O-180

O-180
AN-7189
RR-3142

STATUS OF NPKS AMMONIATION-GRANULATION PLANTS AND TVA PIPE-CROSS REACTOR

For Presentation at the
Fertilizer Industry Round Table
Atlanta, Georgia
October 28-30, 1980

by
David G. Salladay, Chemical Engineer
and
Carl A. Cole, Jr., Chemical Engineer
Process and Product Improvement Section
Division of Agricultural Development
National Fertilizer Development Center

TENNESSEE VALLEY AUTHORITY
Muscle Shoals, Alabama

STATUS OF NPKS AMMONIATION-GRANULATION PLANTS AND TVA PIPE-CROSS REACTOR

The number of ammoniation-granulation plants producing homogeneous NPKS granular fertilizer dropped during the 1970's and there are many opinions concerning the status and future of this aspect of fertilizer production. During summer 1980 TVA surveyed these plants to document their current status and to confirm or change previous TVA estimates of the number of operating plants and the total annual tonnage produced. Previous TVA lists of NPKS granulation plants were updated by means of letters of inquiry to and telephone conversations with the plant production supervisors. About 90 percent of these company personnel contacted were able to provide their plant production tonnages.

The survey showed that during the last year 107 granulation plants operated by 37 companies produced 8.5 million tons of homogeneous NPKS granular fertilizers. Idle granulation plants for sale are not included in this total. Annual production of individual plants ranged from 13,000 to about 300,000 tons. Most of these plants are what TVA terms "regional" NPKS granulation plants as shown in figure 1 with 8-ft diameter by 16-ft long ammoniator-granulators, about 60 tons/hour recycle capacities, and about 30 tons/hour production rates. A few of the plants surveyed, however, have larger ammoniator-granulators, about 11-ft diameter x 22-ft long, with production rates of 60 to 75 tons/hour. This total of 8.5 million tons/year is only homogeneous NPKS granular fertilizer. Any normal superphosphate (NSP), concentrated superphosphate (CSP), monoammonium phosphate (MAP), or diammonium phosphate (DAP) produced by these 107 surveyed plants, or other plants at their locations, were excluded. By comparison to this NPKS total, TVA estimates annual production of these other fertilizers to be 9.4 million tons of DAP, 1.5 million tons of MAP, 4.0 million tons of CSP, and 1.5 million tons of NSP (1). The most popular grades produced are 6-24-24, 10-10-10, 13-13-13, 5-10-15, 10-20-20, 12-12-12, 3-9-18, and 3-9-9. Average annual production at an NPKS granulation plant is 81,000 tons. This average tonnage appears to have been increasing over the past decade, as a smaller number of plants have maintained about the same total annual production. Maximum annual capacity for a "regional" granulation plant having an 8-ft diameter x 16-ft long ammoniator-granulator is about 160,000 tons when routine maintenance and the summer turnaround are considered.

Table 1 shows locations of these plants by states. Twenty-seven states have NPKS ammoniation-granulation plants; 84 percent of these plants are east of the Mississippi River. Table 1 also shows which plants have installed pipe-cross reactors (PCR's). As of September 1980, 23 PCR's had been installed in NPKS granulation plants. Fifteen companies have installed PCR's in one or more of their plants; this is 40 percent of the companies operating NPKS granulation plants. About eight more PCR installations are planned or almost completed. These PCR's have produced millions of tons of product and provided extensive operating experience. The following is a review of the most significant results.

Design and Operation of the Pipe-Cross Reactor

Figures 2 and 3 show current PCR designs and the sleeve insert for the discharge end. Figure 4 shows location of the PCR in an ammoniator-granulator. Many producers are having the entire PCR fabricated of Hastelloy C-276 to ensure almost no corrosion problems during the PCR's life. Without sleeves a PCR has a normal operation range of only 1 to 2 (300,000 to 600,000 Btu/hr-in^2 heat flux). A 6-inch diameter PCR with a 4-inch removable sleeve has an operating range of 1 to 4.5. These sleeves also seem to result in more complete reaction of acids and ammonia. Some producers report lower ammonia losses when this sleeve is used, and the sleeve results in a better spray pattern onto the bed of solids in the granulator. Normal design recommendation for a typical NPKS granulation plant is a 6-inch diameter Hastelloy C-276 PCR with 5-inch and 4-inch inside diameter type 316L stainless steel sleeves for insertion in the discharge. Since nearly all acid has reacted by the time the reactants reach the discharge of the PCR, the stainless steel sleeves show almost no erosion-corrosion after 100,000 tons of production. Figure 5 shows such a sleeve after more than 50,000 tons of production.

