SECTION 5. GROUTING EQUIPMENT

13. INTRODUCTION. Guidance for selecting or approving the specialized equipment necessary for a grouting project is provided below, and operational principles for the equipment are outlined and related to job requirements.

14. DRILLING EQUIPMENT.

a. Percussion Drilling. Percussion drills are operated by air-driven hammers. The best known types are the jackhammer, drifter, and wagon drill. The drill proper consists of a hollow steel rod, fitted with a fixed or detachable bit on one end and a shank on the other.

(i) Operation. Percussion drills are used for drilling in rock. The percussion drill does not reciprocate. Its shank fits into and is held loosely in the chuck at the forward end of the machine, where it is struck by a hammer-like piston actuated by compressed air. The compressor capacity necessary to operate a single-hammer drill ranges from 50 to 200 cfm, depending upon the size of the drill cylinder and the pressure at which air is supplied. During drilling the bit remains in close contact with the rock at the bottom of the hole at all times except during the slight rebound caused by impact of the hammer. Drills are provided with a mechanism that causes the drill steel rod to rotate between blows of the hammer. Cuttings or sludge are removed from the hole by air or water that passes through the machine, down the hollow drill steel rod to the bottom of the hole, and then rises up the hole to the surface. Removal of cuttings by water is preferred for grout-hole drilling but is not mandatory. Jackhammer drills, due to their light weight, are usually held in position by hand. Drifter-type drills are designed for tripod or bar mounts. The wagon drill, as commercially available, is comprised of a drill head mounted in leads that are supported on a track-, wheel-, or skid-mounted chassis.

(2) Application. Percussion drilling produces acceptable grout holes and, generally, is the most economical method of drilling shallow holes. This advantage decreases with depth and disappears at depths from 75 to 125 ft depending on the type of rock. In operation, the edges or wings of the bit wear away so that a progressively smaller hole is drilled. Therefore, when pertinent, the specifications should state the minimum acceptable size of grout hole.

b. Rotary Drilling. Rotary drilling is the process of making a hole by advancing a drilling bit attached to a rotating column of hollow drill pipe. The drill pipe is turned by a motor at speeds ranging from a few hundred to 3,000 or more rpm. Pressure on the bit is applied hydraulically or mechanically. Water is forced through the drill pipe to wash cuttings out of the hole. Drill rigs vary in size from small lightweight machines capable of drilling

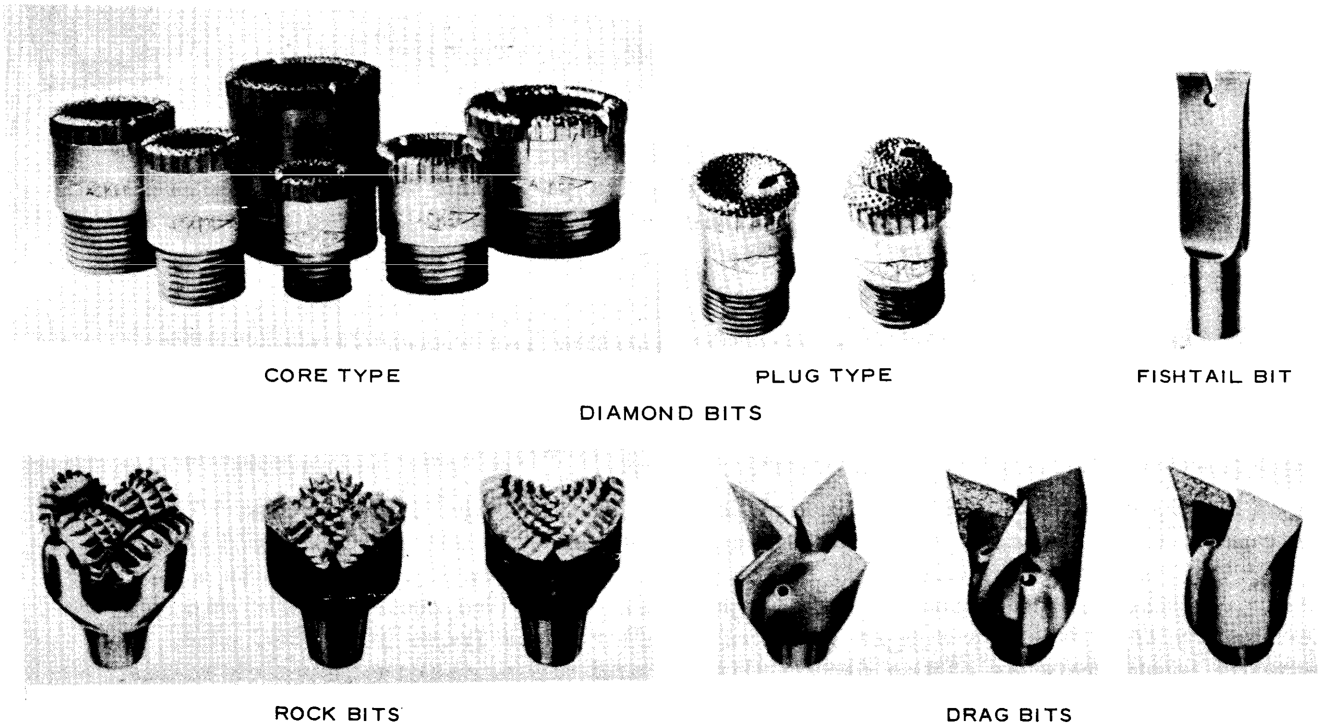


Figure 8. Drill bits

holes only a few hundred feet deep to large rigs that can drill holes miles in depth. The small rigs are usually satisfactory for grout-hole drilling and are desirable from the standpoint of portability. Drill bits adaptable to a great variety of subsurface conditions are available. Some of the common types are shown in figure 8 and are discussed below.

(1) Diamond bits. Diamond bits may be either core or plug type. Both types employ a diamond-studded bit to cut the rock. The bit is coiled and the hole continuously cleaned by water or compressed air pumped through the drill rods.

(a) Core type. The core-type bit consists of a hollow steel cylinder, the end of which is studded with diamonds. The bit is fitted to the lower end of a hollow steel chamber (core barrel) that is rotated rapidly while the bit is held firmly against the rock so that the diamonds cut an annular channel in the rock. The rock that lies within the channel and projects into the barrel constitutes the core.

(b) Plug type. Two varieties of plug bits are available commercially. One is a concave type, the head of which is depressed toward the center; and the other, a pilot type, has a protruding element, cylindrical in shape, but of s mailer diameter than the main bit head. Noncoring diamond bits have a wide field of usefulness in foundation grouting. However, they are more costly than coring bits for drilling in extremely hard foundations and in badly fractured rock because of greater diamond cost. Since they produce only cuttings, more diamonds are required to make a given footage of hole than if a large part of the rock encountered is removed as core. The loss of one or two diamonds from the center of a noncoring bit (a not infrequent occurrence in drilling shattered rock) renders the bit useless for further cutting. The plug bit is less expensive than the core bit in deep holes due to the time saved by not having to pull out of the hole to empty the core barrel or to clean a blocked bit.

(c) Size. The sizes of diamond bits are standard and are generally shown by the code letters EX, AX, BX, and NX. The dimensions of each size are tabulated below. Most diamond-drilled grout holes are EX or AX in size. There is insufficient advantage in larger bits to justify their use. The possible advantage that the larger diameter bit may have in encountering more fractures than the smaller is more than offset by the fact that the greater economy of the small bit permits a closer spacing of holes for the same overall cost.

	Size. in.	
Code	Hole	Core
EX	1-7/16	7/8
AX	1-27/32	1-7/32
BX	2-5/16	1-5/8
NX	2-15/16	2-1/8

(2) Hard metal bits. Drill bits of hardened steel notched to resemble the teeth of a saw can be placed on the core barrel to substitute for a more costly diamond bit. In some soft rocks this type of bit will make a hole much faster, is not as easily blocked, and is much cheaper than a diamond bit. Often the teeth of such bits are faced with one of the alloys of tungsten carbide, or replaceable inserts of a hard alloy are welded into holes cut–into the bit blank. A noncoring bit can also be made with the hard alloys by studding the cap for a piece of drill pipe with bits of the steel rod containing the powdered alloy and adding waterways.

(3) Rock bits. Rock bits, like diamond bits, are attached to the bottom of a column of hollow drill pipe. The bit is made of toothed rollers or cones, each of which turns or rolls on the rock as the bit rotates with the drill pipe. Cutting is accomplished by crushing and chipping. The shape of the teeth, their attitude and number, and the number of rollers vary. Most bits have three or four cones or rollers; some have two. The teeth and other parts of the bits subjected to intense abrasion are made of hard alloys. Cuttings and sludge are washed out of the hole by circulating water or drilling mud through the drill pipe and back to the surface between the drill pipe and the walls of the hole. The roller rock bit is not extensively used for grout-hole drilling because the smallest available size is approximately the same as that of an NX diamond bit.

(4) Drag and fishtail bits. The drag bit is a general service bit for rotary drilling. Capable of drilling soft rock and most soils, it is used extensively in foundation explorations and grout-hole drilling. The fishtail bit is so named because of its resemblance to a fish tail. The divided ends of its single blade are curved away from its direction of rotation. , Other drag bits have three or four blades, which may or may not be replaceable. The cutters or cutting edges of the blades are made of hardened steel or are covered with hard alloys. Almost any desired size is available.

