CHAPTER 6
EQUIPMENT

6-1. 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. Additional guidance for selection of drilling methods is contained in paragraph 4-4.

6-2. Drilling and Grouting Equipment.

a. Drill Rigs. In the selection of a drill, site considerations and job drilling/grouting requirements dictate the type and size of drill to be used. Drilling from the surface may require either a crawler, wheel, or skid mounted unit. On steep abutments a post drill which attaches to the grout nipple may be the only feasible choice, and may be suitable for other drilling. A multipurpose drill embodying auger, rotary, and rock coring capabilities is desirable (fig. 6-1). The size of drill is dependent on the depth and size of holes and the type of formation drilled. Additional requirements may include stable outrigging and a highly visible and centralized control panel. Drilling from within an adit, tunnel, shaft, gallery, or buried structure usually requires small, lightweight, and compact type drills (fig. 6-2 and 6-3). Fast rod coupling, 360-degree angle drilling, self towing, and multiple power options are major considerations for subsurface drills. Comparisons between drilling methods and equipment are discussed in paragraph 4-4.

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

(1) Operation. Percussion drills are used for drilling in rock. The percussion drill does not reciprocate. The shank fits loosely into the chuck at the forward end of the machine, where it is struck by a hammerlike piston actuated by compressed air or hydraulic fluid. The air compressor capacity necessary to operate a single-hammer drill ranges from 50 to 200 cubic feet per minute, depending upon the size of the drill cylinder and the pressure at which air is supplied. The bit remains in close contact with the rock at the bottom of the hole at all times during drilling 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 materials are removed from the hole by air or water that passes through the machine and down the hollow steel drill rod to the bottom of the hole, and then rises up the hole to the surface. Removal of cuttings by water is sometimes preferred for grout hole drilling but is not mandatory in all cases. In some instances, it may be desirable to remove cuttings by

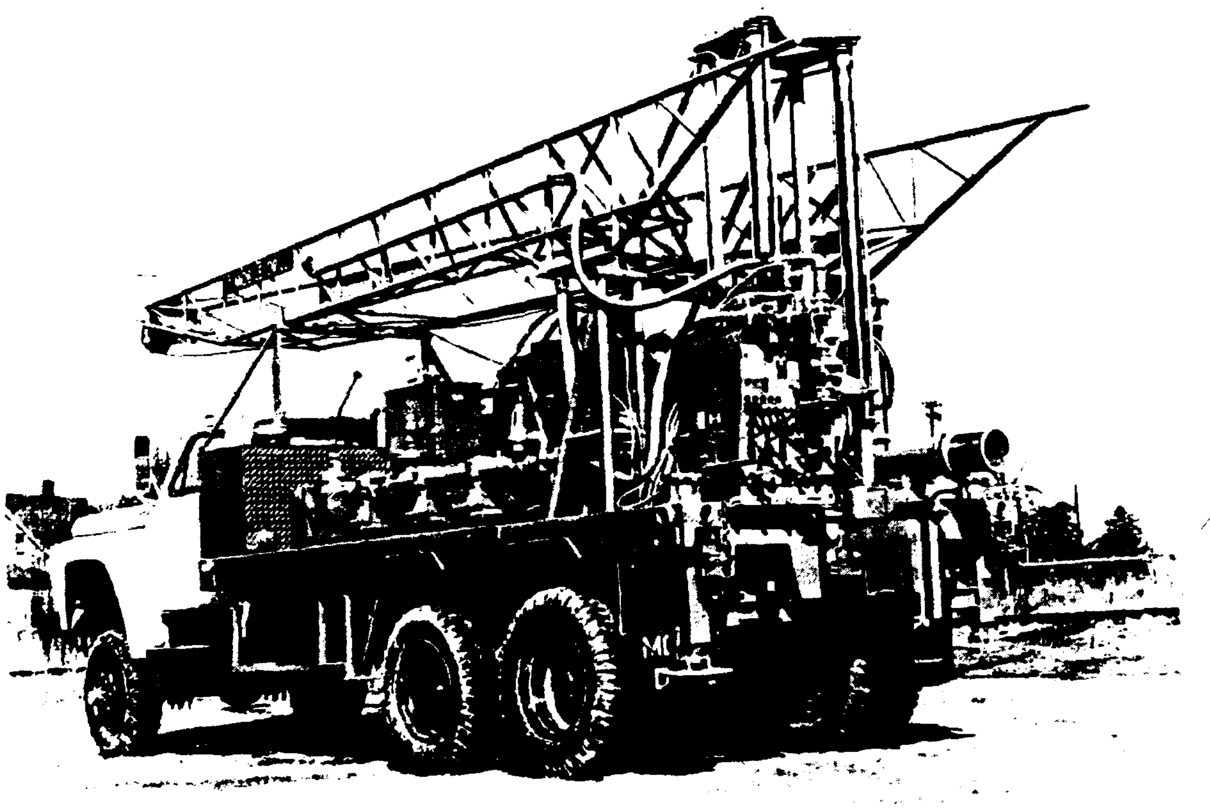
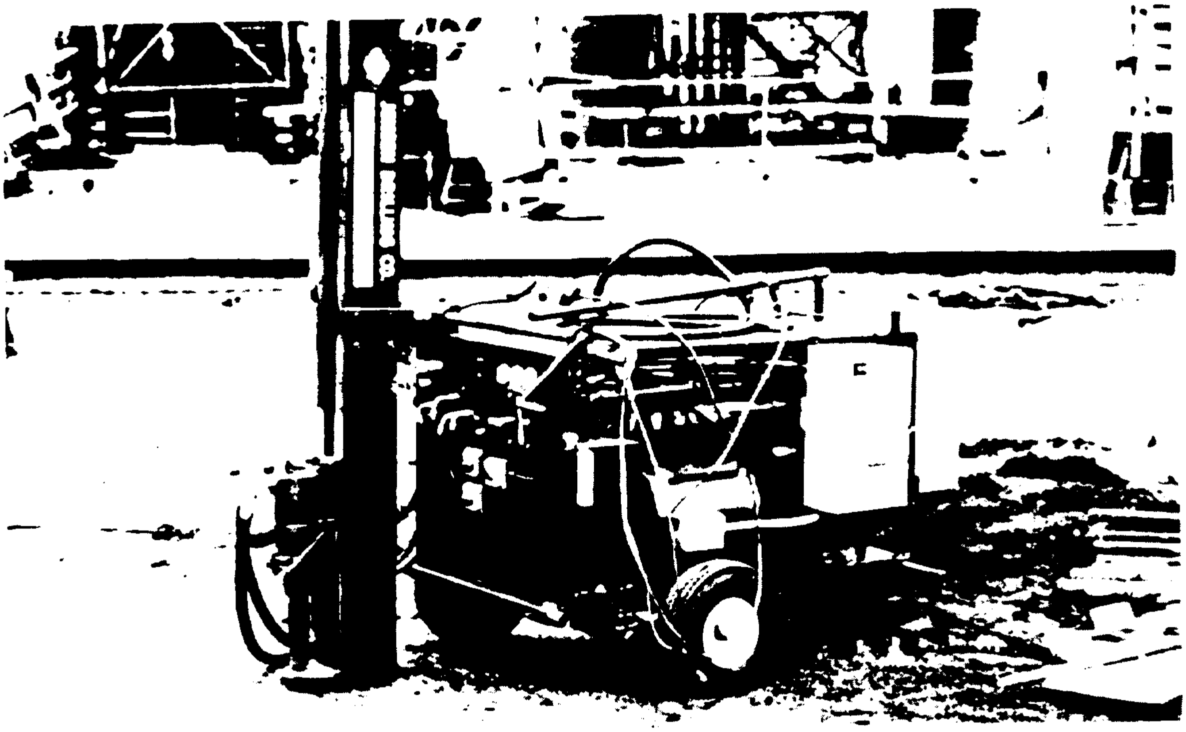


Figure 6-1. Typical truck-mounted drill rig (permission by Mobile Drilling Company)



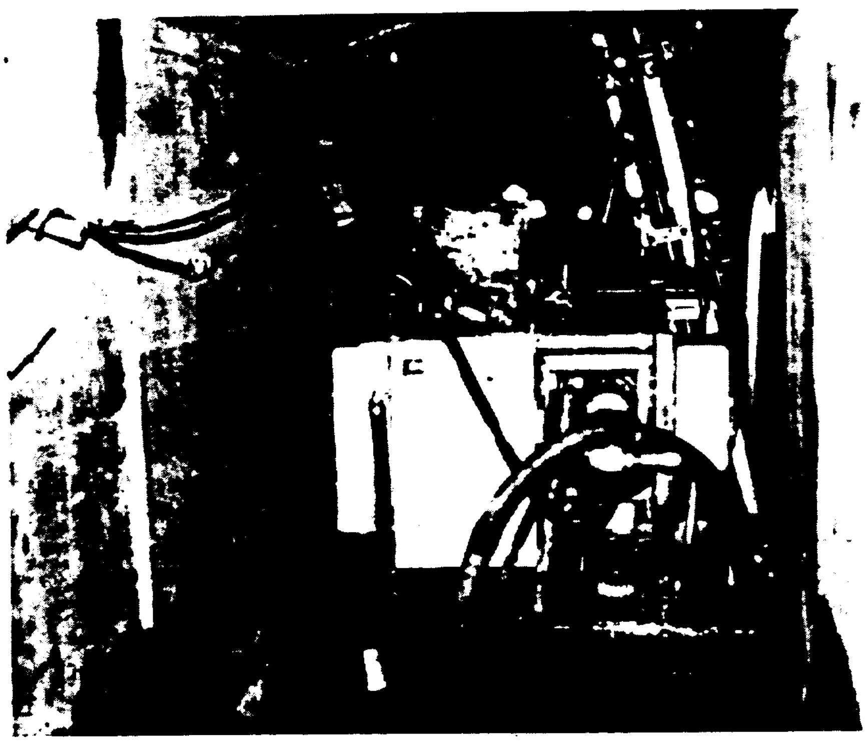


Figure 6-2. Electric over hydraulic drill rigs for gallery grouting

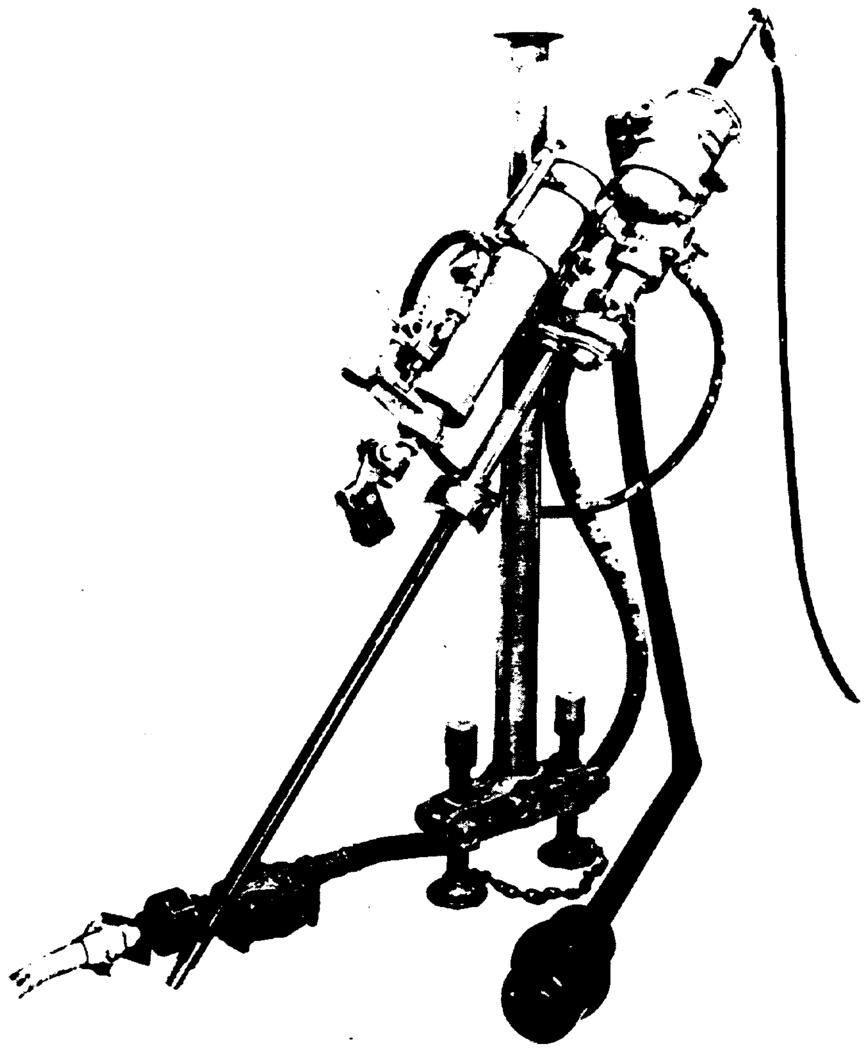


Figure 6-3. Post drill

air. Jackhammer drills are only suitable for shallow work, and due to their light weight, are usually held in position by hand. Drifter-type drills are designed for tripod, bar mounts, or jumbos. The commercially available wagon drill is composed of a drill head mounted in leads that are supported on a track, wheel-, or skid-mounted chassis (fig. 6-4).

