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SELECTING EQUIPMENT AND MATERIALS OF CONSTRUCTION FOR FLUID FERTILIZER PLANTS

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Introduction

The use of fluid fertilizer is growing rapidly, and many producers considering this production route are new to fertilizer manufacturing. Prospective manufacturers face a bewildering array of pumps, agitators, metals, plastics, pipes, valves, and even turn-key plants. The purpose of this paper is to provide a basis to help producers make intelligent decisions on selecting equipment.

Engineers are often asked by producers considering the liquid fertilizer business what kind of plant they should build. An intelligent answer can not be given to this question unless further information such as that shown in table 1 is available. This information includes: (1) the kind of liquid fertilizer to be produced, (2) the production rate, (3) the length of the fertilizer season, and (4) how the equipment will be used.

The kind of liquid fertilizer produced influences selection of materials of construction, types of storage and pumps, and the necessity for cooling. Production should be projected 5 to 10 years to reduce the possibility of selecting equipment that is too small for future needs. A plant of 10,000-ton annual capacity in Florida where the fertilizer season lasts 10 to 11 months can use a lower production rate and smaller equipment than a plant of the same capacity in Minnesota where the season may be only 10 to 12 weeks. A small plant operating 24 hours per day can produce as much fertilizer as a large plant operating only eight hours per day. Since most fluid fertilizer plants do not operate 24 hours per day, much of the equipment in the industry is underused.

An experienced engineer can answer many of the questions in table 1. But questions regarding projected tonnage, operating hours, grades to be produced and length of season can best be answered by the prospective fluid plant owner. Agronomists and economists with state universities and federal agencies can give assistance. Also many private companies are glad to provide this kind of information.

Picking a Pump

The engineer often is asked: what size and kind of pump should be bought. Answers to the questions in table 1 will provide enough information for making that decision. The kind and amount of material to be pumped will determine what kind of pump should be used and of what materials it should be constructed. Most pumps in fluid fertilizer plants are centrifugal pumps; however, if anhydrous ammonia is to be pumped, a suitable positive displacement pump with the proper working pressures should be used. A phosphoric acid pump should be constructed of type 316 stainless steel.

A complete piping layout of the plant should be made in sizing a pump. Many fluid fertilizer plant managers consider this a waste of money. But if the piping layout is not made and the size of lines, the number of fittings and valves in the line determined, and the total pressure drops calculated, the selected pump may either be too small to do the job, or capital which could be better used elsewhere will be spent on excessive pumping capacity.

For example, piping handbooks show that one standard 6-inch elbow is equal to 16 feet of 6-inch pipe. Designs which eliminate only a few elbows and tees can cut pumping costs considerably. After the piping layout is made, pump performance curves should be obtained to determine the size of pump necessary to do the job. Then it may benefit the prospective owner to depart from engineering and scientific practice and to consult with his peers in the fluid fertilizer business who already own pumps. The capacity of the pump required will not vary; however, some pump manufacturers are not familiar with the problems involved in pumping fluid fertilizer. Usually, each producer will have a definite preference for a brand of pump. If enough dealers are consulted, a consensus will emerge and the list will be reduced to 4 or 5 brands. At this point, cost may be the deciding factor. It may be more economical to buy a cheaper pump and expect some down time for repairs. It must be remembered that down time during a

short fertilizer season can lose valuable business especially if spare parts are not readily available. In fact, availability of spare parts is important enough to be given equal weight with the kind of pump and its price.

Picking Pipe

The most commonly used metal in fluid fertilizer piping is carbon steel. Properly designed carbon steel piping should last from 5 to 7 years. However, velocities through this piping must not be excessive to obtain this service life. Since fluid phosphates provide a corrosive-resistant coating on pipe, excessive velocity can wash away this coating and expose the metal surfaces. Also, excessive turbulence will cause erosion problems at elbows and tees. Eight feet per second is usually considered the maximum velocity for good pipe life. Welded construction usually works better than threaded construction because threading reduces the thickness of the pipe and creates stresses in the pipe joints making them more susceptible to corrosion. Working pressures should be known and the thickness of the pipe picked accordingly. This applies to any pipe.

Polyvinyl chloride (PVC) pipe often is used for fluid fertilizers; none of the fluid fertilizers will attack PVC pipe. Care must be exercised, however, in picking the proper type of PVC pipe. Some types will melt and sag if the pipe is heated. This could occur in a plant producing 10-34-0 with the TVA pipe reactor or fluid fertilizer by ammoniating orthophosphoric acid. Polyvinyl dichloride (PVDC) will take temperatures near the boiling point of water. If plastic pipe is used to handle hot products, PVDC should be bought. PVC and PVDC are brittle as compared to carbon steel and often break as a result of improper support, excessive pressure, or impact, such as that caused by a worker using the pipe for a step-ladder or striking it with a vehicle. The use of schedule 80, PVC pipe, even where schedule 40 may take the working pressure, is sometimes recommended to help prevent this problem. Some of the properties of PVC and PVDC are shown in table 2. A sketch of an

effective support is shown in figure 1. Joints in the PVC pipe are usually cemented. Properly made joints will be strong and will not leak; however, improper cleaning and failure to follow the manufacturer's instructions for cementing can cause these joints to leak or even fail during plant operation.