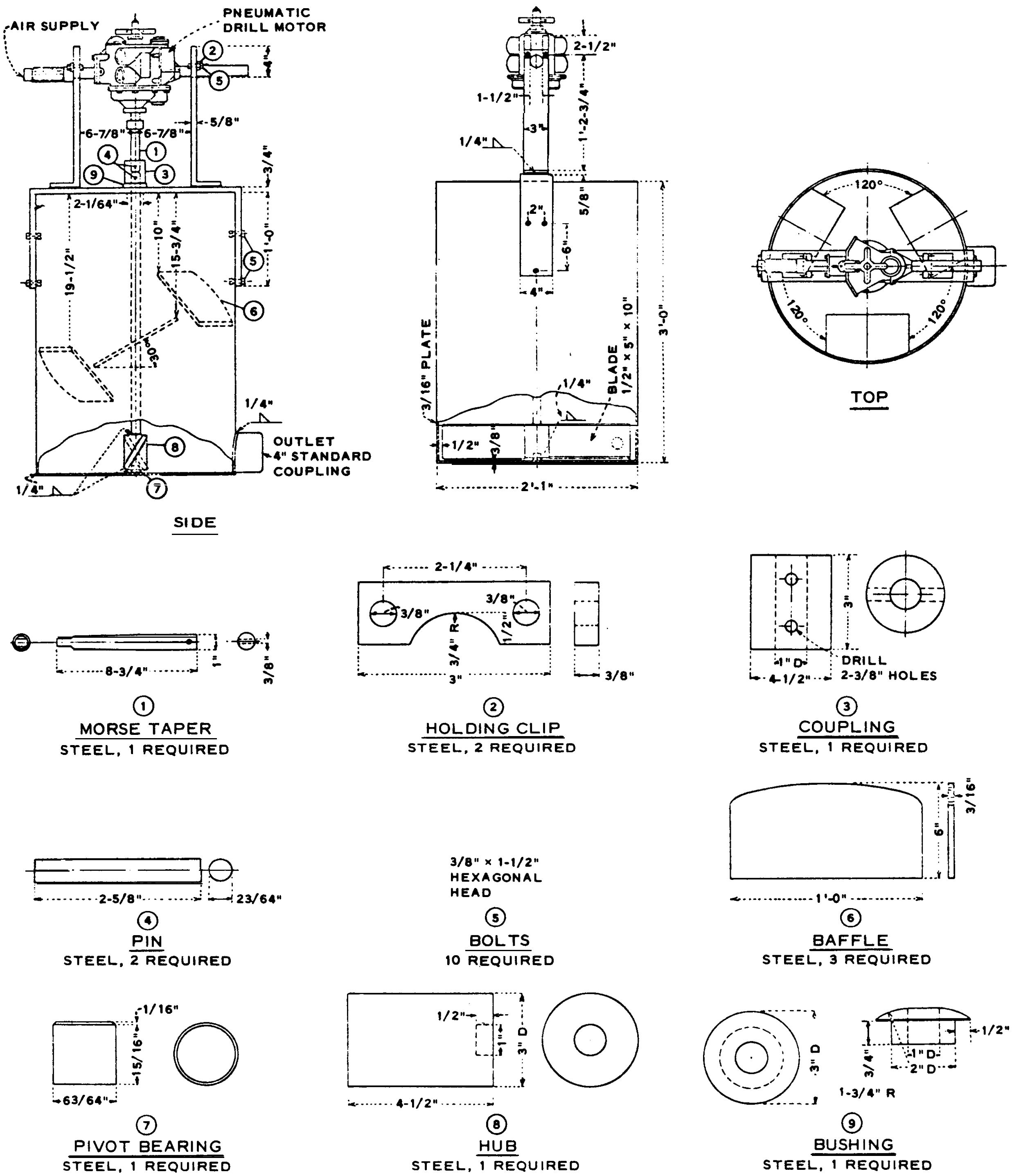
c. Summary. Drill bit types and the materials in which they are generally—used are as follows:

Drill Bit Type	Principal Use	Not Well Suited for
Diamond:		
Core	Rock and concrete	Unconsolidated soils
'Plug	Rock	Extremely hard rock, extremely soft rock, unconsolidated soils, and shattered or fractured rock
Hard metal	Soft rock, hard clay, and cemented soils	Hard rock and unconsolidated soils
Rock	Rock	Unconsolidated soils and very hard rock
Drag and fishtail	Soft rock and soil	Hard rock
Percussion	Rock and concrete	Unconsolidated soils

15. GROUT PLANT.

a. Grout Mixers. Many types of grout mixers have been used, including hand-turned dough mixers, concrete mixers of various sizes, and especially designed grout mixers. Any machine is suitable that has the desired capacity and that mixes the grout mechanically to a uniform consistency. Two mixers can be arranged to discharge into the same sump to satisfy high capacity requirements. Manual stirring of cement and clay grouts in a tub is not satisfactory except in emergencies. Hand-powered dough mixers are not recommended because of their limited capacity.

(1) Central Valley-type grout mixer, 8-cu-ft capacity. During the grouting at several dams of the Central Valley Project, a small, air-operated, lightweight grout mixer was needed that could be set up and operated in a 5- by 7-ft gallery. The mixer shown in figure 9 was designed for



(Courtesy of U. S. Bureau of Reclamation)

Figure 9. Central Valley-type grout mixer, 8-cu-ft capacity

this purpose. It was fabricated in a local shop economically.

(2) Grand Coulee-type grout mixer, 21-cu-ft capacity. In the grouting at Hoover Dam, considerable experimenting was done with various equipment for mixing grout. Concrete mixers were first used but were later discarded for the type mixer shown in figure 10. The body of this mixer is 30 in. (ID) by 48-1/2 in. long. There are 16 paddles in series of 4 mounted on a 2-in. -diameter shaft. The paddle shaft is supported on the back end by an extended babbitted bearing with cap, and on the other end by a split-cap, rigid, babbitted pillow block. The body is made of a 3/16 -in. plate with front head 1/4 in. thick and a removable back head 3/8 in. thick. The removable back head not only facilitates the removal of the paddles but also permits thorough cleaning and chipping out of hardened cement, if necessary. The shaft has supplemental bearing supports in the heads that consist of bronze - bushed, welded-in steel hubs. The charging chute is 18 in. in diameter at the top, 14 in. in diameter at its junction with the body, and 14 in. high. There is a small bag support on a 24- by 36-in. platform. Power is supplied by a 2.65-hp air motor that makes 65 rpm when supplied with air at 100 psi. Its consumption is approximately 85 cfm. A bolted coupling connects the motor to the mixer. The body is supported on two welded reinforced saddles attached to 4-in. I-beam skids which are not shown in the figure.

(3) Grand Coulee-type grout mixer, 27-cu-ft capacity. For the contraction joint grouting at Grand Coulee Dam, two 27-cu-ft mixers, as shown in figure 11, were purchased. They are similar to the 21-cu-ft model. These mixers are easy to run and to clean and are very flexible. They handle batches of grout made from 1 to 10 sacks of cement and do a thorough job of mixing. These mixers were powered by air motors.

(4) High-speed colloidal-type mixers. High-speed colloidal-type grout mixers are commercially available in both the single - and double -drum types. These mixers are equipped with small centrifugal pumps, which cause the grout to circulate at high speed while being mixed. Particles of cement may be broken and rounded to a significant degree in high-speed mixers. This results in an increase in pumpability and penetrability for portland-cement grout. In an emergency, grout can be pumped at low pressures into the foundation or other places with the centrifugal pumps of these mixers.

(5) Water meters. A satisfactory water meter is the single-disk type, size 1-1/2 in., and threaded for pipe connection. This type has a 6 -in. vertical register with a long hand that makes one revolution per cubic foot of water and a short hand that indicates 10 cu ft per revolution. For use in grouting, the meter should have a reset knob to set the hands to zero and a direct-reading totalizer. A screen should be provided if sand or rock particles are present in the water supply.

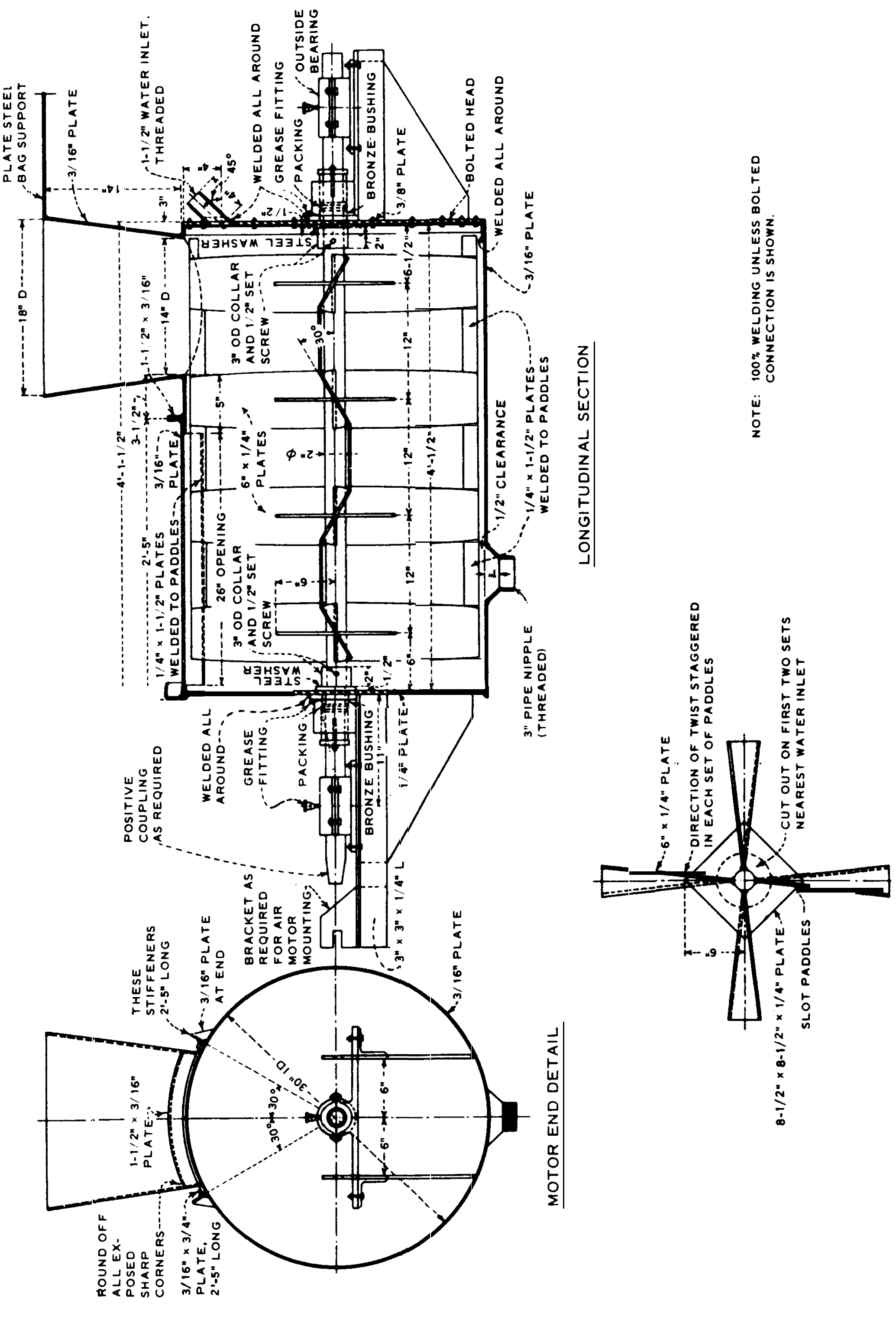
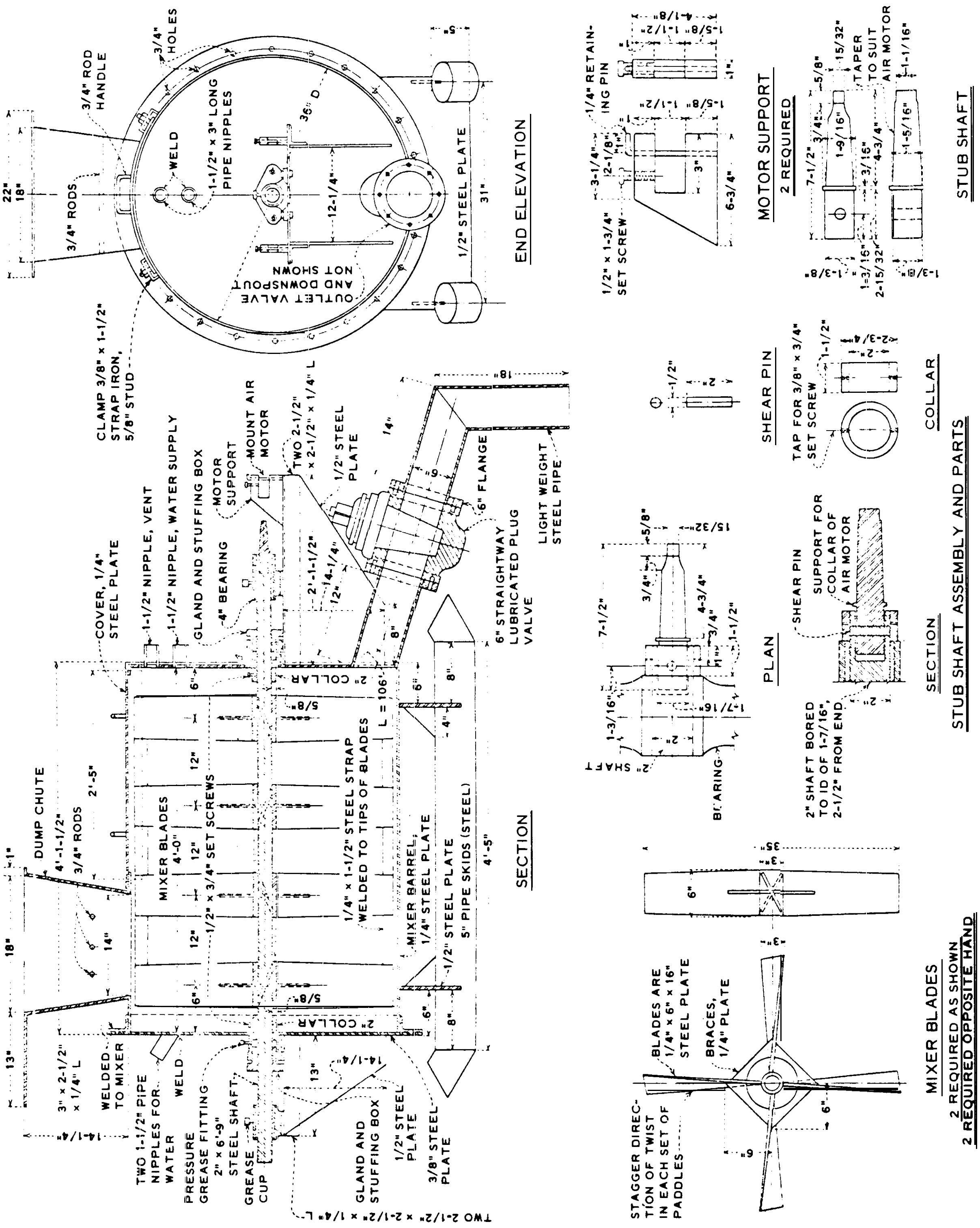