(2) Application. Generally, percussion drilling produces acceptable grout holes and is the most economical method of drilling shallow holes. This advantage decreases with depth. The edges or wings of the bit wear away during the drilling operation, and a progressively smaller hole is drilled.

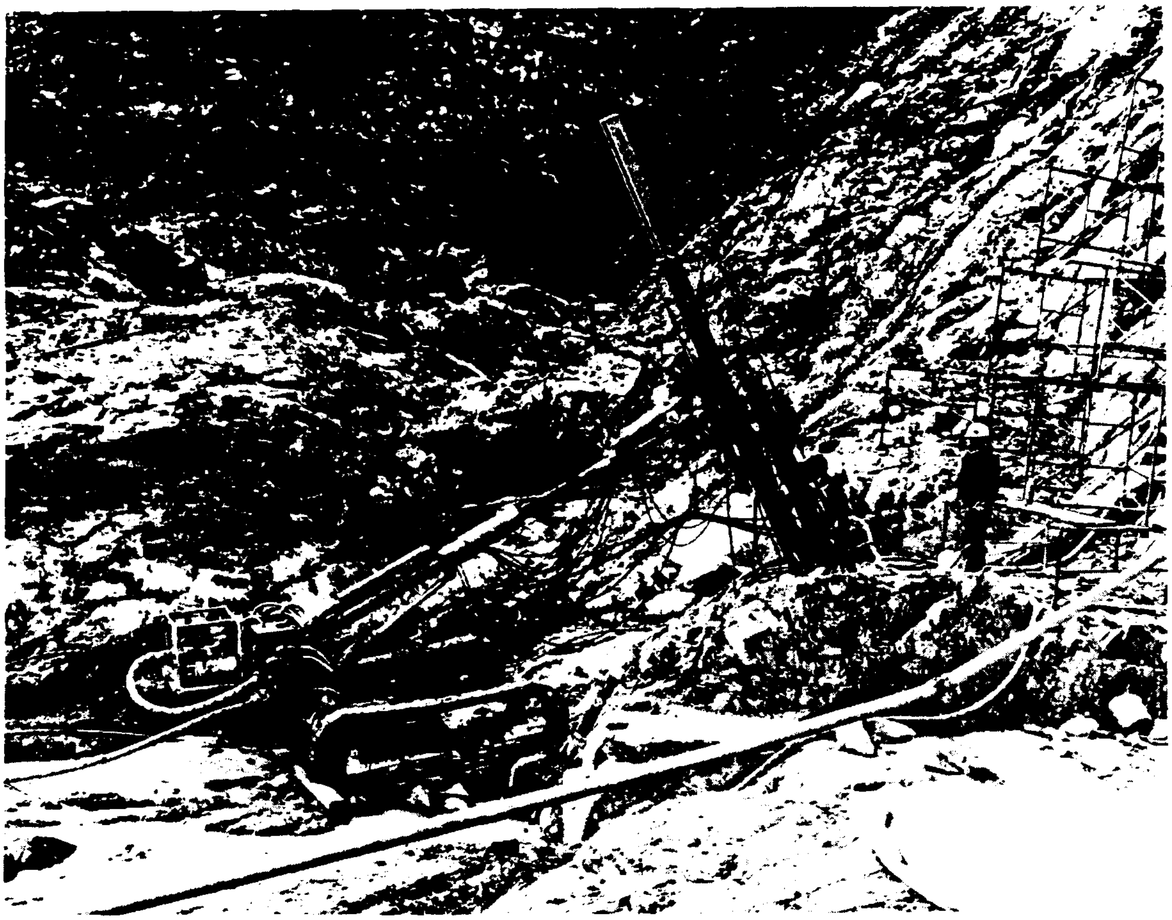
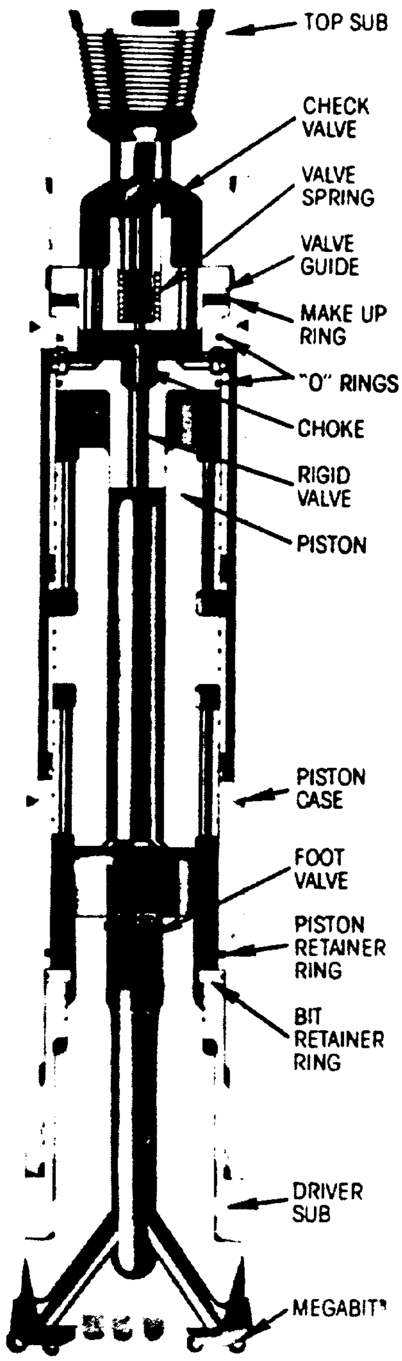


Figure 6-4. Air Trac drill

Therefore, contract specifications should state the minimum acceptable size of grout hole whenever size is a pertinent factor, and provide the method for checking hole size.

(3) Down-hole hammer. Air activated bottom-hole-hammers are used in most types of rock strata. These hammers can be used on most drills that can be slowly rotated and have slow and closely controlled down-hole feed. The hammer air exhaust is released at the bottom of the hole. Cuttings are blown from the hole by exhaust air which cools the bit. The hammer is a versatile tool for the drilling of rock sockets and blast holes in hard rock (fig. 6-5).

c. 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 approximately 200-300 to 3,000 rpm or more. Pressure on the bit is applied hydraulically or



PREPARATION FOR DRILLING

PRINCIPLES OF OPERATION

The piston is the only moving part during operation of the Megadril®. (See Figure 1) The piston's up-and-down strokes are controlled by the flow of high-pressure air through the case.

With bit in extended position (tool off bottom)

The Megadril® is designed to pass full air volume when off bottom, without operating the piston, in order to blow water from the hole or to accelerate periodic cleaning of the hole.

Figure 6-5. Down-hole hammer

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 holes only a few hundred feet deep to large rigs that can drill holes miles in depth. The small rigs are usually satisfactory for grouthole 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 6-6 and are discussed as follows:

(1) Diamond bits. Diamond bits may be either a core or a plug type. Both types employ a diamond-studded bit to cut the rock. The bit is cooled and the hole is 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 is a pilot type and has a protruding cylindrical element that is smaller in diameter than the main bit head. Noncoring diamond bits have a wide field of usefulness in foundation grouting. However, plug bits are more costly than coring bits for drilling in extremely hard foundations and in badly fractured rock because of greater diamond cost. Since plug bits 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 occasionally occurs when shattered rock is drilled and renders the bit useless for further cutting. Except where wire line is used, the plug bit may be less expensive to use 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. A commercially available bit utilizing polycrystalline diamond blanks has proven very effective. Penetration rates reportedly two and three times greater than tungsten carbide and surface set diamond drill bits, respectively, have been obtained.

(c) Size. The sizes of diamond bits are standard and are generally shown by the code letters EW, AW, BW, NW. The dimensions of each size are presented in the tabulation that follows. Most diamond-drilled grout hole sizes are EW or AW.

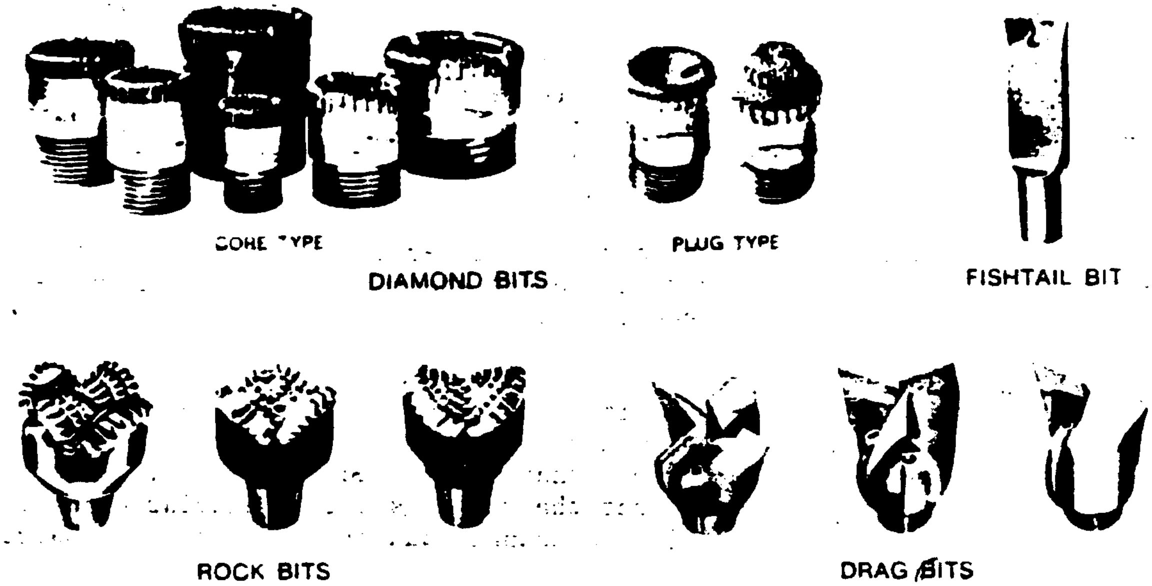


Figure 6-6. Drill bits

Code	Size, inches Hole	Size, inches Core	Size, mm Hole	Size, mm Core
EW	1-31/64	27/32	37.7	21.5
AW	1-57/64	1-3/16	48.0	30.1
BW	2-23/64	1-21/32	60.0	42.0
NW	2-63/64	2-5/32	75.7	54.7

Wire line bits listed below yield the same size hole but not the same size core as the bit shown above.

Code	Size, inches Hole	Size, inches Core	Size, mm Hole	Size, mm Core
AQ	1-57/64	1-1/16	48.0	27.0
BQ	2-23/64	1-7/16	60.0	36.5
NQ	2-63/64	1-7/8	75.7	47.6

(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 makes a hole much faster, is not as easily blocked, and is much cheaper than a diamond bit. The teeth of such bits are often 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. The hard alloys can also be used to make a noncoring bit.

(3) Roller rock bits. Rock bits, like diamond bits, are attached to the bottom of a hollow drill pipe column. The bit is made of toothed rollers or cones, and each turns or rolls on the rock as the bit rotates with the drill pipe. Cutting is accomplished by crushing and chipping operations. The shape, attitude, and number of teeth 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 grouthole drilling because the smallest available size is approximately the same as that of an NW-diamond bit.

(4) Drag and fishtail bits. The drag bit is a general service bit for rotary drilling. The bit is capable of drilling soft rock and most soils and is used extensively in foundation explorations and grouthole drilling. The fishtail bit is so named because of its resemblance to a fish tail. The divided ends of the single-blade bit are curved away from the 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.