Other design details and operating parameters of the PCR have been successful in field operation. For example, if the recommended heat flux range and melt temperature of less than 300°F are maintained along with adequate phosphoric acid in the raw material feeds to the PCR, the Hastelloy C-276 reaction tube can produce at least 500,000 tons of product. A PCR operated in this manner in one plant produced this amount before being installed for continued use in one of the company's other plants. When reinstalled, this PCR showed no significant erosion-corrosion.

The erosion-corrosion rate of the PCR seems to accelerate as the melt temperature increases above 300°F, the amount of sulfuric acid in the feed increases above 50 percent, and the heat (of reaction) flux increases above 600,000 Btu/hr-in^2.

Resistance of Hastelloy C-276 to acid attack drops sharply above 300°F and the manufacturer does not recommend the alloy for use above 300°F. Although this alloy is expensive, there may be cost savings by using cheap byproduct raw materials such as sulfuric acid. Replacing the PCR after only

75,000 or 100,000 tons of production may be economically inconsequential when compared to several dollars per ton savings in raw materials cost. A 6-inch diameter x 10-foot long PCR reaction tube replaced after every 100,000 tons of production still costs only 10 or 11 cents per ton of product.

More producers are adding all of the ammonia to the PCR. Although a more angular-shaped product results, ammonia losses are lower. One producer using the sleeve, the 5^{o} incline of the PCR, and all of the ammonia fed to the PCR loses only 1 to 2 percent of the NH_3 fed in production of 8-24-24 grade product.

Reducing Dryer Fossil Fuel Heat and Electrical Requirements

The savings in fossil fuel heat input to dry fertilizer granules vary from one PCR installation to another. Some producers have completely shut off the burners in their dryers. Others have saved only about half of this heat input since the critical relative humidities of fertilizers produced must not be approached in their baghouses. TVA estimates that an average of about 80 percent of fossil fuel heat input to the dryer for conventional granulation has been saved by using PCR's.

Although plant electrical consumption per ton of product usually is about the same for either conventional or PCR melt granulation, in some cases the PCR has dramatically increased the plant's production rate. At one midwestern ammoniation-granulation plant, the PCR increased production of 6-24-24 grade from 25 to 38 tons per hour. If dryer capacity limits production in a conventional granulation plant, then PCR-melt granulation can result in such an increase in production rate. Electrical consumption of these NPKS granulation plants is in the range of 300,000 $\pm$ 75,000

Btu/ton of product. If this 50 percent increase in production rate is applied to the midwestern plant, production cost would be reduced by about \$1.45 per ton (assuming an electrical cost of 5 cents per kWh). Savings for production of 50,000 tons of this 6-24-24 grade would be \$72,500.

Production of MAP, 11-53-0-2S, at a Regional NPKS Granulation Plant

Over the past three years a regional NPKS granulation plant has been upgrading its equipment, which includes an 8-ft diameter x 16-ft long ammoniator-granulator with a dam 3 ft from the discharge end. This granulator has a rubber lining and two ammonia sparger-steaming knives extending almost vertically into the bed of solids in the granulator. The plant also contains a 9-ft diameter x 60-ft long dryer with four cyclones and an 8-ft diameter x 54-ft long rotary cooler, also with four cyclones. Recycle capacity of this plant is about 90 tons per hour. Screening and size reduction equipment includes two oversize cagemills, two 4-ft x 15-ft Tyler Hum-Mer screens and a spare fines screen. This plant also has a second rotary cooler for product before it goes to the storage bins. A Hastelloy C-276 PCR which is 6 inches in diameter x 10 ft long has been installed and is designed according to current TVA recommendations. It has a centered sparger for aqua ammonia and a sparger for scrubber liquor located to the side of it on the flange at the feed end. Air flow in the ammoniator-granulator recently has been increased to 11,000 cfm. This exhaust air goes into a Venturi scrubber for ammonia scrubbing. Recycle control by means of a split valve on a product split duct also has been installed.

Raw materials for the granulation plant are supplied by two 30,000 gallon anhydrous ammonia tanks and a heated, sparged, rubber-lined phosphoric acid tank of 1,500 tons capacity. This plant has 21,000 tons of product storage.