Stainless steel often is used in fluid plants to handle acids. Precautions given for carbon steel pipe also apply generally to stainless pipe, although a lower schedule number can usually be used because no allowance for corrosion is required. Some attention should be given to corrosion rates of the material to be transported in stainless steel. For example, for phosphoric acid type 316 stainless steel is satisfactory, whereas type 304 is not.

Other kinds of pipe, such as fiberglass and polyethylene are available. Rubber hose often is used where flexibility is required. These materials have advantages and disadvantages. Suppliers of these products, especially rubber hose, should know the intended use, including kind of material to be transported, its temperature, viscosity, and the percent solids present when this is applicable.

Aluminum pipe most often is used for nitrogen solutions; however, PVC and carbon steel are satisfactory if the product contains no free ammonia and is properly inhibited. Most stainless steels are also effective, although they are expensive.

Purchasing Storage Tanks

Materials used in making storage tanks are much like those of pipe; namely, carbon steel, aluminum, fiberglass, stainless steel and plastics. Carbon steel tanks are usually the most economical for ammonium phosphate or ammonium polyphosphate fertilizers. Tank life varies from 5 to 10 years. If tanks fail in less than 5 years it is usually because of carelessness. Keeping carbon steel tanks full of some material, even if it

it is only water, will greatly extend their life. Diluting products to be stored for long periods so that the tanks will be full during storage is worthwhile. An analysis can be made on the diluted product or the final analysis calculated so the product can be used when the plant is started again.

Liners, paints, and floating oil on top of the fluid fertilizer in the tank can extend tank life; however, making an effort to keep the tanks as full as possible when they are not being used is probably the most economical method of extending tank life.

Rubber lining is required when carbon steel is to be used for storing acids. Reliable lining companies are available to provide this safe, economical way of storing acids. Testing of the tank for leaks after it has been installed is a good precaution. These tanks seldom leak; but if a leak does develop during transportation and installation, the results can be disastrous, especially in these days of concern over spills and stream and ground water pollution.

Fiberglass is economical and effective for storage of phosphoric acid and other corrosive materials. Results with fiberglass tanks have been excellent for the past few years. But because of previous problems, these tanks have not completely overcome their bad reputation. These problems mainly were caused by poor quality control during manufacture. Present manufacturers generally have much better quality control, and results obtained with these tanks have improved greatly. The best advice is to buy a fiberglass tank from a reliable manufacturer. All tanks should be properly ventilated during filling, but this is especially important with fiberglass tanks. Improper venting causes pressure buildup in tanks which may split the tank.

Tank foundations are important, especially for cone bottomed or fiberglass tanks; however, all tanks should be kept level as they are filled and emptied. Figure 2

shows an economical and effective tank base for flat bottom metal tanks. This kind of foundation is not recommended for fiberglass and cone-bottomed tanks. Fiberglass and cone-bottomed tanks should be placed on concrete foundations reinforced with steel. Building a foundation is an engineering problem because of the weight and bearing area of the full tank. Fiberglass tanks can rupture if they tilt. Cone-bottomed tanks have a high center of gravity and can turn over if the foundation fails. Coating the top of the foundation with epoxy tar paint can prevent damage to the foundation by spilled product.

Cone-bottomed tanks are best for storing wet-process phosphoric acid and suspensions. Solids tend to settle out of these products and collect in the area away from the tank outlet as shown in figure 3. This hinders their removal. Cone-bottomed tanks as shown in figure 4 tend to collect the solids in the cone where they can be removed either during use or recirculated to the top of the tank for resuspension. The more slope on the bottom of the tank the better; however, even in tanks without steep slopes, sludge will tend to build up until its angle of repose has been reached. Also, sludge removal is simpler in cone-bottomed tanks.