(5) Summary. Drill bit types and the materials in which they are generally used are as follows:

Drill Bit Type	Principal Use	Not 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

e. Auger Drills. The auger drilling rig powers either short, spiral-shaped tools or drill rods with continuous helical fluting. The spiral-shaped tool is run on a torque bar and serves as a platform to remove cuttings. The drill rod acts as a screw conveyor to remove cuttings produced by an auger-drill head, and is also referred to as a continuous-flight auger. The auger bits are made of hard steel or tungsten-carbide-tipped cutting teeth. The larger diameter continuous-flight augers are available with a hollow tube/ stem through which grout can be placed. Auger drilling is conducted in soils and very soft rocks to depths rarely exceeding 100 feet.

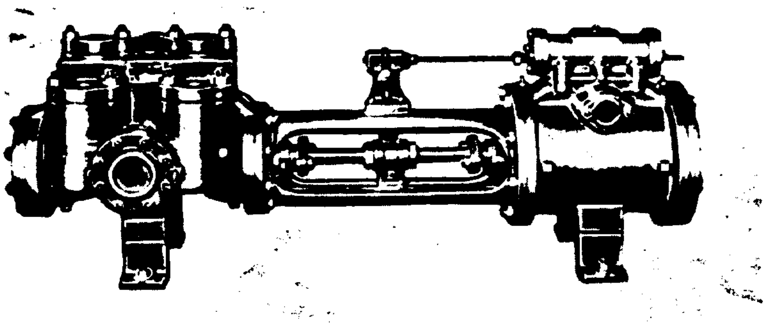
f. Grout Pumps. A great variety of grout pumps of various makes and sizes is available for the placement of grout. They can be air, gasoline, or electrically powered. The air-powered type of pumps have become more prominent in grouting operations. Constant speed-type pumps are powered by electric motors or internal combustion engines. The air-powered pumps provide variable speeds. Grout pumps should be carefully selected to ensure a built-in flexibility that provides close control of pumping pressures and variable rate of injection. The pumps should be the type that can be easily and quickly serviced during grouting operations. Pumps for most grouting projects should be of the minimum surging or nonsurging type, which avoids the pulsating effect transmitted to a hose, pipeline, drill stem, or grout hole at the completion of each compression stroke of a reciprocating-piston pump. Air or electrically powered pumps are best suited for shaft, tunnel, silo, or other similar types of underground work. Spare pumps and spare parts should be available during all grouting operations (fig. 6-7 and 6-8).

(1) Line-type slush pumps. Slush pumps have the discharge valves located directly above the suction valves. This arrangement helps in expediting the removal of both types of valves for cleaning or correcting malfunctions; however, the valves are not interchangeable.

(2) Sidepot-type sump pumps. Sump pumps are designed with each valve in a separate chamber or pot, each with its own cover. This arrangement provides for the removal of the suction valves without disturbing the exhaust valves. One problem, especially with sanded grouts, is the necessity of having to remove cement and sand that frequently collect in the bottom of the pots.

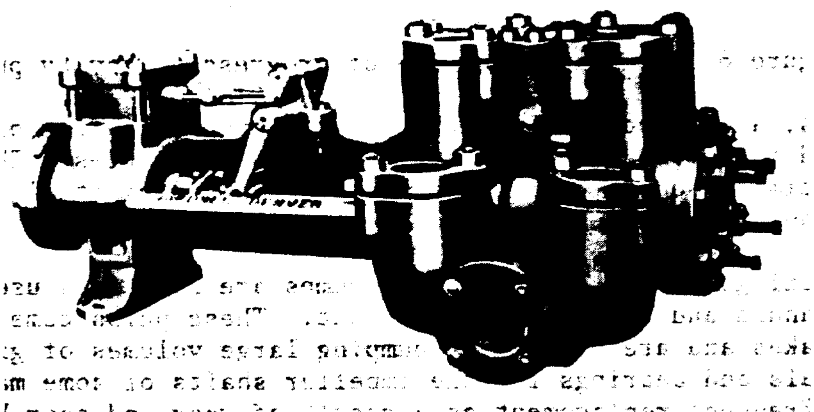
(3) Divided fluid-cylinder valvepot-type pumps. Valvepot pumps are somewhat heavier than the line-type pump that has comparable capacities. The valves and seats of this pump are interchangeable, and the fluid end is easily cleaned.

(4) Progressive cavity pumps. Cavity pumps under the trade name Moyno or Roper are two of the most popular pumps currently used in a wide variety of grouting applications. The major components of this type of pump consist of a wormlike hardened steel screw rotor that rotates in a helically formed stator in which grout is forced forward. The larger pumps will pass particles up to a size of approximately 1-1/8 inches. It is a valveless unit and has few working parts and comparatively is more trouble free. Progressing cavity pumps can generate pressures up to approximately 1,000 pounds per square inch and have a top capacity of approximately 200 gallons per minute. The stator liner can be exchanged to provide a stator for handling highly abrasive grouts,



a. SIDE-POT-TYPE PUMP

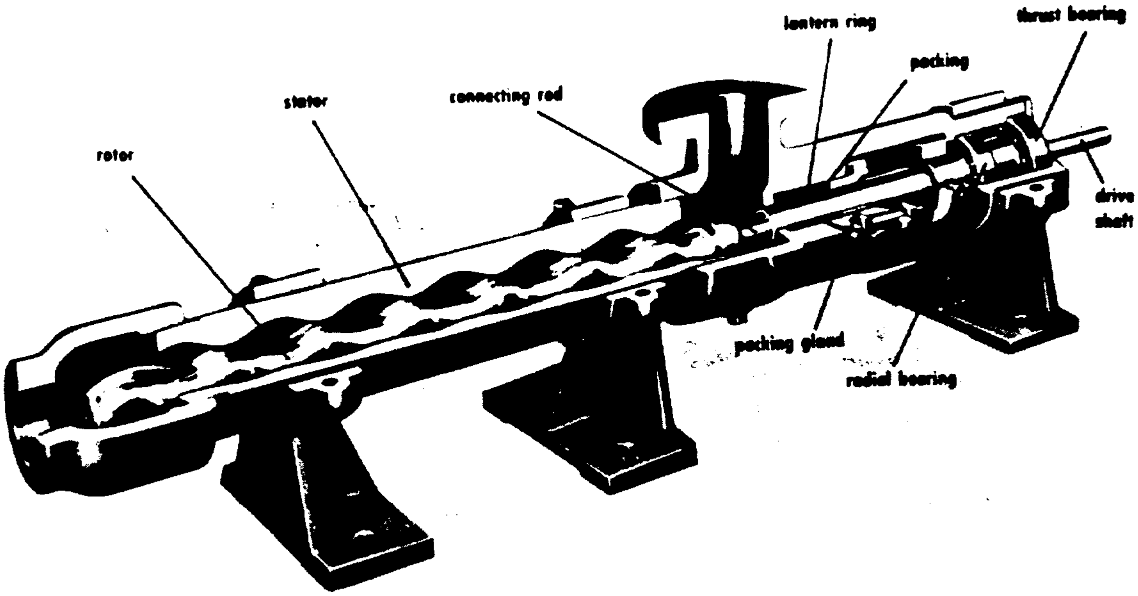
(Courtesy of Wagener Pump Division, Canton Stoker Corp., Canton, Ohio Bulletin No. WS-150A)



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

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

Figure 6-7. Slush pumps



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

Figure 6-8. Cutaway section of progressive cavity pump

chemical grouts, and petroleum products. These pumps are free of pulsation and can be used to pump a great range of grout consistencies. The larger pumps are sometimes used to pump sanded grouts containing steel fibers. The open-throat types are the best suited for handling grouts containing fillers.

(5) Centrifugal pumps. Centrifugal pumps are sometimes used to pump highly fluid sanded and unsanded cement grout. These pumps come in a variety of sizes and makes and are capable of pumping large volumes of grout at low pressures. Seals and bearings for the impeller shafts of some makes of these pumps require frequent replacement as a result of wear and tear by abrasion.

g. Concrete Pumps. Concrete pumps are occasionally used to pump sanded and unsanded cement grouts in cases where the consistencies of such mixtures range from moderate to near minimum fluidity. The latter mixture is often described as being stiff or having a standard slump cone consistency ranging between 4 and 8 inches. These pumps can easily handle aggregate to a maximum size of 1 inch and are also capable of pumping grouts containing steel fibers. These units are composed of reciprocating pistons housed at the bottom of a stowing type hopper. The piston delivers the grout directly into 4-inch or larger steel pipelines through a swedged head-type coupling. The pumps are normally either truck or trailer mounted and gasoline powered. They are not used in grouting applications that require close pressure controls but are mainly used in filling large cavities, and at times are used to deliver grout to tremies when such cavities are filled with water.

h. Grout Mixers. The first consideration in the selection of a grout mixer is to ensure that it has the desired capacity and will produce a homogeneous mixture in a desired period of time.

(1) Tub mixers (fig. 6-9). Tub mixers of various capacities and arrangements of mixing blades are the most common type used. They are usually air powered, and the grout is mixed by several horizontal blades mounted on a vertical spindle. These mixers are used individually but more often than not consist of two or more tubs that are either parallel or in a series. The paddle blades are arranged in pitch to force grout to the lower section of the tub where the grout is discharged through either a quick-opening syrup/petroleum

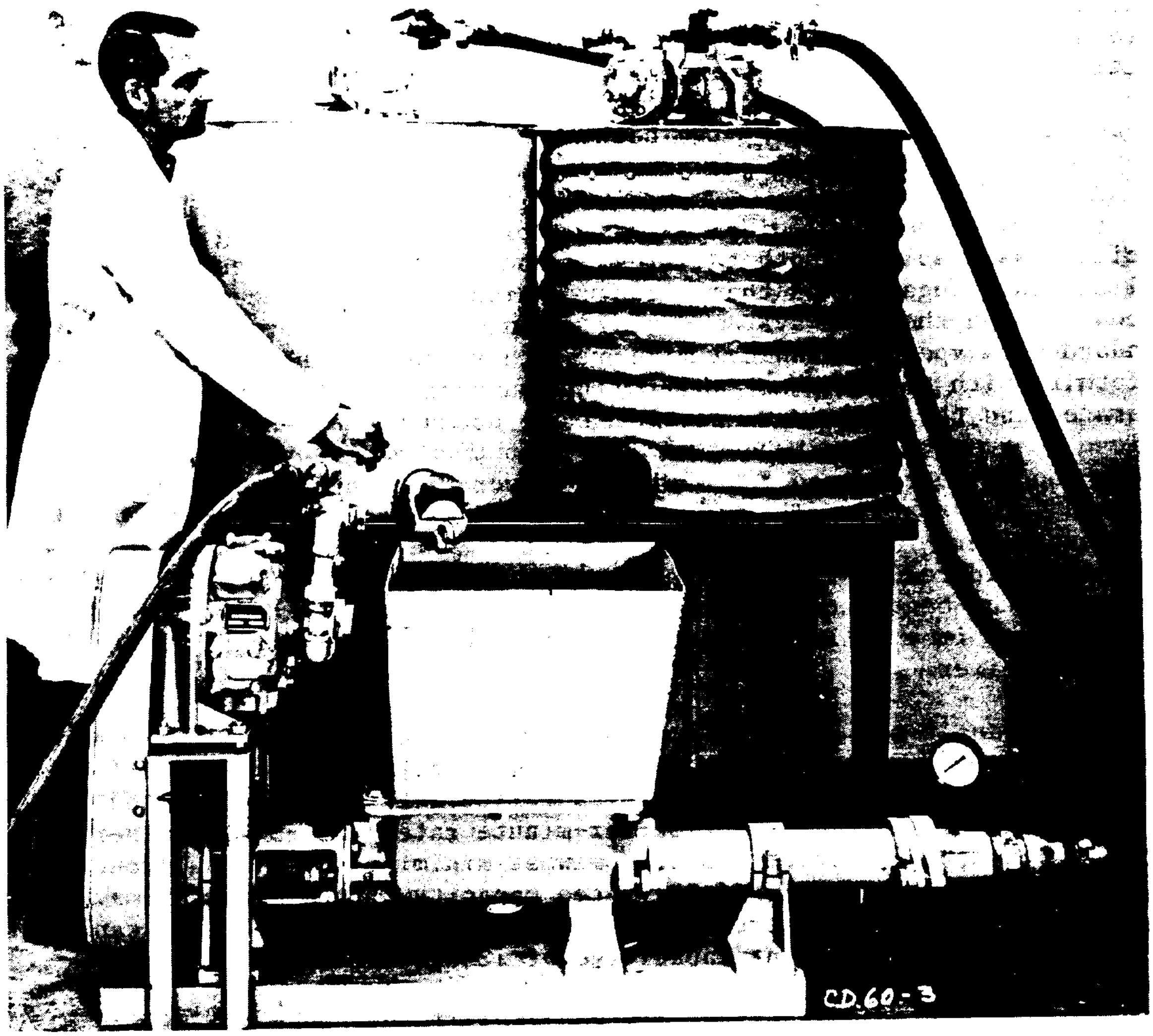


Figure 6-9. Two tub-type grout mixers and open throat progressing cavity pump

or similar type valve into a sump. These types of mixers are seldom designed to mix more than 1/2 cubic yard of grout. Four- to fifteen-cubic-foot-capacity tubs are the most convenient sizes for use in most grout applications. Outstanding features of tub mixers are that they can be easily charged, observed, and cleaned.