During startup of the PCR in this plant, the first grade produced was a 11-53-0-2S produced at 12.5 tons per hour. The 6-inch pipe-cross reactor was equipped with a 4-inch type 316 L stainless steel sleeve in the discharge. This sleeve gave a heat flux of about 380,000 Btu/hr-in^2. The formulation contained 280 lb/ton of anhydrous ammonia, 2,050 lb/ton of 52.5 percent P_2O_5 phosphoric acid, and 78 lb/ton of 66° Bé. sulfuric acid. This particular startup was the most trouble free and easily executed. Company representatives attending this startup were extremely pleased with the initial production run for the 11-53-0-2S grade. The phosphoric acid feed was split 50/50 between the pipe-cross reactor and the ammoniator-granulator bed; later, when the production rate was increased to 16 tons per hour, a 60/40 phosphoric acid split was used. Plant personnel noted that there was far less airborne dust within the plant during these pipe-cross reactor tests than during conventional MAP production using the preneutralizer.

Use of Byproduct Sulfur Sources in the 16-8-8-XS Grade

An increasingly popular grade easily produced with the PCR process is 16-8-8-XS. Table 2 shows three formulations that have been used in commercial plants. These allow for ample use of byproduct sulfuric acid and ammonium sulfate. Although 16-8-8-XS grade formulations normally contain about 15 percent sulfur, fertilizer producers still hesitate to register sulfur content of this or other grades. A specified percentage of sulfur in a grade is a fourth constraint in the nominal grade, which may interfere with least cost programming with available raw materials. However, TVA expects sulfur content of fertilizers to become increasingly important as atmospheric deposits of sulfur compounds onto the land are decreased by air pollution control regulations. Already about 45 percent of sulfur production in the United States is from secondary recovery sources (2). These secondary sources are oil and gas production facilities, but high-sulfur coal in the eastern United States where most of the NPKS granulation plants are located should begin to contribute to this sulfur tonnage in the near future.

PCR Process Advantages over Conventional Bed Granulation

In past publications (3, 4, 5) TVA has reported advantages of the PCR process over conventional bed granulation. Table 3 lists advantages experienced by a fertilizer company that has been using a PCR for about three years. Especially significant are the first and last items on this list. Improved quality of the homogeneous granular fertilizer was directly reflected in a ninety percent decrease in customer complaints over the past year. Figure 6 is a photograph of a conventionally produced and a PCR processed 15-15-15 grade product from a company that recently installed a PCR. The larger-sized dust particles entering the baghouse result in almost 1,000 bags lasting longer than they did during conventional granulation. Probably not as many small particles are abrading the fabric of the bags.

Another advantage often not considered is related to item three. With greater accuracy in formulating with the PCR process, fewer nutrients are given away by exceeding nominal quantities of nutrients in the grade.

Investment Cost and Payback

Installing a TVA pipe-cross reactor in an existing regional NPKS granulation plant is extremely attractive economically. Replacement cost of a typical granulation plant is about $10,000,000, and almost $100,000 per year will be spent on equipment in a properly maintained plant. Thus, investment to retrofit a PCR into one of these plants is relatively small.

Table 4 entitled "Economics for PCR Installation" (6) shows energy savings, investment costs, and payback times. This typical PCR installation cost about $60,000. At late 1979-early 1980 prices, the PCR itself cost about $10,000. Normally an extra $50,000 is required for pumps, piping, meters, and valves. Since these installations are retrofits, exact equipment needs vary.

Payback time will normally be less than one year as shown in table 4. This payback is calculated on the basis of eliminating steam and reducing fossil fuel drying from the granulation process. A conservative natural gas price of $2.68 per 1,000 cubic feet was used. If increased production rates reduce electrical consumption per ton of product, as discussed previously, or cheap byproduct raw materials can be used with the PCR, payback times of 3 to 4 months are obtained. Under such circumstances, many companies choose to add other needed capital investment to PCR projects. In some cases several hundred thousand dollars can be attached to the PCR installation project before the company's minimum acceptable return on investment is reached. In some cases installation of the PCR has significantly upgraded overall condition of the granulation plant. With an average sized plant producing 30 tons per hour of product, new investment in the PCR can be paid back in about 6 months from savings in fossil fuel drying and steam only. This payback period is very short for the fertilizer industry.