Figure 10. Grand Coulee-type grout mixer, 8-cu-ft capacity



(Courtesy of U. S. Bureau of Reclamation)

Figure 11. Grand Coulee-type grout mixer, 27-cu-ft capacity

b. Agitators.

(1) Agitator sumps. After mixing, grout should be agitated to prevent settlement while it is being pumped. This can be done by pumping the grout into a sump equipped with a stirring blade. Figure 12 shows a type of agitator that has proved satisfactory. The agitator should have the same capacity as the mixer so that one batch of grout can be pumped while the next batch is being mixed. When emptying the grout from the mixer into the agitator, the grout should pass through a 1/8-in.-mesh screen to remove pieces of sacks, strings, wire, ties, or other foreign matter that may be dropped into the mixer.

16. PUMPS.

a. Types of Pumps. Pumps for cement grouting should be sufficiently flexible to permit close control of pressure and to provide for a variable rate of injection without clogging of valves and feed lines. With constant-speed pumps, special arrangements of the supply piping systems and valves are needed to provide close control of the grouting operation. Constant-speed pumps are powered by electric motors or internal-combustion engines. Variable speed pumps are hand operated, steam driven, or air driven.

(1) Hand pumps. Hand-operated pumps are used infrequently; they are satisfactory only when the amount of grout to be injected at any one time is very small. Their weak points are the check valves, which usually become plugged and stick after a short period of operation, and the packing, which frequently leaks grout as the pumping pressure is built up.

(2) Air-driven pumps. A number of air -driven pumps are commercially available. The reciprocating slush pump shown in figure 13 is available in sizes from 20 to 100 gpm at pressures from 200 to 500 psi when supplied with air at pressures of 100 psi. This type of pump is suitable for most cement and clay grouting.

(3) Power-driven pumps. Power -driven pumps have the same grout ends as the air -driven pumps, but require an external power source. This source is connected to the pump by gear, chain and sprocket, or V-belt drives. A wide variety of power sources are available.

b. Reciprocating Slush Pumps.

(1) Line -type pumps. The advantage of the line -type slush pump (fig. 13) is the accessibility of the valves. The discharge valves are located directly above the suction valves so that both can be removed through the same opening in the top of the pump "for cleaning or repair. The disadvantage of this type of pump is that it requires two types of suction and discharge valves and valve seats.

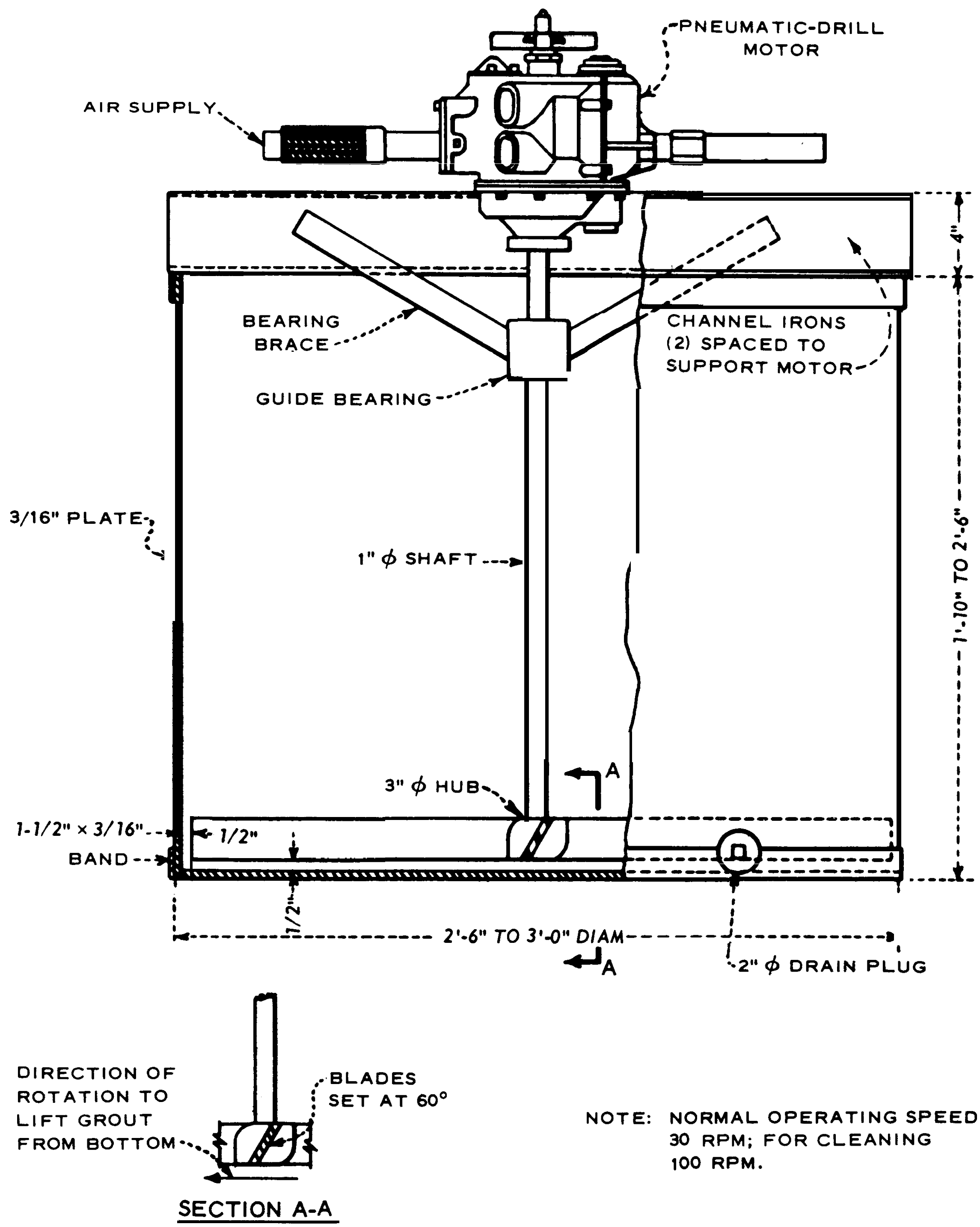
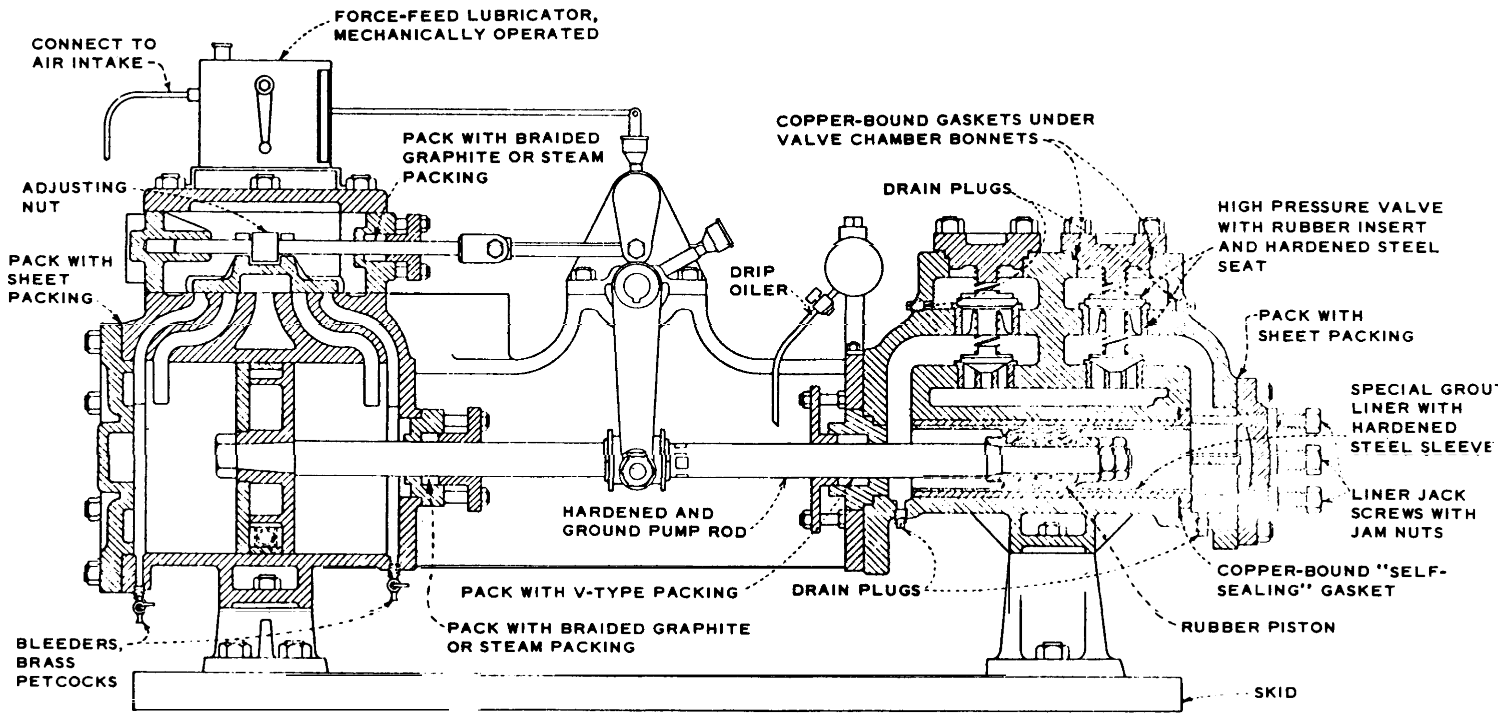


Figure 12. Grout agitator



NOTE: SECTION THROUGH NEAR CYLINDERS.

