

IFA Technical Conference

**Kallithea, Greece
5-7 October 1982**

OPTIMIZING USE OF ENERGY IN THE PRODUCTION OF
GRANULAR AMMONIUM PHOSPHATE FERTILIZER

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The most popular phosphate fertilizers in the U.S. are granular ammonium phosphates. About 10 million tonnes of granular diammonium phosphate (DAP) and about 1.8 million tonnes of monoammonium phosphate (MAP) are produced annually (1). The total energy requirement for production of these fertilizers is about 2.8 billion kcal which is equivalent to about 300 million liters of fuel oil per year (2). The average energy consumption in the manufacture of these two granular ammonium phosphates is shown in the following tabulation:

Average Energy Consumption in Production
 of Ammonium Phosphates

Product	kcal/t ^a x 10 ³			Total
	Fuel	Electricity	Import Steam	
DAP	81.4	95.5	48.0	224.9
MAP	136.6	122.2	21.9	280.7

a. Metric ton

These data show that in the manufacture of DAP, about 43 percent of the energy is consumed as electrical energy and 36 percent as fossil fuel to dry the product. The remaining 21 percent is consumed as imported steam, which in most instances is delivered as surplus steam from sulfuric acid plants. In the manufacture of MAP, larger quantities of fossil fuel are required to dry the product (49% of total) and larger quantities of electrical energy are required for the equipment (about 44% of the total). Also, a larger total amount of energy is required to manufacture MAP as compared to DAP, 280,700 versus 224,900 kcal/tonne. Processes for production of MAP and DAP are based on technology developed in the late 1950's and early 1960's (3) (4).

A flow diagram for the conventional process for production of MAP and DAP is shown in figure 1. In this process phosphoric acid flow to the system is divided between the scrubber and the preneutralizer to maintain the N:P mole ratio in the scrubber between 0.35:1 and 0.7:1. With these operating parameters there is minimum evolution of fluorine from the scrubber (5). Water is added to the scrubber in controlled amounts to maintain the specific gravity of the scrubber slurry in the range, 1.3 to 1.5. The partially neutralized scrubber slurry is then pumped to the preneutralizer where more phosphoric acid and water are added and the slurry is ammoniated to an N:P

mole ratio of 1.45:1. Slurry from the preneutralizer is then sprayed onto recycled material (fines, crushed oversize and product) in the ammoniator-granulator (hereafter called the granulator) and further ammoniated to DAP. This granular product is then dried, cooled and screened to remove product-size material. Concentration of acid used in the process usually depends upon locations of the phosphoric acid and granulation plants. If both plants are at the same location, acid strength is usually about 40 percent P_2O_5 . At this strength only a minimum amount of water must be added to the scrubber and preneutralizer. If the acid is shipped to a distant location, it is usually shipped as merchant-grade acid containing 52-54 percent P_2O_5 . When this strength acid is used, a large quantity of water must be added to both the scrubber and preneutralizer. Usually the preneutralizer is operated so that the moisture content of the slurry fed to the granulator is about 15 percent for production of MAP and 20 percent for DAP. Product from the granulator is dried, cooled, and screened to remove product-size material. Oversize is crushed and recycled with fines to the granulator.

This paper shows procedures for minimizing the amount of water added to the system and describes improved methods for removing moisture from the granulator so that the amount of fossil fuel required to dry the product can be significantly decreased. By removing more water from the granulator it is also possible to decrease the recycle rate required to efficiently granulate the products. Therefore, less electrical energy is required to produce the products. Use of steam can and should be eliminated in the production of MAP or DAP.

There has been considerable increase in the quantity of merchant-grade phosphoric acid used in international trade. In 1980 about 1 million tons of P_2O_5 as merchant-grade phosphoric acid was exported from the U.S. Many transportation companies now offer ships that can transport 25,000 to 30,000 tonnes of acid. Many of these ships are involved with suitable economically interesting backhaul combinations. Therefore, more phosphoric acid will probably be shipped in the future. There is increased shipment of phosphoric acid in the U.S. In the past few years considerable amounts of phosphoric acid have been shipped by barge on the Mississippi River. This acid has been converted to either DAP or MAP at a location some distance from the phosphoric acid unit. TVA and others have developed processes that efficiently use energy stored in this phosphoric acid.

MONOAMMONIUM PHOSPHATE

MAP is becoming very popular in the U.S. both as 10-50-0 to 11-55-0 MAP grades and as monoammonium phosphate sulfate (MAPS) grades of 16-20-0-13S, 11-48-0-4S, etc. Significant amounts of these materials are also produced in other countries. The most popular procedure for manufacture is to receive merchant-grade phosphoric acid and dilute it as it is added to the preneutralizer and scrubber. This is done so that the slurry from the preneutralizer can be pumped and sprayed into the granulator. TVA has found that adding water is not necessary if a small quantity of sulfuric acid is used as a scrubbing medium for the granulator exhaust gases and if the pipe-cross reactor (PCR) such as shown in figure 2 is installed inside the granulator. By using this equipment and operating procedures, difficulty with pumping

viscous ammonium phosphate slurries is eliminated. The merchant-grade phosphoric acid can be fed directly to a PCR where it is reacted with ammonia, scrubber liquor, and a small quantity of sulfuric acid. The hot melt, at about 150°C and containing 2 percent H_2O , is used to granulate recycled material fed to the granulator. The temperature of melt from the PCR is usually kept below 150°C by addition of scrubber liquor to a separate sparger within the PCR. The plant and the PCR operate well when about 50 pounds of sulfuric acid per ton of product is added to the PCR. This amount of sulfuric acid helps prevent scale from forming inside the reactor and prevents plugging of the PCR.

Table 1 shows a summary of data from three separate plants in which MAP was produced from merchant-grade phosphoric acid containing 52-57 percent P_2O_5 . In the first two tests an 11-53-0-2S grade was produced and in the third test the nominal grade was 12-48-0-5S. In the first two tests a conventional TVA-type rotary ammoniator-granulator was used and part of the acid and ammonia was added to the granulator; however, 75-90 percent was added to the PCR. In the third test a rotary granulator was used and the depth of material in the bed was very shallow, about 20 centimeters. In this plant no acid or ammonia was added to the rotary granulator and the melt was spread onto the rolling bed by a specially designed melt distributor shaped similar to a flooding nozzle used to broadcast fluid fertilizers.

In all tests, water was used as a scrubbing medium and its pH was adjusted to pH 3.0-5.0 by adding a small quantity of sulfuric acid. There was almost no loss of ammonia or fluorine from the plant stacks. In the first two tests the PCR was operated so that heat flux was between 9,800 and 11,700 kcal/hr.cm². The reactor operated satisfactorily at these heat fluxes; however, it performed better at higher heat fluxes of 19,500 and 23,000 kcal/hr.cm². At the lower fluxes there is a tendency for the PCR to drool and occasionally form some oversize because of nonuniform distribution of the melt across the bed. In production of the 12-48-0-5S grade a heat flux of about 60,000 kcal/hr.cm² was used. At this flux a specially designed melt distributor is required so that the bed within the granulator will not be displaced. Best results have been received when the optimum flux of 23,000 kcal/hr.cm² was used. Although in some instances optimum conditions in the PCR were not maintained, excellent heat conservation was achieved. All of these plants formerly used preneutralizers to produce MAP and consumed between 111,000 and 139,000 kcal/t as fossil fuel to dry the products. By using the PCR (test 1) and an acid containing 52.5 percent P_2O_5 , plant operators were able to decrease fuel requirements by 80 percent. In another plant (test 2), an acid containing 57 percent P_2O_5 was used; no fuel was required to dry the product. Test 3 was conducted in another plant and larger quantities of sulfuric acid were added in the PCR along with merchant-grade phosphoric acid containing 52.5 percent P_2O_5 so that the resulting grade was 12-48-0-5S. By using this quantity of sulfuric acid in the formulation it was possible to produce an excellent 12-48-0-5S grade without need for fuel in the dryer; only a small pilot burner was used.

