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AMMONIUM POLYPHOSPHATE FLUID FERTILIZERS
MADE FROM MERCHANT-GRADE ORTHOPHOSPHORIC ACID

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About two million tons of suspension fertilizers was used in the United States in 1981. Much of this material was used in the northern areas of the country where temperatures well below zero are encountered frequently. Suspensions that are made from 10-34-0 grade ammonium polyphosphate (APP) solution, which is made from superphosphoric acid, usually will store well at these low temperatures, but cost of those suspensions is high. Lower cost suspensions made from monoammonium phosphate (MAP), diammonium phosphate (DAP), or merchant-grade (54% P_2O_5) wet-process orthophosphoric acid, however, usually will solidify at temperatures below about 20° to 30°F.

Recently, the Tennessee Valley Authority (TVA) developed (1) and patented (2) an energy-efficient process for production of APP fluid fertilizers from merchant-grade orthophosphoric acid. This APP fluid can be produced, shipped, stored, and marketed in all areas of the United States, and because it contains 20 to 30% of its P_2O_5 as polyphosphate, it can be stored at temperatures at least as low as minus 5°F

for short periods without freezing. A TVA demonstration-scale plant was built and has been operated as needed since September 1981 and about 10,000 tons of nominal 9-32-0 grade APP suspension has been produced. The products were shipped without difficulty by rail, truck, and barge to some 22 distributors in 13 states as part of TVA field programs. There have been no reported difficulties with storage or use of the products as long as the material was agitated frequently during storage.

The nominal grade of the APP product made by this process purposely is limited to 9-32-0 so that the fluid in process contains no crystals at 80°F. This allows the fluid to be cooled in conventional packed or slatted evaporative coolers, which are the types commonly used in existing pipe-reactor plants that produce 10-34-0 APP solution fertilizer. Thus, some of the existing pipe-reactor plants can be modified to produce both 9-32-0 APP fluids from merchant-grade acid (53-54% P₂O₅).

Process Description

A flow diagram of the TVA 20-ton-per-hour demonstration-scale plant for production of 9-32-0 APP suspension fertilizer is shown in Figure 1. The process consists of feeding merchant-grade (53-54% P₂O₅) wet-process orthophosphoric acid and all of the ammonia through heat exchangers, which use heat generated in the process, to an enlarged pipe reactor to produce an APP melt containing 20 to 30% of its P₂O₅ as polyphosphate. The melt discharges into a reactor surge tank where water of formulation is added to produce the nominal 9-32-0 grade fluid.

The APP fluid then is cooled in a packed-tower evaporative cooler and 2% by weight of attapulgite clay is added in a clay-mix tank. The clay is added to suspend any ammonium phosphate crystals or impurities that might precipitate during low-temperature or long-term storage and to provide extra clay for cold blending the 9-32-0 with other materials to obtain mixed-grade fertilizers as described later in this report. Small-scale tests have shown that even though the 9-32-0 fluid without clay does have some settling of small-size impurities, it is considered to be acceptable for use as a base liquid fertilizer, if it is used soon after production (5-11 weeks).

(Figure 1)

Chemical and physical properties of 9-32-0 grade APP suspensions made by this process are given in Table I.

Uses of 9-32-0 Grade Base Fluids

Mixed Grade Suspensions

The primary use for the 9-32-0 grade APP base suspension is to produce high-analysis suspension mixtures that will have good cold-weather storage characteristics. The 9-32-0 base suspension can be used in conventional cold-mix plants and does not require elaborate high-intensity mixing equipment; however, this type of agitation does not have an adverse effect on the suspension. A typical satisfactory mix tank for use with 9-32-0 base suspension and other fertilizer materials

is shown in Figure 2. This tank should be equipped with a small propeller- or turbine-type mixer. Also, the tank should be equipped with a good recirculation pump that has a discharge diameter of at least 4 inches. Transfer pipes also should be at least 4 inches in diameter. The pump should discharge tangentially to the walls of the mix tank and in the same direction as the rotation of the mixer. This fluid flow will cause the mixture in the tank to swirl so that potash can be easily dispersed into the mixture.

(Figure 2)

Typical formulations for popular ratios of plant nutrients that use 9-32-0 and TVA nitrogen suspensions (31% N and 1.5% clay) are shown in Table II. These formulations are based on plant tests and show that when these two TVA products are used, essentially all ratios can be produced without addition of supplemental clay. The highest possible grade should be produced for each ratio; otherwise, supplemental clay will have to be added to the mixture. Table III shows formulations with the 9-32-0 base suspension and a typical commercial urea-ammonium nitrate solution (28-0-0). In this series of formulations, supplemental clay is required in the production of most of the grades because the commercially supplied nitrogen solution does not contain clay.

Polyphosphate Additive

Another use of the 9-32-0 grade base fluids is to supply polyphosphate to improve the storage characteristics of orthophosphate suspensions made from commercial MAP, DAP, or merchant-grade orthophosphoric acid. Plant tests have shown that if 9-32-0 base suspension

containing 25% of its P_2O_5 as polyphosphate is used to supply part of the P_2O_5 , so that the resulting polyphosphate level of the product is 5% of the total P_2O_5 , an excellent 11-33-0 grade suspension can be produced from most sources of commercial MAP (11-52-0). A typical formulation for the production of 11-33-0 base suspension from these materials is shown in the following tabulation:

<u>Materials</u>	<u>Pounds/ton</u>
Water	472
Clay	12
9-32-0, 2% clay	413
MAP (11-55-0)	1016
Ammonia	87

When commercial MAP products that have relatively high iron and aluminum contents ($Fe_2O_3 + Al_2O_3 > 4\%$) are used, the base grade needs to be lowered to 10-30-0 and 10% of the P_2O_5 needs to be polyphosphate. The following is a typical formulation for this base suspension grade.

<u>Materials</u>	<u>Pounds/ton</u>
Water	451
Clay	5
9-32-0, 2% clay	750
MAP (10-50-0)	720
Ammonia	74

Mixed-Grade Liquids

As stated previously in this paper, the 9-32-0 APP fluid without clay is acceptable for use as a base liquid fertilizer, if it is used soon after production (5-11 weeks). Small-scale tests show that

good liquid fertilizers, such as 7-21-7, 6-18-6, 4-10-10, and 8-25-3, can be made from 9-32-0 APP fluid without clay and commercial urea-ammonium nitrate solution. Application tests show that when the 9-32-0 base liquid and other comparable grades made from MAP are used to produce mixed-grade liquids, gravity-flow application equipment should be avoided and the mixed-grade liquids should be metered by a metering pump, such as a hose pump or piston pump.

Storage of the 9-32-0 Grade Base Fluids

TVA has stored 9-32-0 APP suspension for several months during severe winter conditions in the Midwest at temperatures as low as minus 15°F. The crystals in the suspension remained small, and the cold 9-32-0 suspension was easy to pump and handle.

TVA recommends that all suspensions be stored in tanks equipped with air spargers or other means of agitation. A typical storage tank of this type is shown in Figure 3.

(Figure 3)

In storage of liquid or solution-type fertilizers, hydraulic agitation is sufficient; however, when these materials are stored, they tend to separate with a clear layer of liquid on top and a dark layer at the bottom. Therefore, the material should be recirculated from the bottom to the top of the tank. This can be accomplished with the pump normally used to transfer the fluid from the storage tank. Air sparging also works well for this purpose.

Description of Plant and Operating Procedures

The TVA demonstration-scale plant (Fig 4) is located outside, in a small diked area, and is designed to operate continuously 24 hours per day. Most of the pumps and the pipe reactor were installed in duplicate to allow round-the-clock operation. Typical production data (flow rates, temperatures, retention times, etc.) for operation of the demonstration-scale plant at production rates of 10, 15, and 20 tons per hour are given in Table IV. Figures 5 through 10 are detailed drawings showing sizes and materials of constructions of some of the major pieces of equipment. As shown in these figures, most of the equipment and piping in contact with acid or hot APP fluid are constructed of stainless steel (AISI Type 304, 316, or 316L). Also, to protect personnel, to conserve process heat, and to make the process more energy efficient, the piping containing the hot acid, ammonia, and hot APP fluid and the ammonia heat exchanger, pipe reactors, and reactor surge tank are insulated with a 2- or 2.5-inch-thick layer of calcium silicate protected by a metal covering. Most of the other equipment and piping are constructed of mild steel or plastic (PVC and ABS piping).