Mix Tanks

Mix tanks face the same corrosion problems as pipe and storage tanks. They must, however, have more resistance to stress and heat deformation when acid and ammonia or hot water are used. This is necessary because of exothermic chemical reactions and violent dissolutions in mix tanks. Most mix tanks are made of types 304 or 316 stainless steel. Type 304 will work satisfactorily with phosphoric acid because residence time of the unammoniated acid in the tank is usually short. Type 316, however, gives longer life and the extra cost probably is a good investment. Carbon steel tanks offer low initial investment and longer life than most people expect when no chemical reaction is involved. A common problem with carbon steel tanks is formation of rust flakes that get into the fertilizer and sometimes cause stoppages in the

application equipment. Straining of fluid fertilizers made in mild steel equipment is recommended. This is good practice with all fluid fertilizers. It is also more difficult to maintain the appearance of carbon steel than stainless steel tanks. Carbon steel tanks always appear rusty regardless of how many times they are sandblasted and painted.

Mix tanks are usually mounted on pipe lever scales and sometimes corrosion on these scales, as well as occasional buildup of solids around the moving parts, results in inaccuracies and excessive maintenance. Scales of the ribbon type are less susceptible to interference by solids buildup and corrosion. At least one mix tank manufacturing company uses a hydraulic scale upon which to mount their mix tank. These scales have proven accurate and reliable in fertilizer service. Electronic scales with digital readout have not been widely used but they can be expected to appear on the scene in the near future because of several unique advantages such as remote readout.

Agitators vary from crude homemade types such as pieces of screw conveyor stuck on a shaft and driven by a small motor to commercially manufactured high sheer agitators driven by 80-hp motors. The mixer that is chosen will depend upon the job to be done. Clear liquids produced by cold blending a liquid phosphate base, urea-ammonium nitrate solution, and potash requires very little agitation, and almost any kind of mixer will be satisfactory. These mixtures can be produced by merely recirculating with a pump. However, the amount of agitation required is a function of the production rate and should be given the same scientific consideration as that used to select a pump. Normally, turbine agitators with blades pitched at a 45° angle, such as shown in figure 5, are used for the suspension of solids in a fluid medium. This kind of agitator causes a downward pumping action which creates a vortex causing solids dumped onto the surface of the fluid to be sucked through the agitator, pumped to the bottom of the tank and then recirculated again to the top so they suspend effectively. If a chemical reaction

occurs, such as that between ammonia and phosphoric acid, it is better to have the blades of the turbine placed vertically as shown in figure 6 so that the maximum agitation will occur at the end of turbines. Spargers should discharge near the ends of the blades.

High shear mixers as shown in figure 7 are normally used when solids other than potash are used in the mixture. These solids generally are mono and diammonium phosphate in the United States although triple superphosphate and other materials can be used when adequate agitation is available. Although agitators usually are made of either types 304 or 316 stainless steel, satisfactory agitators which give good service and long life can be made from carbon steel.

The shaft should be of sufficient diameter to resist torque created by starting the agitator in thick fluids having viscosities of 1,000 centipoises and above and to prevent vibration due to flexing of the shaft during operation. To prevent flexing some agitators have bearings not only at the top of the shaft but also on the bottom of the tank.

Valves

The valves most commonly used in the fluid fertilizer industry are butterfly, ball, eccentric plug, and gate. Globe valves with suitable working pressures often are used with anhydrous ammonia. Butterfly valves are most commonly used for flow control. These valves are reliable, easily repaired or replaced, comparatively low in cost, and may be made with a body of low cost carbon steel and internal or wetted parts of corrosion-resistant stainless steel. Carbon steel gate valves often are used as closures for storage tanks where only an on-off action is required. Eccentric plug valves are less popular because of the tendency to bind due to the corrosive action of fertilizer. Although ball valves are very satisfactory, they are expensive and are seldom seen in fluid fertilizer plants.

A common problem with all valves used for flow control in fluid fertilizer plants, especially those with quick opening devices used in conjunction with large pumps, is the tendency for operators to close the valve too quickly, resulting in damage to the valves or other portions of the piping system by the velocity head. This can be eliminated by putting hand wheels and screwed closures on the valves; however, this results in slow action and lower production rates. Another solution is to place an air compression chamber somewhere in the system to absorb the inertia in the fluid when the valve is closed. This can be done easily by merely placing a 5-foot vertical section of capped 6-inch pipe somewhere in the system between the pump and the valves so that air is trapped. The inertia is then absorbed by compressing the air in the chamber.

Some plants use automatic control valves. These valves are air operated but it is likely that some electronically-operated valves will be used in the near future as fluid fertilizer plants become more sophisticated. The question of whether to use manual or automatic valves often arises during discussions of plant design. This kind of equipment can cut labor costs and increase the production rate. A careful analysis should be made of the plant requirements to determine if the extra money invested in these valves and in auxiliary equipment to operate them is justified. If labor costs are not decreased or the production rate increased, automatic valves may not be necessary.