PUMPS OF THIS TYPE CAN BE OBTAINED IN SIZES VARYING FROM 5-1/4 × 3-1/2 × 5 IN. TO 10 × 7-1/4 × 10 IN. SIZES COMMONLY USED ARE 6 × 4 × 6 IN., 7 × 3 × 10 IN., 10 × 3 × 10 IN., AND 10 × 4-1/2 × 10 IN.

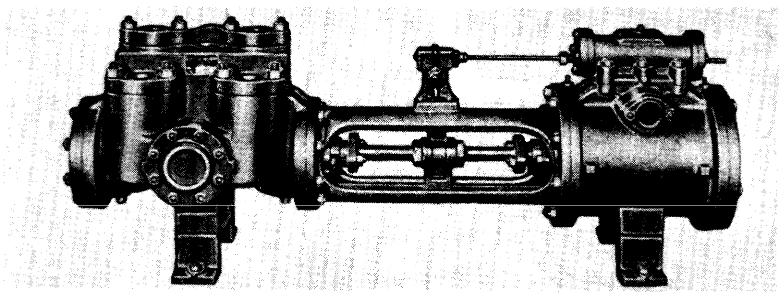
5-1/4 IN. IS DIAMETER OF AIR PISTON, 3-1/2 IN. IS DIAMETER OF LIQUID PISTON, AND 5 IN. IS THE STROKE.

(Courtesy of U. S. Bureau of Reclamation)

Figure 13. Reciprocating slush pump

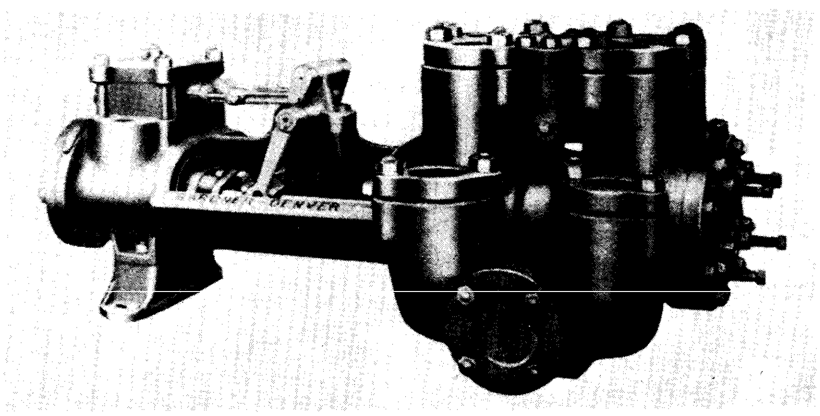
(2) Side-pot-type pumps. In the side-pot-type slush pump, each valve is in a separate pot or chamber with its own cover (fig. 14a). The advantage of this type of pump is that all valves and seats are interchangeable, and since each valve has a separate cover plate, the suction valves may be removed and cleaned without disturbing the exhaust valves, as is necessary in the line -type pump. Disadvantages are that grout usually collects in the bottoms of the valve pots and that the suction and exhaust ports are inconveniently arranged for cleaning.

(3) Divided fluid-cylinder valve -pot-type pumps. Although the action of this type of pump (fig. 14b) is not as smooth as that of a line -type pump, its interior parts are more readily accessible for cleaning. It is somewhat heavier than a line -type pump built for the same working pressure, the valves and seats are interchangeable, and the best pumps of this type have removable cover plates at convenient places for cleaning grout from the interior passageway.



a. SIDE-POT-TYPE PUMP

(Courtesy of Wagener Pump Division, Canton Stoker Corp., Canton, Ohio, Bulletin No. WS-150A)



b. DIVIDED FLUID-CYLINDER VALVE-POT-TYPE PUMP

(Courtesy of Gardner-Denver Co., Quincy, Ill., Composite Catalog 62-63)

Figure 14. Slush pumps

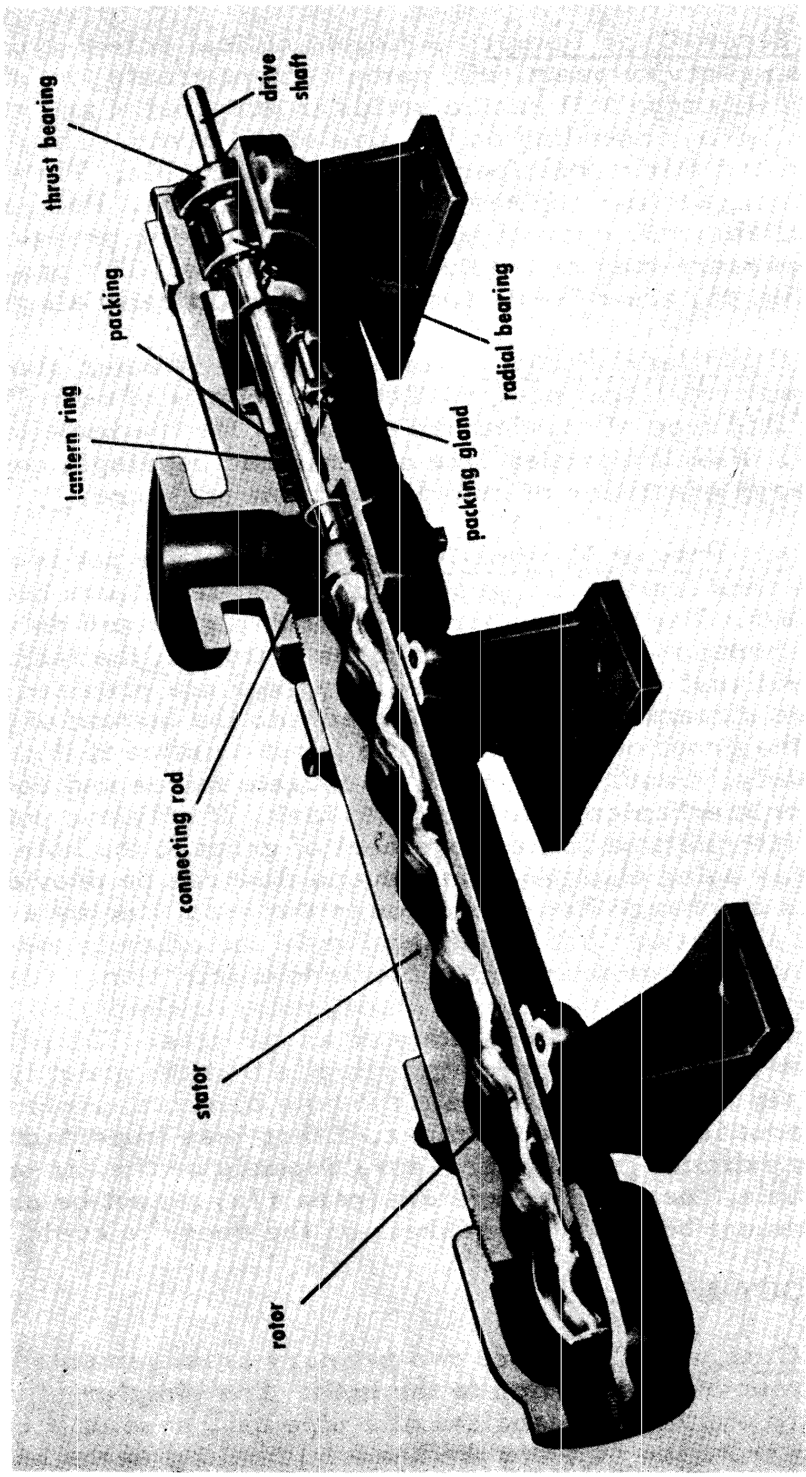
c. Screw-Type Pumps. A double helical screw-type pump, also called progressing-cavity pump, will pump cement grouts and other slurries. Pumps of this type will handle solids in suspension and will pass particles up to 7/8 -in. size, depending on the size of the pump. They have few working parts and are fairly free from mechanical trouble. They can be driven by air motors, gasoline engines, or electric motors. Pumps of this type presently available will operate up to 600 -psi working pressure. Pumps for higher pressure may be available in the future. The progressing-cavity type pumps (fig. 15) are suitable for pumping practically all grouts.

d. Centrifugal Pumps. Cement grout and other slurries have been pumped by centrifugal pumps. The weak points of centrifugal pumps when used for this type of service are the seals for the impeller shafts and their bearings. With the proper type of seals and bearings, centrifugal pumps can handle large quantities of materials at low pressure.

e. Air Pots or Pneumatic Grouters. An air pot is a cylindrical steel pressure tank from which grout or other material can be forced by compressed air. The tank is charged through a gasketed door at the top and discharged through the grout outlet at the bottom of the tank. Taps for air -inlet and air -exhaust valves and a pressure gage are provided. A small valve-controlled stream of air is introduced into the bottom of the tank, usually through the grout outlet, to keep the grout agitated if it cannot be discharged immediately. Grout is mixed in a separate mixer and conveyed through pipe or hose or mechanically to the grout tank. If only one pot is used, grouting must be intermittent since movement of grout to the hole stops while the chamber is being charged. Continuous flow can be provided by two pots, each having its discharge line connected to the grout line by a wye valve and being operated so that one pot is charged while the other is discharged. Pots with twin chambers also provide for continuous injection. The equipment is simple and can be shop made in an emergent y, or Gunite or pneumatic-concreting equipment can be adopted as air pots. The principal disadvantage of air-pot-type equipment for grouting is that the grout in the tank is not visible and air may be injected into the hole before the, operator is aware that all the grout is out of the chamber. Other less important disadvantages are: (1) the maximum grouting pressure depends on the air pressure available, (2) a double -line grouting system (para 17a) cannot be used, and (3) constant attention must be given the gaskets on the doors to avoid air leaks.