(2) Horizontal drum mixers, ribbon and paddle types (fig. 6-10 and 6-11). Grouting jobs that require moderate to large quantities of grout frequently utilize a horizontally positioned drum having length-to-diameter ratios that range from approximately 2:1 to 4:1 and are capable of mixing approximately 8 cubic yards of grout. The drum is placed in a fixed horizontal position with a drive shaft centered along its long axis that is supported by bearing blocks enclosed in steel hubs. Affixed to the shaft are a series of paddles placed at selected intervals and normal to the shaft, or the drum may contain a series of metal segmented or continuous spiraling strips that are positioned near the inside perimeter of the drum and supported from the shaft by a series of struts. These mixers have a charging chute at the top of one end and a discharge valve at the bottom near the other end. They are usually air-powered; however, some are driven from truck-powered takeoff shafts.

(3) High-speed colloidal mixers. Colloidal mixers (fig. 6-12) are commercially available in both the single- and double-drum types. These units utilize centrifugal pumps that circulate highly fluid grout mixtures at high speeds through the drum system during mixing. These mixers are superior to standard slow speed mechanical mixers in that they produce grout of greater uniformity with better penetrability and pumpability. Cement clusters are separated and the individual particles are often broken and rounded to a significant degree making it possible to grout tighter fractures. Colloidal mixers should be required for mixing and hydrating bentonite. Bentonite should be mixed in a separate mixer and fully hydrated before being introduced into the grout mixer. The bentonite mixer must not be contaminated with cement because it would reduce the swell properties and, thus, the grout stabilizing ability of the bentonite. Hydration of bentonite can be accomplished in less than 1 minute in a colloidal mixer as compared to approximately 24 hours in a slow speed mixer.

(4) Transit mix and skip-loaded concrete mixers. Transit and skip-loaded mixers are sometimes used as grout mixers; however, mixer efficiency is sacrificed as a result of the lack of shearing action being imparted to the mixture because of slow revolution-per-minute rates. When such mixers are used for grout, the problem can be somewhat minimized by mixing grout volumes that do not exceed one half of the rated capacity of the mixer drums. One major benefit of these mixers is the large quantity of grout that can be mixed since some units have mixing capacities of 12 cubic yards.

(5) Jet mixing units. Jet mixers generally produce less mixing efficiency than most mixing systems. These units consist of a large metal funnel mounted atop and in line with a metal water line. The dry bulk cement or dry

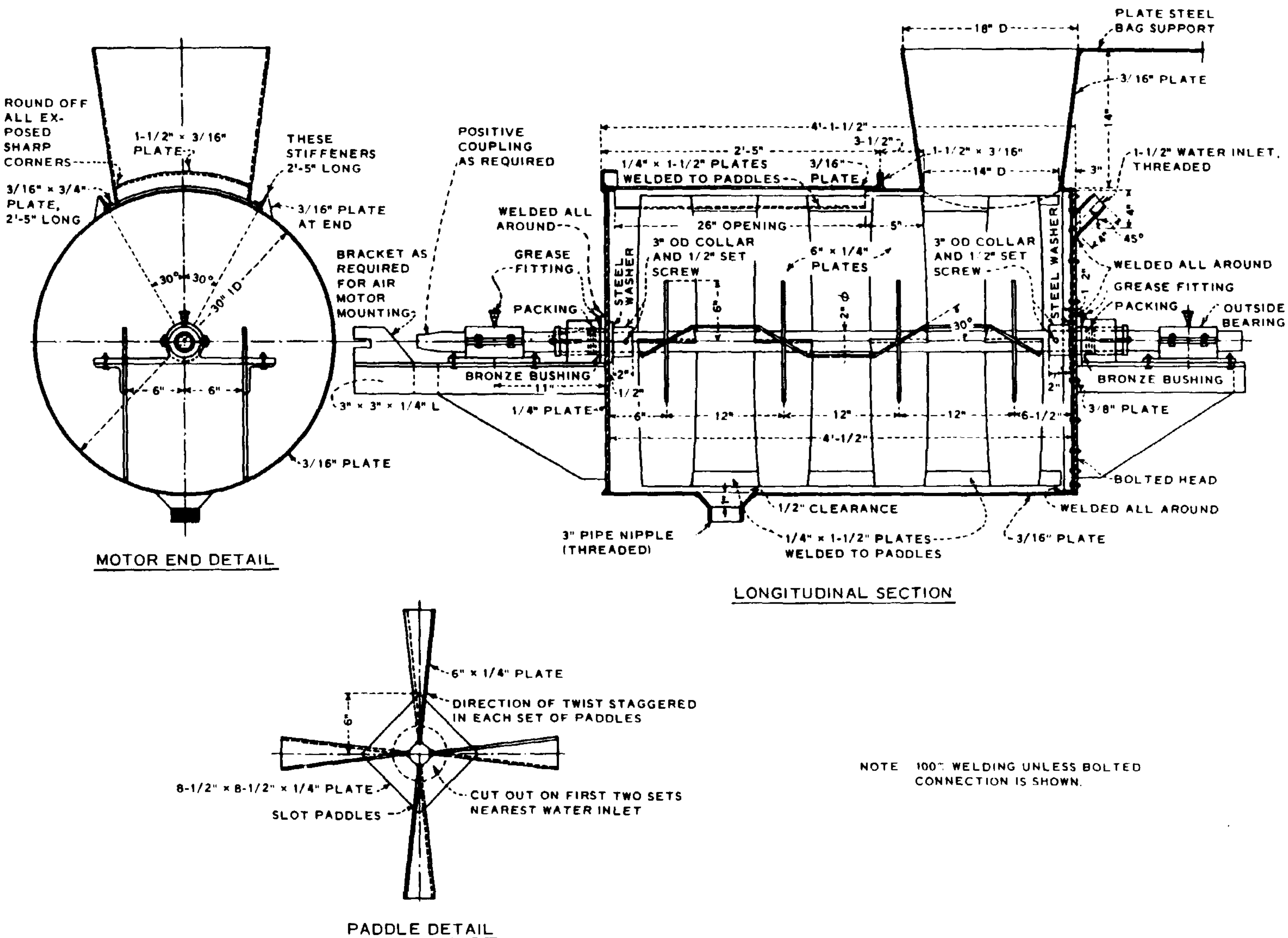
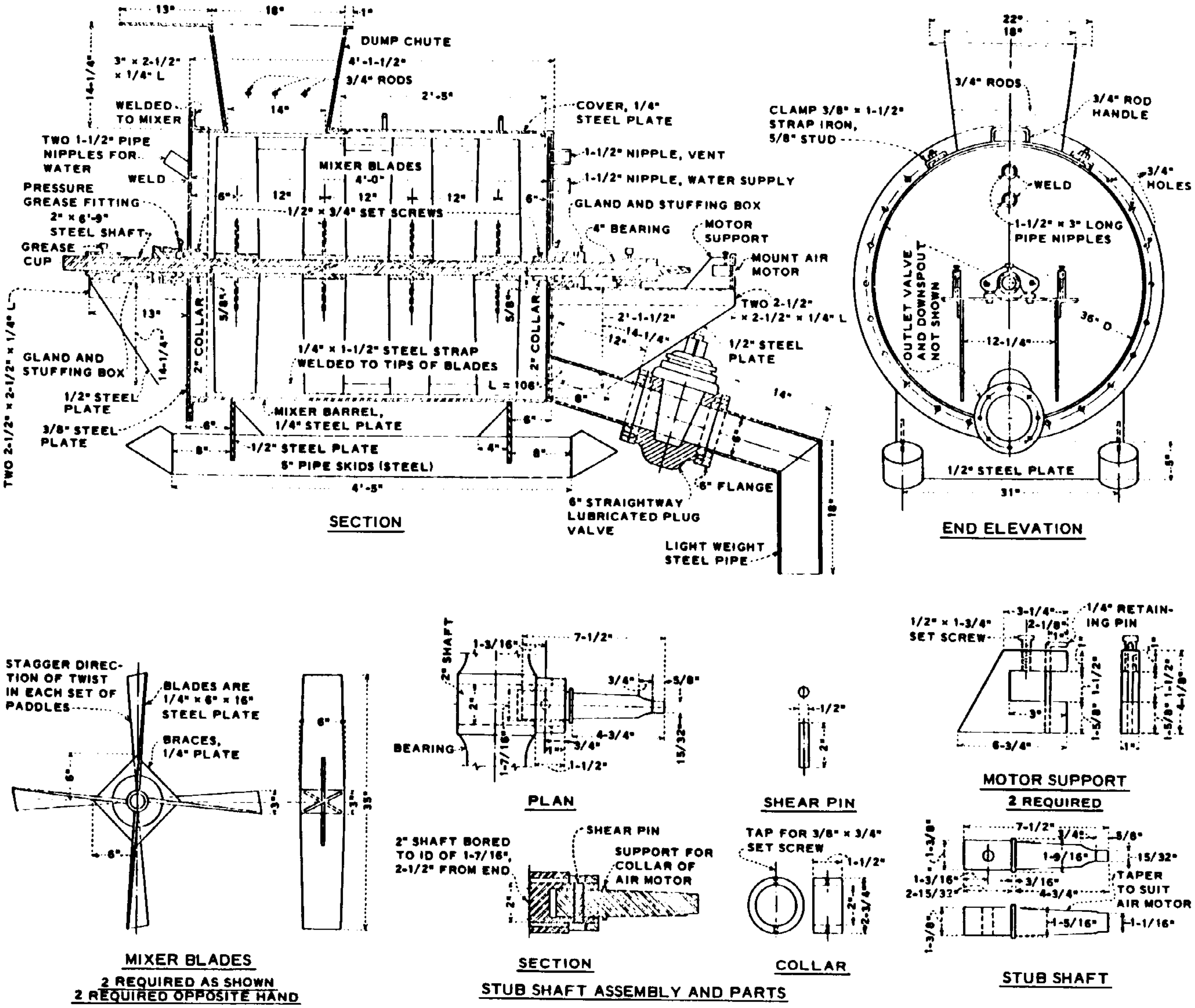
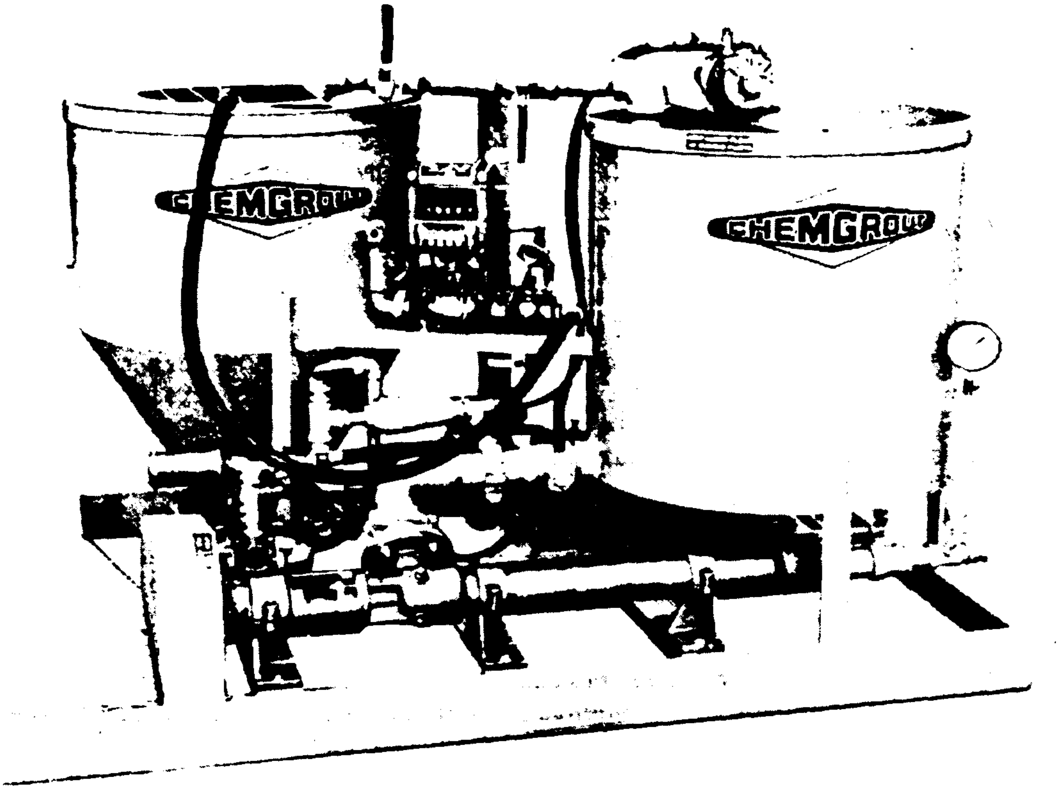