(Figures 4-10)

Some of the unique operating procedures involving the major pieces of equipment and variables that affect polyphosphate content of the product are discussed in the following paragraphs.

Acid Heat Exchanger

The 450-square-foot plate-and-frame acid heat exchanger (Fig 1) heats the feed acid to between 190° and 205°F with heat supplied by hot

(190°-210°F) APP fluid from the reactor surge tank. The overall heat-transfer coefficient is about 60 Btu/h·ft²·°F. During operation, there is some buildup of solids on the APP fluid side of the heat exchanger that would eventually plug or lower the efficiency of the heat exchanger. However, this is prevented without interrupting operation by switching the flows of APP and acid to opposite sides of the heat exchanger for about 15 minutes every 8 hours of operation. Switching the flows allows the acid to dissolve the solids.

Ammonia Heat Exchanger

The ammonia heat exchanger (Fig 1) is a shell-and-tube type. It contains 420 square feet of surface area and has an overall heat-transfer coefficient of about 65 Btu/h·ft²·°F. Hot APP fluid from the acid heat exchanger flows through the shell side. Ammonia, is fed to the tube side where it is vaporized and heated to between 160° and 185°F. The feed ammonia is at a gage pressure of 250 pounds per square inch to ensure that it is in liquid form to allow accurate metering by the ammonia turbine flowmeter. The ammonia flow rate is controlled to give an optimum pH of about 6.7 (undiluted) in the APP fluid discharged from the evaporative cooler.

Pipe Reactors

As shown in Figure 1, the plant is equipped with two pipe reactors with piping and valves to allow operation to be switched from one pipe to the other without interrupting operation of the plant. Both pipe reactors are 14 inches in diameter and 9 feet tall, as shown

in Figure 5. During operation, scale buildup inside the operating pipe reactor reduces the effective diameter of the reactor and thus increases throughput per unit volume. This eventually would cause the level of polyphosphate in the product to decrease and would plug the pipe reactor. Use of the dual pipe-reactor configuration, however, allows operation to be shifted to the second pipe while the first pipe is cleaned by passing aqua ammonia (10% of formulated ammonia and part of the water of formulation) through the pipe. The scale is a metal ammonium phosphate salt and is soluble in either wet-process acid or aqua ammonia. Aqua ammonia for cleaning the pipe reactors is made in the converter shown in Figure 6. During operation, the pipe reactors are switched for cleaning once each shift. Aqua ammonia is passed through the pipe reactor being cleaned until aqua ammonia flows from the top sampling port (Fig 5), which usually is the last port to unclog.

Figure 7 shows the pipe-reactor mixing tee. Hot ammonia is fed through a 2-inch-diameter lance-type sparger which extends through the center of the tee and about 3 inches into the reactor. Hot acid enters the branch of the tee and flows through the annular space between the pipe tee and ammonia sparger and into the pipe reactor. The acid and ammonia react in the pipe reactor, resulting in a temperature of about 450°F at the discharge end of the reactor. The resultant molten APP, steam, and unreacted ammonia flow from the pipe reactor through an insulated 6-inch-diameter line about 14 feet long to the reactor surge tank. The transfer line discharges these reaction products about 10 inches under the surface in the storage tank.

Surge Tank

As shown in Figures 1 and 8, hot APP fluid from the reactor surge tank is divided into two streams. One stream of about 375 gallons per minute (at a production rate of 20 tons/h) is pumped first through the acid heat exchanger to heat the acid and then through the ammonia vaporizer to vaporize and heat the ammonia; this stream is returned to the surge tank. The second stream (about 140 gal/min at a production rate of 20 tons/h) is fed to the top of the packed-tower evaporative cooler where it is cooled to 80° to 90°F as it flows down through the cooler. Temperature in the surge tank is controlled at about 200°F by returning a portion of the cool APP fluid to the surge tank. Water of formulation (cleanup water from process sump or water from process waterline) is added to the reactor surge tank, either directly or through the idle pipe reactor during the cleaning cycle. The waterflow rate is adjusted to maintain the desired density (11.7 lb/gal) of the fluid in the evaporative cooler reservoir.

Cooler

Hot APP fluid from the reactor surge tank is distributed onto the bed of packing at the top of the cooler (Fig 9) by seven nozzles. The exhaust fan located at the top of the cooler pulls air in through a grating at the bottom of the cooler and up through the tower counter-currently to the flow of APP fluid. Airflow through the cooler is controlled by an adjustable damper located just below the fan. The volume of air is varied to obtain an APP fluid discharge temperature usually

of 80° to 90°F. Any entrained fluid in the airstream is removed in a demister section before the air is exhausted to the atmosphere.

The reservoir at the bottom of the cooler is equipped with high- and low-level alarms and is operated at a volume of about 1000 gallons. The gravity overflow discharge system from the cooler reservoir is somewhat unique in that it controls both the level in the reactor surge tank and cooler reservoir with use of only the reactor surge tank pump. This system is made possible by elevating the reactor surge tank so that the desired operating levels in the surge tank and cooler reservoir are the same. A 6-inch-diameter line between the cooler and surge tank maintains the level in the surge tank; the flow rate of APP fluid through this line is determined by the surge tank pump. The 4-inch-diameter discharge line to the clay-mix tank is located 35 inches above the 6-inch line and controls the level in the cooler reservoir. The flow rate of APP fluid through the 4-inch line is the same as the production rate of the plant.

Originally, part of the cooled recycled APP fluid was fed to the two nozzles at the top of the cooler to help control flooding; however, flooding was not a problem and all of the recycled APP fluid now is pumped tangentially back into the reservoir to impart a circular movement to prevent solids from accumulating on the flat bottom of the cooler.

Clay-Mix Tank

The clay-mix tank (Fig 1 and 10) is equipped with two centrifugal recirculation pumps which provide the shear-type agitation required to gel the clay (2% by wt). The pump or pumps usually are operated at maximum capacity, and an orifice in the discharge line provides a head pressure of 60 pounds per square inch gage to improve efficiency of the pump. Recycle from the pumps enters the clay-mix tank tangentially to provide agitation in the tank. Operating volume for the clay-mix tank is about 1000 gallons. Retention times at different production rates are listed in Table II.

In general, the viscosity and gel strength of the suspensions increase as (1) the number of passes through the mixing pump is increased, (2) the amount of clay is increased, and (3) the polyphosphate content is increased. Currently, it appears that about 2% attapulgitic clay is the maximum amount that should be added to suspensions containing 20 to 25% of their P_2O_5 polyphosphate, to obtain products that will store satisfactorily for long periods in tanks equipped with agitation devices. The suspension overflows from the clay-mix tank by gravity to a standpipe above the product pump. The product suspension (100° - 110° F) is then pumped to a storage tank that is equipped with an air sparger.

Process Pumps

Following is a description of the major pumps used in the process:

Pumps, (see Fig 1)	Size diameter, in			Rating		Impeller		Material
	In	Out	Cavity	hp	gal min	Dia, in	Tip speed ^a	
Surge liquor	4	3	11	25	400	9	69	CF-8M ^b
Recycle liquor	3	1½	11	15	55	7⅝	58	D.I. ^c
Suspension recirculation	6	4	13	100	1800	13	99	CD-4MCU
Suspension product, A	3	1½	11	10	85	10½	80	CD-4MCU
Suspension product, B	3	1½	11	10	75	9⅝	73	CF-8M ^b

^a All impellers rotated at 1750 r/min.
^b Cast equivalent of AISI Type 316 stainless steel.
^c Ductile iron.