17. GROUT LINES.

a. General. There are two primary arrangements of piping used to supply grout from the pump to the hole. The simpler of the two is the single-line system. It consists of a pipe or a hose or a combination of both, extending from the pump to the header (d below) at the hole. The pump speed controls the rate of injection. The second arrangement is the double -line or circulating system. This system has a return line from the header to the



(Courtesy of Robins and Myer, Pump Division, Springfield, Ohio, Bulletin No. 30-C)

Figure 15. Cutaway section of progressing-cavity pump

grout sump in addition to the pump line of the single -line system. Thus, if the header connection to the hole is closed, grout can be continuously circulated from the grout sump to the pump, through the pump line, through the header, and back to the sump through the return line. While grouting, the amount of grout entering the hole through the header can be varied by opening or closing a valve on the return line without changing pump speed. The double-line system is generally preferred because it permits better control of grouting pressures and allows less material to settle out of the mix to plug the lines.

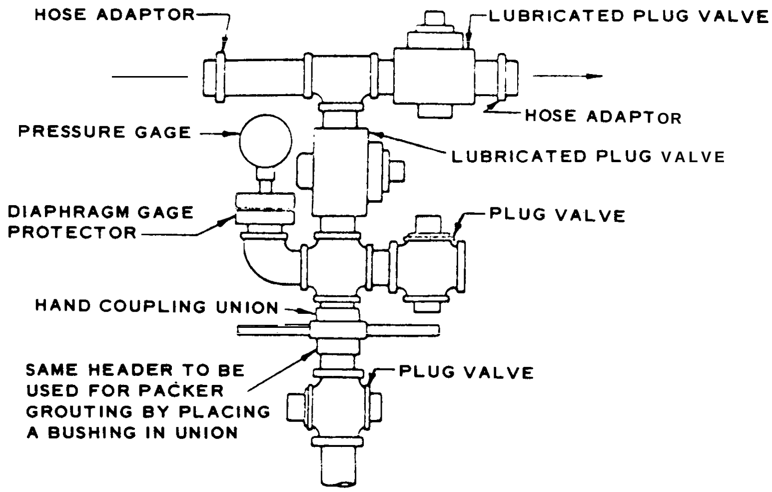
b. Hose. Flexible hose is most commonly used for suction and discharge lines. If the length of the discharge line is such that pipe is necessary, a short length of hose should be provided at the pump discharge and at the connection to the grout header. The hose should be not less than 1-1/2-in. diameter (inside) and capable of withstanding the maximum grouting pressure with an ample margin of safety. The suction line from the grout sump and water tank may be either pipe or hose of suitable diameter and should be as short as feasible. It should be provided with fittings at both ends. Hose is preferable to pipe because its flexibility permits ready interchange of the suction end between the sump and water tanks. Pipe; on the other hand, requires the installation of valves that will permit the pump to draw either grout or water as the occasion demands. It has been found that difficulty often arises because of clogging of the water valve on the grout line side.

c. Piping. Black steel pipe and fittings 1-1/2 in. in diameter are nor-really-suitable for pressure lines; but where large quantities of grout are to be injected and the supply line is long, it may be desirable to provide a larger size pipe and connection hoses. Pipe must be capable of withstanding at least the maximum pressure to be applied in the grouting operation.

d. Grout Header. The grout header is usually assembled as a unit in order—that it may be moved from one grout hole to another. The assembly consists of the operating valves, a pressure gage, pipe, and the necessary fittings to attach the header to the hole and to attach the grout supply and return lines. The gage and the valves are de scribed in more detail in e and f below. A header assembly is shown in figure 16. It should be noted that the pressure gage is so connected that by closing one valve it can be used for pressure-drop observations without interrupting the circulation of grout in the pump system.

e. Pressure Gages.

(1) Reliable pressure gages are essential in pressure grouting. They constitute the principal index to the behavior of the hole and the stresses that are being produced in treated material. If the hole is more than 100 ft horizontally or 20 ft vertically from the pump, there should be two gages in the



NOTE: ALL PIPE AND FITTINGS ARE 1-1/2" SIZE. PLUG VALVES TO BE USED THROUGHOUT FOR PRESSURES ABOVE 250 PSI. GROUT HOSE TO BE 1-1/2" WITH SCREW-TYPE COUPLINGS.

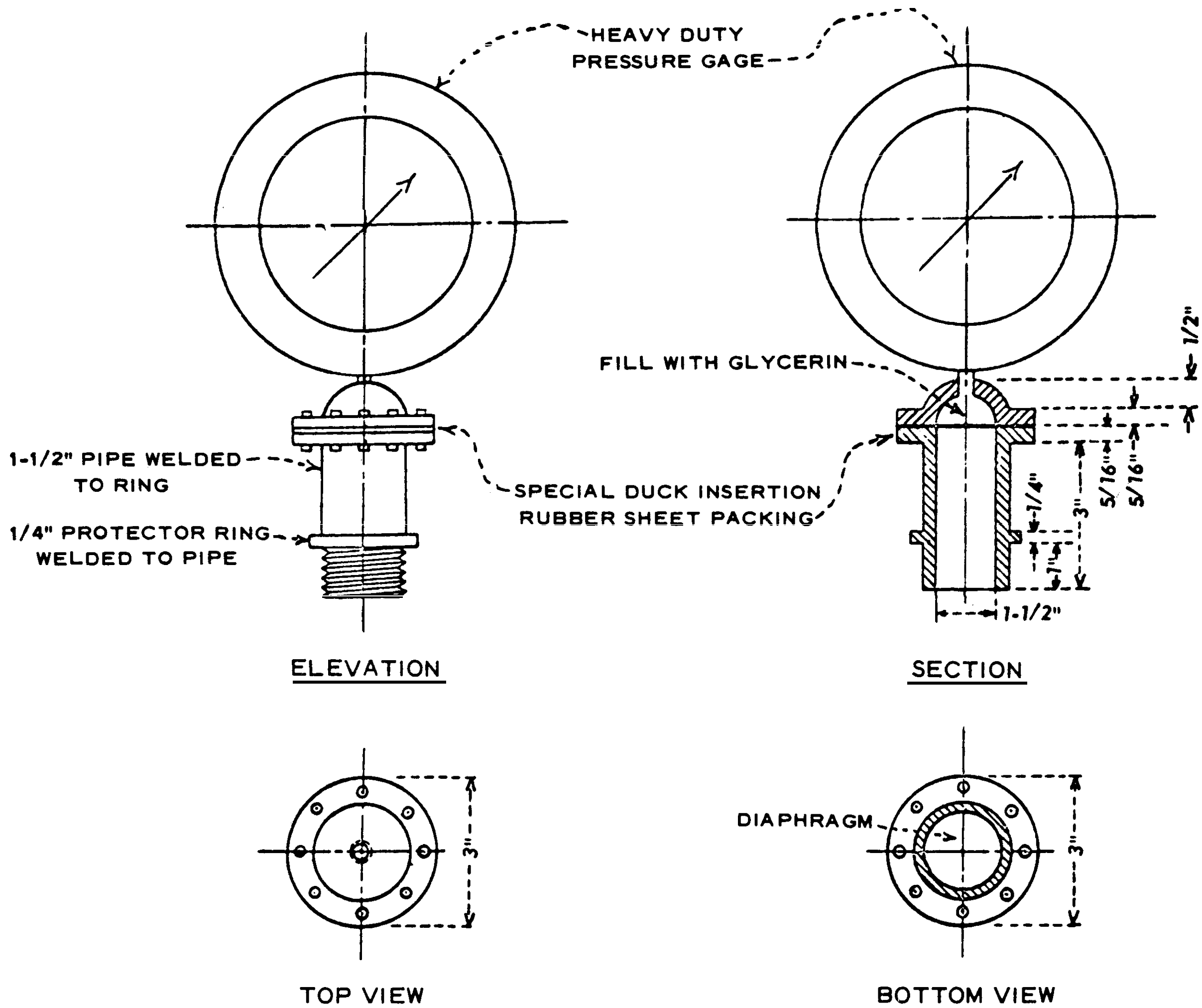
(Courtesy of American Society of Civil Engineers)

Figure 16. Direct grouting header (see ref 16)

grout line, one at the pump and the other at the hole for control. When there is the possibility of doing serious damage by the application of too much pressure, all gages should be installed in duplicate. Structures have been damaged by the unintentional application of excessive pressure occasioned by gage failure or sticking. Gages, the glass faces of which have been broken, should be condemned. Dust and grit tend to reduce the accuracy of the gage. This causes the gage to register falsely and results in pressures higher than those indicated being applied, with attendant higher grout injection. The gage used should have a pressure range comparable to that required. Thus, a 200-psi-capacity gage is not appropriate for grouting where a maximum pressure of 50 psi is contemplated.

(2) The moving parts of the gage must, for obvious reasons, be protected from direct contact with the grout. The simplest protective device for pressures greater than 200 psi is a short oil- or grease-filled siphon (pigtail) located between the gage and the grout. This consists of a 1/4-in. pipe with a 3-in. loop in its center. The pipe is filled with a light grade of water-proof grease. An alemite fitting, located between the gage and the pigtail, enables the operator to force open the passage should it become obstructed. However, grease makes the gage sluggish and its readings are not always consistent due to the effect of temperature changes on the fluidity of the grease. The most satisfactory device consists of a piece of 1-1/2- or 2-in.-diameter pipe 18 in. long that is stubbed off vertically above the grout line. The gage is fitted to the top of this stub by means of suitable bushings. All

joints should be made tight with litharge and glycerin or lead since the device is, in effect, an air dome and any small air leak will render it ineffective. The gage is very sensitive with this arrangement and the violent oscillations of the needle make exact readings difficult; but this objectionable feature can be largely obviated and the gage given additional protection by installing a gage saver, as shown in figure 17, between it and the air dome.



