Chapter 3
Grouting Equipment and Methods

3-1. Grout-Mixing Equipment

a. Mixing and blending tanks. Mixing and blending tanks (Figure 3-1) for chemical-grouting operations should be constructed of materials that are not reactive with the particular chemical grout or with individual component solutions. Tanks can be of aluminum, stainless steel, plastic, or plastic-coated as appropriate. Generally, the capacity of the tanks need not be large. The number and configuration of the tanks depend on the mixing and injection system used.

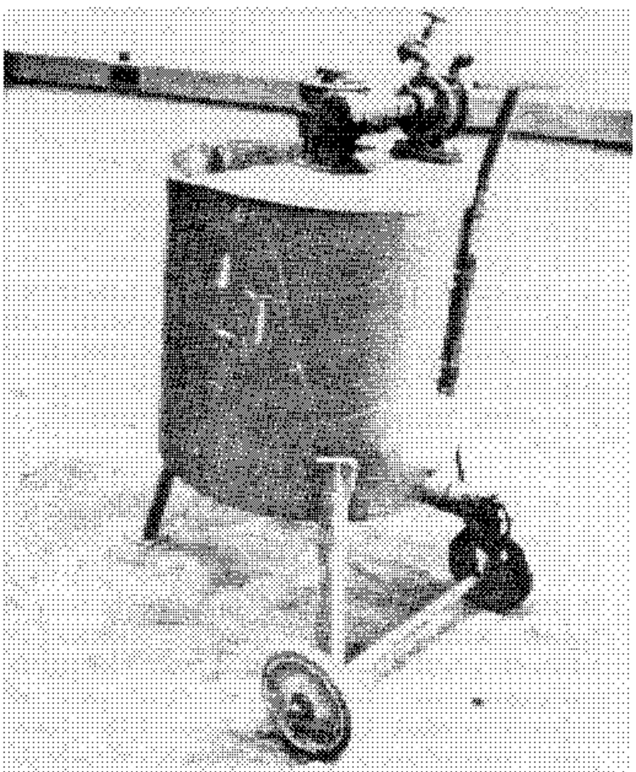

Figure 3-1. Mixing tank with mechanical mixing action

b. Batch system. The simplest grout-mixing system is the batch system commonly used in conventional portland-cement grouting. In the batch system, all of the components including the catalyst are mixed together at the same time, generally in a single tank. While this method allows for simplicity, the disadvantage is that pumping time is limited to the gel time; if the grout sets before pumping is completed, pumps, pipes, and flow channels may become clogged.

c. Two-tank system. A more advantageous method involves the use of two tanks with one tank containing the catalyst and the other tank containing all of the other components (Figure 3-2). In this method, material from both tanks are delivered into a common pump where the catalysis is initiated. The grout is then fed through a hose to the injection point. Pumping time is independent of gel time, which cannot be initiated until all components are mixed.

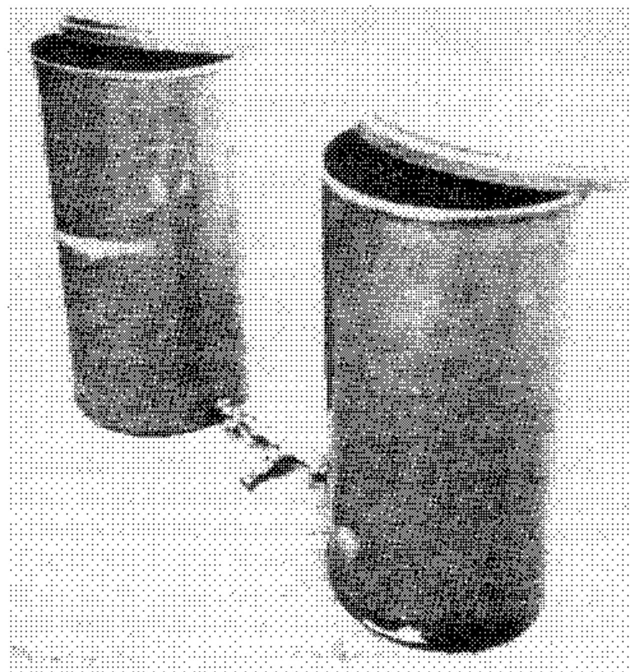

Figure 3-2. Dual mixing-tank arrangement

d. Equal-volume method. A variation of the two-tank procedure is the equal-volume method (Figure 3-3). In this method, identical pumps are attached to each tank and are operated from a common drive. The components in each tank are mixed at twice the design concentration. The equal-volume system offers the advantage that mistakes in setting metering pumps cannot occur and the concentration of the two grout components can be tailored by the manufacturer.

3-2. Pumping Equipment

Pumps that could be used satisfactorily for chemical grouting include positive-displacement and piston pumps.