Solids Handling

Probably the most frequent bottleneck preventing fluid fertilizer plants from attaining design production rates is the solids handling equipment. In some plants, large amounts of capital have been invested in mixing and pumping equipment while the solids are handled with a small grain auger. Some suspension grades, such as 3-10-30, are almost one-half potash. If excessive time is required to get the potash into the

mixture, money spent on high quality mixing equipment will be wasted and the design production rate never attained. Solids handling equipment requires the same careful engineering study as pumps, mix tanks, pipes and other equipment. It should be remembered that a 30-ton per hour auger or bucket elevator takes 2 minutes to get a ton of solid into the mix tank. If a 10-ton batch requires 4-1/2 tons of potash, 9 minutes is needed to get potash into the mixer and the money invested in high shear equipment to suspend potash quickly has been wasted. The pounds per minute rate of solids handling equipment should be considered rather than the ton per hour rate. This is then figured into the production rate per hour along with the time required for adding fluid bases. Pump-out times and change-over times should also be figured into production rates. If solids other than potash are used, the bottleneck caused by small solids handling equipment can be even worse.

An alternative to large augers or elevators is the suspending of hoppers over the mix tank. Hoppers allow the solid raw materials to be accumulated while others mixing operations are being performed. These hoppers can then be emptied quickly by remotely operated or mechanically operated openings on the bottom of the hoppers. This allows potash to be added quickly to the tank thus maintaining the designed production rate. These hoppers should not be too big. If they are, solids left in them during shutdowns will pressure-set or pick up moisture from the atmosphere making the solids difficult to remove. Hoppers should be emptied when the plant is to be shut down for any length of time.

Conclusion

Before equipment is chosen for a fluid fertilizer plant, the production rate and grades should be determined, the length of season projected, raw materials selected, and future tonnages predicted. Physical properties of the raw materials and products should be studied and the materials of construction evaluated.

It may appear that services of a design engineer are required for even the smallest plant. This is not true because most producers building a plant know the grades required and the projected production requirements better than anyone else. Corrosion rates and other physical properties of the material to be handled can be obtained easily from the suppliers of the material. Pump sizing and plumbing requirements usually can be done by vendors of equipment if the information listed in table 1 is available.

Table 1

Data Required for the Selection of Equipment and Materials of
Construction for Fluid Fertilizers

1. Kind (10-34-0, suspension, acid and ammonia, potash grade, etc.)
to be produced.
2. Viscosity
3. Vapor pressure
4. Density
5. Corrosion rate
6. Production rate required (length of season, operating hours, etc.)
7. Location of plant (on rail, near highway, drainage, etc.)
8. Will plant be inside or outside. If inside will plant be heated.
9. Ventilation required (will pesticide be handled, etc.)
10. Kind of electric service available (220 V, 440 V, etc.)
11. Average relative humidity in area (if cooling is required)
12. Average temperature in area
13. Possible snow loads
14. Bulk solids to be handled (potash, MAP, DAP, micronutrients, etc.)
15. Will bagged solids be handled (micronutrients, clay, etc.)
16. Waste disposal (sewers or special handling required)
17. Water supply (city water or well, flow rates)

Table II

Properties of Polyvinyl Chloride Pipe

<u>Physical Characteristics</u>	<u>Type of PVC</u>		
	<u>PVC Type 1</u>	<u>PVC Type II</u>	<u>PVC High Temp.</u>
Flexural strength, lb/in ²	14,500	11,500	14,500
Heat distortion temperature, °F* at 264 lb/in ²	165	155	215
Impact strength at 73°F, ft-lb/in notch**	0.8	12	6.3