These data show the PCR made it possible to remove about 206 kilograms of water per tonne of product added to the system without need for fuel to dry the product. However, some companies using the PCR have found it

advisable to use about 20 percent of the fuel formerly used when operating the preneutralizer. They report this fuel is necessary to keep exhaust gases from the dryer and cooler above their dew point so that wet material will not form in the dry dust collecting systems.

In many instances the phosphoric acid plant is located near the ammonium phosphate unit; therefore, there is little or no advantage in concentrating phosphoric acid used in these complexes. Usually the acid is concentrated to about 40 to 45 percent P_2O_5 and is used to produce DAP or MAP with the conventional preneutralizer process.

This past year TVA engineers have worked with companies using the PCR to produce MAP, MAPS, and DAP from this medium strength acid. The following data was obtained from one of these plants. Obviously, with the lower strength acid more water must be removed from the granulator to avoid condensation of moisture within the bed of material in the granulator. This, in turn, will cause increased recycle rate and higher moisture content in the product discharging from the granulator into the dryer. Fortunately, partial pressure of water vapor above material in the granulator is relatively high and the partial pressure of the ammonia above this solution is low. Figure 3 shows a curve of the partial pressure of water and ammonia at N:P mole ratios for the ammonia-phosphoric acid-water system at 75°C (6). The highest temperature at which partial pressures were obtained was 75°C. This is about 25°C less than the nominal operating temperature in the granulator. At 75°C the partial pressure of water above the saturated solution having an N:P mole ratio of 1:1 (MAP) was about 127 mm Hg. This and other data were used to calculate this partial pressure above the saturated solution at 100°C and it was found to be about 220 mm Hg. At this high partial pressure for water it should be relatively easy to remove water vapor from the granulator by passing enough air through the granulator. Unfortunately most granulators are sealed on their feed end. Exhaust air is withdrawn at the discharge end of the granulator. However, most of this air is pulled through the open end of the hood at the discharge end of the granulator and through the discharge chute between the granulator and dryer. Usually very little air is drawn into the feed end of the granulator.

In the commercial plant tests a 16-20-0-13S MAPS was produced using phosphoric acid containing about 43 percent P_2O_5 . Originally, the company had encountered problems in removing moisture from the granulator and full benefit of the PCR was not realized. The feed end of the granulator was opened as much as possible so that air could be drawn into and through the granulator. Also, the large 41 centimeter diameter support beam was used as an air duct to convey air into the feed end of the granulator. Figure 4 shows a sketch of this granulator. To use the central support beam as an air duct the company installed two 20 centimeter nipples into the large 41 centimeter diameter support beam. In this way air was drawn into the open feed end of the granulator and through the support beam. With this equipment arrangement it was possible to have increased air flow through the granulator. Material from the granulator was dried in a standard rotary dryer and no attempt was made to cool the product. Crushed oversize and fines were returned to the granulator.

When this plant was operated in a conventional manner without the increased air flow through the granulator, the average production rate was 363 tonnes per day of the 16-20-0-13S grade. By using the PCR and increasing air flow through the granulator it was possible to increase the production rate to 544 tonnes per day.

Table 2 shows the operating data and formulation used in this plant. The PCR was 15.2 centimeters in diameter and 6.1 meters long. The PCR was constructed so that it had a slotted discharge 1.3 centimeters wide and 1.5 meters long. All phosphoric acid used in the formulation was added to the scrubber. Also sulfate liquor containing 7 percent N, 8 percent S and 67 percent H₂O from a sulfuric acid plant was added to the scrubber. The scrubber slurry was maintained at an N:P mole ratio of 0.4:1 by splitting the phosphoric acid feed so that a small quantity was added directly to the PCR. All scrubber slurry and sulfuric acid used in the formulation were also added to the PCR. Ammonia was premixed with enough water to maintain a H₂O:NH₃ weight ratio of 0.4:1 to 0.5:1. This quantity of water helped to maintain a PCR skin temperature of about 127°C; this skin temperature is usually about 20 percent less than the temperature of the melt discharged from the PCR. In this test enough ammonia was added so that the resulting N:P mole ratio of the melt from the PCR was 1.0:1. It was estimated that the recycle rate was about 3.8 tonnes of recycle per tonne of product. The temperature of the material discharged from the granulator was 93°C. Airflow through the granulator was kept at about 425 cubic meters per minute; the calculated equivalent air velocity was 1.4 meters per second (effective airflow area equal 70% of granulator cross section). The amount of fuel used in the dryer was decreased to about 55,600 kcal per tonne, which is about 40 percent of the normal requirement. The dust load from the granulator did not appear to increase; it was measured to be only 0.46 percent of the total production rate. Ammonia loss was acceptable, though higher than anticipated. It is believed that part of the higher ammonia loss was due to a poorly designed ammonia sparger in the granulator. Figure 4 shows the recommended design for the ammonia sparger.

DIAMMONIUM PHOSPHATE

Using the PCR and increasing the airflow through the granulator should also be helpful in production of DAP. TVA has made many pilot-plant tests of the production of DAP using the PCR. However, only one commercial plant in the U.S. uses a PCR for producing DAP; it is used in combination with a conventional preneutralizer. In this plant the scrubber is operated at an N:P mole ratio of 0.4:1 to 0.7:1. With these operating conditions there is very little loss of fluorine from the scrubbers. The scrubber slurry is further ammoniated in a preneutralizer so that the slurry within the preneutralizer has an N:P mole ratio of 1.45:1 and a temperature of 118°C. The preneutralizer is operated at the boiling point; at this temperature the specific gravity of the slurry is about 1.5.

Data shown in the curve of figure 3 indicate that at this N:P mole ratio the partial pressure of water above the saturated solution in the preneutralizer should be high; whereas, the partial pressure of ammonia

remains relatively low. Unfortunately, the preneutralizer is usually operated in a near-equilibrium state. Only enough exhaust gas is withdrawn from it to insure that there is no loss of ammonia into the surrounding area. Larger quantities of water could be exhausted from the preneutralizer if air were blown into it. The partial pressure of water vapor above the saturated solution in the preneutralizer at 118°C was calculated to be about 720 mm Hg using the formula established by D. A. Kruglov, et al of the Ivanov Institute of Chemical Technology in the USSR (7). Partial pressure of ammonia above saturated solution at this temperature is about 40 mm Hg. Therefore, if air were passed through the preneutralizer relatively large quantities of water could be removed without adversely affecting ammonia loss from the plant since the exhaust gas from the preneutralizer is scrubbed with phosphoric acid. In this way it should be possible to use phosphoric acids containing <40 percent P_2O_5 without adversely affecting the plant production rate; and some of the energy required to concentrate the acid from filter grade containing 28-30 percent P_2O_5 to medium strength acid containing 40-45 percent P_2O_5 could be avoided. One objection given to the use of a forced-air blower to pass air into the preneutralizer has been fear of entrainment loss from the preneutralizer.

Probably a more convenient means of using high partial pressure of water in the saturated solution is to use a pipe reactor such as the TVA-PCR as a preneutralizer and install this reactor inside the granulator. By using a preneutralizer of this design it is possible to spray the hot slurry across an air stream that passes through the granulator. This equipment arrangement is shown in figure 4. Other companies are considering the use of a forced-air blower to pass air into the feed end of the granulator. This design is shown in figure 5. The large center support beam used to hold the ammonia spargers in the granulator is also used as a duct to convey forced air into the granulator.