Originally, the suspension recirculation pumps and suspension product pumps were constructed of ductile iron. However, the impellers in both sets of pumps wore rapidly and the pumps were replaced with the material of construction shown above which appears to be performing well.

All of the pumps have packing-type seals and water in the lantern rings. The water pressure is maintained at a pressure slightly above the pump pressure to keep the APP fluid out of the seals.

Variables Affecting Polyphosphate
Content of the Product

The polyphosphate contents of the 9-32-0 APP suspensions produced in this plant have ranged from 14 to 29% of total P₂O₅, depending primarily on the pipe-reactor throughput and the concentration and

TABLE I (continued)

Formulation, lb./ton ^a								
Ratio	Grade	Super-phosphoric acid, 76% P ₂ O ₅	Ammonia	Urea-ammonium nitrate soln., 32% N	Urea, 46% N	Potassium chloride, 62% K ₂ O	Water	Salting out temp., °F.
3-3-1	15-15-5	395	112	-	452	161	880	19
4-3-1	16-12-4	316	90	-	535	129	930	29
	5-12-10	316	90	81	-	323	1190	26
1-1-0	16-16-0	421	119	694	-	-	766	26
1-1-0	16-16-0	421	119	-	483	-	977	-14
1-2-0	10-20-0	526	149	240	-	-	1085	7
1-2-0	10-20-0	526	149	-	167	-	1158	-3
1-3-0	11-33-0	868	248	50	-	-	834	- ^c

^a

No overformulation.

^b

Based on N:P₂O₅ weight ratio of 0.309.

^c

Because of supercooling, the salting out temperature was not determined. The solution withstood storage at 0° F.

water content of the hot feed wet-process acids. Product polyphosphate contents generally increase with decrease in throughput or increase in acid concentration as shown in the following tabulation.

Suspension poly content, % of total P ₂ O ₅	Production rate, tons/h	Pipe-reactor throughput		Wet-process acid, % by wt	
		$\frac{\text{lb P}_2\text{O}_5}{\text{h}\cdot\text{ft}^2}$	$\frac{\text{h}\cdot\text{ft}^3}{\text{h}\cdot\text{ft}^3}$	Total P ₂ O ₅	K.F. ^a H ₂ O
14	20	95-96	0.9	53.0	18.6
20	20	95-96	0.9	54.1	17.4
21	15	72-73	0.7	53.7	17.6
24	15	72-73	0.7	54.1	16.6
19	13	61-63	0.6	53.0	18.6
28	13	61-63	0.6	53.8	17.2
18	10	45-58	0.4	53.0	18.6
28	10	49-56	0.4	53.8	17.2
27	8	38	0.3	54.7	17.4
29	8	38	0.3	54.1	16.6

^a Karl Fischer.

REFERENCES

1. Mann, Horace C., Kenneth E. McGill, and Thomas M. Jones, "Production of Ammonium Polyphosphate Suspension Fertilizer, Phase I," *I&EC Product Research & Development* 21 (3) 1982, 488-495 (TVA Reprint X-559).
2. Mann, Horace C., and R. S. Meline, U.S. Patent 4337079, June 29, 1982.

TABLE I

Chemical and Physical Properties of Nominal

9-32-0 Grade Ammonium Polyphosphate Suspension

Nominal grade	<u>9-32-0</u>
Chemical analysis, % by wt	
Total N	9.1-9.8
Total P ₂ O ₅	31.7-32.6
Available P ₂ O ₅ (% of total P ₂ O ₅)	100
Polyphosphate (% of total P ₂ O ₅)	20-30
N:P ₂ O ₅ wt ratio	0.28-0.31
Attapulgate clay, % by wt	2
pH (undiluted)	6.6-6.8
Density (80°F), lb/gal	11.7
Viscosity, cP	
At 80°F	100-300
At 32°F	300-400
At 0°F	400-600
Solidification temp, °F	-5 to -15
Salt-out temperature, °F	25-35
Saturation temperature, °F	45-50

TABLE II

Formulations for Suspension Mixtures Using TVA 9-32-0 Grade

Ammonium Polyphosphate Containing 2% Clay and TVA 31-0-0

Grade Nitrogen Suspension Containing 1.5% Clay

<u>Ratio</u>	<u>Grade, wt %</u>			<u>Quantity, lb</u>				<u>Additional clay</u>	<u>Clay in final mixture, wt %</u>
	<u>N</u>	<u>P₂O₅</u>	<u>K₂O</u>	<u>TVA 9-32-0</u>	<u>TVA 31-0-0</u>	<u>KCl 0-0-62</u>	<u>Water</u>		
1:1:0	18	18	0	1125	835	-	40	0	1.8
1:3:0	10	30	0	1875	101	-	24	0	2.0
1:1:1	14	14	14	875	649	452	24	0	1.4
1:2:1	10	20	10	1250	282	323	145	0	1.5
1:3:1	8	24	8	1500	81	258	161	0	1.6
1:2:2	9	18	18	1125	254	581	40	0	1.3
1:2:4	7	14	28	875	198	903	24	0	1.0
1:3:3	6	18	18	1125	60	581	234	0	1.2
1:3:6	5	15	30	938	50	968	44	0	1.0
2:1:0	22	11	0	688	1220	-	92	0	1.6
2:1:2	16	8	16	500	887	516	97	0	1.2
3:2:1	18	12	6	750	944	194	112	0	1.5
4:3:1	16	12	4	750	814	129	307	0	1.4
4:3:2	16	12	8	750	814	258	178	0	1.4

TABLE III

Formulations for Suspension Mixtures Using TVA 9-32-0 Grade

Ammonium Polyphosphate Suspension Containing 2% Clay

and Commercial Nitrogen Solution 28-0-0

Ratio	Grade, wt %			Quantity, lb					Clay in final mixture, wt %
	N	P ₂ O ₅	K ₂ O	TVA	Commer-	KCl	Water	Additional clay	
				9-32-0	cial 28-0-0	0-0-62			
1:1:0	17	17	0	1063	873	-	50	14	1.8
1:3:0	10	30	0	1875	112	-	11	2	2.0
1:1:1	13	13	13	813	667	419	90	11	1.4
1:2:1	10	20	10	1250	312	323	111	4	1.5
1:3:1	8	24	8	1500	90	258	151	1	1.6
1:2:2	9	18	18	1125	281	581	9	4	1.3
1:2:4	7	14	28	875	219	903	-	3	1.0
1:3:3	6	18	18	1125	66	581	227	1	1.2
1:3:6	5	15	30	938	55	968	38	1	1.0
2:1:0	20	10	0	625	1228	-	127	20	1.6
2:1:2	14	7	14	438	859	452	236	15	1.2
3:2:1	18	12	6	750	1045	194	-	11	1.5
4:3:1	16	12	4	750	901	129	207	13	1.4
4:3:2	16	12	8	750	901	258	78	13	1.4

TABLE IV

Typical Production Conditions for Nominal 9-32-0 GradeAmmonium Polyphosphate Suspensionin Demonstration-Scale Plant

Nominal production rate, tons/h	<u>10</u>	<u>15</u>	<u>20</u>
Acid			
Source	Florida		
Rate, tons/h	6.1	9.1	12.2
Temperature to pipe reactor, °F	190-205		
Ammonia			
Rate, tons/h ^a	1.2	1.8	2.3
Temperature to pipe reactor, °F	160-205		
Moles per mole H ₃ PO ₄	1.5-1.6		
Water			
Rate, tons/h	3.1	5.2	7.5
Pipe reactor			
Diameter, in	14		
Length, ft	9		
Temperature, °F	450-475 ^b		
Pressure (acid feed inlet), lb/in ² g	4	4	5
Throughput			
Lb P ₂ O ₅ /h·in ²	50	72	96
Lb P ₂ O ₅ /h·in ³	0.5	0.7	0.9
Reactor surge tank			
Temperature, °F	190-210		
Retention time, min	40	25	20
Packed-tower cooler			
Airflow rate, ft ³ /min	15,000-17,000		
Air temperature, outlet, °F	145-175		
Pool temperature, °F	85-125		
Retention time, min	35	25	20
Clay-mix tank			
Temperature, °F	100-130		
Attapulgate clay, lb/h (at 2% by wt)	408	612	816
Retention time, min	35	25	20

^a Calculated using NH₃:H₃PO₄ mole ratio of 1.5 and 54% P₂O₅ acid.