* Temperature at which pipe will distort

** Measured by IZOD impact test

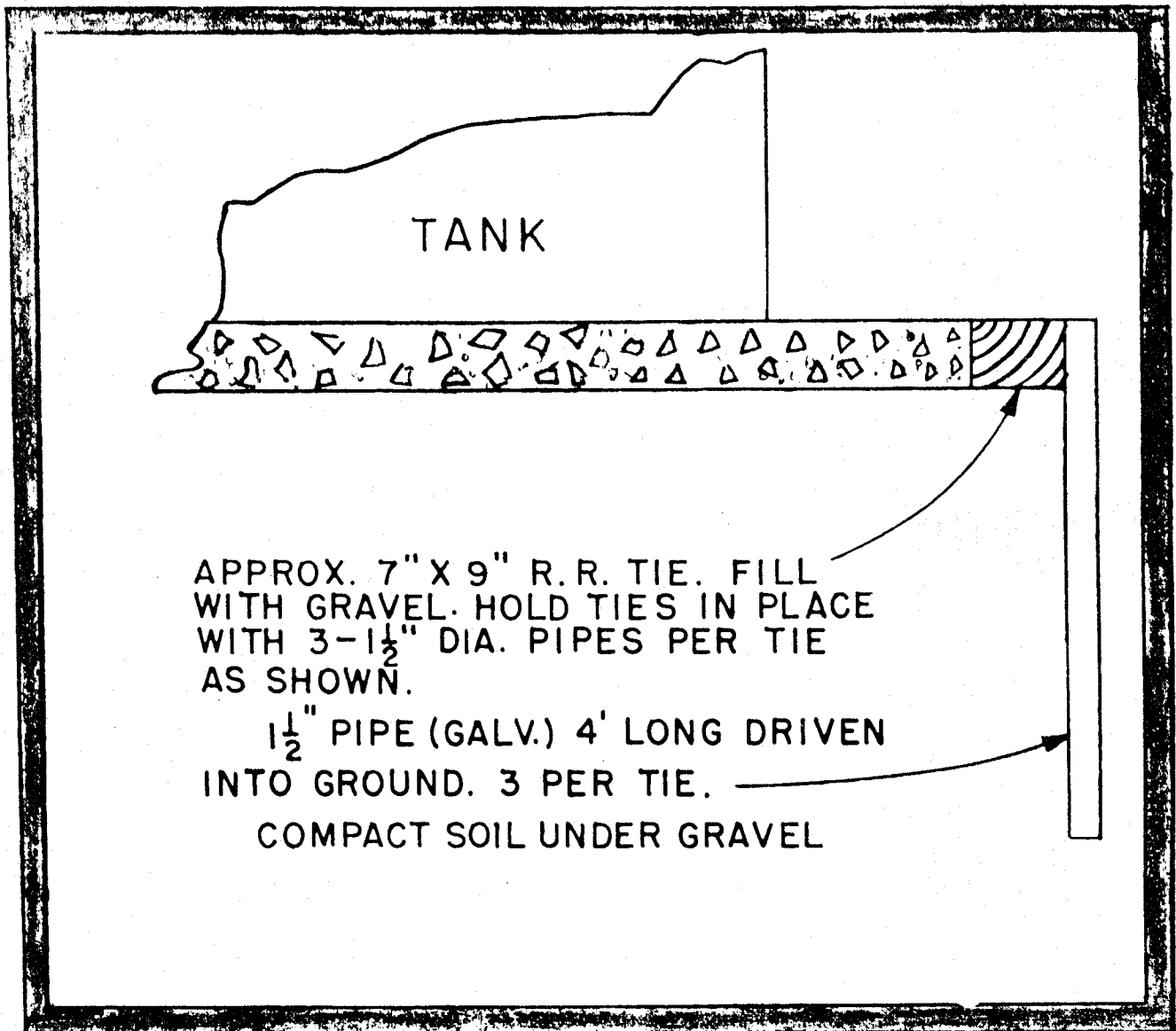


FIGURE 2

TANK FOUNDATION