(Courtesy of U. S. Bureau of Reclamation)

Figure 17. Glycerin-filled gage saver

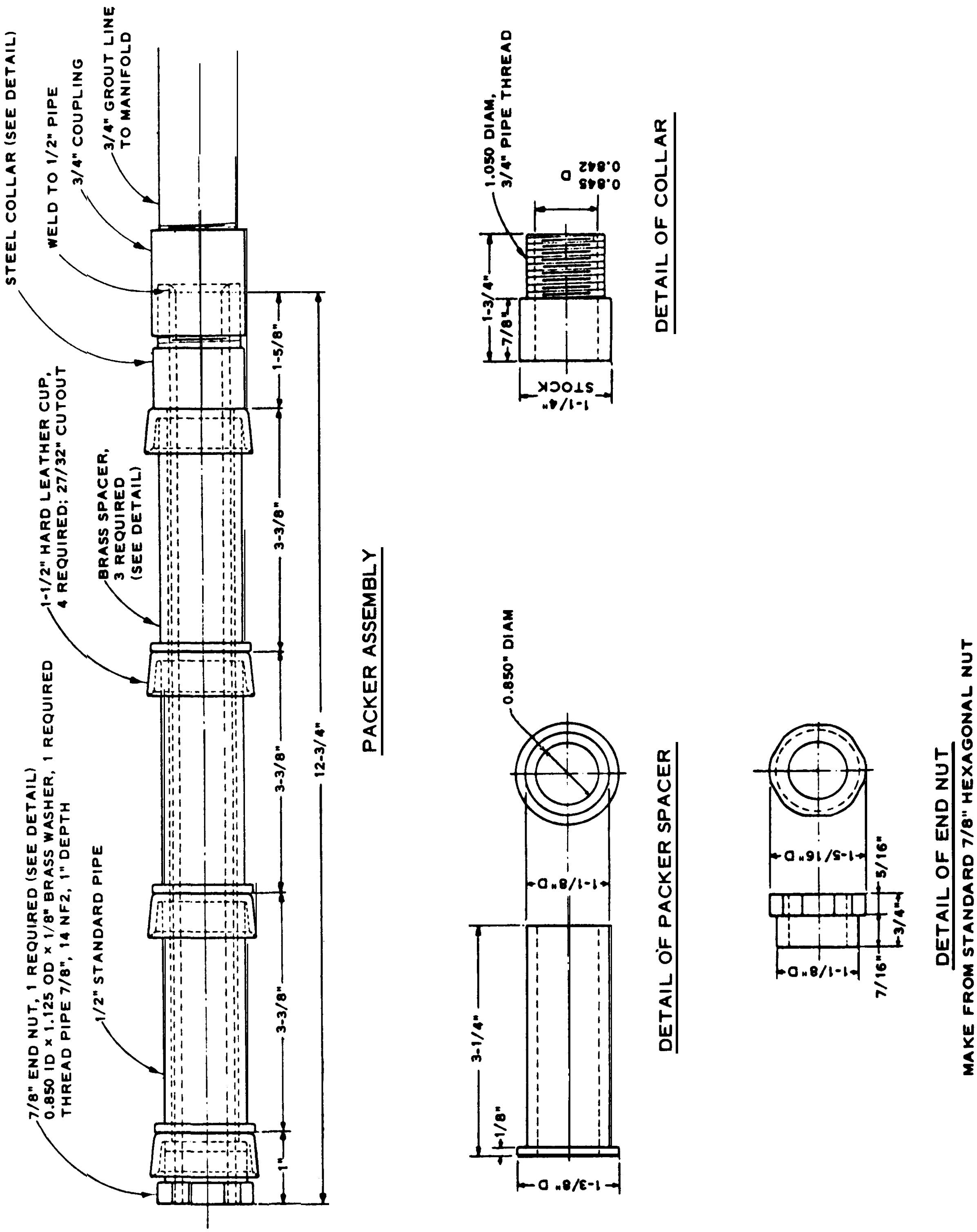
f. Valves for Grout Line. Plug valves should be used to control the flow of grout. Pressure relief valves are sometimes installed in the grout line as an added precaution in controlling grout pressures, but should not be relied upon. Vigilance and hand-operated, quick-acting valves afford the only reliable means of controlling pressures. There are two types of quick-acting valves that are satisfactory for the grout lines. These are the so-called lubricated and nonlubricated plug valves. Lubricated valves should be installed throughout the entire system except for the first valve above the grout hole, where a nonlubricated valve should be used. They should be of a diameter to fit the pipe size, have threads inside, and should be capable of withstanding nonshock, cold water pressure equal to at least the maximum pressure to be applied. Both body and plug should be made of iron or semi-steel. The plug of the valve should be ground into its body to ensure perfect contact over the entire surface of the plug and to give smooth operation and perfect seating. The valves should be square headed, similar and equal to Walworth Company's standard iron cock No. 651.

18. PACKERS.

a. Introduction. There are three general types of grout packers in common use, the cup leather, the mechanically expanded rubber ring, and the pneumatically expanded rubber sleeve. Various methods of mechanically expanding the rubber ring or rings have been used, and each has its place for a particular condition. No effort will be made to illustrate all of the packers that have been used as all types are frequently modified and improved to fit local conditions. Each general type does, however, have characteristics making it most suitable. Initially, AX (2-in.) or BX (2-3/8 -in.) holes were thought to be the smallest size adaptable to the use of packers, but now they have been developed for all sizes from EX (1-4/2-in.) to NX (3-in.). Some difficulties arise when smaller holes are used. The packers to be described here are all for EX size holes.

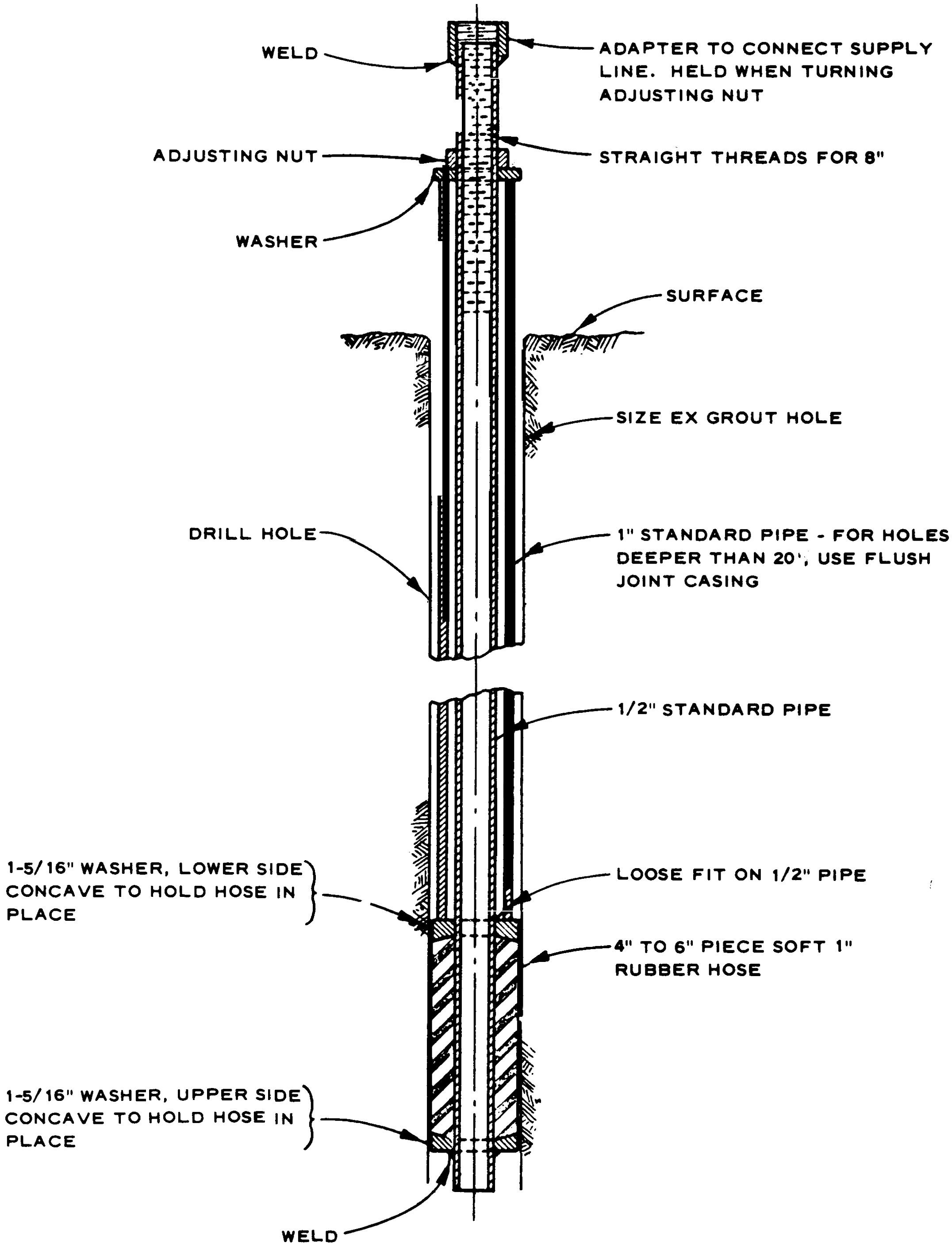
b. Cup Leather Removable Grout Packer. The cup leather type shown in figure 18 is best suited to fairly hard rock where the drilled hole is not oversize and the walls are relatively smooth and true. This packer when suitably anchored has been used successfully for grouting pressures up to 750 psi. It is simple to construct, easy to maintain, and only requires a single pipe to lower it in the hole. Where high grout pressures are feasible, it is probably the best type of packer to use. If it should accidentally become stuck in the hole, a right-left coupling enables the crew to save the supply pipe string and the packer itself can be drilled out, if necessary.

c. Mechanical Packer. The mechanically expanded type shown in figure 19 is adaptable to softer rock than the cup leather type, but it may be difficult to seat if the drill hole is too much over size. Its positive expanding action gives it an advantage in that it can be positively seated at any location if the hole is not too enlarged. When used at depths greater than 20 ft, flush-joint tubing is required and it is somewhat award to handle in a deep hole. Once seated the packer too can withstand fairly high pressure and has been used on many jobs.



(Courtesy of U. S. Bureau of Reclamation)

Figure 18. Removable grout packer



(Courtesy of U. S. Bureau of Reclamation)

Figure 19. Mechanical packer

d. Pneumatic Packer. The pneumatic packer shown in figure 20 has proved suitable in soft and thin-bedded rocks where the drill holes are often somewhat over size. In fact the EX (1-1/2-in.) size can be seated in a 4-in. pipe when the proper rubber tubing is used and it is properly attached at the ends. The length of rubber sleeve should not be less than 18 in. Under conditions requiring large expansions and relatively high expanding pressure, double -tapered collars at either end may be necessary to prevent rubber breakage. It is not suitable for high grout pressures, but it will withstand 100 psi under poor conditions and will hold up to 200 psi if the hole is not too large or uneven. In weak sedimentary formations of alternating layers of shale and sandstone or lime stone, this packer has proved invaluable. It is now widely used where low pressures are dictated by foundation conditions.