The PCR is usually operated at an absolute pressure of 2 to 5 atmospheres. At the higher pressures the partial pressure of water above the saturated solution in the PCR is substantially higher than when the reactor is operated at atmospheric pressure. When melt is discharged from the reactor, partial pressure of the water vapor in the melt is an average between the partial pressure at atmospheric pressure and at the elevated pressure within the reactor. Therefore, the potential for removing more water from the melt and granules is greater when the pressure-type reactor such as the PCR is used. The one U.S. company using the PCR for producing DAP has fabricated the reactor from type 316L stainless steel common pipe fittings. The reactor is shown in figure 6. It was originally made of 25.4 centimeter pipe. It was later altered so that most of the pipe was 15.2 centimeter in diameter with a 10.2 centimeter circular pipe discharge. The granulator is 3.4 meters in diameter and 7.6 meters long.

The plant has a throughput capacity of about 454 tonnes per hour. The flow diagram for the process is the conventional one and is similar to that shown in figure 1. In a production test a rate of 89 tonnes per hour was maintained for several days. Results from this test are shown in table 3.

Weak phosphoric acid containing 30 percent P_2O_5 was fed to the scrubber along with some medium strength acid containing 42 percent P_2O_5 . Average strength of the acid fed to the scrubber was about 38 percent P_2O_5 . This scrubber slurry was fed both to the preneutralizer and to the PCR. Calculations show that about 23 percent of the total production was made by the PCR and the remainder was made through use of the preneutralizer. The proportions of phosphoric acid fed to the scrubber and to the preneutralizer resulted in an N:P mole ratio of 0.80:1 in the scrubber slurry. Ammonia was added to the preneutralizer and to the PCR. The average recorded feed rates showed that the N:P mole ratio of the slurry from the preneutralizer and PCR should be about 1.46:1. Chemical analysis of grab samples of this slurry shows the mole ratios to be somewhat higher than the desired ratios. Temperature of the slurry from the preneutralizer was $125^{\circ}C$ and from the PCR $160^{\circ}C$ at 3.47 atmospheres gage pressure. Because the reactor is operated under pressure, it is possible to increase heat content of the melt discharged from the reactor as compared to the slurry sprayed from the preneutralizer.

The plant operated well under these conditions and a nominal 18-46-0 DAP was produced which had good particle size distribution and excellent hardness. The recycle:product weight ratio in this test appeared to be substantially less than the 5:1 recycle ratio normally required in DAP plants. Moisture content of the product from the granulator was only 2.9 percent, which is significantly less than the 4 percent moisture normally obtained for this product when the conventional DAP process is used (8). Unfortunately there was low airflow through the granulator during this test. However, in spite of this adverse condition, this company has experienced an increased production rate from about 1,633 tonnes per day before the PCR was installed to about 2,178 tonnes per day after its installation. It is believed that although the PCR operation does not account for all of the increased production rate, it is the major reason. Also the company reports some savings in the amount of fossil fuel required to dry the product.

IMPROVED DRYING EFFICIENCY

There are many design criteria for rotary dryers and coolers normally used in U.S. plants producing ammonium phosphates. In this paper, however, we discuss optimum operating conditions and alterations that can easily be made to improve drying efficiency.

Some companies producing ammonium phosphate have found it advantageous to use exhaust gases from the cooler as secondary air to the dryer. A flow diagram of a plant using this system is shown in figure 7. Exhaust gases from the dryer can be either filtered in a bag filter or passed through a scrubber. When the bag filter is used the exhaust temperature from the dryer must be high enough to insure that the gas remains above its dew point when passing through the bag filters. Some companies pass the air from granulators through the dryer. In these instances the amount of water added to the granulator is kept as low as possible. This procedure may not be practical for plants producing ammonium phosphate.

The retention time is sometimes low in dryers used to dry ammonium phosphate. In some instances it is as low as 6 minutes. Pilot plant data have shown that in drying ammonium phosphate fertilizers, retention time in the dryer should be 20 minutes (9). A 20-minute retention time may not be practical, but most design engineers associated with the U.S. fertilizer industry agree that this retention time should be between 10 and 20 minutes. Some companies have increased retention time in rotary dryers and coolers by installing larger retaining rings at the discharge end of the rotary equipment. One other important factor to improve drying efficiency is to maintain a desirable velocity of the drying gas through the dryer. Pilot plant and commercial plant results show that the optimum velocity of air through a dryer should be about 2 meters per second. At this velocity there should be a good drying efficiency without excessive dust losses.

SUMMARY

Optimum use of energy in the fertilizer industry has become increasingly important because of the dramatic increase in its cost. These energy costs will continue to increase. Some ways of improving the efficiency and use of energy in the manufacture of granular ammonium phosphate (MAP and DAP) are:

1. Use pressure reactors such as the TVA-PCR for ammoniating phosphoric acid. By using the pressure reactor it is possible to increase the energy level of the ammonium phosphate slurry as it is pumped into the reactor.
2. Increase airflow through the granulator. This increased flow should help to lower the moisture content of the product from the granulator. Therefore, less fossil fuel is required to dry the product.
3. Increase retention time and airflow through rotary dryers and coolers. The optimum practical retention time in rotary dryers and coolers is between 10 and 15 minutes. The optimum air velocity is about 2.1 meter per second.
4. Use cooler exhaust gas as secondary air to the dryer. In this way the sensible heat of the cooler exhaust can be used.

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Table 1

Production of Monoammonium Phosphate
Using the TVA-Type Pipe-Cross Reactor (PCR)
and Merchant-Grade Phosphoric Acid (52-57% P₂O₅)

<u>Test Number</u>	<u>1^a</u>	<u>2^b</u>	<u>3^c</u>
Grade	11-53-0-2S	11-53-0-2S	12-48-0-5S
PCR diameter, cm	15.2	20.3	15.2
PCR length, m	3.05	5.49	3.05
Production rate, tonnes/hr	22.7	22.7	25.0
Formulation, kg/tonne			
PCR			
Anhydrous ammonia	73.0 ^d	100 ^d	138 ^a
Phosphoric acid ^f			
52.5% P ₂ O ₅	765	-	944
57.0% P ₂ O ₅	-	837	-
Sulfuric acid			
93% H ₂ SO ₄	42	35	-
96% H ₂ SO ₄	-	-	64.5
Water (to PCR ammonia sparger)	25	30	44
Scrubber liquor to PCR	NM ^g	NM ^g	45
Total water to PCR (calculated)	-	-	237
Granulator			
Anhydrous ammonia	64.5	37.5	-
Phosphoric acid			
52.5% P ₂ O ₅	252.4	-	-
PCR Operating Conditions			
Temperature, °C	129	127	132
Heat flux, kcal/hr.cm ²	11,718	9,843	60,157 ^h
Ammonia loading, gNH ₃ /hr.cm ³	30	13	61
N:P mole ratio	0.6	0.77	1.0
Granulator Operating Conditions			
Recycle rate, tonnes/hr	86.2	72.6	72.6
Recycle ratio,			
tonnes recycle/tonne product	3.8	3.2	2.9
N:P mole ratio	1.0	1.0	1.0
Airflow,			
estimated across bed, m ³ /min	198.2	198.2	-
Air velocity m/sec	0.91	0.76	-
pH fertilizer	4.0	3.9	4.0
Moisture	-	-	2.9
Dryer Fuel Requirement, kcal/tonne	27,201	0	0 ^j
Scrubber, pH	4.0-5.0	4.0-5.0	3.5-4.0
Product Chemical Analysis (%)			
N	11.2	11.4	10.2 ^k
P ₂ O ₅	53.4	52.8	45.8
Al ₂ O ₃	1.6	-	-
Fe ₂ O ₃	1.6	-	-
F	0.3	-	-
S	2.5	-	-
H ₂ O	1.0	1.6	1.14
Screen Analysis (%)			
+6	0.3	0	-
-6 +14	96.7	93.1	-
-14 +16	98.7	98.7	-
-16	100.0	100.0	-
Average Crushing Strength, kg	4.49	-	4.44

a. 2.4 x 4.9 meters granulator Ohio U.S.A.