^b Temperature measured inside of transfer line next to discharge end of pipe reactor (~ 9.5 ft from feed end of pipe).

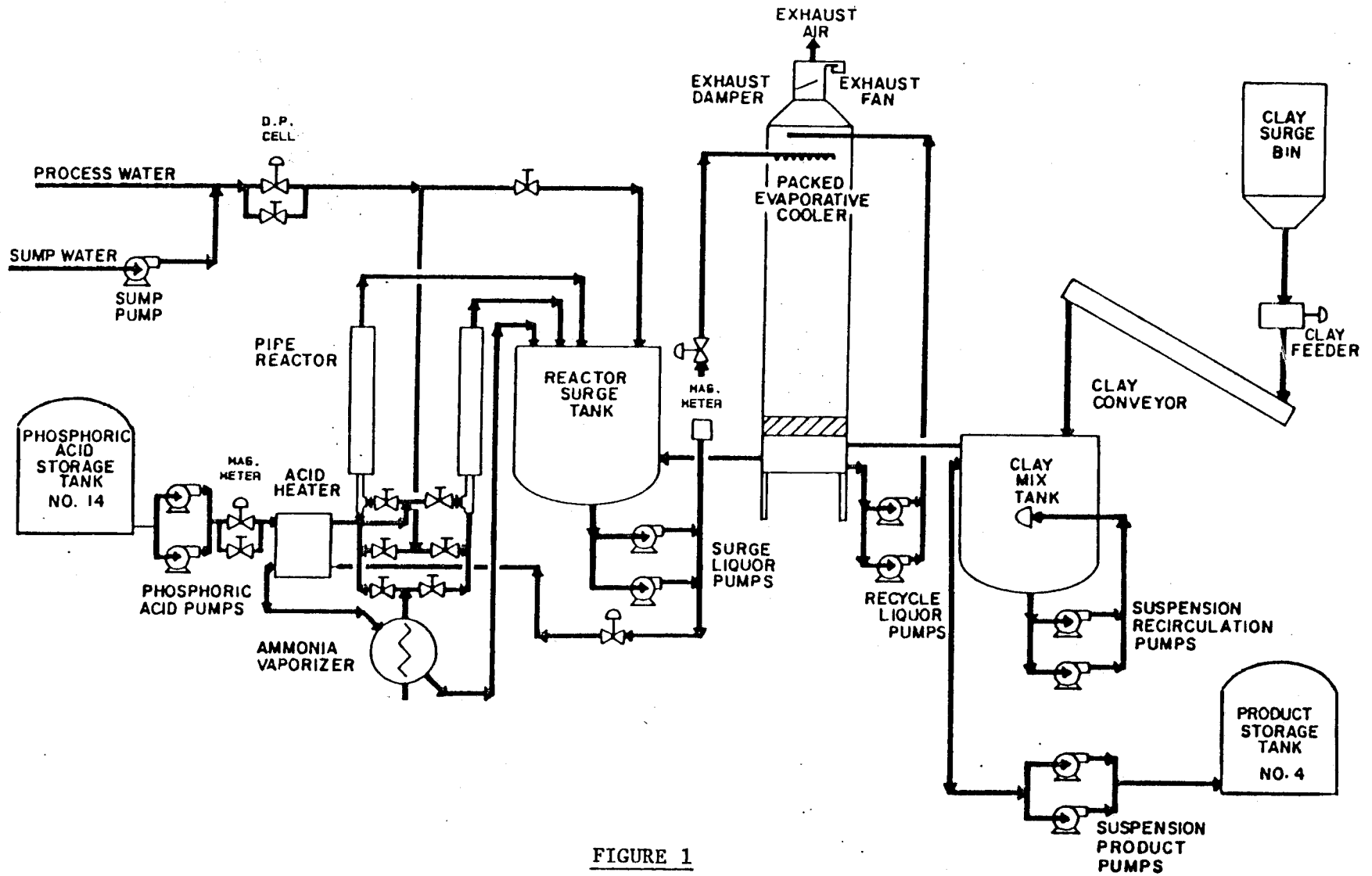


FIGURE 1

Flow Diagram of Demonstration-Scale Plant for Production
of 9-32-0 Ammonium Polyphosphate Suspension Fertilizer