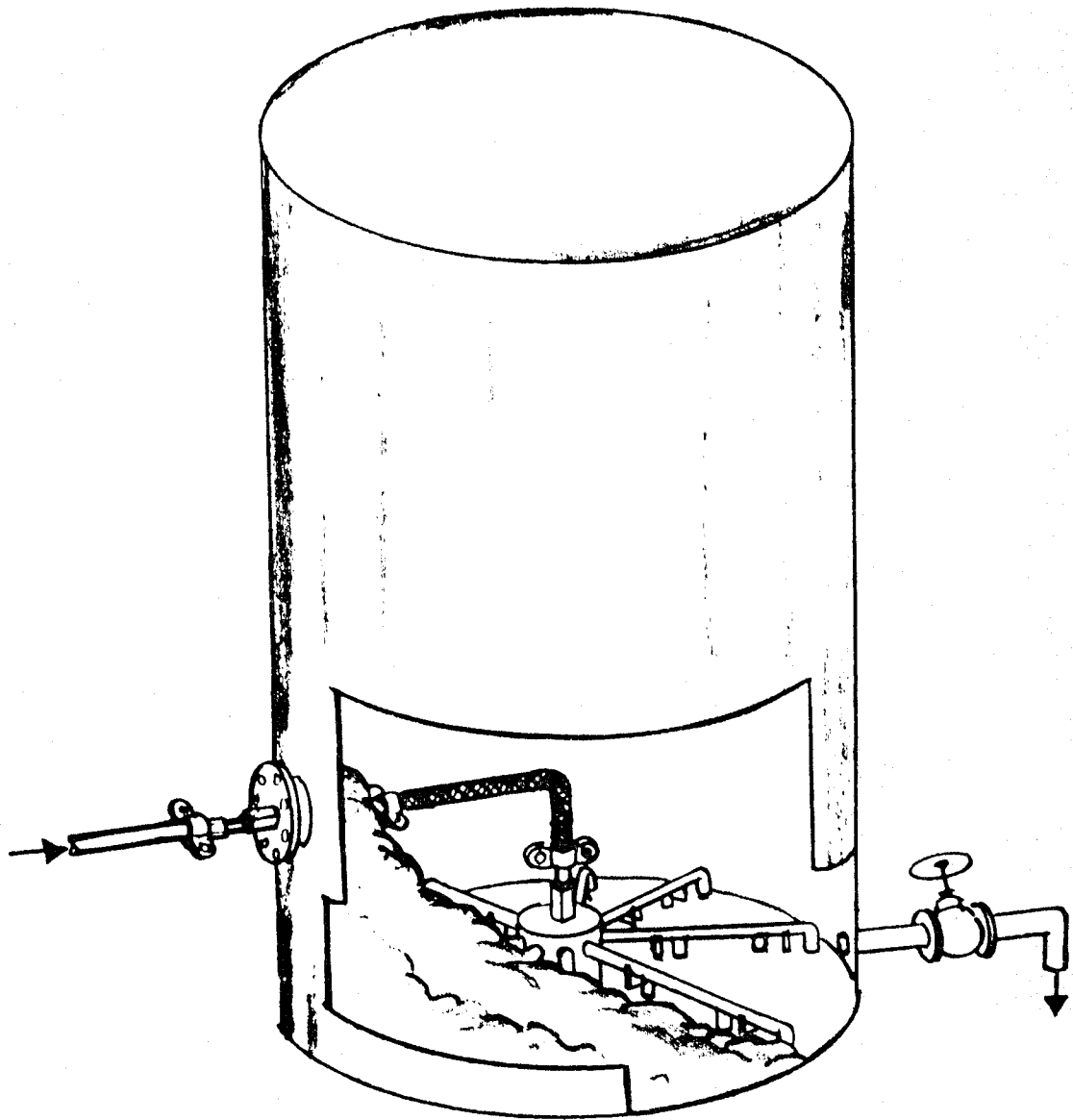


FIGURE 3

FLAT BOTTOM STORAGE TANK

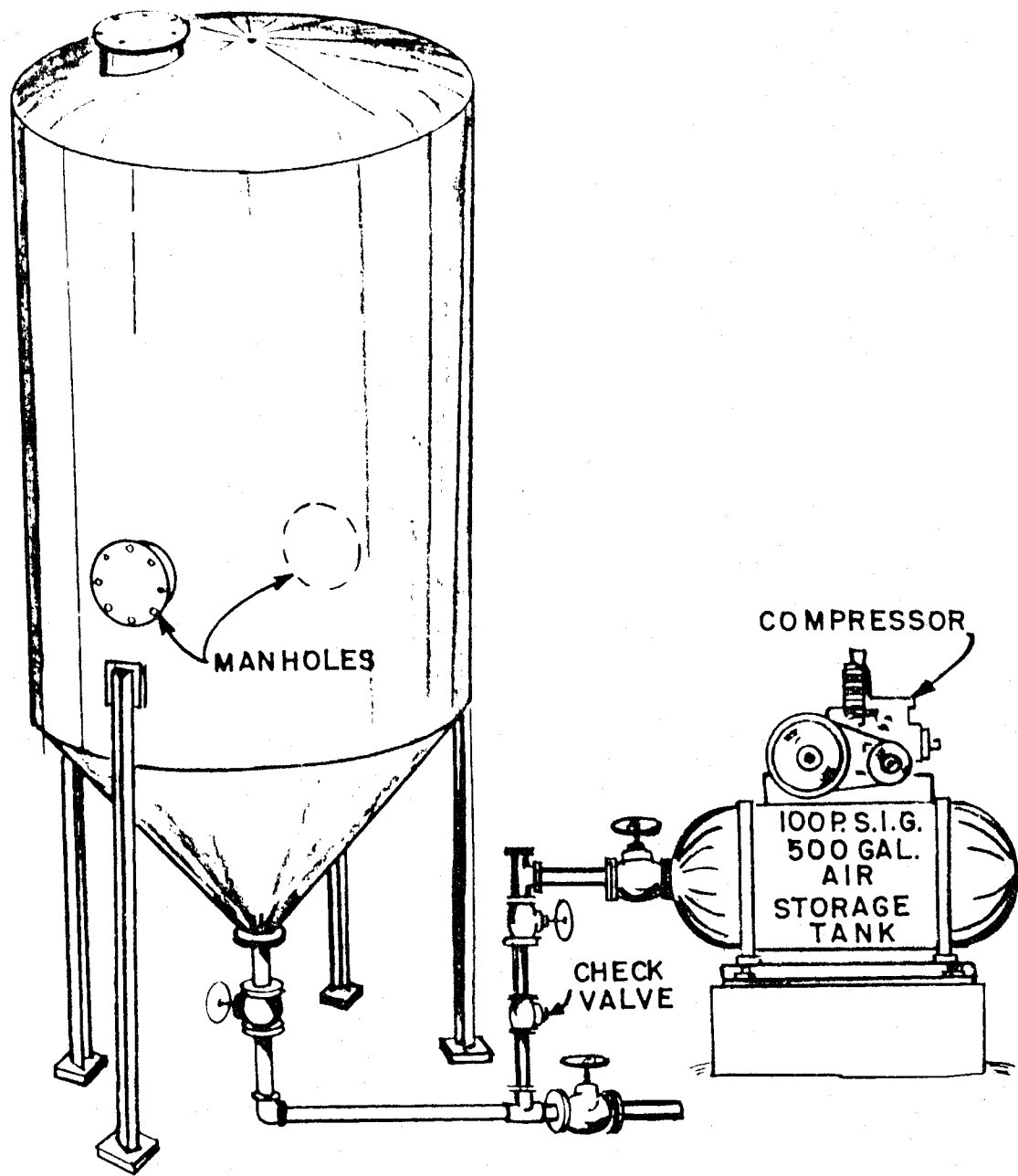


FIGURE 4