Summary

Of the 107 NPKS ammoniation-granulation plants producing about 8.5 million tons of homogeneous NPKS granular fertilizers, 23 have installed

TVA PCR's. Use of byproduct sulfuric acid and ammonium sulfate in high nitrogen grades produced in PCR's is increasing. Annual per plant tonnage is increasing, enabling many of these plants to undertake more extensive maintenance and capital improvement programs. These NPKS granulation plants should continue to be an important part of the fertilizer production system in the United States.

Acknowledgement

TVA greatly appreciates the cooperation of fertilizer industry personnel in providing data for the NPKS ammoniation-granulation plant survey.

References

1. Fertilizer Trends 1979, (Bulletin Y-150), National Fertilizer Development Center, Tennessee Valley Authority, p. 23 (January 1980).

2. Chemical Marketing Reporter 217, (54), pp. 9 and 64, (June 23, 1980).

3. Achorn, Frank P. and David G. Salladay. "Production of Monoammonium Phosphate in a Pipe-Cross Reactor," presented at the Annual Meeting of the Fertilizer Industry Round Table, Washington, DC, November 4-6, 1975.

4. Achorn, Frank P. and David G. Salladay. "Conservation of Energy in Ammoniation-Granulation Plants," presented at the Annual Meeting of the Fertilizer Industry Round Table, Washington, DC, October 25-28, 1977.

5. Salladay, David G. and Edwin D. Myers. "Use of TVA's Pipe-Cross Reactor to Conserve Energy in Fertilizer Granulation Plants," presented at the Fifth National Conference on Energy and the Environment, Cincinnati, Ohio, November 1-3, 1977.

6. "Energy Conservation in Ammoniation-Granulation Plants," Centec Corporation, Reston, Virginia, and Fort Lauderdale, Florida, p. 23, (1980).

Table 1

NPKS Ammoniation-Granulation Plants and TVA Pipe-Cross Reactor Installations

State	NPKS Plants	PCR'(s)
Alabama	4	3
California	3	1
Georgia	12	1
Idaho	1	1
Illinois	5	2
Indiana	5	-
Iowa	1	-
Kentucky	4	-
Maine	1	-
Maryland	4	1
Michigan	3	1
Minnesota	1	-
Mississippi	4	-
Missouri	3	1
Nebraska	1	-
New Jersey	3	-
New York	5	-
North Carolina	11	2
Ohio	5	3
Pennsylvania	4	-
South Carolina	4	1
Tennessee	5	1
Texas	5	3
Utah	1	-
Virginia	8	1
Washington	1	-
Wisconsin	3	1
Totals	107	23

Table 2

Formulations for 16-8-8-XS Grade

Production rate, tons/hr.	25	25	15
Raw Materials, lb/ton			
PCR			
Phosphoric acid (54% P_2O_5)	220	150	195
Anhydrous ammonia	28	19	31
Sulfuric acid (72% H_2SO_4)	320	404	976
Anhydrous ammonia	80	101	244
Bed			
Phosphoric acid (54% P_2O_5)	80	150	105
Anhydrous ammonia	17	25	18
Normal superphosphate (18% P_2O_5)	33	33	-
Anhydrous ammonia	2	2	-
Ammonium sulfate (21% N)	1,066	988	400
Potash (60% K_2O)	267	267	267
Mole Ratios (NH_3:H_3PO_4)			
PCR	1.0	1.0	1.23
Bed	1.65	1.29	1.32
Overall	1.16	1.13	1.26
pH	4.8	4.8	5.3
Heat flux - Btu/hr-in^2	531,000	608,000	807,000

Table 3

Advantages of PCR Process over Conventional Bed Granulation

1. The PCR process gives a much more homogeneous chemical blend and uniform appearance thus restoring the traditional superiority of granulated fertilizer over blends which gradually eroded as high analysis materials such as DAP have been substituted in formulations.

2. Large amounts of acids can be used in formulations; this is an advantage when acids are relatively cheap. Use of large volumes of acid is also desirable when tank car demurrage becomes threatening.

3. Metering liquids is simpler, more precise, and allows better fine tuning of the process than is possible when weighing and handling dry materials.

4. A further advantage that follows item No. 3 is that dry material shrinkage is reduced because less dry material is handled.

5. Because there is less dry material handling, labor costs will be decreased and maintenance costs on handling equipment such as elevators and tractors should likewise be reduced.

6. When all anhydrous ammonia enters via the pipe-cross, N losses are significantly less than losses incurred during conventional granulation.

7. There is decreased use of fuel for drying when grades are properly formulated.

8. Chute plugging, caused by tacky ammoniated material (conventional bed formula), has been essentially eliminated because of flash drying of the product in the ammoniator during the PCR process.

