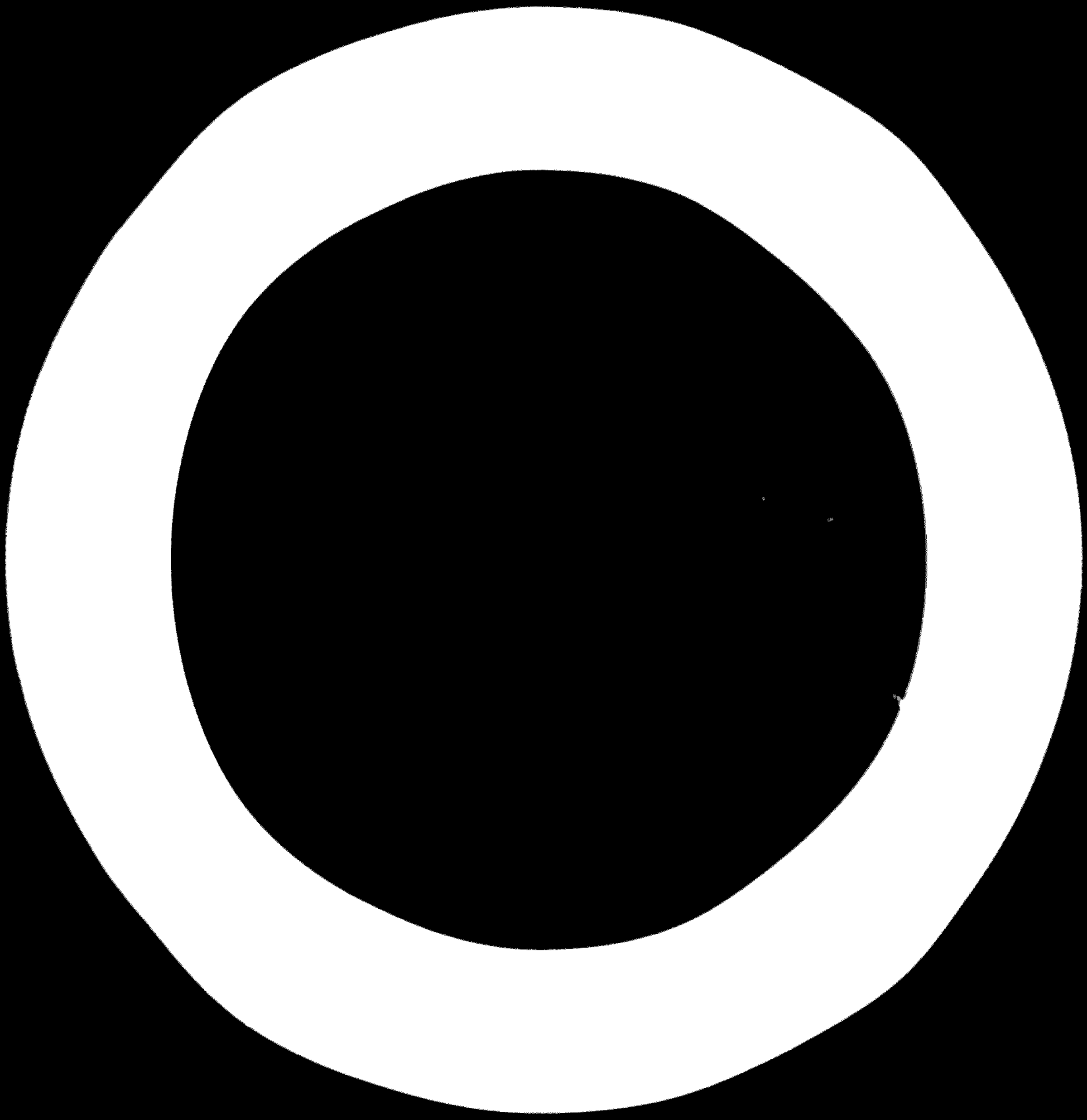
4. **Relationship with other Technical Assistance Projects:** Nil

5. **Project Components, Duration and Estimated Costs:**

Field of Activity	**Duration**	**Costs**
A Marketing Expert	6 months	

6. **Request approved:**

For UNIDO	Date	FOR UNDP	Date



JOB DESCRIPTION

Post Title: Marketing Expert

Duration: Six months.

Date required: As [illegible]

Duties: The expert will be [illegible] to work with the agricultural [illegible] services [illegible] ammonia plant [illegible] farmers, [illegible] with the farm extension services, the most likely proportions of ammonium sulphate and urea [illegible] farmers in the service area [illegible] in the foreseeable future. He shall [illegible] determine the [illegible] quantity of the two fertilizers to be stored [illegible] in the various warehouses in the area. He shall also assist the management in [illegible] overall marketing programme to distribute the products of the plant.

Qualifications: University degree in marketing with at least [illegible] years experience [illegible] with the marketing of fertilizers.

Language: English

Background Information: The ammonia plant [illegible] expansion of [illegible] at Gresik [illegible] completed in late 19[illegible] and [illegible] early 197[illegible]. It is designed to produce 7[illegible] tons per [illegible] of ammonia of which [illegible] tons are excess and the balance will be converted into urea and ammonium sulphate. Tentative plans are for a production of [illegible] tons per year of urea and 15[illegible] tons per year of ammonium sulphate. However, these tonnages can vary over a fairly wide range, depending on market conditions. However, once the warehouses are full of a certain product mix, it is too late to determine if the farmers preference is for the same ratio of products as found in the warehouses.

The plant at Gresik can only be an economical producer if the ammonia plant is operated at maximum capacity throughout the year.

76.02.06