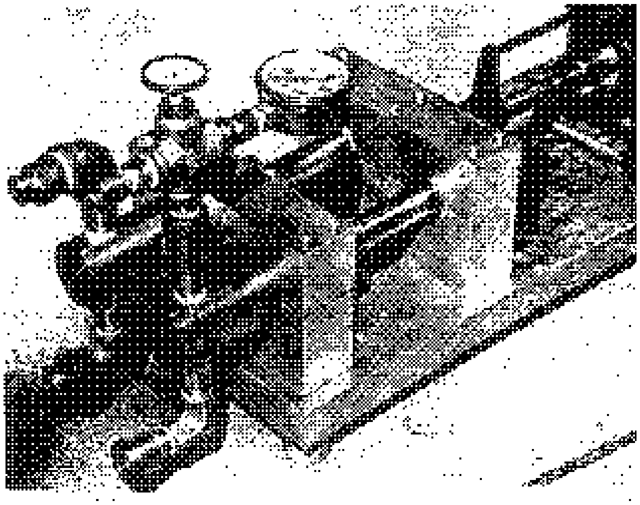

Figure 3-3. Equal-volume system

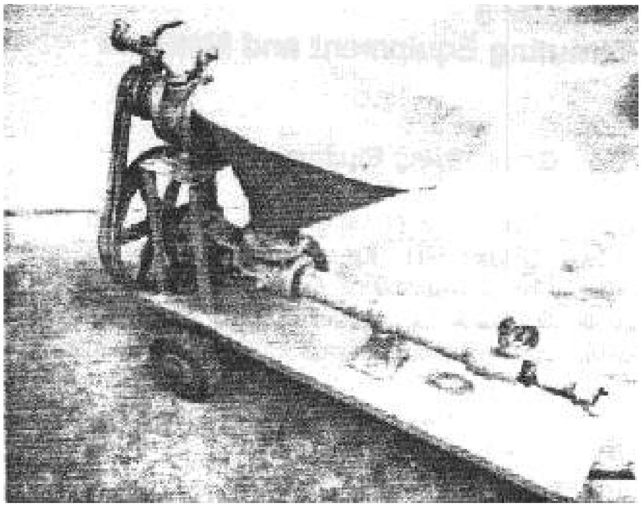

Figure 3-4. Positive-displacement screw pump

a. Positive-displacement pumps.

(1) Probably the most commonly used positive-displacement pump is the screw, in which a stainless-steel rotor turns within a flexible erosion- or chemical-resistant stator, forming voids that carry the material toward the discharge end of the pump at a constant rate (Figure 3-4).

(2) A pumping arrangement which can be adapted to chemical grout (and which can be operated by one man) consists of dual positive-displacement pumps mounted on a single frame. The pumps operate from a single power unit; however, the gear ratio of one pump can be varied, whereas the other pump has an unvarying gear ratio. This arrangement enables the operator to make a quick change in the proportion of reactant and the gel time by changing the gear ratio of the pump. The pump with the variable gear ratio is generally used to pump the ingredient of the grout that initiates reaction.

(3) Positive-displacement pumps produce less pulsation and thus are able to maintain a more uniform pressure, especially at low pressures, than piston pumps.

b. Piston pumps.

(1) In the event piston pumps are used, there are some advantages of specific varieties that should be recognized. Better volume and pressure controls in the lower ranges can be obtained using simplex pumps. The simplex pump (Figure 3-5) operates with the one piston activating four fluid valves and produces a flow that pulsates more than that of the duplex. The duplex operates with two pistons and eight fluid valves. Because of their smaller size, simplexes are more suitable for use in tunnels and shafts where space is a problem. Piston pumps typically can develop higher pressures than the positive-displacement pumps such as the progressive cavity pumps. Piston pumps may require more lubrication and attention to wear because of the metal-to-metal contact and close tolerances built into these units. Piston pumps developed for point and other high-viscosity liquids have been adapted for grouts. These designs are often useful because of their ease of disassembly for cleaning.

(2) There are no limitations as to type, size, or style of pump to be used in chemical-grouting operations; however, a number of features and characteristics should be considered in the selection of a pump. These include pumping rate; capacity or size; mass; maximum and minimum pressure requirements; limitations, mobility, maintenance, and availability of repair parts; and resistance to attack by the ingredients of the chemical grouts. Ease of assembly and disassembly during operation is very important. The chemical action in some chemical grouts may be accelerated or possibly retarded by the reaction of some of the grout solutions with parts of the pump. The possibility of a chemical reaction between the grout and metals and other materials in the pumps and its effect on the grout must be considered in choosing any particular pump. Because of differences in the metals used in piston pumps, it is prudent to consult the pump supplier when a grout job is being planned.