b. 2.7 x 6.1 meters granulator Missouri U.S.A.

c. 2.7 x 11.0 meters granulator Sweden

d. Ammonia at room temperature

e. Ammonia at -33°C Sp Gr 0.62

f. Produced from Florida phosphate rock

g. Not measured

h. 10 cm insert in discharge end of PCR

i. Assume only 70% granulator cross-section available for airflow

j. Pilot burner on low fire

k. Grade low because recycle contained superphosphate

Table 2

Production of Monoammonium Phosphate Sulfate Using TVA
Pipe-Cross Reactor and Medium Strength Phosphoric Acid (40-50% P₂O₅)

<u>Test Number</u>	<u>4</u>
Production rate, tonnes/hr	22.7
Grade	16-20-0-13S
Granulator size, D x L, m	3.05 x 6.1
PCR diameter, cm	15.2
PCR length, m	6.1
Formulation, kg/tonne	
PCR	
Phosphoric acid ^a (43.5% P ₂ O ₅ , 30% H ₂ O)	394
Byproduct ammonium sulfate liquor (7% N, 8% S, 67% H ₂ O)	215
Sulfuric acid (93% H ₂ SO ₄)	462
Ammonia	182
Water	88
Scrubber seal tank slurry (60% H ₂ O)	70
Total water PCR (calculated)	424
Granulator	
Weak acid slurry (23% P ₂ O ₅ , 25% CaSO ₄ , 43% H ₂ O)	132
Ammonia	16
PCR Operating Conditions	
Temperature, °C (skin temperature)	127
Total, kcal/tonne	267,509
Ammonia loading, gNH ₃ /hr.cm ³	20
Slurry to PCR, N:P mole ratio	0.4
Melt from PCR, N:P mole ratio	1.0
Granulator Operating Conditions	
Temperature material, °C	93
Recycle rate, tonne/hr	86.2
Recycle ratio	3.8
Granulator	
N:P mole ratio	1.0
Airflow, m ³ /min (estimated across bed)	425
Air velocity, m/sec	1.4
pH	4.8
Electricity, kcal/tonne	88,000
Dryer fuel, kcal/tonne	56,000
Dust loss from granulator, kg/hr	104.3
% of total product/hr	0.46
Ammonia loss from granulator	
kg/hr	421.8
% of total NH ₃ in process ^c	9.4

a. Via scrubber

b. Premixed with ammonia in ammonia sparger

c. Recovered by phosphoric acid in scrubber

Table 3

Production of DAP using PCR and Preneutralizer

<u>Test Number</u>	<u>5</u>
Production rate, tonnes/hr	89
Formulation, kg/tonne product	
<u>To Scrubbers</u>	
Weak phosphoric acid (27.1% P ₂ O ₅)	462
Strong phosphoric acid (44.2% P ₂ O ₅)	783
Calculated acid strength, % P ₂ O ₅	19
<u>To Preneutralizer</u>	
Scrubber liquor (N:P mole ratio 0.80)	970
Ammonia (gaseous)	61
<u>To PCR</u>	
Scrubber liquor (N:P mole ratio 0.80)	287
Ammonia (gaseous)	19
Calculated % total production for PCR	23
Production rate PCR	20
<u>To Granulator</u>	
Ammonia (gaseous)	61
Operating Results	
<u>Preneutralizer</u>	
N:P mole ratio	1.46 ^a (1.60) ^b
Temperature slurry, °C	125
Sp Gr slurry	1.57
<u>PCR</u>	
N:P mole ratio	1.46 ^a (1.54) ^b
Temperature melt, °C	160
Pressure, atm gage (psig)	3.47
Sp Gr	1.54
<u>Granulator</u>	
N:P mole ratio	1.73 ^a (1.92) ^c
Material discharge temperature, °C	100
<u>Calculated Results</u>	
Recycle ratio (from screen analysis)	
tonnes recycle/tonne product	2.0
Heat flux PCR, kcal/hr.cm ²	5,273
Ammoniating volume gNH ₃ /hr.cm ³	11.1

- a. Obtained by titration during operation (average)
b. Based on chemical analysis of sample
c. Chemical analysis of composite sample