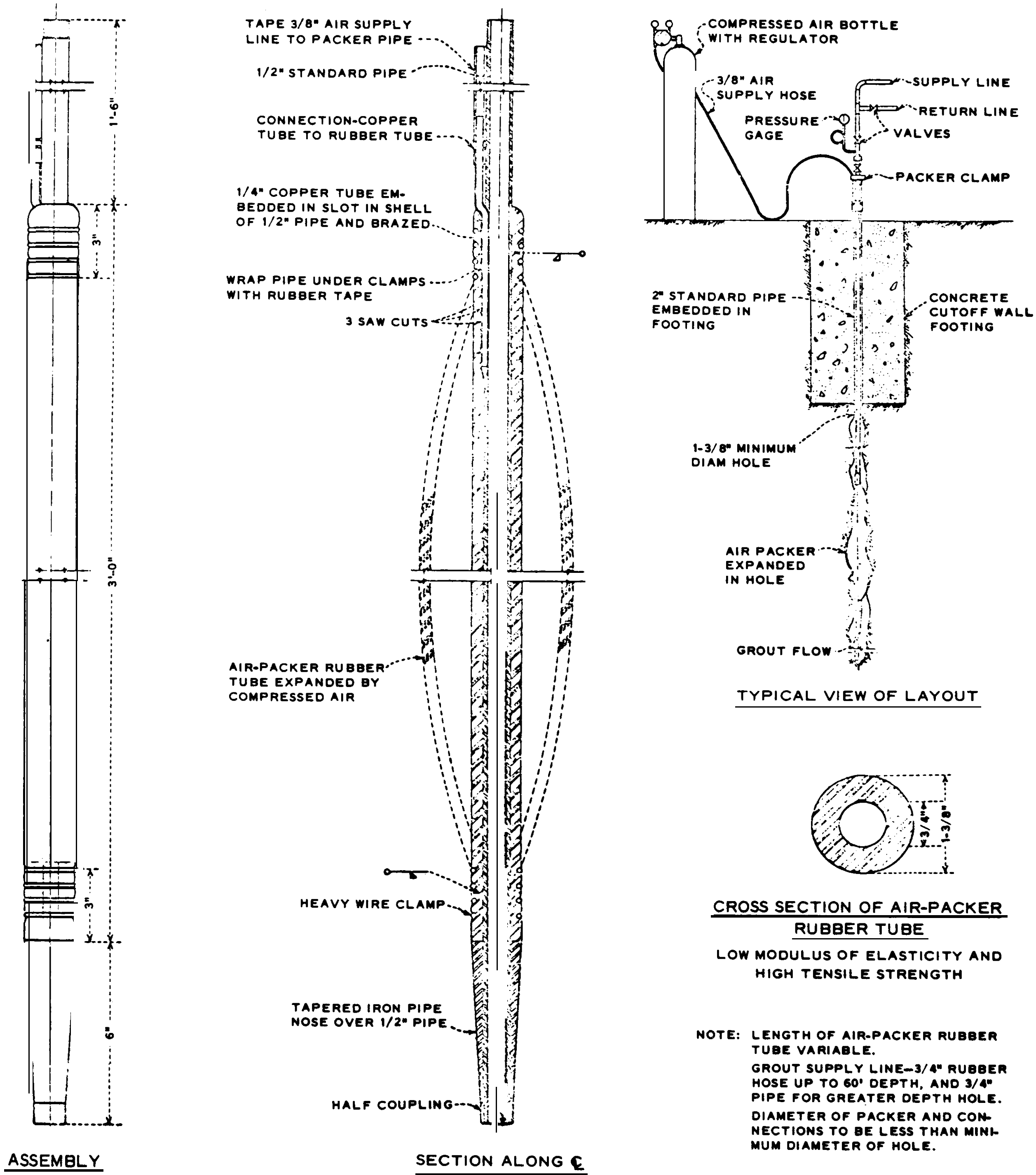
19. ASPHALT GROUTING EQUIPMENT. Commercial asphalt heaters similar to those used by roofing contractors have been found satisfactory for heating asphalt for grouting. The heater should have a baffle near the outlet to prevent lumps from entering the supply line. Gear pumps, reciprocating pumps with ball valves, or 1-in. boiler-fed piston pumps have been used to pump hot asphalt grout through 1-1/2 -in. black iron pipe. Mixers are not needed for either hot asphalt or asphalt emulsions. A typical hot asphalt grout plant is shown in figure 21. Cement grouting equipment can be used for asphalt emulsions.

20. CHEMICAL GROUTING EQUIPMENT. The equipment required for chemical grouting will vary depending on the chemicals being used. Basitally this equipment consists of mixing tanks; variable speed, positive - displacement-type pumps, control valves; and gages so that the proportioning of chemicals can be closely controlled. Self-contained mobile units are available that include all necessary components for the grout system. Generally, the se units have been developed by the grout manufacturer and are designed for a specific chemical process. In any case, all grouting equipment should be of a material that will not react with the chemicals being used.

21. PLANT LAYOUT.

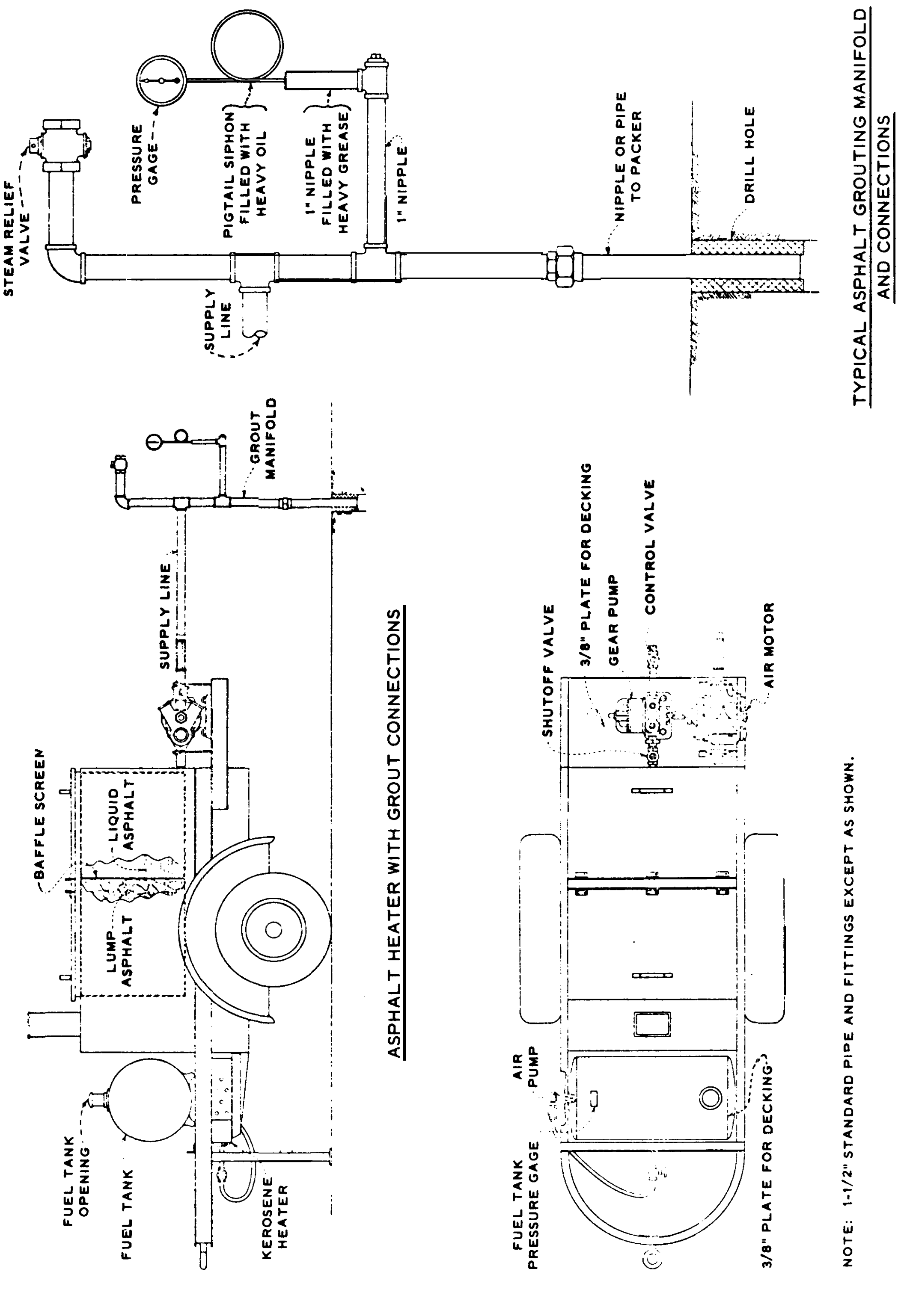
a. Cement Grouting.

(1) Plants. The grout plant should consist of a mixer, agitator. sump, pump and necessary valves, gages, and lines to control the operation. Standby equipment may be required depending on the nature of the job. Cement grout plants vary in size from compact systems that may be truck-mounted to large automated systems that require dismantling for moving. Figures 22 and 23 illustrate the two extremes. In figure 22 both the single and return line pumping systems are shown with locations of valves and gages. The return line system is often preferred where grout take is small because of (a) good pressure control with no waste, (b) reduction of grout-line clogging



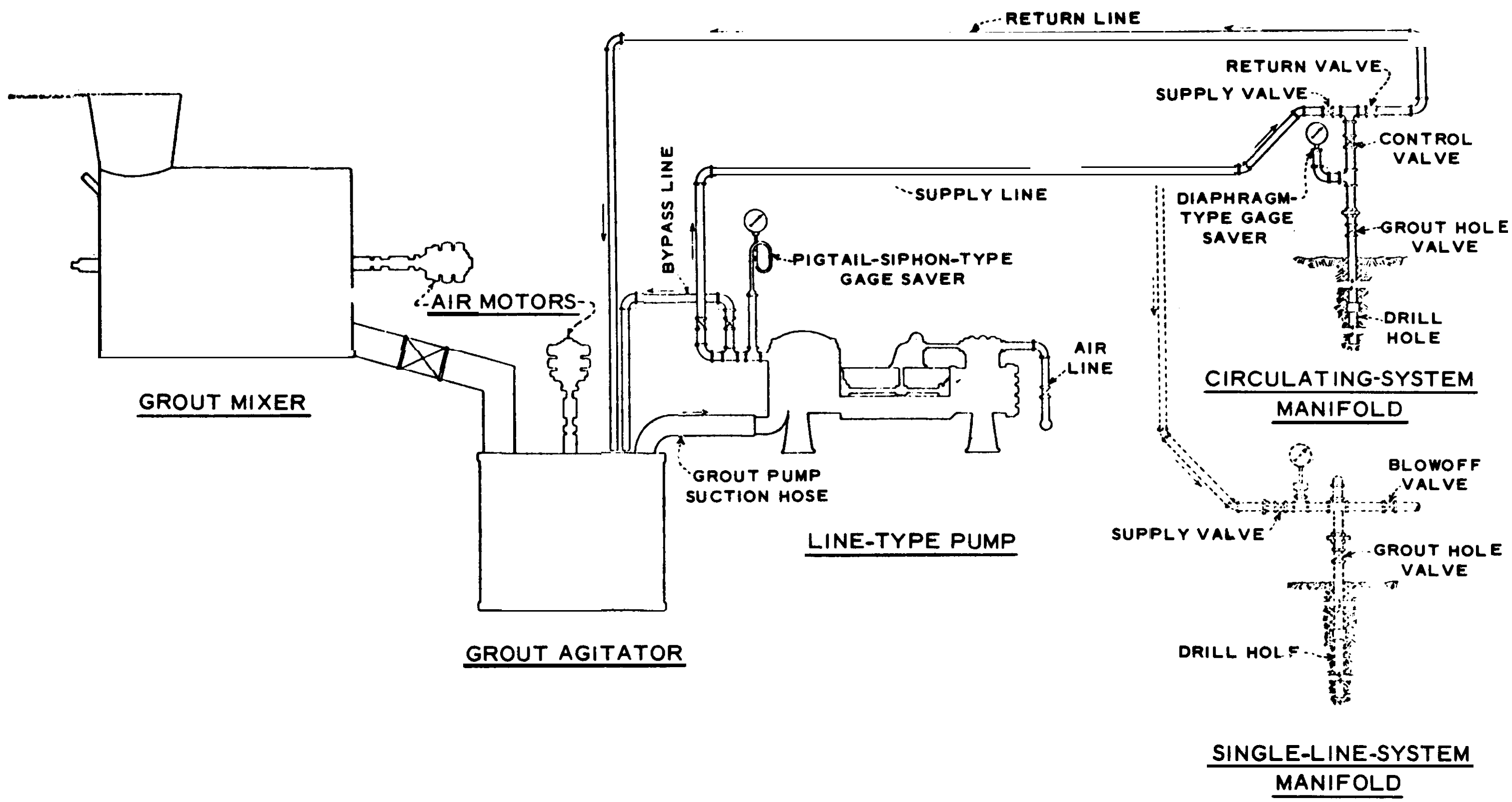
(Courtesy of U. S. Bureau of Reclamation)