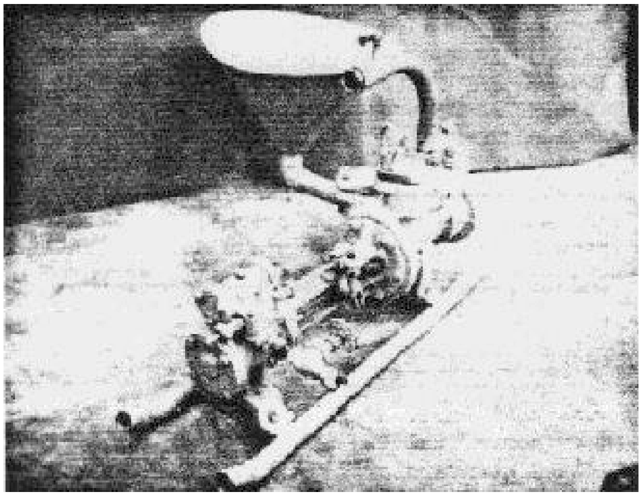

Figure 3-5. Simplex pump

Often valves and fittings are more easily corroded than the pistons and cylinders. Details in pump construction are important.

(3) Pressures up to 70 MPa and higher and pumping volumes ranging from a fraction of a 1iter to hundreds of liters per minute can be obtained with commercially available pumps. Pumps can be obtained that will operate on air, gasoline, or electricity. Reversible air motors are helpful for unclogging plugged lines, especially when fillers are used in the grout. Air motors are also durable, are simple to operate, and have a low silhouette. Air motors should be considered for use in shafts and tunnels from the standpoint of safety. Generally, they are smaller than gasoline or electric motors capable of an equal horsepower output.

c. Accessory equipment. For the most part, accessory equipment for chemical-grouting operations such as hoses, valves, fittings, piping, blowoff relief valves, headers, and standard drill rod can be the same as that for portland-cement-grouting operations. Possible exceptions include connections between pumps, mixing and blending tanks, and injection lines or pipes. These connections should be of the quick-release type because of the rapid gel time that can be obtained with some chemical grouts. In some cases, it can become necessary to disconnect and disassemble equipment for cleaning. The material of which the pump and accessory equipment is constructed may have an effect on gel time. For this reason, each grout should be checked against the entire injection system prior to use.

3-3. Pumping Systems

Pumping systems that can be used to satisfactorily inject chemical grout are listed below:

a. Variable-volume pump system or proportioning system.

(1) This system (Figure 3-6) is used to vary gel times, pumping rates, and pumping pressures and allows one man to control all of these factors rapidly by mechanical means. The need for solution composition or concentration adjustment is eliminated during an application.

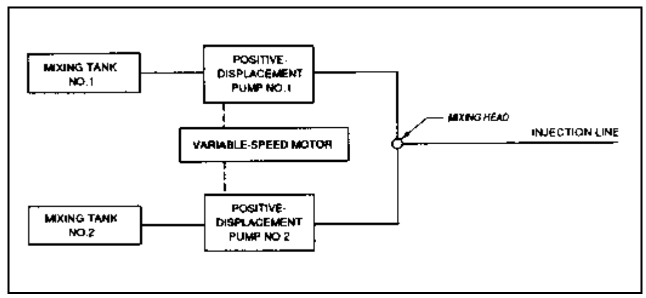

Figure 3-6. Variable-volume pump system or proportioning system

(2) By the use of two variable-volume motors (Figure 3-7), the gel time can be changed without appreciably changing the basic chemical concentration of the final mixture, and total volume pumped can be changed without changing the gel time. It may be desirable to add a third pump, or a third pump and tank, to a metering system. Figure 3-7 Shows an early version of this type of unit.

b. Two-tank gravity-feed system.

(1) This system (Figure 3-8) normally permits only one predetermined gel time. Any attempt to change gel time requires that carefully weighed amounts of catalysts and accelerators are added to the proper tanks.

(2) The mixing tanks should be of identical size and volume, and the surface of the solutions should be at the same height in the respective tanks. Equal volumes of solutions are drawn from the two mixing tanks into the