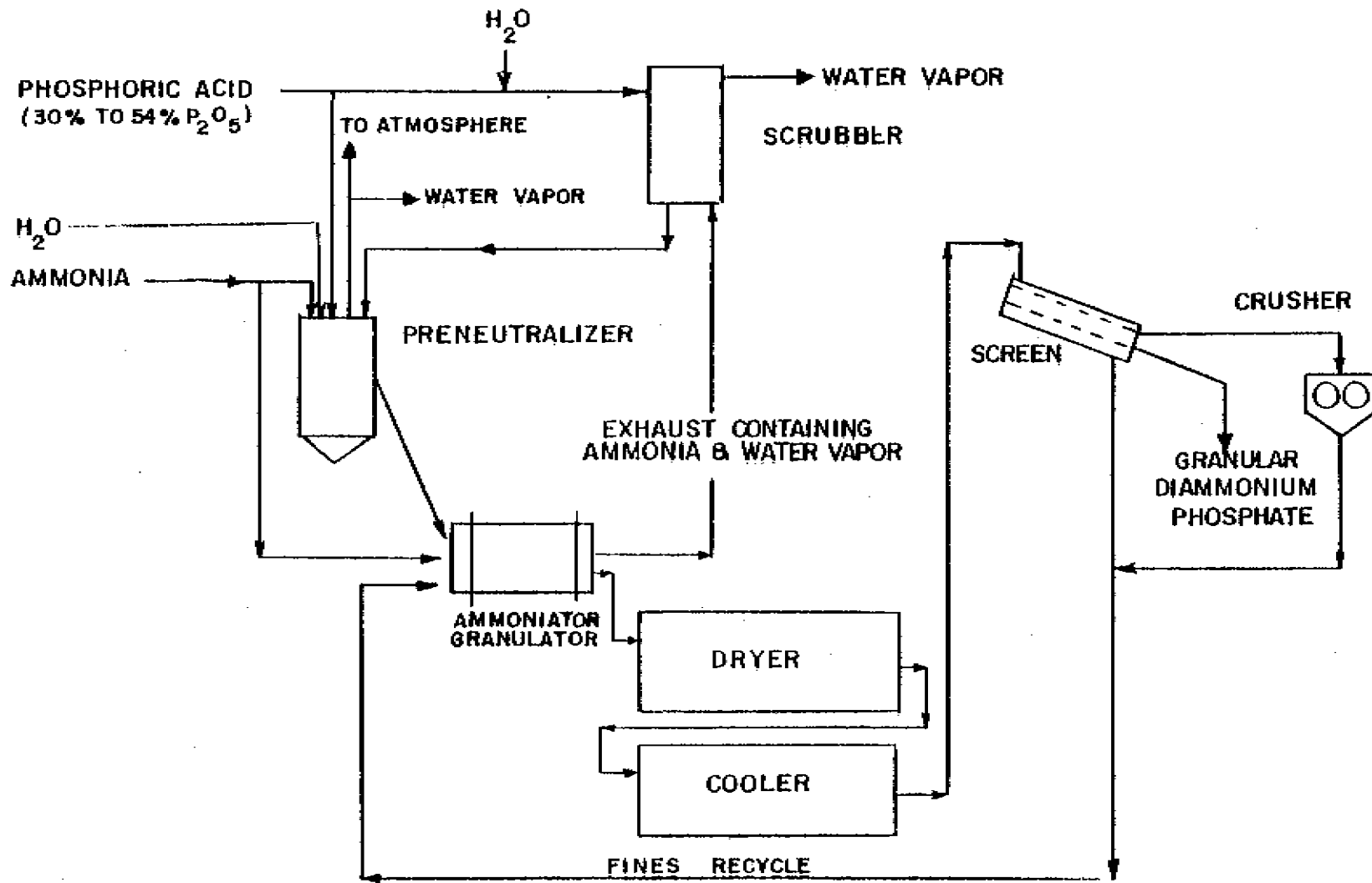


FIGURE 1
 FLOW SHEET OF CONVENTIONAL PROCESS FOR PRODUCTION OF
 GRANULAR MONOAMMONIUM OR DIAMMONIUM PHOSPHATE

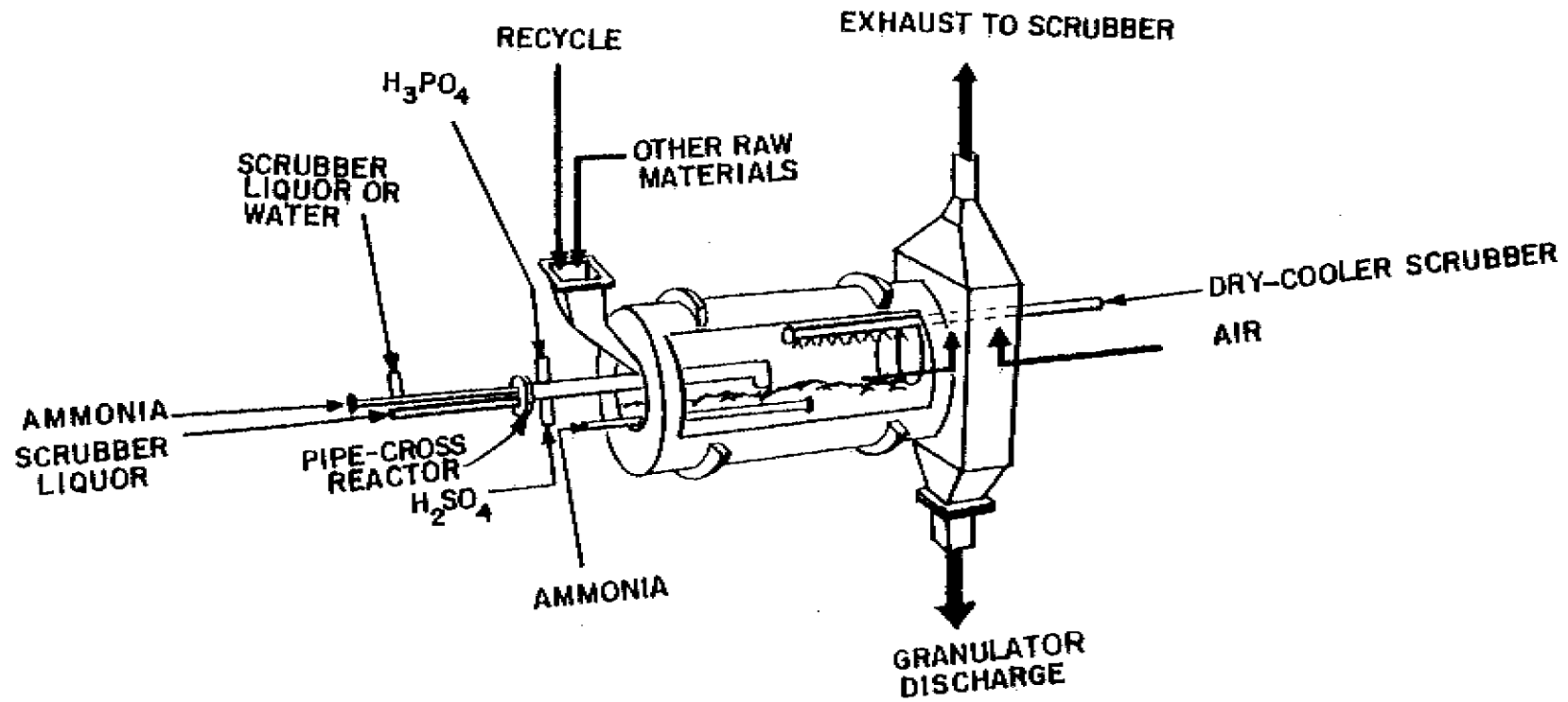


FIGURE 2
PIPE-CROSS REACTOR FOR GRANULATION PLANTS

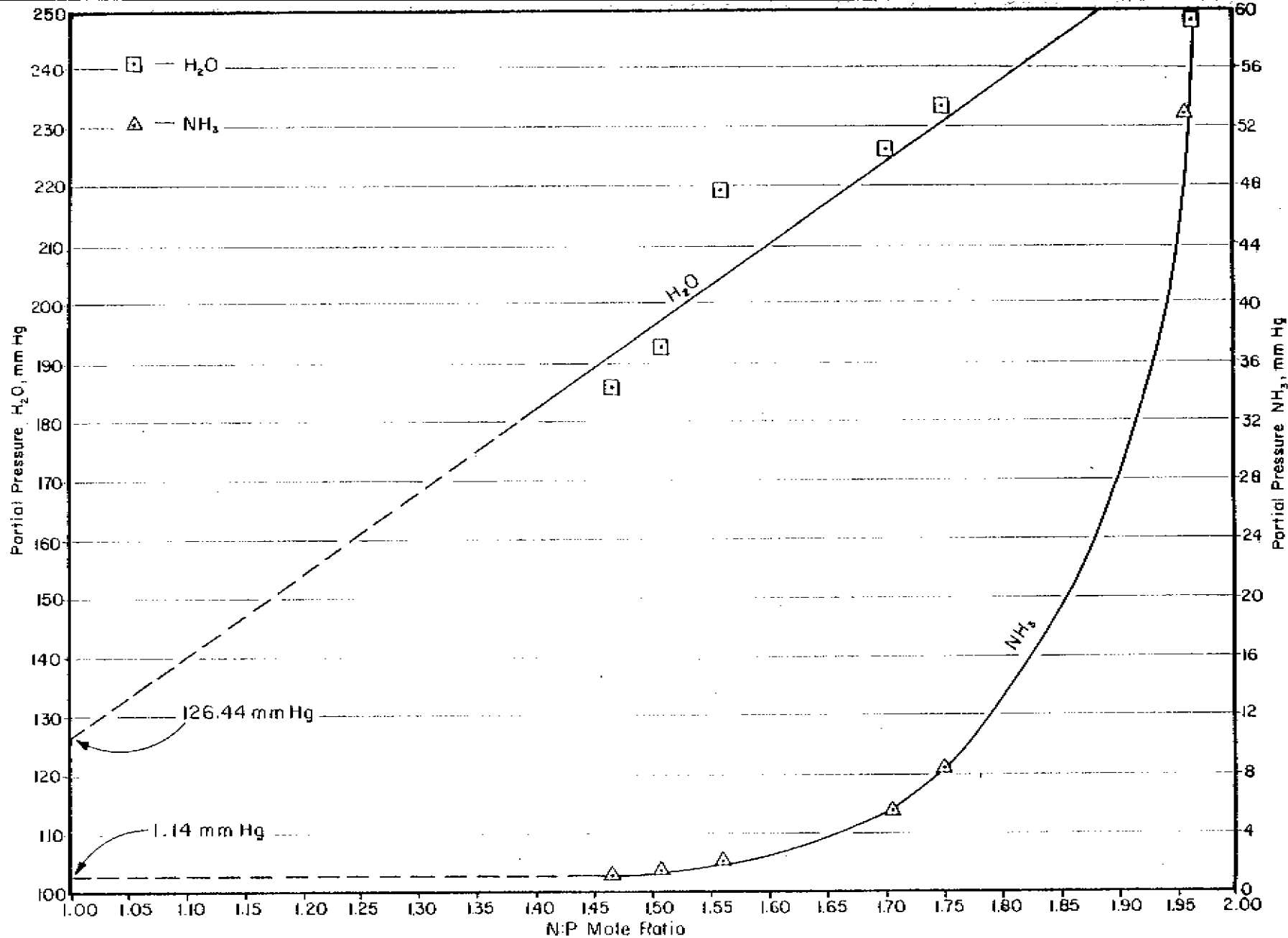


FIGURE 3
 PARTIAL PRESSURES of H₂O and NH₃ vs. N:P MOLE RATIO
 for AMMONIA-PHOSPHORIC ACID WATER SYSTEM (75°C)