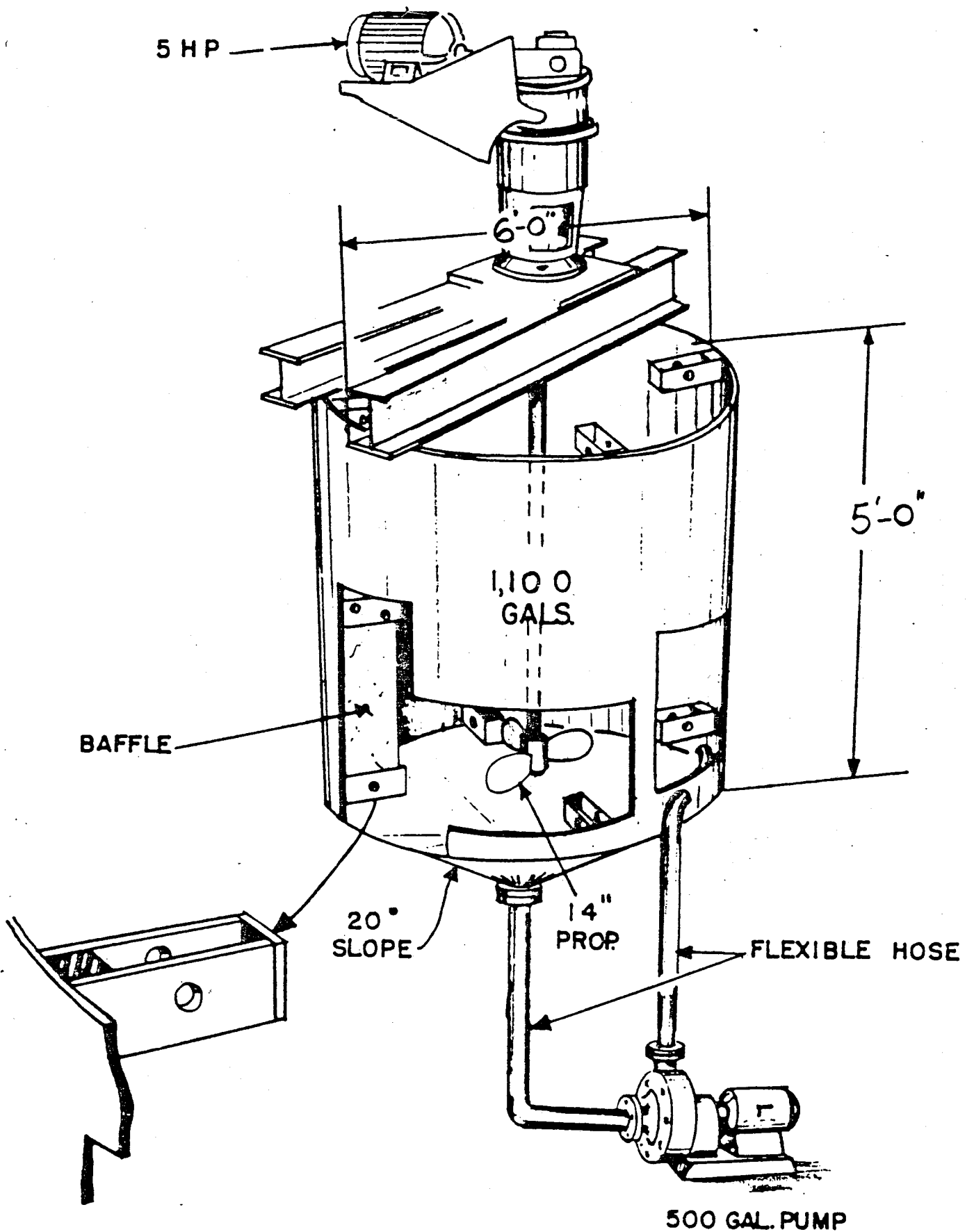


FIGURE 2

Mix Tank for Production of Suspension Fertilizers

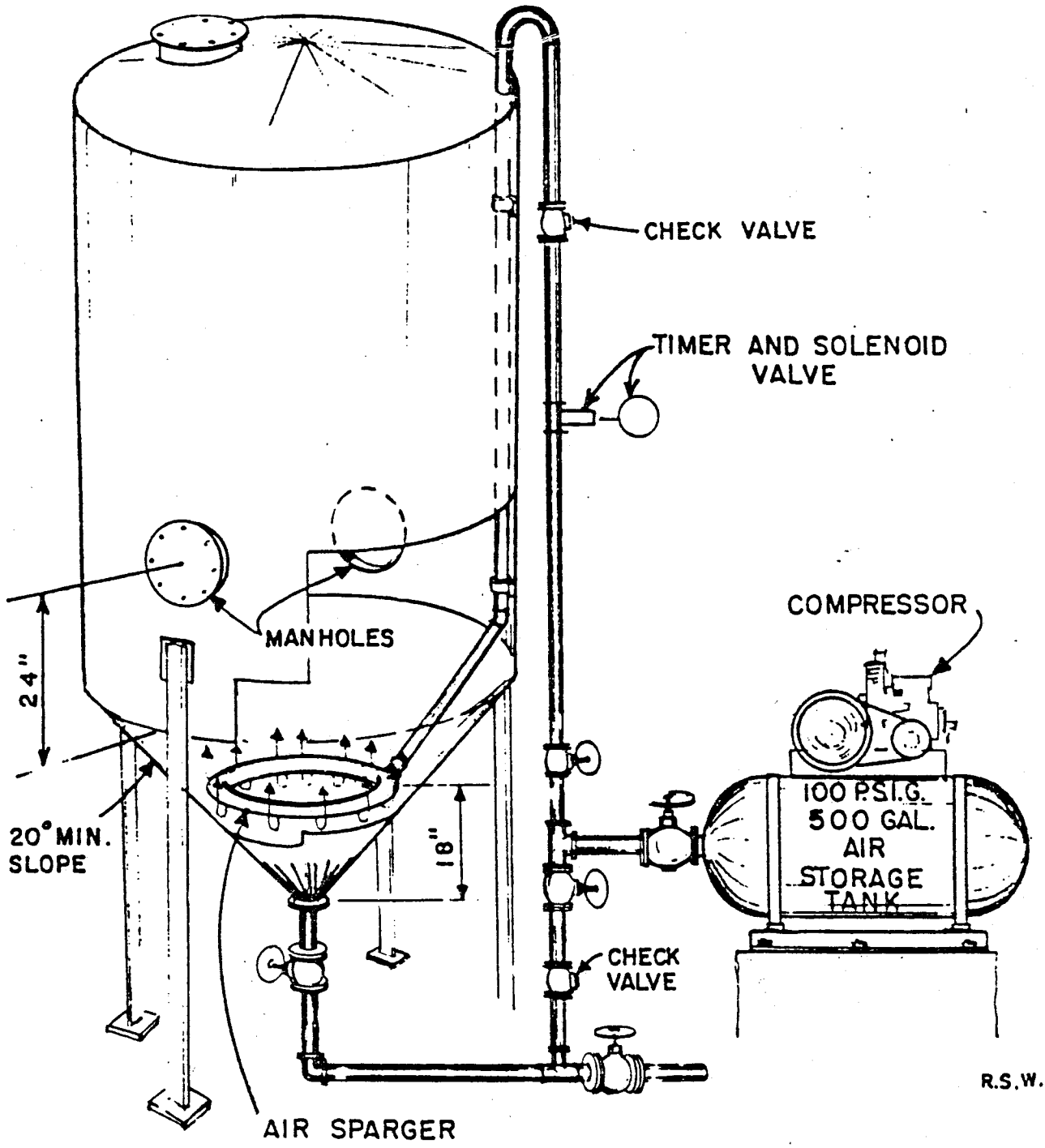


FIGURE 3
Cone-Bottom Suspension Storage Tank