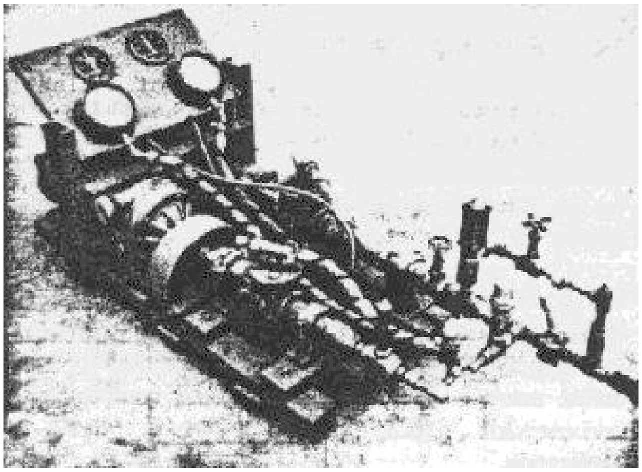

Figure 3-7. Variable-volume pump arrangement

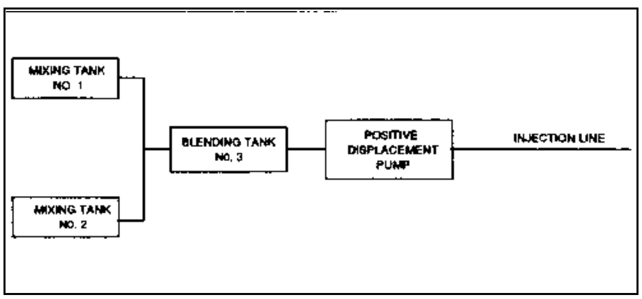

Figure 3-8. Two-tank gravity-feed system

blending tank, where they are mixed and fed to the pump. This system can be modified by using two pumps of equal capacity driven by the same motor (Figure 3-9).

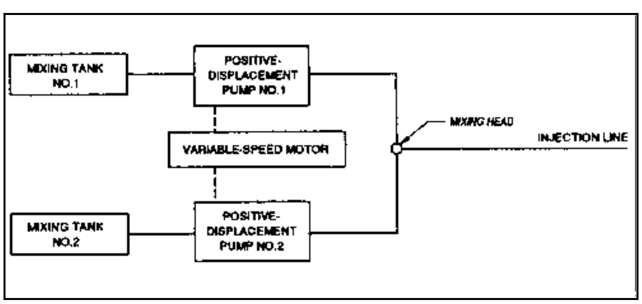

Figure 3-9. Two-tank gravity-feed system (variation)

This will eliminate the use of a blending tank. Short gel times are possible with this system; however, a disadvantage of the system is that experience is needed to obtain accurate changes in gel time while dispensing from premixed solutions.

c. Batch system. In this system, all materials are mixed in one tank (Figure 3-10). This system has three basic limitations:

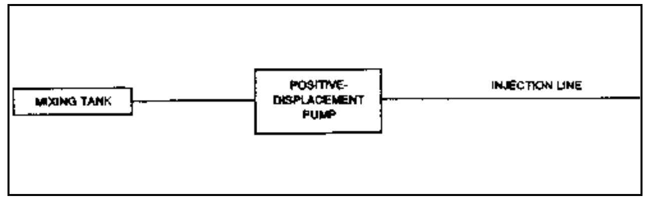

Figure 3-10. Batch system

(1) The entire batch must be placed during the established gel time; however, because pumping rates often decrease as injection continues, this is not always possible, and the danger of gelation in the equipment is always present.

(2) Difficulty is experienced in varying the gel times during pumping.

(3) Very short gel times cannot be used unless only small batches are used.

d. Gravity-feed system. In some instances, it may be desirable to pump or pour the grout to its desired location and allow the grout to seek its own level. The most economical means of doing this would be to discharge directly from mixing units; however, a pump is required if the area to be grouted is some distance from the mixing setup and the mixing setup cannot be moved.

3-4. Injection Methods

a. General. The ultimate goal of grouting is to place a specified amount of grout at some predetermined location. Grout placement downhole can be accomplished by several means. The simplest grouting situation is to pump or pour the grout directly onto surface or into an open hole or fracture. The simplest downhole method using pressure for placement involves the use of one packer to prevent the grout from coming back up the hole while it is being pumped.

b. Packers. Selective downhole grouting, for use in a competent hole, can be accomplished by placing two packers, one above and one below the area to be treated, and then injecting the grout. Another selective grout placement method is by use of "tubes à manchettes." This method entails using a tube with a smooth interior that is perforated at intervals and sealed into the grout hole. The perforations are covered by rubber sleeves, "manchettes," which act as one-way valves. Selective grout placement is obtained by a double-packer arrangement that straddles the perforations.

c. Other methods. Other methods include driving a slotted or perforated pipe into a formation; grouting, or driving, an open-end pipe to a desired elevation; and then grouting. The pipe can be kept open by temporarily plugging the open end with a rivet or bolt during driving. When the desired elevation is reached, the pipe is raised several inches to allow the rivet or bolt to work free from the open end when pressure is applied by grouting. The pipe may also be unplugged by placing a smaller rod inside the injection pipe to the total hole depth and slightly beyond. The rod is withdrawn from the pipe, and grout is injected. Another method, which can be used with the two-solution process, is to drive a perforated pipe a certain distance and inject the grout solution. This process is continued until the total depth is reached; then, grout solutions of the remaining chemicals are injected to complete the grout hardening reactions as the pipe is extracted.