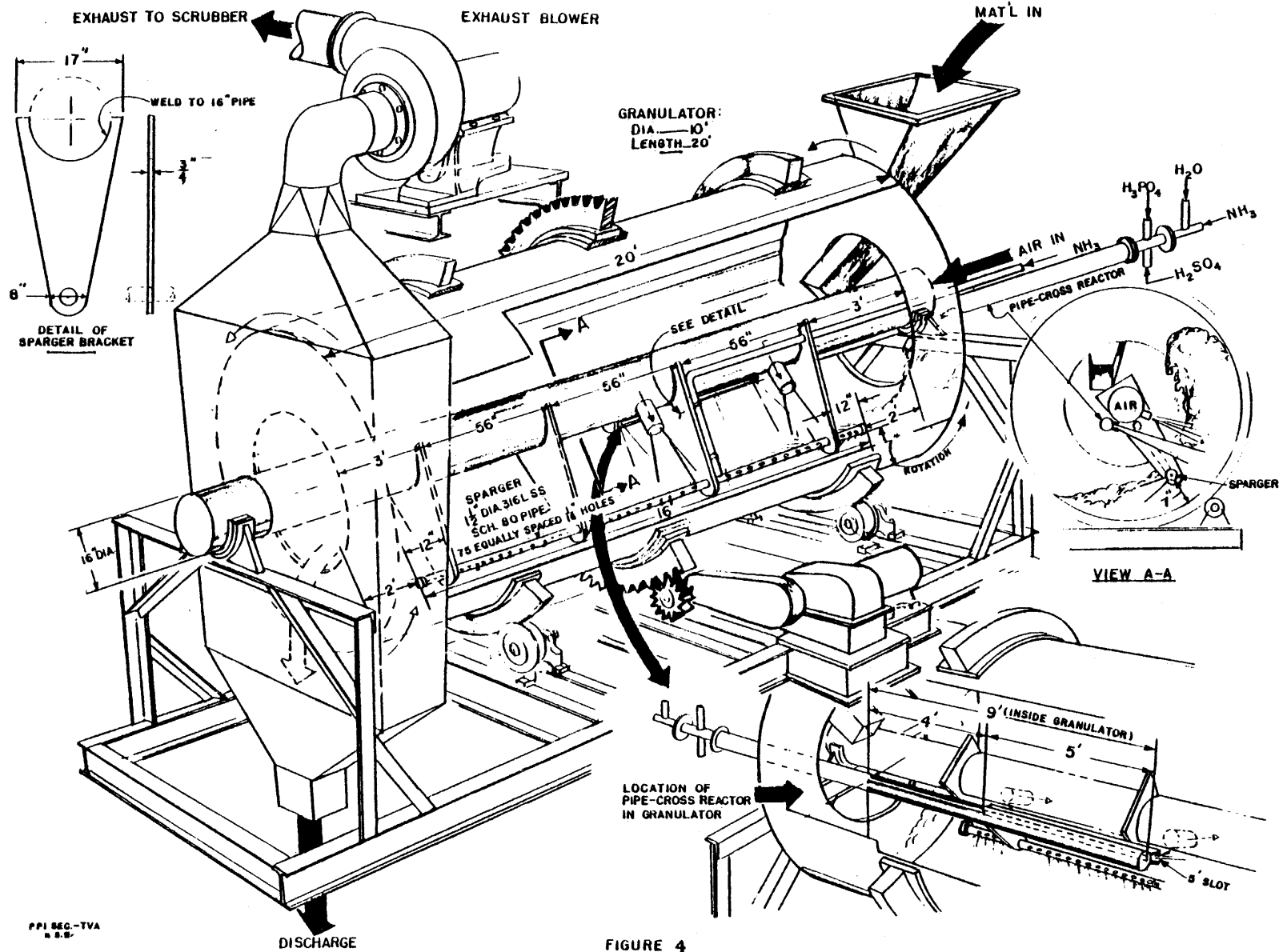


FIGURE 4

AMMONIATOR GRANULATOR WITH INCREASED AIR FLOW THROUGH GRANULATOR WITH 1 1/2" NH₃ SPARGER