with Air-Sparger System

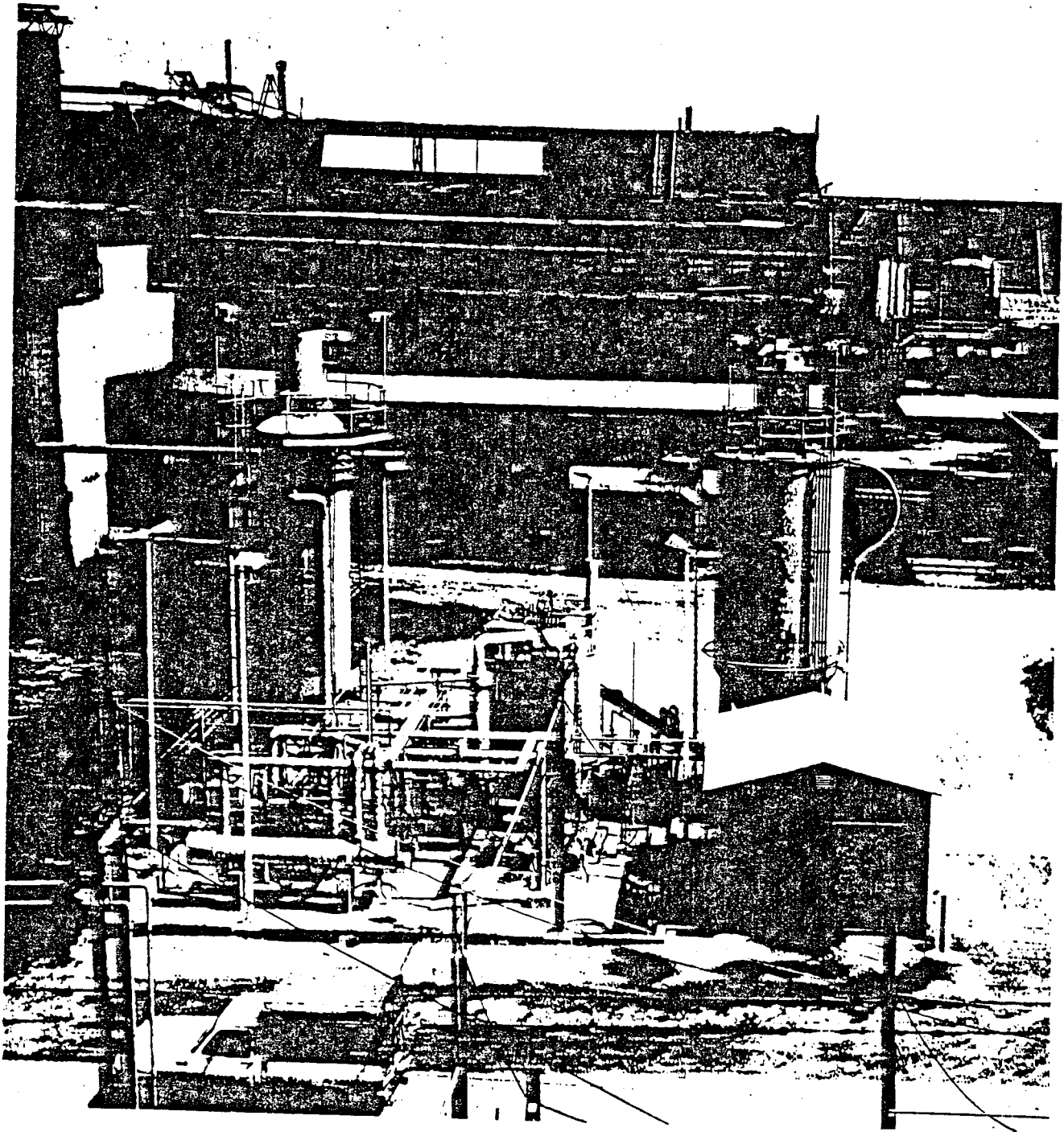


FIGURE 4

9-32-0 Ammonium Polyphosphate Suspension Plant

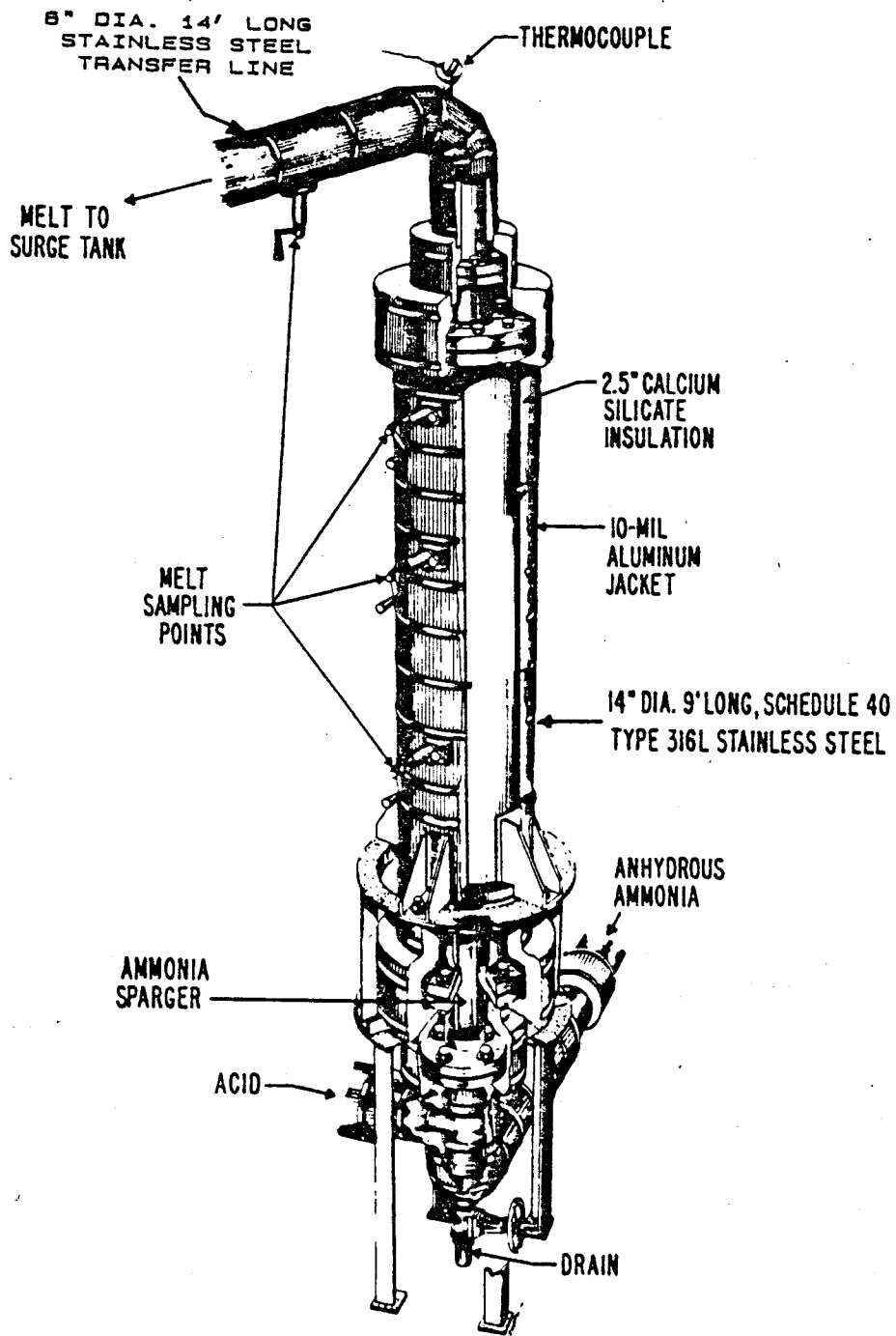


FIGURE 5

Pipe Reactor