Figure 6-10. Horizontal drum grout mixer, 8-cubic-foot capacity



(Courtesy of U. S. Bureau of Reclamation)

Figure 6-11. Horizontal drum grout mixer, 27-cubic-foot capacity



This larger version of the CG-600 is 68" wide, 102" long, and has 17 cubic feet mixing and holding tanks. Output ranges up to 20 gpm depending upon the mix. The standard discharge pump has a pressure of 225 psi and is capable of pumping sanded mixes. Higher pressure pumps (up to 1500 psi) are also available. Controls are centrally grouped for ease of operation. All drives are mechanical to minimize costly, unnecessary downtime. Cleanup is less than 10 minutes/shift.

CG-650

Type	Power	Quantity
Air	100 psi	370 cfm
Electric	230/460	54/27 amps
Gasoline	Available	
Diesel	Available	

Figure 6-12. Colloidal mixer

bulk blended grout materials are continuously metered into the funnel by means of a flapper valve. A forced stream of mixture water is continuously metered by pipe just below the orifice of the funnel which causes shearing and turbulent mixing action. The resulting mixture is jetted into a holding tank, is measured for designed weight and fluidity, and, if needed, is adjusted for corrections to cement and water metering. When the mixture is properly adjusted, the suction side of large pumps picks up and transfers the grout to a discharge pump. Large volumes of grout can rapidly be placed using this method. This unit is sometimes used to place quick-setting mixtures; however, no holding tanks are in the system. A sampling "T" for providing a degree of control is in line.

(6) Compressed-air tank mixers. Compressed-air mixers are occasionally used for accurate batching and mixing. These types of mixers may range in capacity from a few cubic feet to 500 cubic feet. Dry materials are fed to the tank through a pipe connection located at the tank side below the water level. Air and mixing water provided through vertical connections discharge into the interior of the tank. The air-mixed grout is discharged from a connection located at the base of the mixing cone.

i. Agitator Holding Tanks. To provide a high volume and continuous injection of grout, two mixers are usually set up to alternately discharge into an agitator holding tank that has a capacity at least two and preferably up to three times the capacity of the mixing system. Tub or horizontal type mixers operated at slow speeds are frequently used for agitating holding tanks. Agitator holding tanks can be similar in design to the tub-type mixers shown in figure 6-9. Volumes of grout used from the agitator holding tanks can be measured by marks at different levels in the tanks.

j. Grout Lines. Two primary arrangements of grout piping are used to supply grout from the pump to the hole. The simpler of the two, the single-line system, is used in a variety of grout placements. The system consists of a pipe or a hose or a combination of both extending from the pump discharge to the header at the hole collar. The pump speed controls the rate of grout injection. The second arrangement, which provides a circulating system, is composed of a double line, and one of the lines serves as a return line from the header to the grout pump, sump, or holding tank. This line provides for the continuous circulation of the grout through the single line and pump. The double-line system can also be used to meter a desired amount of grout downhole by simply varying the openings of a valve on the return line without changing pump speed. Pressure is controlled by one or more valves on the control line. A circulating grout header should normally be required for foundation grouting.

(1) Hose lines most commonly used for discharge and suction are the flexible type, usually made of reinforced rubber or plastic. The inside diameter of these hoses for most grouting applications ranges from 1 to 2 inches. The larger the diameter of a given type of hose, the less the working pressure.

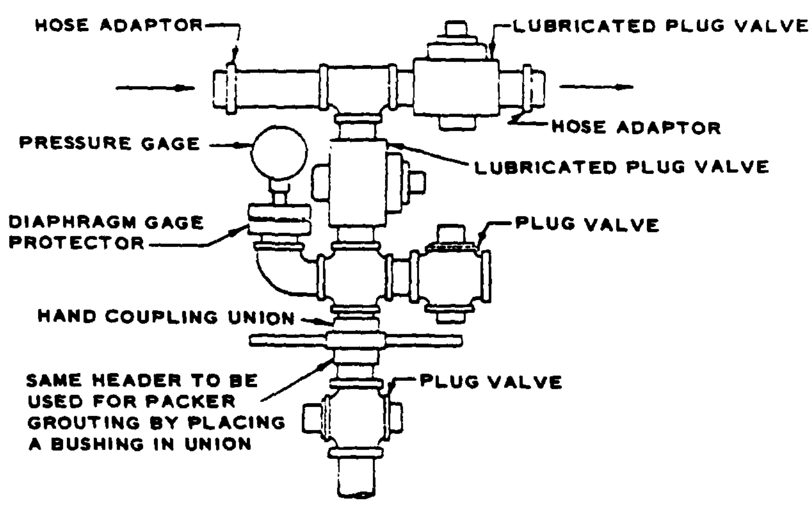
Hoses should be selected that have working pressures at known temperatures that will withstand the maximum pressures anticipated with an ample margin of safety. Damaged hoses should be discarded.

(2) Pipelines of black steel are sometimes used in long runs from the pump to an array of holes to be grouted. The lines should be at least one half again the diameter of the flexible lines and should not contain any sharp bends or constrictions.

k. Headers. Headers permit grout injection through downhole lines as well as provide continuous circulation at the surface. Headers may also permit grout injection through downhole lines and return up the annular space between tubing and hole. See figures 6-13 and 6-14.

l. Valves. Valves for grout lines and header systems should be the quick-opening type, easily regulated, and resistant to corrosion and abrasion. They should be capable of accurately controlling pressures in all positions. When in the full open position, valves should not present a restriction to the flow of grout. Diaphragm-type valves have proven to be effective. Pressure relief valves should be installed in grout lines as an added precaution.

m. Packers. Packers are often required in pressure grouting to confine the injection of grout to certain foundation zones, to isolate a lost circulation zone, to separate grout stages, to grout sections of slotted or perforated



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 6-13. Direct grouting header

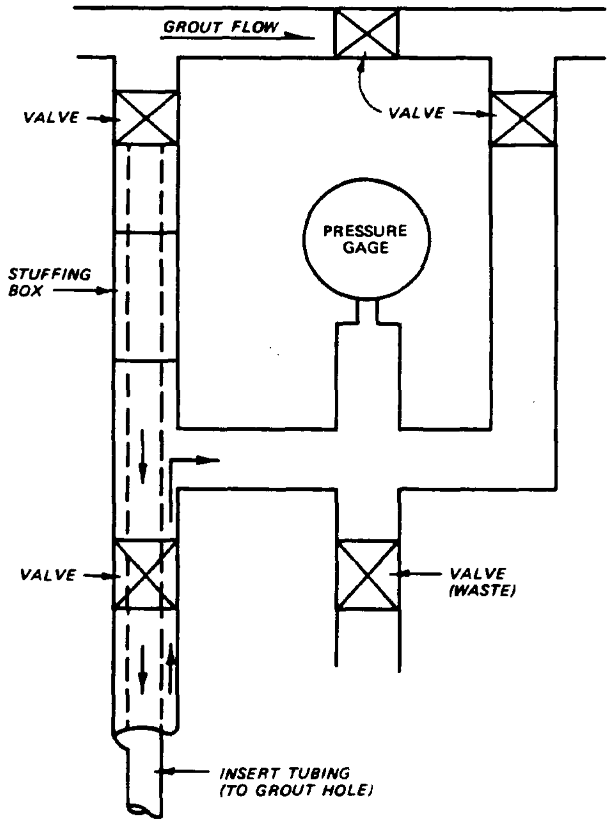


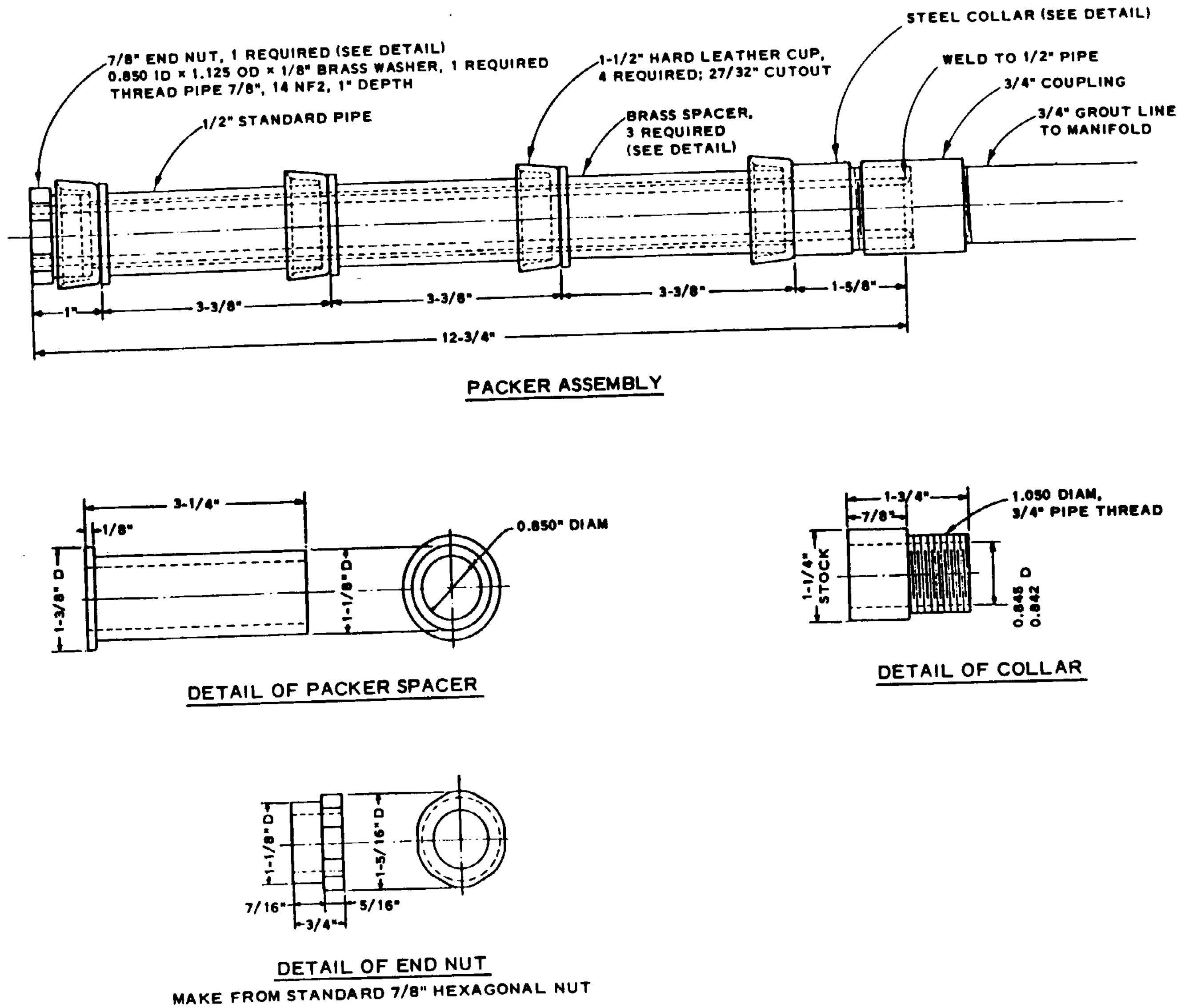
Figure 6-14. Circuit grouting header (not to scale)

casing, and to make surface connections. The three most commonly used packers are shown in figures 6-15 through 6-17.