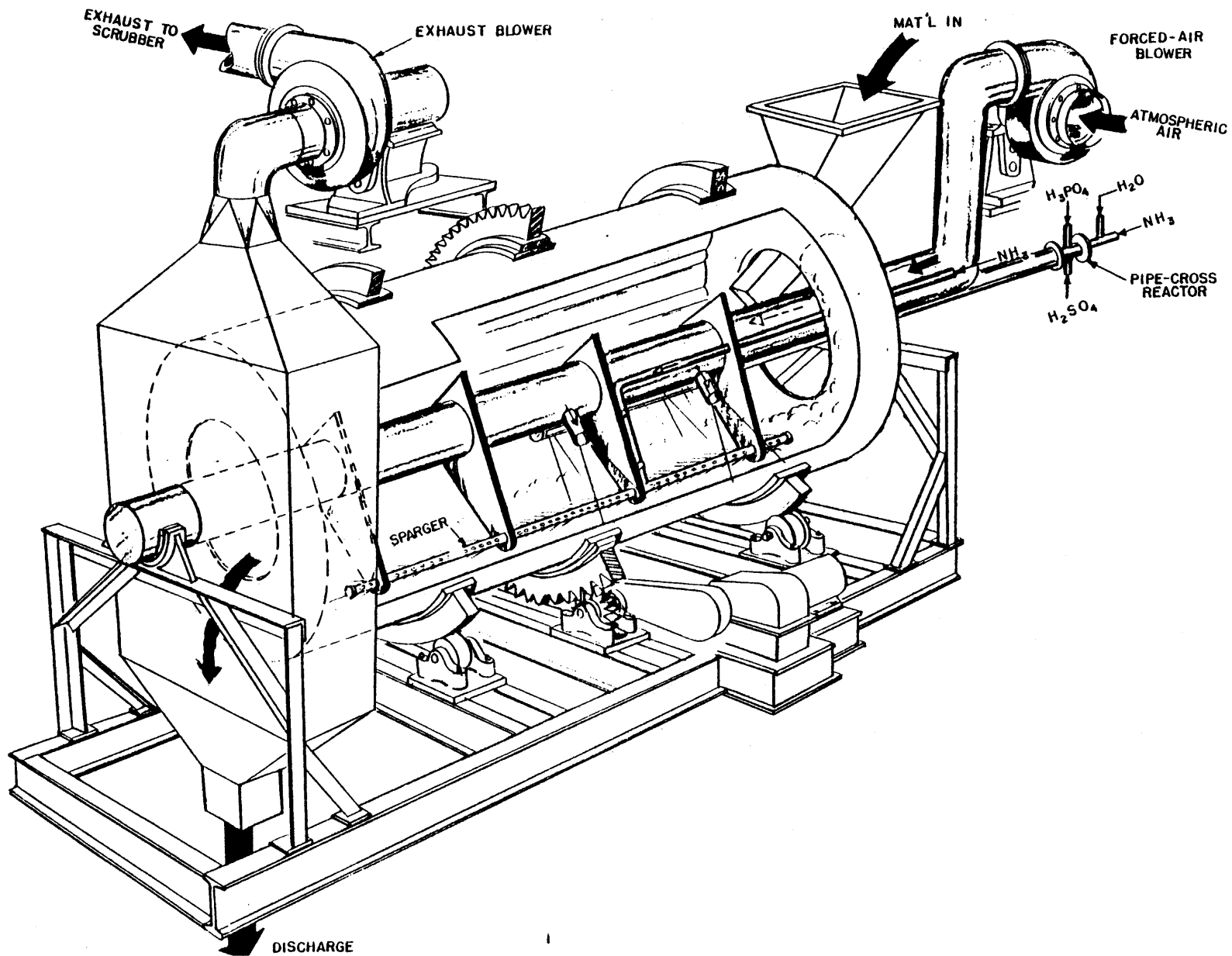


FIGURE 5
AMMONIATOR-GRANULATOR WITH FORCED-AIR BLOWER

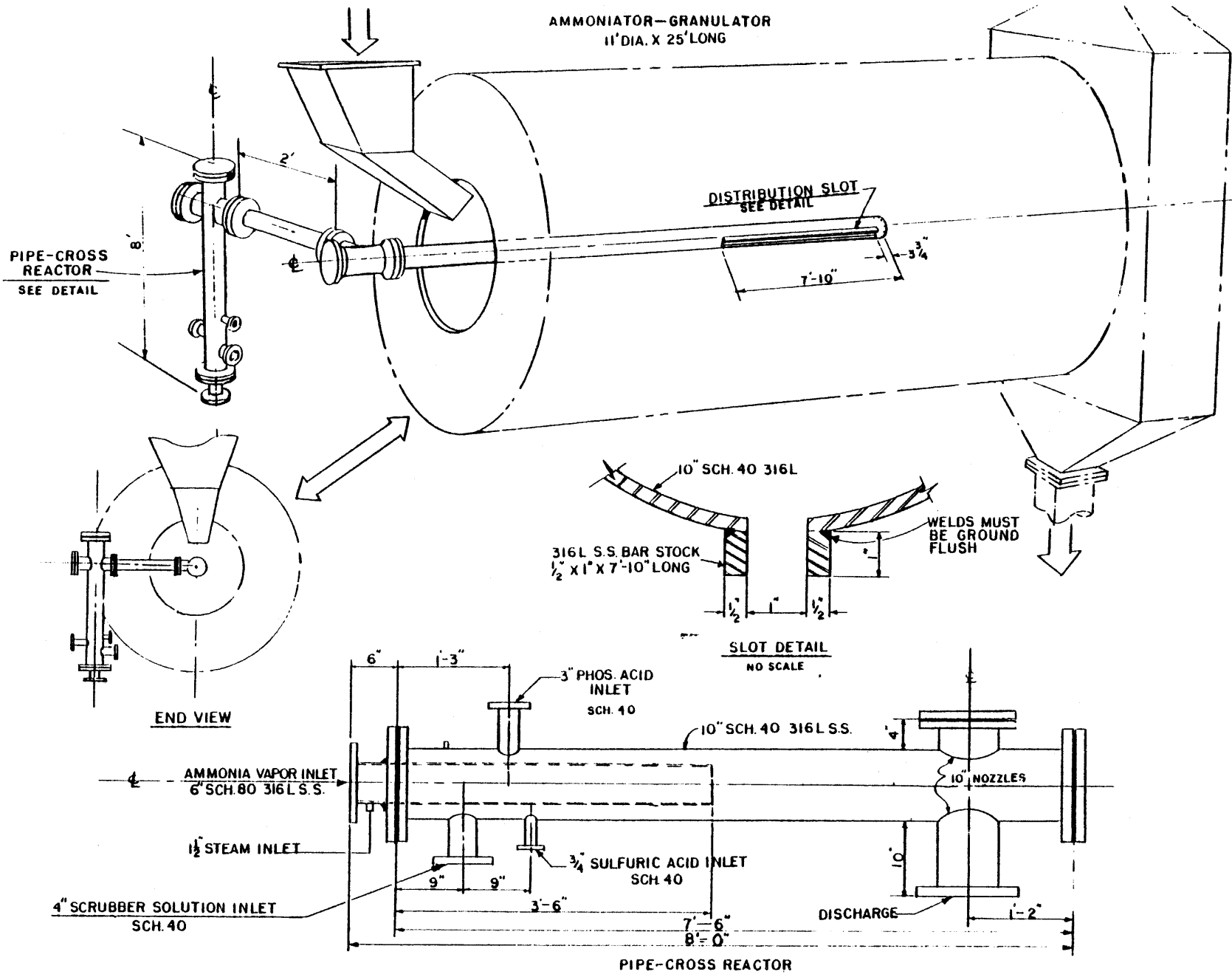
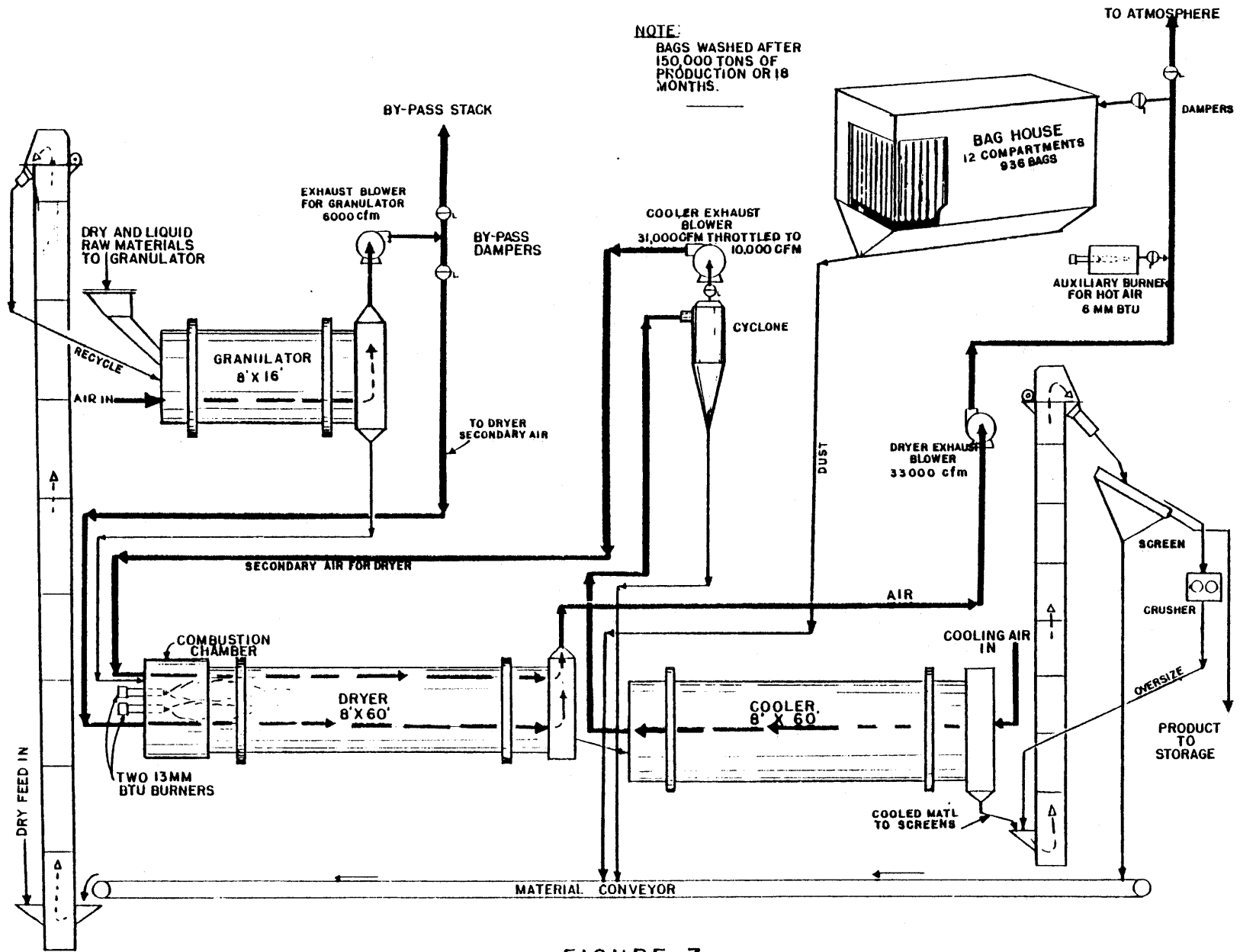