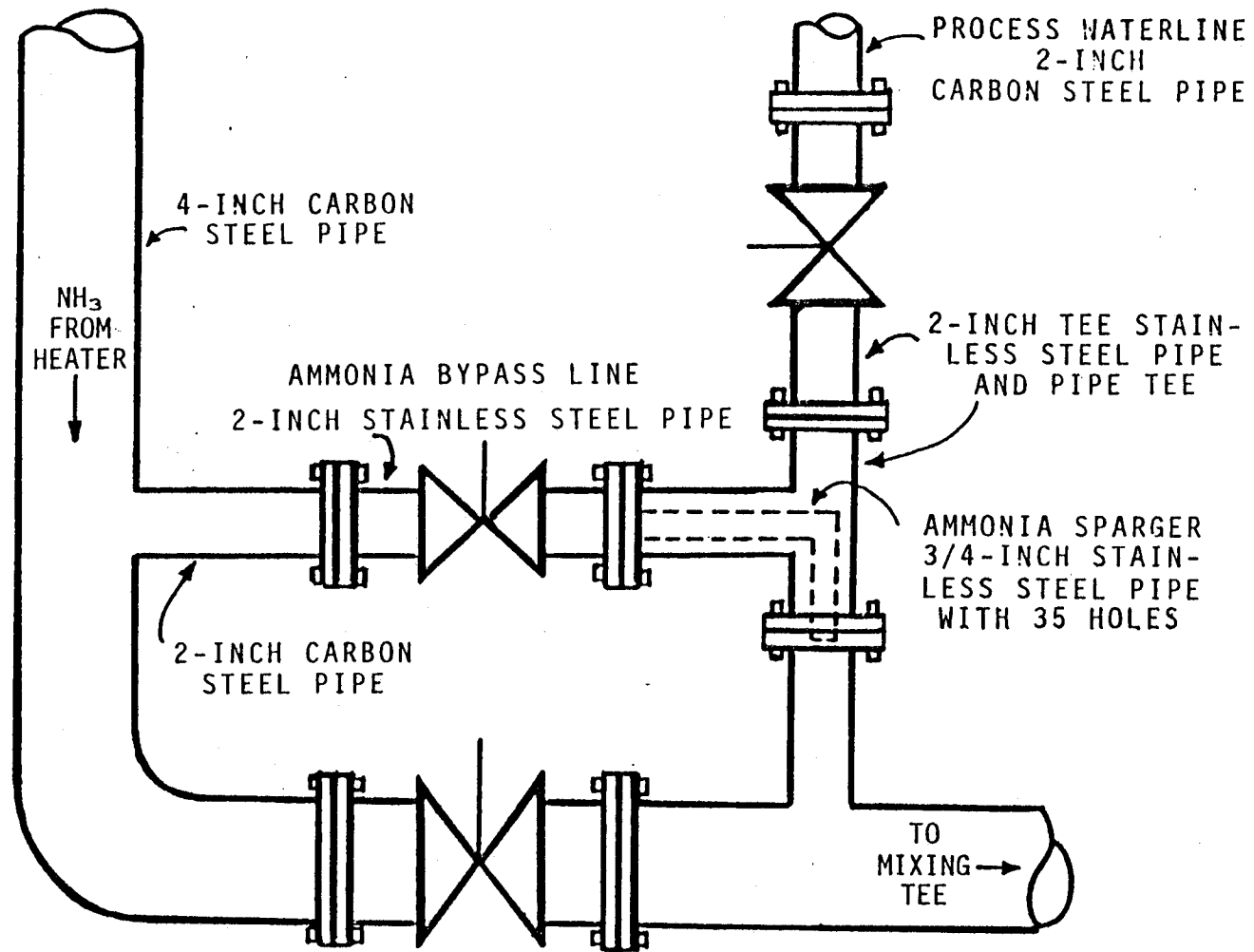


FIGURE 6

Aqua Ammonia Converter

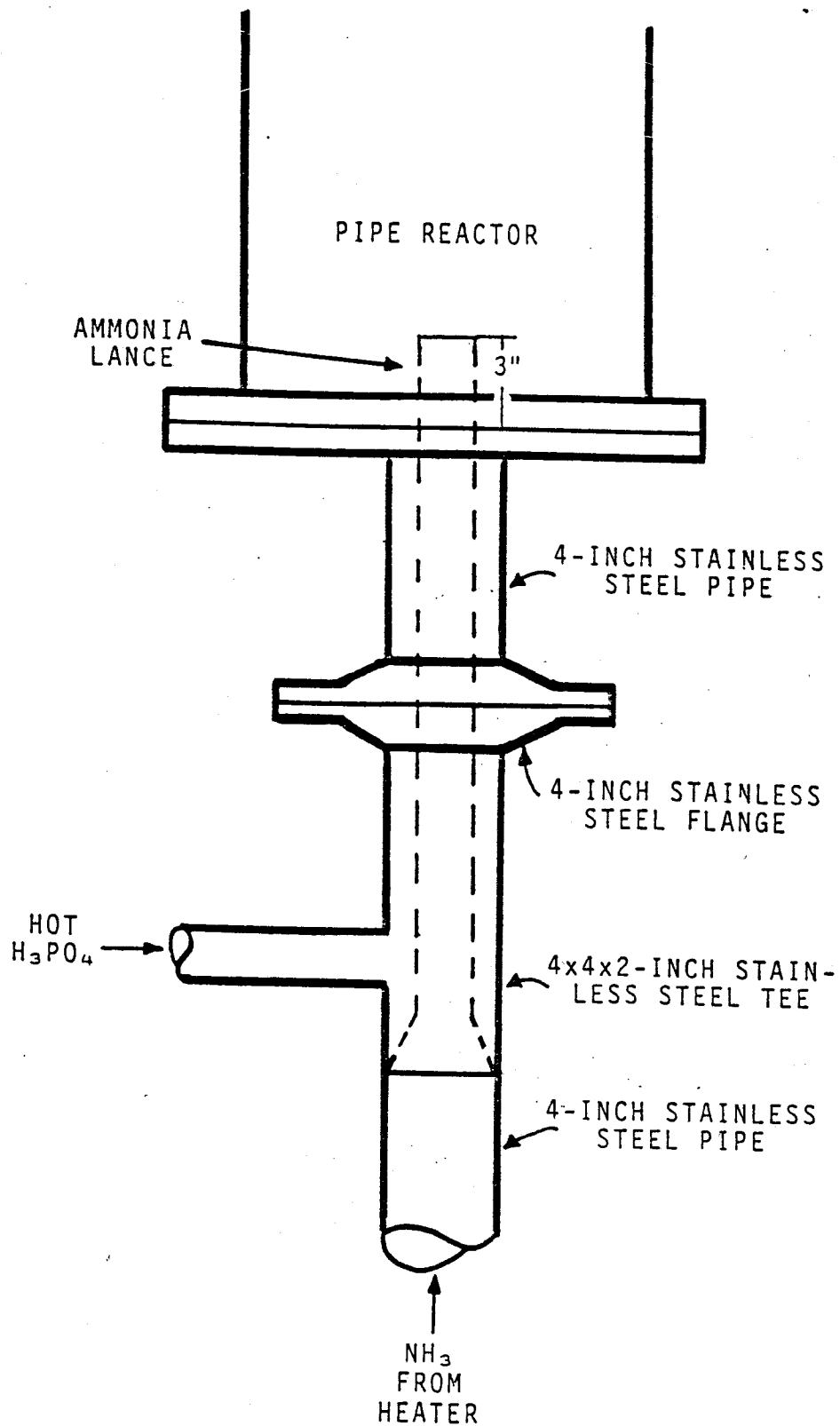


FIGURE 7

Acid-Ammonia Mixing Tee

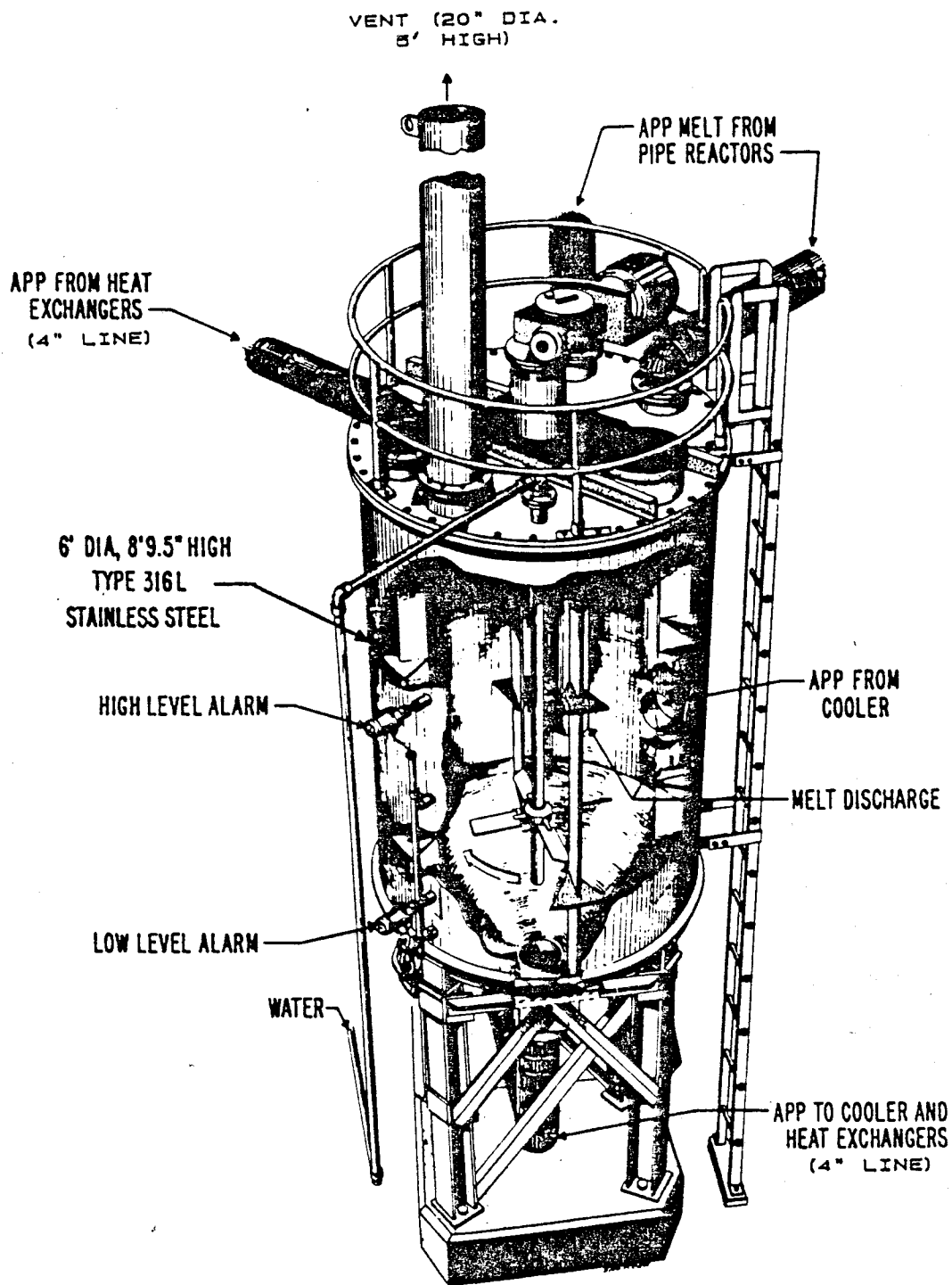