CONE BOTTOM STORAGE TANK

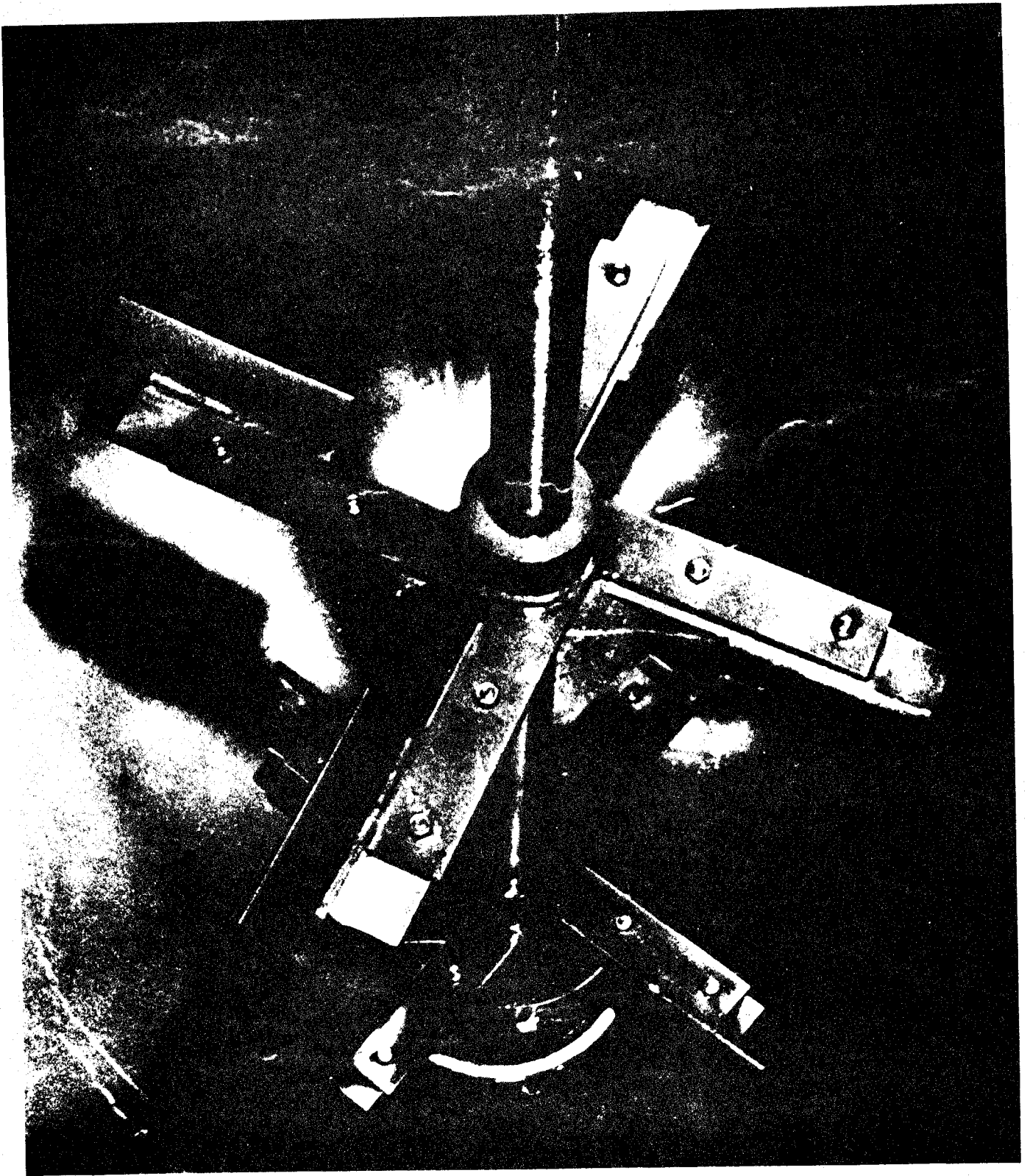


FIGURE 5
TURBINE-TYPE AGITATOR WITH PITCHED BLADES



FIGURE 6
TURBINE-TYPE AGITATOR