9. The final product is harder and, therefore, not as dusty.

10. Increased production rates, in some cases, are possible.

11. Baghouse leakage of sub-micron particles is less than half that occurring during non-PCR operation.

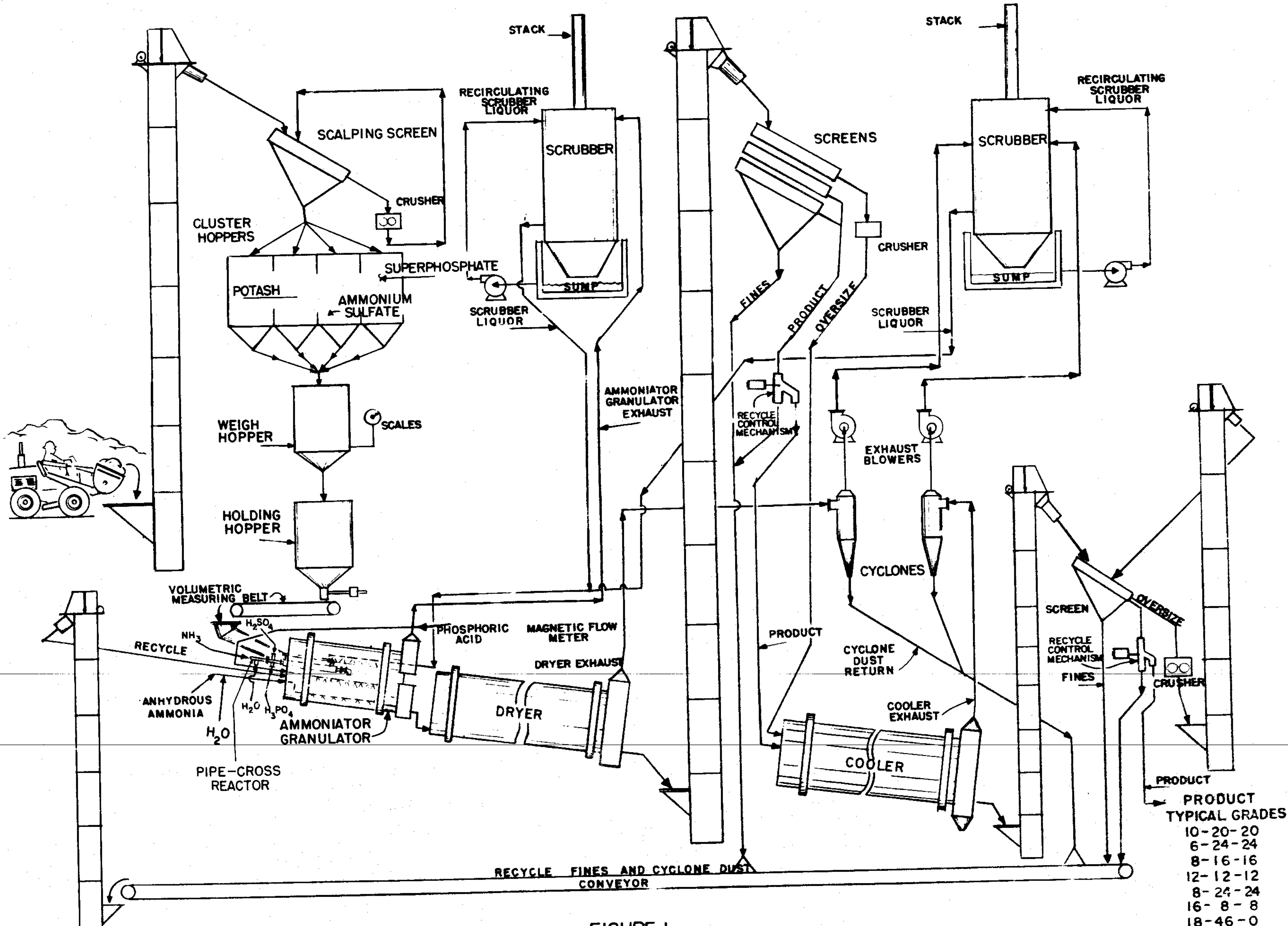


FIGURE I
AMMONIATION-GRANULATION PLANT WITH
PIPE-CROSS REACTOR