Figure 20. Air packer



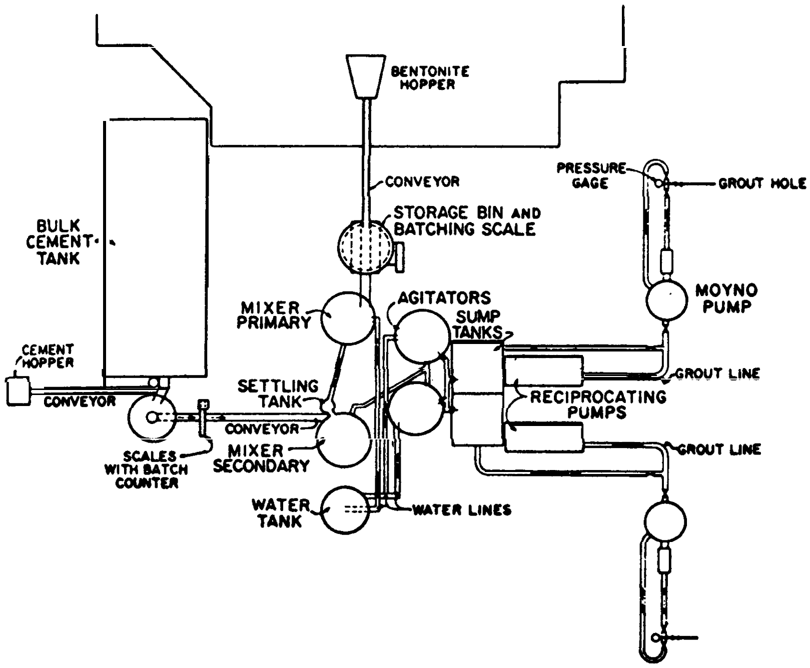
(Courtesy of U. S. Bureau of Reclamation)

Figure 21. Asphalt grouting equipment and connections



(Courtesy of U. S. Bureau of Reclamation)

Figure 22. Circulating and single-line grouting systems



(Courtesy of American Society of Civil Engineers)

Figure 23. Schematic of large grout plant (see ref 31)

due to sedimentation, and (c) maintenance of circulation with hole closed down If the grout take is large, a single -line system may be preferred because of its simplicity.

(2) Operation. The batch system is more satisfactory than continuous mix. The necessary water for each batch should be run into the mixer and the cement dumped in as needed. After mixing thoroughly, the batch of grout should be dumped into the agitator for pumping, and the next batch started in the mixer to prevent delays between batches. On slow holes or where only small quantities of grout are injected at one time, one man may be able to operate both mixer and pump. On some portable plants the pump and mixer are mounted with control valves arranged so that one man can operate both pieces of equipment. For large operations, batching systems may be set up for automatic control with one operator.

b. Clay Grouting.

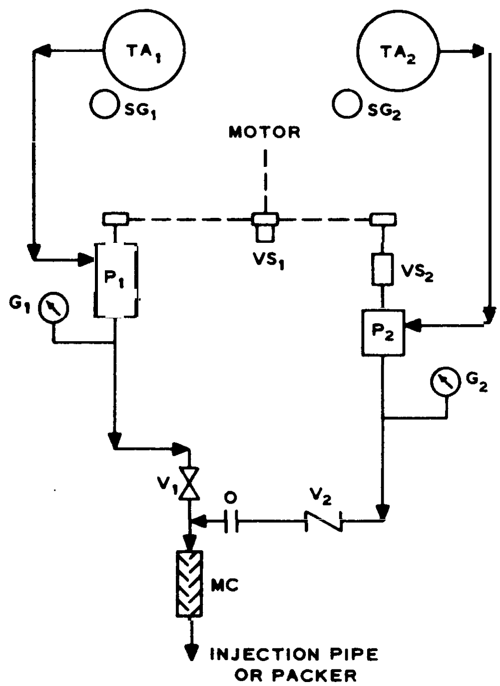
(1) Plant. Where processed clays such as commercial bentonites are used as the grout material, the grout plant and operation are similar to those used in cement grouting. When natural soils are used, the plant may have to be modified to allow for processing the raw material. Where this is necessary, in addition to the basic plant as shown for cement grouting, a drying

shed, crusher or grinder, screening equipment, and premixer may be required. The grout lines and control system are the same as for cement grouting.

(2) Operation. Normally the batching method is best suited to mixing clay grouts. For processed clays such as bentonite, the operation is similar to that for cement. For cement grouts containing bentonite, the cement should be mixed with water before adding bentonite. When natural soils are used, the raw material is delivered to the plant by truck, scraper, or conveyor and stockpiled under a storage shed if necessary. Where the grout design requires predrying, the soil is spread and worked to facilitate drying. Predrying may result in easier mixing, better dispersing, and better water control in the grout. Moist clay will require vigorous mixing for complete dispersion. The usual procedure is to crush or grind the raw soil and mix the water to disperse the particles. The mix is then discharged on screening equipment to remove lumps, foreign matter, and coarse material. The screened slurry is then run into the mixer for the addition of admixtures or into the sump for pumping to the holes.

c. Chemical Grouting. The equipment required and the assembly of a chemical grout plant are dependent on the chemical system employed. Adequate storage facilities for both dry and liquid components, mixing tools, proportioning systems, pressure control, and flushing lines are required. When a commercially produced chemical system is used, the manufacturer's recommendations for equipment and operations should be closely followed. For projects using custom design chemical processes, the plant equipment and operational procedures should be specified by the person or organization designing the mix. In any case, extreme caution should be exercised at all times to protect workmen from dangerous chemicals and fumes. An ample supply of water is required on all chemical grouting jobs. Figures 24 and 25 show schematic layouts for typical plants used for one of the commercial chemical grouts.

d. Asphalt Grouting. The principal items of equipment required for grouting with hot asphalt are heating tank, pump, supply lines, and gages in suitable arrangement such as shown in figure 21. The pressure gage is protected from the asphalt by using a 1-in. nipple and pigtail siphon. The nipple is filled with grease and the siphon with oil. In cold-weather operations, it may be necessary to heat supply lines. One method is to insert a heavy, insulated iron wire in the grout line. One end of the wire is connected to the bottom of the supply line, and the other to a high-amperage, low-voltage generator, such as used in commercial welding machines. The machine is grounded to the supply line to complete the circuit. Steam has also been used for heating lines, but has proved cumbersome and costly. When the asphalt is pumped in the hole, steam will form if water is present in the hole. Some of the steam will be caught in the supply line, and provisions should be made for bleeding if off to prevent it from blowing back into the heater. Extensive



KEY OF COMPONENT PARTS

TA_1 - MIXING TANK FOR AM-9 CHEMICAL GROUT, CATALYST DMAPN, AND KFe

TA_2 - MIXING TANK FOR AMMONIUM PERSULFATE

SG - SIGHT GAGES

P_1 - POSITIVE DISPLACEMENT PUMP

P_2 - POSITIVE DISPLACEMENT PUMP

VS_1 - VARIABLE SPEED DRIVE

VS_2 - VARIABLE SPEED DRIVE

G_1 - DIAPHRAGM PRESSURE GAGE

G_2 - DIAPHRAGM PRESSURE GAGE

V_1 - QUICK OPENING VALVE

V_2 - SPRING LOADED CHECK VALVE

O - ORIFICE

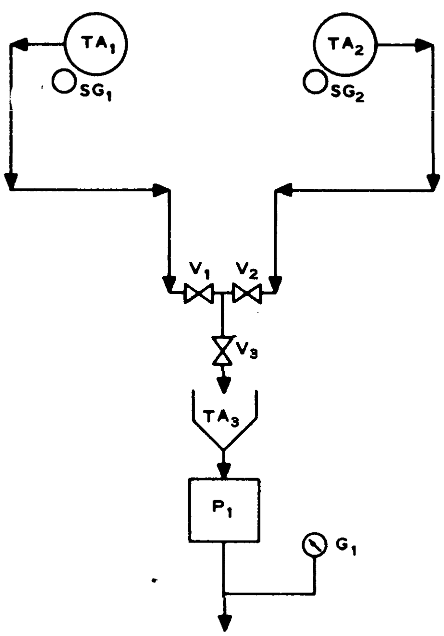
MC - MIXING CHAMBER

TA_2 THROUGH MC SHOULD BE ALUMINUM, TYPE 316 STAINLESS STEEL, RUBBER, OR SOME PLASTICS

TA_1 THROUGH V_1 CAN BE MILD STEEL, ALUMINUM, STAINLESS STEEL, RUBBER, OR PLASTICS

(Courtesy of American Cyanamid Co., Wayne, N. J.)

Figure 24. Proportioning system (see ref 40)



KEY OF COMPONENT PARTS

TA_1 - MIXING TANK FOR AM-9 CHEMICAL GROUT, CATALYST DMAPN, AND KFe

TA_2 - MIXING TANK FOR AMMONIUM PERSULFATE

SG - SIGHT GAGES

V_1, V_2, V_3 - QUICK OPENING VALVES

TA_3 - BLENDING TANK FOR AM-9 CHEMICAL GROUT, CATALYST DMAPN, AND AMMONIUM PERSULFATE

P_1 - POSITIVE DISPLACEMENT PUMP

G_1 - DIAPHRAGM PRESSURE GAGE

TA_2 THROUGH V_3 SHOULD BE ALUMINUM, TYPE 316 STAINLESS STEEL, RUBBER, OR SOME PLASTICS

TA_1 THROUGH P_1 CAN BE MILD STEEL, ALUMINUM, STAINLESS STEEL, RUBBER, OR PLASTICS

(Courtesy of American Cyanamid Co., Wayne, N. J.)

Figure 25. Two-solution system (see ref 40)

precautions should be taken to protect workmen engaged in asphalt-grouting operations. Gloves, goggles, and ointments for application on exposed skin should be used by all grouting personnel.