FIGURE 6
PIPE-CROSS REACTOR
DAP PRODUCTION TEST



NOTE:
 BAGS WASHED AFTER
 150,000 TONS OF
 PRODUCTION OR 18
 MONTHS.

FIGURE 7
 EXHAUST GAS FILTERING SYSTEM OF TYPICAL AMMONIATION-GRANULATION PLANT

TA/82/5 Optimizing use of energy in the production of granular ammonium phosphate fertilizer, by F.P. ACHORN, D.G. SALLADAY, (Tennessee Valley Authority, USA)

DISCUSSION : (Rapporteur : P. BECKER, COFAZ SA, France)

Q - Mr. K.J. BARNETT, Norsk Hydro Fertilizers Ltd, United Kingdom

The paper describes how 41 centimeter support beam is used to duct cold air through the granulator. Has there been any attempt to channel the cold air towards the rolling bed?

A - Yes, through drilling holes to face the bed and with the use of the TVA-PCR and additional air flow we were able to increase the production rate of a 16-20-0 grade from 400 (with preneutralizer) to 600 tons per day (with PCR).

Q - Mr. P. CHINAL, Générale des Engrais SA, France

On figure 2, wash liquor is to be introduced at 2 different places of the pipe reactor. What are the reasons?

A - A small amount of scrubber liquor or fresh water is added directly to the anhydrous ammonia sparger to help the reactor operate smoothly with a minimum of vibrations and ammonia loss. The other quantity of scrubber liquor is added to help control temperature of the melt within the reactor.

Q - Mr. J.Th. BOONTJE, UKF, The Netherlands

Have you made some calculations about the amount of water actually being evaporated in the acid scrubber?

A - We have always assumed that the scrubber operated adiabatically. Therefore, any water that enters the scrubber is evaporated and discharges from the stack of the scrubber. In actual practice we find no difficulty with the water balance around the scrubber and granulator. This is probably because some ammonia is lost from the granulator and the scrubber functions as a first-stage reactor.

Q - Mr. Y. COTONEA, Générale des Engrais SA, France

Don't you have problems with the granulator exit air flume? Don't you have excessive condensations?

A - We have experienced some condensation of water from exit gases from the granulator. This condensation has not caused any problems. Air sampling tests show there are entrained droplets of water in the exit gases from the granulator which carry over into the scrubber. These calculations show that in some instances the exhaust gases are saturated 165% of total saturation. However, the steam and water convey some heat to the scrubber and some heat is added to the scrubber by neutralization of the ammonia loss from the granulator. Therefore, about the same amount of water is lost from the scrubber as is conveyed to it from the granulator.

Q - Mr. P. NIEHUES, Uhde GmbH, Germany

Although TVA has been publishing for a long time that the production of DAP is possible with the pipe reactor there is no plant through-out the world according to our investigations that produces DAP exclusively according to the TVA pipe reactor process.

In case of the plants in the USA only 23% are produced by means of the pipe cross

reactor. The plant in Australia is obviously run more humid and thus no energy is economized (please refer to proceedings of the 27th annual meeting Fertilizer Round Table 1977, discussion on page 81).

What are the reasons for the fact that no producer has decided up to now to build a new DAP-plant acc. to the TVA PCR process? Even the new plants of Grace and IMC having been put into operation this year were again built with a pre-neutralizer.

Has the blockage problem of the PCR which mainly occurs in case of a higher mol. ratio, i.e. when producing DAP, been solved?

- A - I believe all three questions concerning the utilization of the TVA pipe-cross reactor for the production of diammonium phosphate relates to its acceptance by the fertilizer industry. TVA recognizes the fact that this process has not been accepted by the diammonium phosphate industry and we do not have a good reason for this non-acceptance. We have enough pilot plant data to show that through the use of the pipe-cross reactor it is possible to conserve some energy in the production of diammonium phosphate. These data and data from one plant indicate that through the use of the PCR it also may be possible to increase production rate of the plant. Further, it is believed that because of low retention time in the PCR it is possible to produce a granular DAP of low citrate insoluble P_2O_5 content as compared to those products using a preneutralizer process.

A second question relates to the blockage problems of the PCR. The one commercial firm that now uses the PCR in combination with a preneutralizer reports they no longer encounter problems with PCR blockage if it is cleaned periodically using a mixture of steam and ammonia. This is accomplished by using the correct shut-down procedure for the PCR, namely shutting off the acids prior to the ammonia. Before the ammonia addition is discontinued steam is mixed with the ammonia for a short period of time. Then the ammonia and condensed steam are allowed to remain in the pipe for several hours. At the end of this period the scale that has formed in the reactor will be easily blown from it when it is again reactivated. This cleaning is usually accomplished during the weekly turn-around period that these plants take for maintenance purposes.

- Q - Mr. E. AASUM, Norsk Hydro, Norway

For DAP, what is the expected minimum water content in the melt fed into the granulation before particle size formation will determine the recycle ratio?

- A - The minimum water content is usually about 10% when the PCR is operated in the DAP mode. At this water content the recycle ratio was calculated to be about 2.0:1 pounds recycle per pound product.

Pilot plant data show that through the use of the PCR it is possible to produce DAP with a recycle ratio of 2:1.

- Q - Mr. N. KOLMEIJER, Windmill Holland, The Netherlands

Is it really possible to introduce scrubber liquor in a pipe reactor when making chloride containing NPK?

Is there not too much corrosion?

- A - Yes, we have used scrubber liquor into the PCR. These PCR are made of HASTELLOY C 276 which resist corrosion by chlorides. Probably one of the reasons is the chlorides are in the form of ammonium chloride because the reactor is operated at a N:P mole ratio of 1.0 and the scrubbers are operated at a pH of 5.0.

Q - Mr. J.D. CRERAR, Norsk Hydro Fertilizers Ltd, United Kingdom

In table 3, you give a recycle ratio of 2.0. How can this be compatible with the declared output of 89 t/h with a solid circulation of 454 t/h. The recycle ratio is 4.0, I believe.

A - Obviously the full capacity of the circulating load was not utilized. The recycle ratio was calculated from screen analysis of the product from the granulator, dryer and cooler as I indicated in the table.

I have substantiated these results with pilot plant results which show that when the PCR is used the recycle ratio is usually between 2.0 and 3.0 pounds of recycle per pound of product.

Q - Compared with the draft tube pressure neutraliser which operates at up to 2 atmospheres (without an agitator), what are the thermodynamic advantages of the pipe cross reactor?

A - I cannot make the comparison because I am not aware of a draft tube reactor.