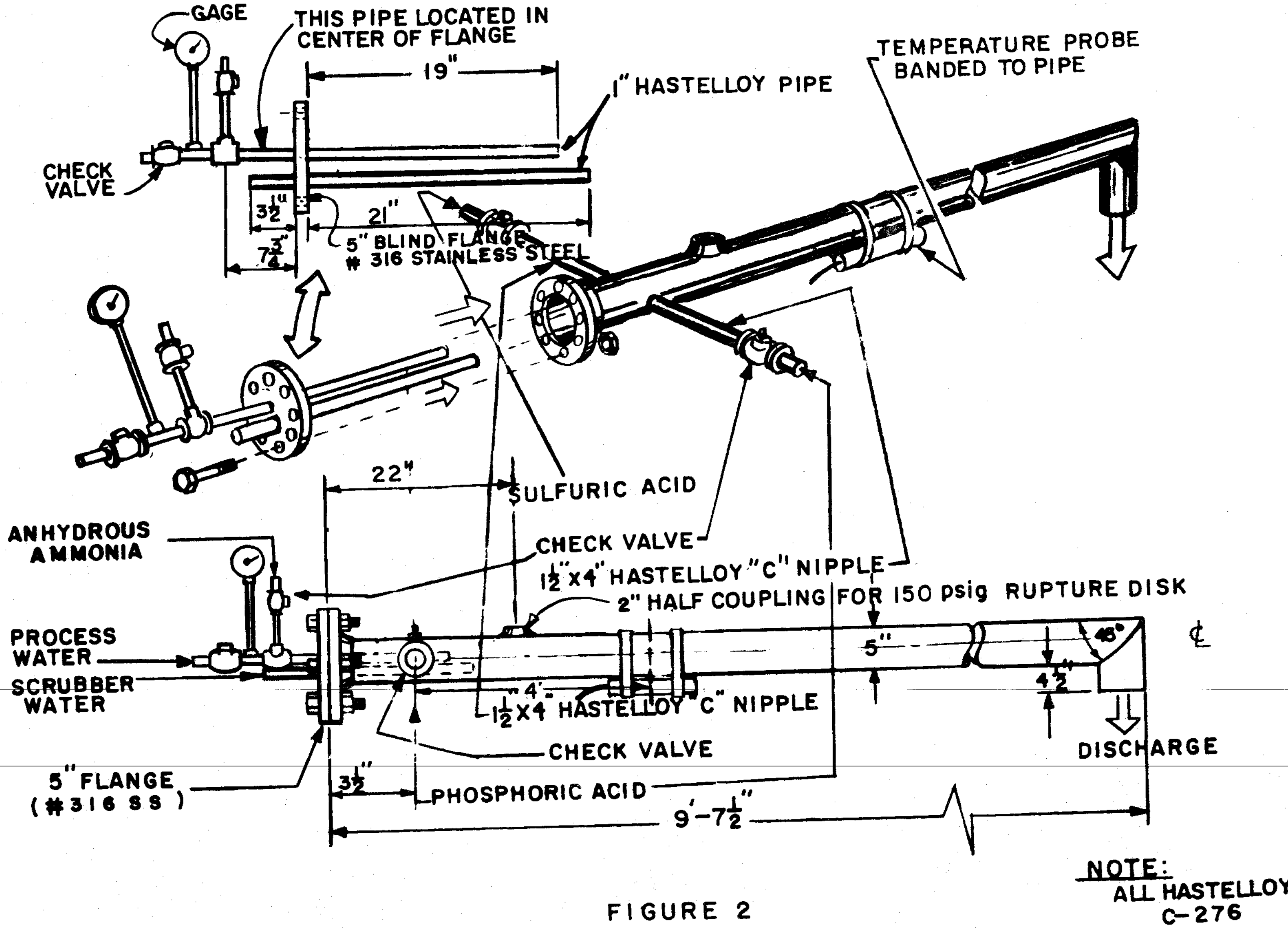


FIGURE 2

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

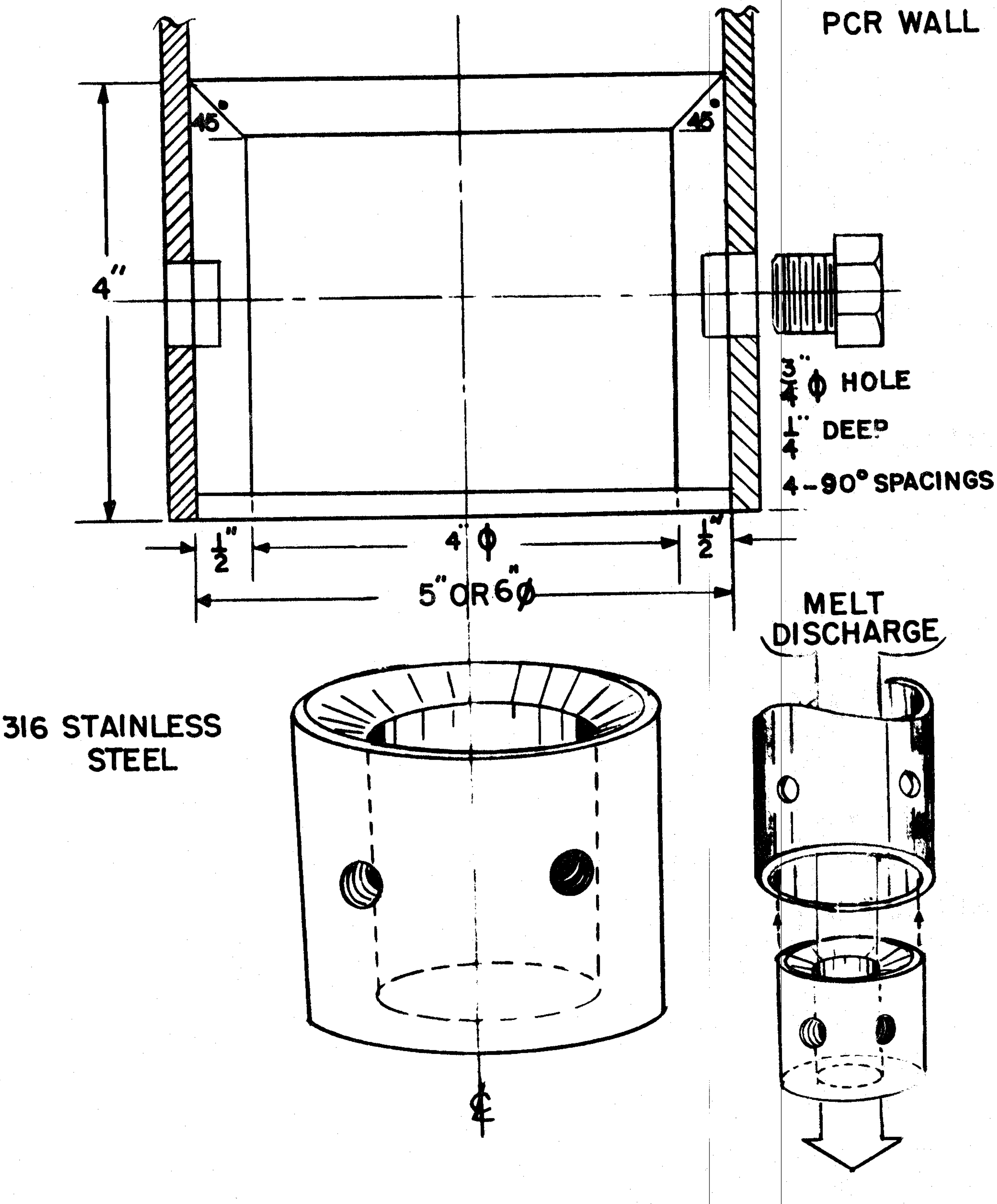
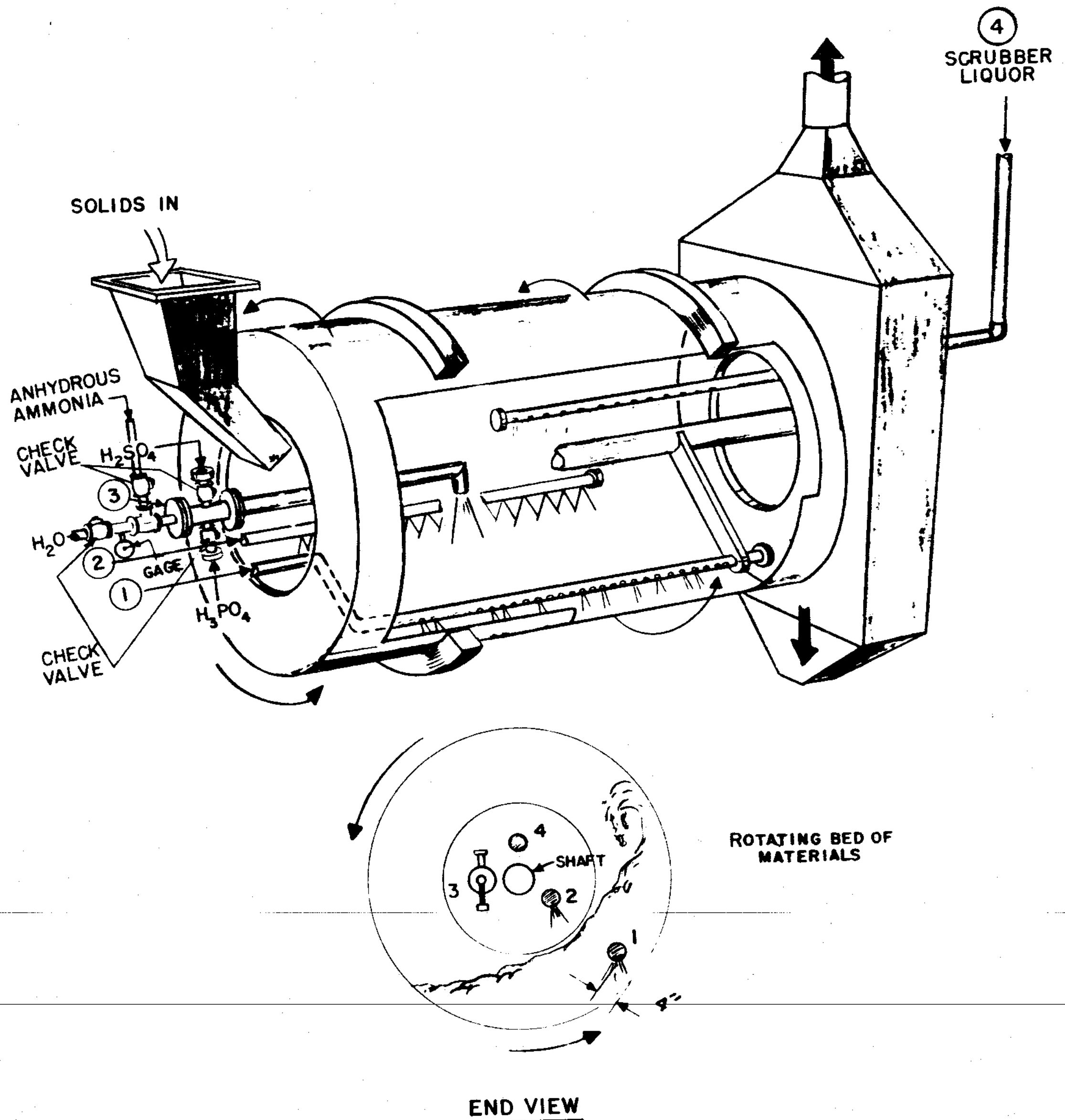