(1) Cup leather removable packer. The cup leather removable packer is best suited for use in holes drilled in moderately hard to hard rock and where the walls of the holes are relatively smooth and of the proper dimensions. This packer is attached to a single pipe for placement downhole. When properly assembled and positioned, the packer can withstand pressures approaching 1,000 pounds per square inch.

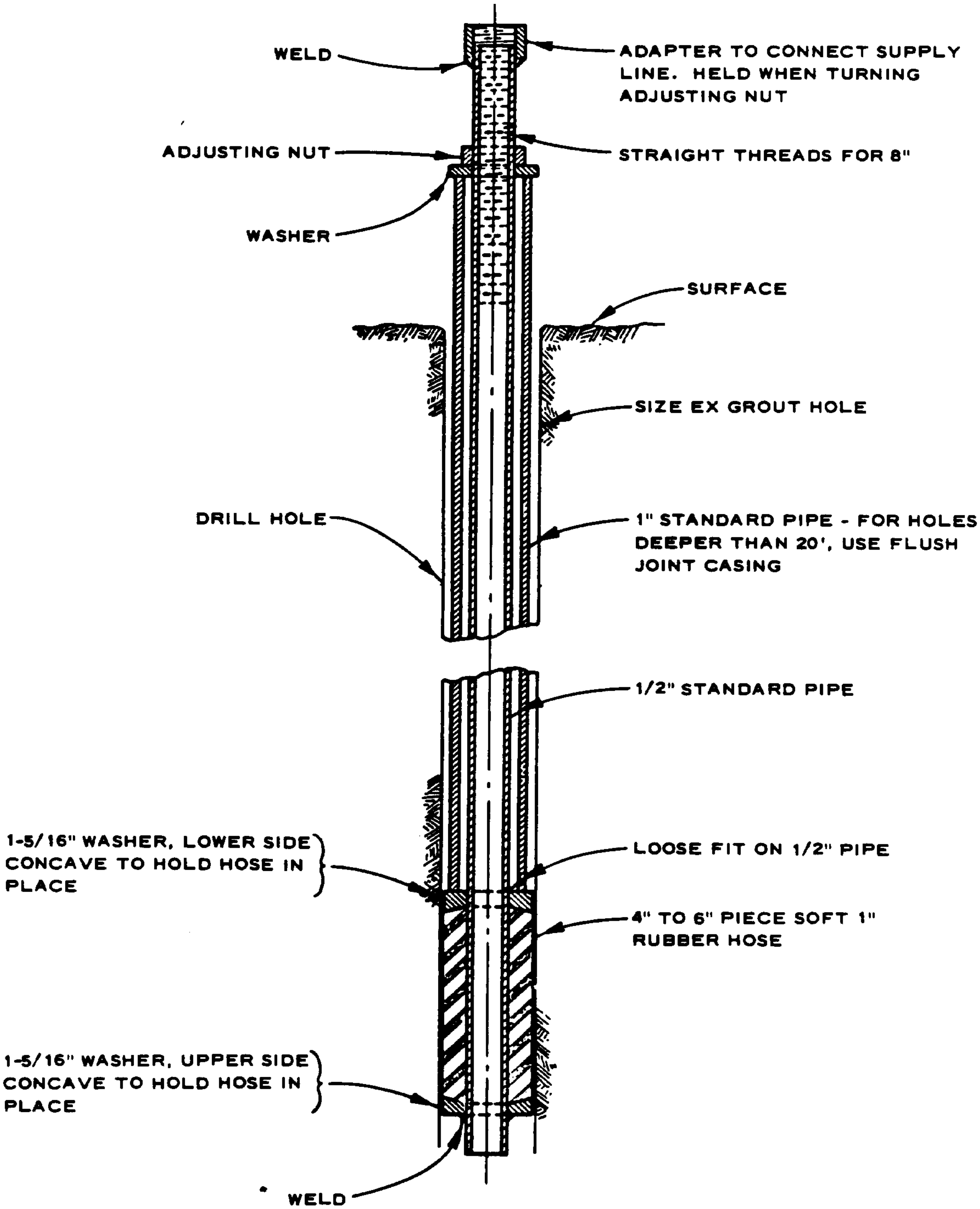
(2) Mechanical packer. This packer is an expandable type. It is difficult to properly seat if the hole is rough or oversized and easily bypassed in fractured rock. When properly assembled, expanded, and seated in good rock, the mechanical packer can also withstand pressures of approximately 1,000 pounds per square inch. This type of packer is widely used in rock formations that vary from soft to hard.

(3) Pneumatic packer. The pneumatic or air packer can be used in



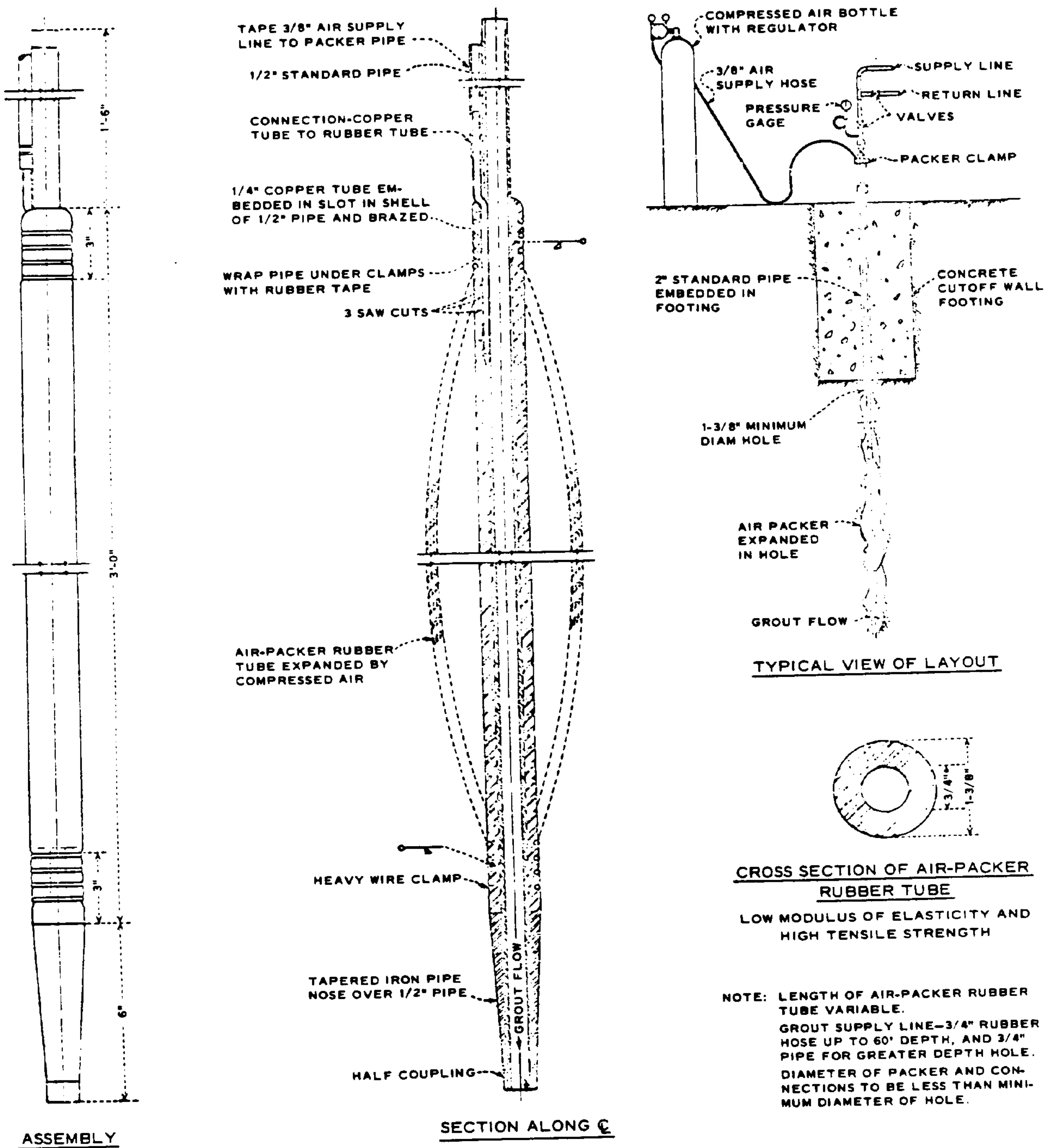
(Courtesy of U. S. Bureau of Reclamation)

Figure 6-15. Removable grout packer



(Courtesy of U. S. Bureau of Reclamation)

Figure 6-16. Mechanical packer



(Courtesy of U. S. Bureau of Reclamation)

Figure 6-17. Air packer

oversized holes because of its expansivity. As an example, an EM size may be seated in 3- or 4-inch-diameter hole or casing, providing that the hole condition is good. The packer is well suited for use in soft, fractured, and thin-bedded rocks. Grout injection pressure should be less than packer inflation pressure to prevent bypass of the grout.

n. Centralizers. Centralizers are sometimes required to position casing or injection pipe in the center of holes, particularly when casing or pipe is to be a part of a permanent subsurface type of installation. Assembled leaf springs with limit rings serve as centralizers and provide a uniform annulus around the casing or the pipe, which can then be properly filled with grout. The centralizers aid casing and pipe to negotiate irregularities and doglegs. Commercially available centralizers are fabricated with hinges to facilitate their attachment to casing or pipe strings (fig. 6-18).

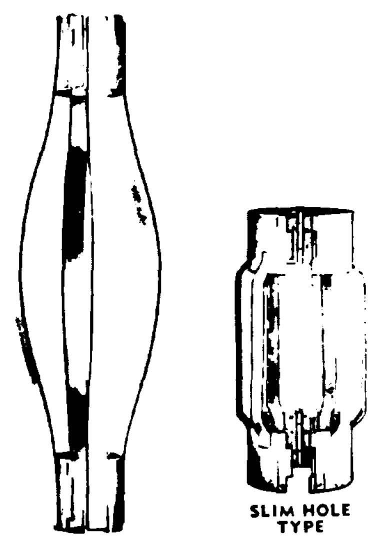
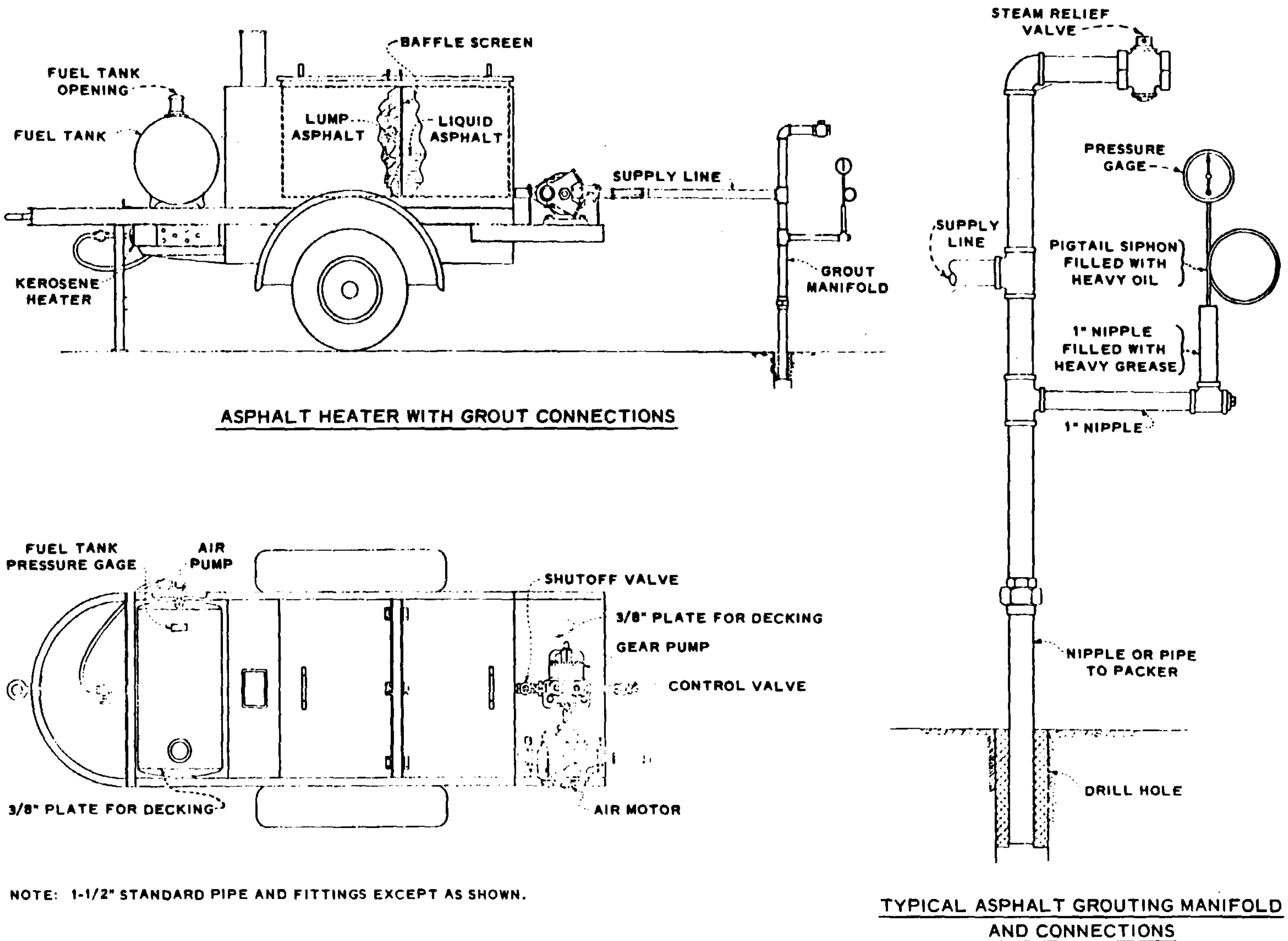