WITH BLADES HAVING NO PITCH

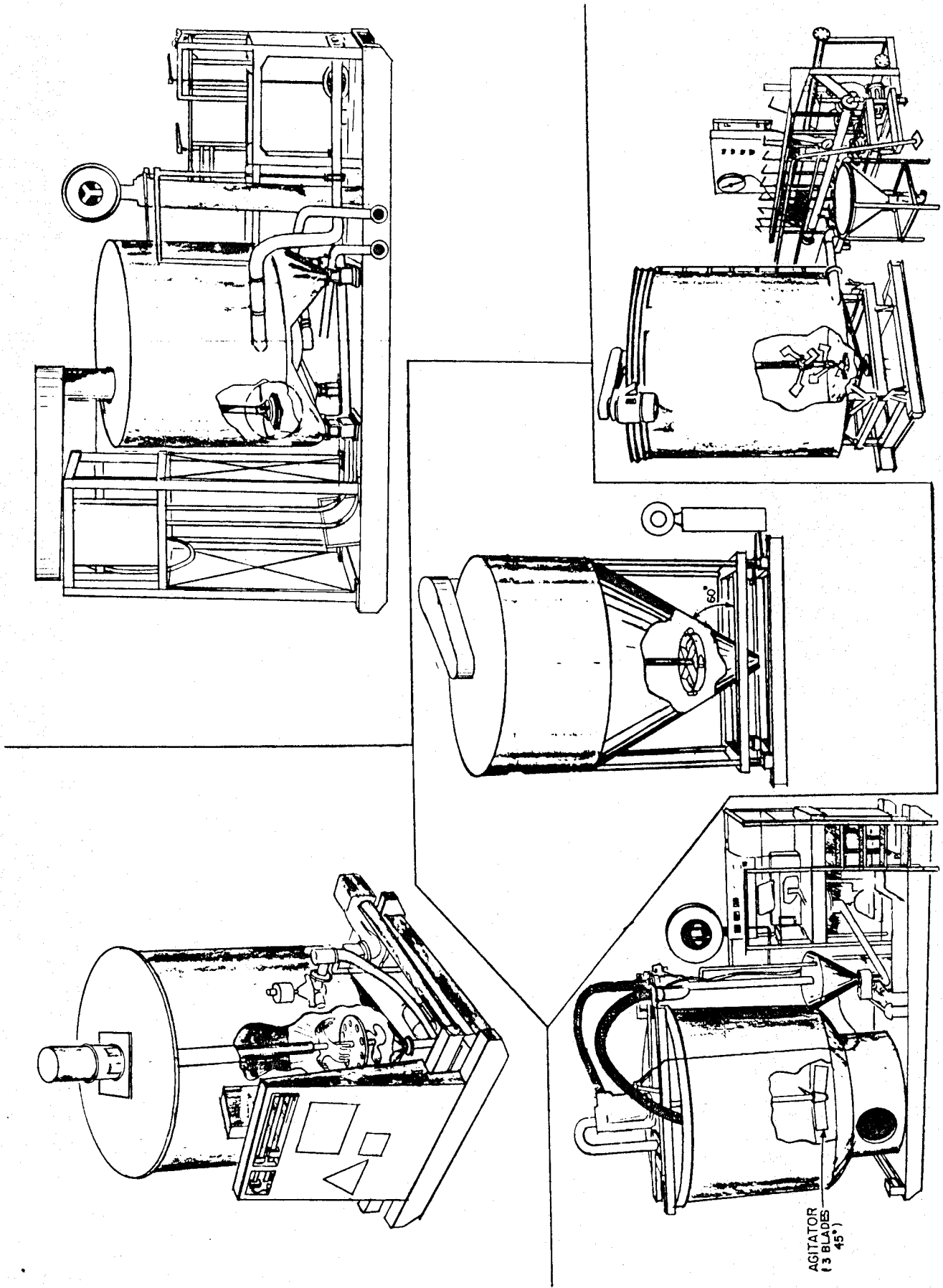


FIGURE 7
FIVE TYPES OF MIX TANKS FOR SUSPENSIONS

AGITATOR
(3 BLADES
45°)