FIGURE 3

DISCHARGE NOZZLE FOR 5" OR 6" PCR.



(1) AMMONIA SPARGER — LOCATED AT THE 4 O CLOCK POSITION $4\frac{1}{2}$" FROM GRANULATION SHELL WITH HOLES FACING THE ROTATING STREAM OF MATERIALS. OVERALL LENGTH-12 FEET. ONE HUNDRED AND FORTY TWO $\frac{1}{16}$" HOLES ON ONE INCH CENTERS WITH SMALL QUANTITY OF WATER ADDED TO PREVENT CAKE AROUND SPARGER.

(2) PHOSPHORIC ACID SPARGER — LOCATED TO DISCHARGE PHOSPHORIC ACID ONTO THE TOP AND NEAR THE CENTER OF THE ROTATING BED OF MATERIALS. OVERALL LENGTH-8.9 FEET. SIXTEEN $\frac{3}{8}$ INCH HOLES ON THREE INCH CENTERS.

(3) PIPE-CROSS REACTOR — LOCATED TO DISCHARGE NEAR THE LONGITUDINAL CENTER OF THE BED AND AT A POINT ONE THIRD FROM THE BOTTOM EDGE OF THE BED OF MATERIAL IN THE GRANULATOR.

(4) SCRUBBER WATER — LOCATED ABOVE THE BED IN GRAN-ULATOR TO DRIBBLE SCRUBBER WATER ONTO BED.

FIGURE 4

LOCATION OF PIPE CROSS REACTOR IN ROTARY AMMONIATOR—GRANULATOR

Figure 5.

Stainless steel sleeve removed from pipe—cross reactor after 50,000 tons of production