Figure 6-18. Centralizers,
Courtesy Halliburton, Inc.

o. Tube Wiping/Displacement Plugs. Tube plugs are used in special grouting applications for displacement of a measured amount of grout down a hole. A hard rubber plug with a series of rubber discs is forced down the inside of a steel tube by a fluid head acting on a steel ball seated atop the plug. The ball and plug are discharged into grout or retained in a plug catcher attached to the bottom of the drill tubing.

p. Asphalt Grouting Equipment. Portable asphalt heating kettles commonly used by contractors for pavement crack sealing, roofing coatings, and similar applications have served well in heating asphalt for grouting (fig. 6-19). Hot asphalt heating should be maintained below the flash point of the asphalt.



(Courtesy of U. S. Bureau of Reclamation)

Figure 6-19. Asphalt grouting equipment and connections

Reciprocating pumps with ball valves, or 1-inch boiler-fed piston pumps and gear pumps, have been used to pump hot asphalt through 1- to 2-inch black iron pipe. Conventional type cement grouting equipment can be used for asphalt emulsions.

q. Chemical Grouting Equipment. Grouting equipment has been generally developed by the manufacturer to mix and place that particular chemical grout system. Conventional grouting equipment may be used for a number of processes, especially when single batching will meet the job requirements. Closely controlled proportioning systems are frequently recommended for handling two or more components of a given formulated grout. Detailed descriptions covering chemical grouting equipment are discussed in EM 1110-2-3504.

r. Large-Capacity Mixing and Pumping Systems. During the middle years of the twentieth century, an enormous surge began to take place in the growth of organizations that have developed highly specialized equipment, materials, and techniques for grouting operations, especially those operations requiring large, continuous mixing and pumping systems. One single pumping system is capable of mixing and placing approximately 35 cubic yards per hour. Pumps are capable of developing 20,000 pounds per square inch. These capabilities have mainly been developed as a result of an increasing demand to solve underground problems associated with energy sources, large foundations, deeply buried structures, and other grouting operations similar in scope and complexity. Much of the equipment used in these types of grouting operations is mobile; some systems are skid mounted and others are barge mounted. Companies specializing in large-scale grouting operations as well as oil well cementing/grouting companies are providing this type of grouting capability worldwide. Some of the major pieces of equipment and storage facilities used in large-capacity mixing and pumping systems are shown in figure 6-20.

s. Tremie Equipment. Steel sections of pipe and tubing fabricated from a few inches to as large as 6 or more inches in diameter and to lengths ranging from a few feet to desired lengths are the major items that make up a tremie system for the gravity placement of grout. The sections are usually joined loosely end to end by means of short lengths of steel-linked chain in forming a continuous and somewhat flexible pipe string. The tremie system with a gathering hopper or chute attached to the top section is positioned initially with its discharge end immediately above the point of grout placement.

t. Casing. The casing commonly used in grouting work is either steel or plastic tubing. The tubing is lowered into a borehole to prevent collapse of the hole or entry of loose rock, gas, or liquid or to prevent loss of circulation fluid into permeable formations. Casing is used to isolate zones to be grouted through perforated casing. Additional information regarding casing is presented in EM 1110-2-1907 and EM 1110-2-3504.

u. Pressure Testing Equipment. The major items of equipment normally needed to conduct pressure testing include single or straddle packers, a water

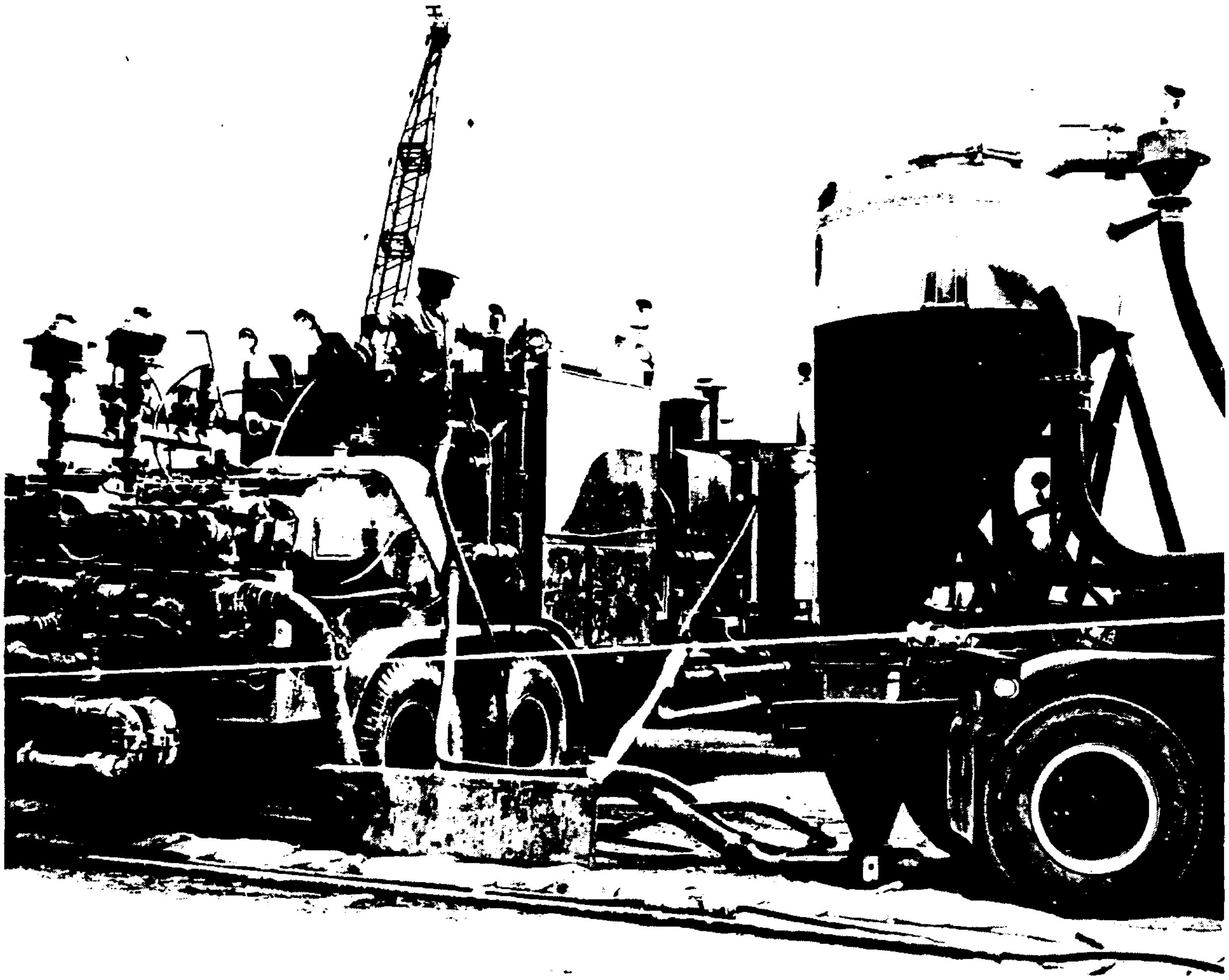


Figure 6-20. Standard twin HT-400 cementing unit fully rigged with jet mixing cone and slurry reservoir. Courtesy, Halliburton Services

meter, a nonpulsating type pump, pressure gages, a suitable pipe or base for connection to the hole collar or downhole, and a stop watch. Water meters and pressure gages should be tested for accuracy prior to use as these items provide essential numerical data for analysis.

v. Meters. An accurate and expeditious method of controlling grout water contents is by using volume-measuring water meters. These meters can be obtained with measurements in either gallons or cubic feet and can usually be read to the nearest quarter of a gallon or tenth of a cubic foot. A meter should be checked for accuracy before it is used and, if necessary, should be calibrated. Meters for measuring quantity of grout placements either may consist of something as simple as a vertical graduated stick or rod gages placed

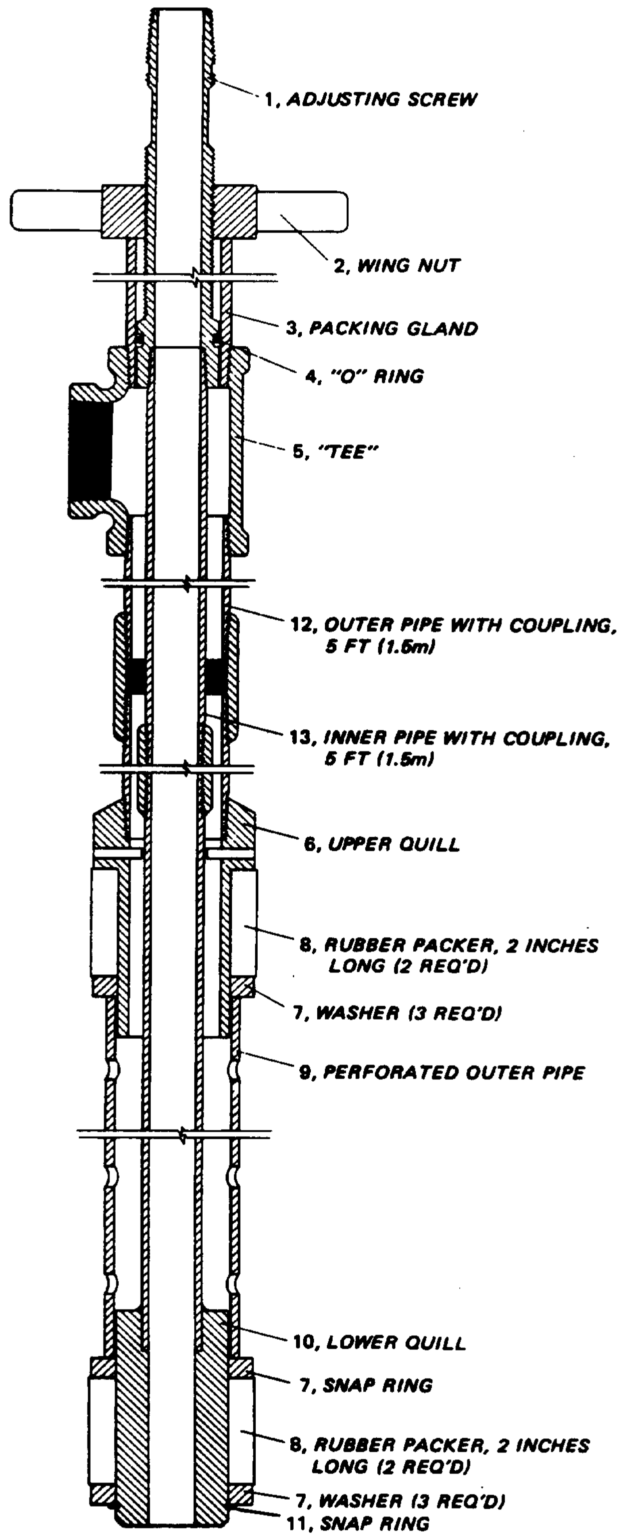


Figure 6-21. Pressure testing packer assembly

in mixers or agitator trucks, or may use calibrated spindles placed in the grout line and geared to counters or strip recorders (fig. 6-21). These meters may be designed to measure barrels, cubic feet, gallons, or fractions of these units.

w. Pressure Gages.