FIGURE 8

Reactor Surge Tank

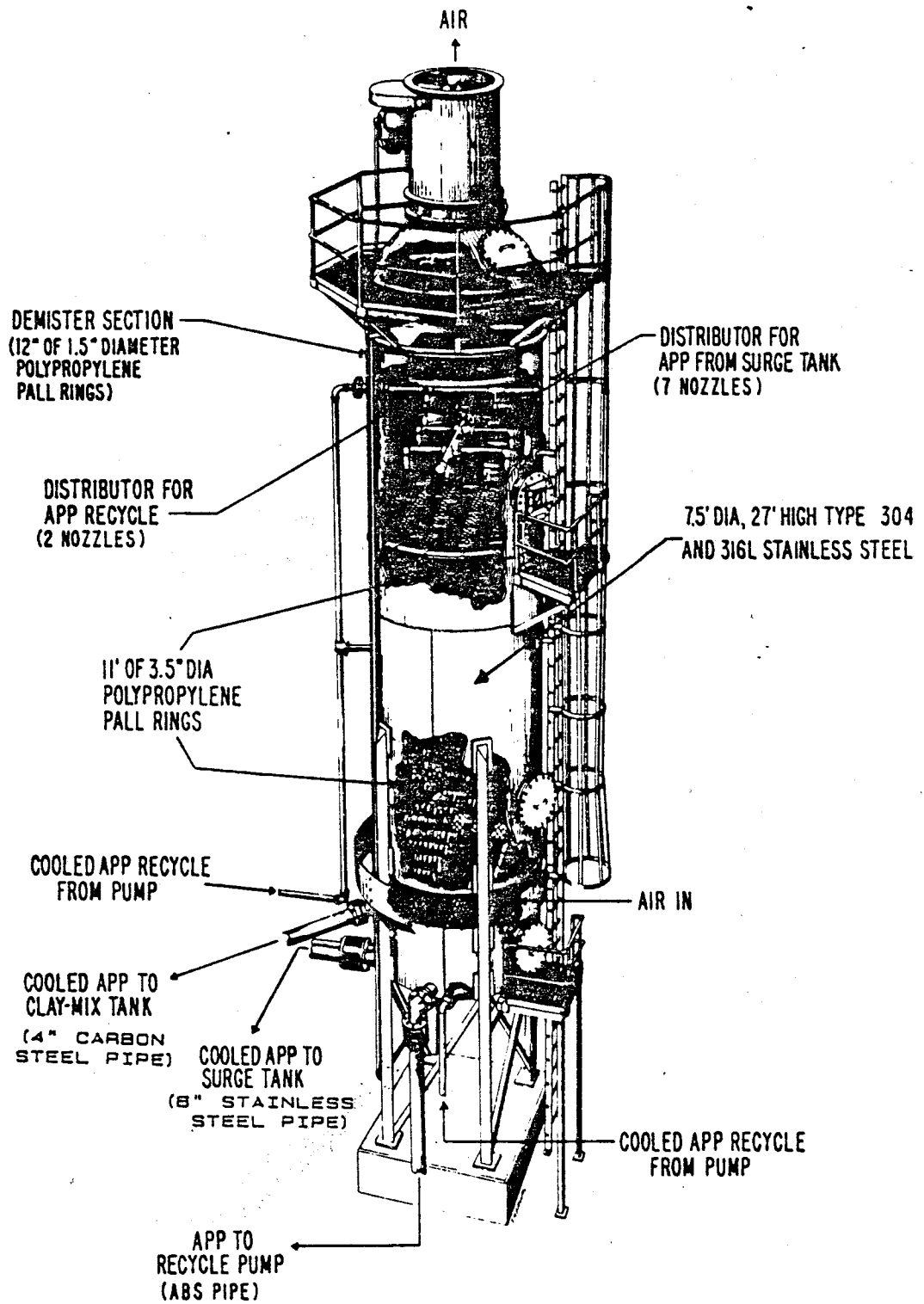


FIGURE 9

Packed-Tower Evaporative Cooler

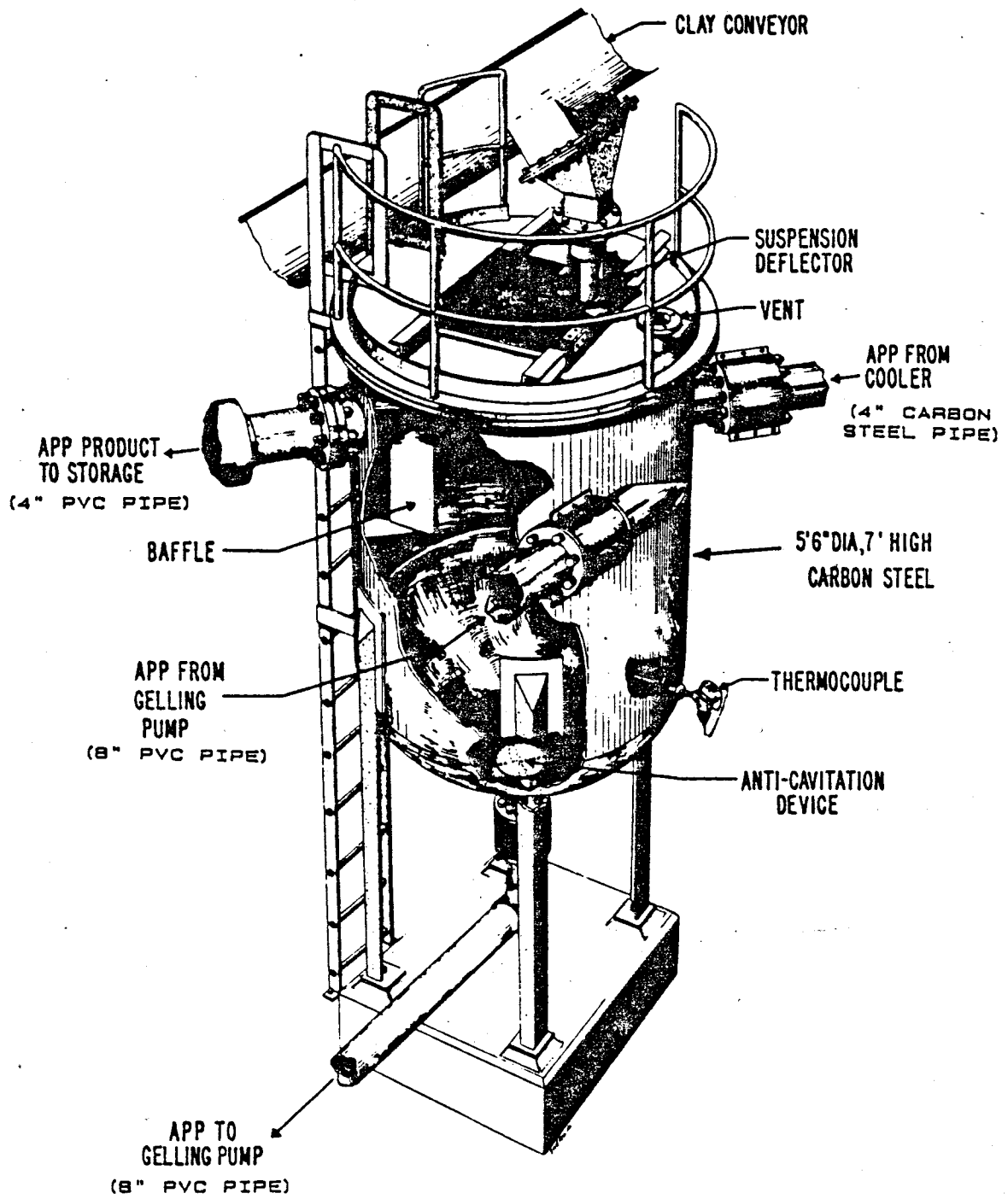


FIGURE 10

Clay-Mix Tank