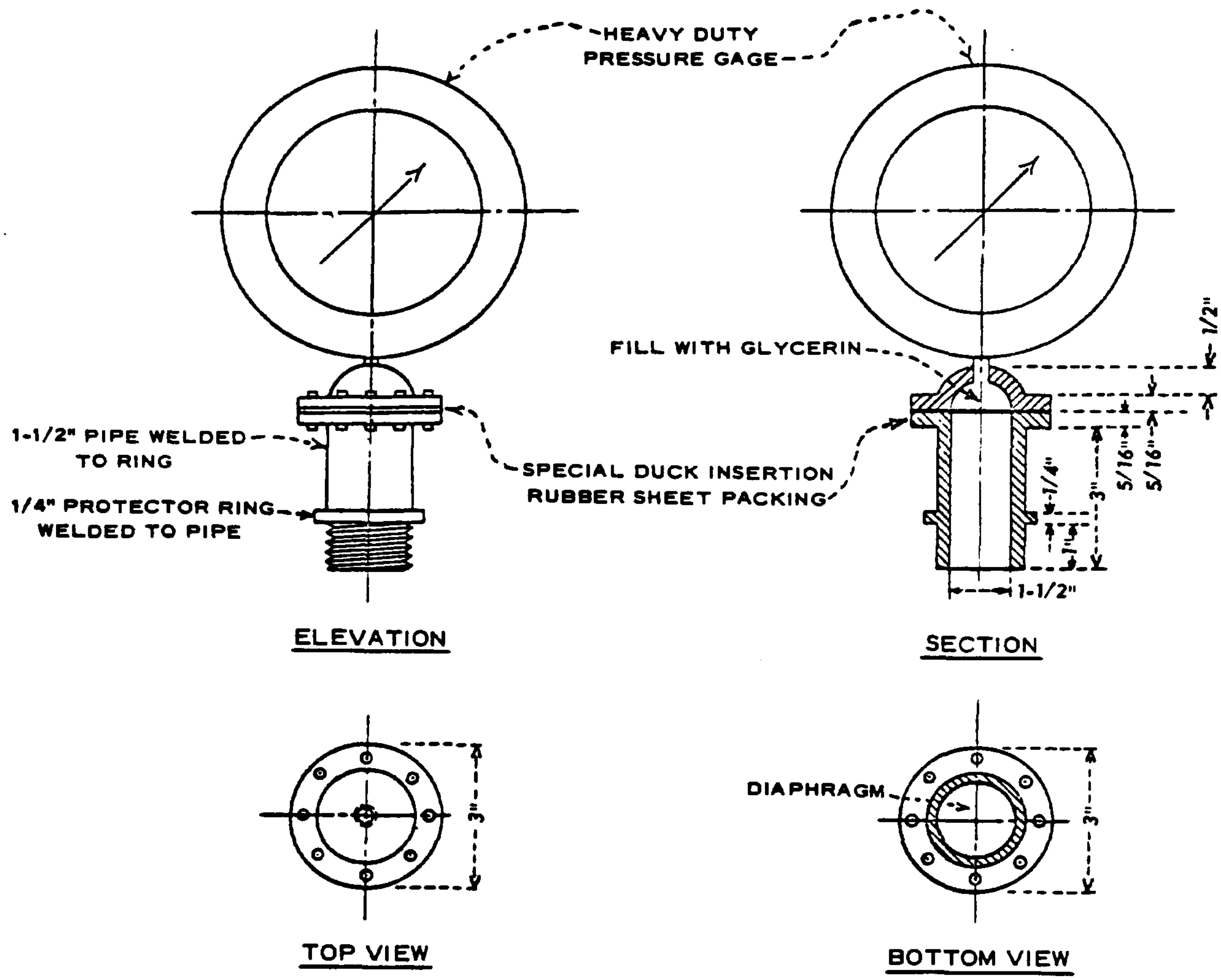
(1) Pressure gages are essential in virtually all types of grouting and pressure testing, and they must be reliable. Malfunctioning gages have resulted in damage to structures and rock formations as a result of excessive pressures. Gages should be tested for accuracy prior to use and periodically during the work. The moving parts of the gage should be protected from dust and grit and from direct contact with the grout.

(2) Gages that are available commercially consist of diaphragm systems to provide the necessary protection. A diaphragm glycerin-filled gage saver is shown in figure 6-22.

6-3. Special Monitoring Equipment. A structure has precise, measurable dimensions in virtually all respects; however, the foundation of the structure can only be described in general terms. The quality of grout being placed in the foundation and the location, movement, and behavior of grout in place may need constant monitoring during a grouting operation. Some of the monitoring methods in use are described below.

a. Grout Level Detection Equipment. Monitoring the progress and adequacy of subsurface grouting operations is extremely important under some circumstances; i.e., grouting voids under structures which must be completely filled with grout. Such monitoring can be accomplished by grout level detection systems that include electronic readouts from probes located in an array of satellite drill holes surrounding the grout injection hole. The probes usually consist of electrode pairs that measure capacitance or resistance of freshly placed grouts. These probes, prior to placement downhole, are calibrated in air, water, mud, diluted grout, and the designed grout. With these data available, the system can be used to determine the quality of the grout being placed, and its vertical and lateral movements. The data also provide information relative to decisions to modify mixtures during placement, such as to use a quicker or slower setting mixture, to increase or decrease density, to add lost circulation material, and to incorporate tracers. Remote recordings can be obtained on printers or oscilloscopes. One application of grout level detection equipment is presented in WES MP SL-79-23 (app A).

b. Downhole Temperature Measurements. Temperature profiles of the subsurface area to be grouted are very helpful in furnishing information on the anticipated effects of temperatures on the setting times of grouts. Thermocouples or thermistors left in place will indicate the presence of grout as a result of temperature rise caused by the hydration of the cement or the reaction of the catalyst system in chemical grouts.



(Courtesy of U. S. Bureau of Reclamation)

Figure 6-22. Glycerin-filled gage saver

c. Downhole Sampler. A sampler that is useful in sampling grout to depths some few hundred feet downhole may be described as a small bottom-discharge bailer. It works on the same principle as the old-time water well bottom-discharge bailer, which is composed of a metal tube approximately 1 to 2 feet in length and approximately 3 inches in diameter. The bailer has one line for lowering and raising and one line for operating the valve located in the bottom.

d. Tracer Materials. Color tracers used in water and grout can be helpful in determining the extent of a groundwater or a grout communication system. Color pigments normally used in portland cement grouts as tracer materials are basically finely ground iron and chromium oxides, which provide a wide range of distinct colors. Five to ten pounds of one of these pigments per sack of cement is usually sufficient to produce a distinct color. Other dyes include fluoresceins and rhodamines. The manufacturer of the chemical grout to be used should be contacted as to type and concentration for use in a particular product.

e. Flow Cone. The flow cone measurement may be used both in the laboratory and in the field for determining the flow of grout mixtures by measuring the time of efflux of a specified volume of grout from a standard cone. This test is used to ascertain the fluidity of grout mixtures. The method of testing is covered in CRD-C 611.

f. Slurry Scales. The unit weight of grout mixtures may be determined by using either the standard API-approved mud scale balance shown in figure 6-23 or by a unit weight container, precisely calibrated, that ranges from 0.25 to 1.0 cubic foot and has a set of scales graduated to tenths of a pound and a weighing capacity of at least 250 pounds.

g. Densimeters. Densimeters are very helpful devices that are frequently used in large scope and continuous grouting operations for measuring and controlling the densities of grout mixtures. These units are normally placed in-line and ahead of the surface recirculating system to provide a means for

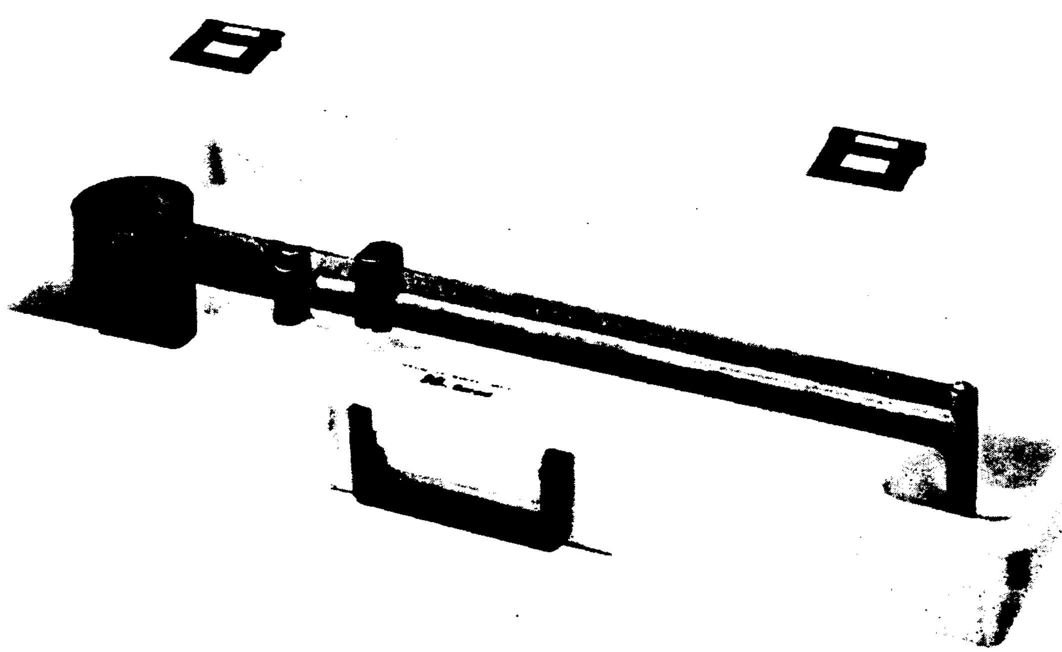


Figure 6-23. Mud balance

adjusting mixtures to designed densities. The devices operate on various principles; one such device is designed on the principle of a force-balanced U-tube; a second operates on a radioactive source. Both systems are equipped with remote continuous readouts.

h. Slump Cone. The consistency of very thick grouts may be determined by measuring the slump. The cone is a metal frustum that has a base of eight inches, a top of four inches, and a vertical height of 12 inches. The grout is placed in the cone in three equal layers, and each layer is rodded 25 times. The cone is removed vertically, and the slump of the grout is measured in inches from the top of the slump cone to the top of the grout. This method of test for slump is described in CRD-C 5.

i. Air Content Measurements. There are five methods that may be used for determining the air content of portland cement grout mixtures: gravimetric, high pressure, micrometric, pressure, and volumetric. These methods are described, respectively, in CRD-C 7, C 83, C 42, C 41, and C 8. Methods CRD-C 7, C 41, and C 8 are for freshly mixed grout and CRD-C 83-58 and C 42-83 are for hardened grout air contents, usually determined in the laboratory.

j. Time-of-Setting Apparatus. The initial and final sets of portland cement grouts are determined by the use of a mechanical device known as the Vicat apparatus. The apparatus is designed to measure with time the depth of penetration or no penetration of a blunt needle into a small cuplike receptacle containing a sample of the grout. This test can be conducted in the laboratory or field. The method of test is described in CRD-C 614.