APPENDIX III

NOTES FOR THE INSPECTOR

1. STICK GAGES. A stick gage calibrated in cubic feet to measure the volume of grout in an upright cylindrical tank can be made, if none is available when the equipment is brought to the jobsite. Given: a tank 2-1/2 ft high and 3 ft in diameter. The volume of this tank is 17.7 cu ft ($\pi r^2 \times$ height). The height of the tank, 30 in., divided by 17.7 gives the depth of a cubic foot of grout in the tank in inches. Each cubic foot of grout fills approximately 1.7 in. of the tank. The stick gage may be made from a piece of 1- by 2-in. lumber. For ease in reading, the gage should be marked so that the correct reading for the amount of grout in the tank appears at the rim of the tank when the tip of the stick touches the grout. If there was 9.0 cu ft of grout in the tank described in the example, the mark for 9.0 cu ft would be 14.7 in. above the bottom of the gage. The gage may also be prepared by metering the water into the sump tank by the cubic foot and marking the gage appropriately for each level. If the tank has an outside well for the pump suction or a bulky agitator, this method of calibration is the most accurate.

2. THINNING OR THICKENING CEMENT GROUT.

a. The quickest way to change a given quantity of cement grout from one mix to another is by using conversion tables or charts. However, the inspector should be able to make the necessary computations without hesitation, if such tables or charts are not available.

b. The first step for controlled thinning or thickening of a given quantity of grout is to determine the amount of cement it contains. This is done by dividing the cubic feet of grout by the number of cubic feet of grout obtained from a one-sack batch of that grout, keeping in mind that a sack of cement in water has a volume of 0.5 cu ft. Examples: Find the number of sacks of cement in 12.6 cu ft of 4:1 grout, 1.5:1 grout, and 0.75:1 grout. In the order listed, 12.6 is divided by 4.5, by 2.0, and by 1.25, and the sacks of cement in 12.6 cu ft of grout for the three mixes in the same order are 2.8, 6.3, and 40.4.

c. To thin a grout add cubic feet of water equal in number to the number of sacks of cement in the grout to be thinned multiplied by the difference between the figures representing the water in the water-cement ratios for the grout on hand and the mix desired. Example: Find the cubic feet of water necessary to thin 7.2 cu ft of 1:1 grout to 3:1 grout. The number of sacks of cement in 7.2 cu ft of 1:1 grout is 7.2 ÷ 1.5 or 4.8. The difference between the figures representing the water in the water-cement ratios of the two mixes (3:1 and 1:1) is two. Two times 4.8 is 9.6. Therefore, 9.6 cu ft of water must be added to 7.2 cu ft of 1:1 grout to have 3:1 grout.

d. To thicken a grout, the volume of the cement solids, in cubic feet (one~half the number of sacks of cement in the grout) is subtracted from the cubic feet of grout to obtain the volume of water in the grout. Enough cement is added to have the desired water-cement ratio with this volume of water. It is preferable to add only whole sacks of cement.

Examples:

To thicken 9.0 cu ft of 4:1 grout to 1:1 grout
Mix contains 8.0 cu ft water and 2.0 sacks cement
Need to have 8.0 cu ft water and 8.0 sacks cement for 1:1 ratio
Add 6.0 sacks cement

To thicken 5.6 cu ft of 3:1 grout to 1:1 grout
Mix contains 4.8 cu ft water and 1.6 sacks cement
Need to have 4.8 cu ft water and 4.8 sacks cement for 1:1 ratio
Could add 3.2 sacks cement
But to avoid fractions of sacks of cement, add 0.8 cu ft water and 4.0 sacks cement

To thicken 5.4 cu ft of 4:1 grout to 0.75:1 grout
Mix contains 4.8 cu ft water and 1.2 sacks cement
Need to have 4.8 cu ft water and 6.4 sacks cement for 0.75:1 ratio
Could add 5.2 sacks cement
But to avoid fractions of sacks of cement, add 0.6 cu ft water and 6.0 sacks cement

e. Most chemical grouts are liquid grouts consisting of mixtures of liquids, and the consistency is usually not changed. The application and penetration of these grouts depend upon the gel or setting time, which can be regulated as required. As previously noted, chemical grouts vary widely in their physical properties and should be used under close consultation with or under the direction of personnel trained in the use of the particular chemicals being used.

3. PRESSURE OF GROUT COLUMN. As in changing grout from one mix to another, the quickest way to determine the pressure exerted by a column of grout is by using a chart. In case a chart similar to figure 4 (main text) is not at hand, the pressure in pounds per square inch exerted by a 1-ft column of any grout can be found by dividing the weight of a cubic foot of the grout by 144 (the number of square inches in a square foot). For portland-cement grout with no fillers or admixtures, it is necessary to know that a cubic foot of water weighs 62.4 lb and a sack of cement weighs 94 lb. Thus, for 2:1 grout a one-sack batch of grout contains 124.8 lb of water and 94 lb of cement for a total weight of 218.8 lb. Since a one-sack batch of 2:1 grout makes 2.5 cu ft, 218.8 lb must be divided by 2.5 to obtain the weight of 1 cu ft of the grout. Then 1 cu ft of 2:1 grout weighs 87.5 lb and exerts a pressure

of 0.61 psi (87.5 ÷ 144). In computing cubic-foot weights of cement grouts containing one or more additives, the weights of all additives in a single batch of the grout and the volume of the batch must be known. The most certain way to determine the volume of a batch containing several ingredients is by gaging the sump tank after a batch has been discharged.

4. CHECKING LOW-PRESSURE GAGES. Low-pressure gages should be checked before each use when that use is to register pressures of less than 5 psi. It is necessary that gages used for the first stage of grouting in stage grouting and the topmost stop in stop grouting be sensitive to pressures of 2 or 3 psi. The needle of a gage whose dial is marked to show pressures less than 5 psi can be moved from the peg by lung pressure. This is a quick check of gage sensitivity. Precise tests can be made as follows: A transparent plastic tube several feet long that can be attached to a gage and filled with water provides a means of an accurate check of low pressures. Each vertical foot of water in the tube above the level of the gage exerts a pressure of 0.43 psi. Thus, if the tube is held so that the water level is 5 ft above the gage, the gage should read slightly more than 2 psi. A U-tube of mercury can also be used to check low-pressure gages. One end of the open U-tube is connected to the gage by a tube containing a valve for the injection. of air. Air pumped into the connecting tube causes the mercury to stand at different levels in each arm of the U-tube. Each 2 in. of differential between the mercury-column levels represents a pressure of approximately 1 psi. A differential of 10.17 in. of mercury should register on the gage as 5 psi.

5. LIFTING CLUES. When grout is injected at pressures greater than the rock can withstand, the rock is lifted or heaved. Surface evidences of lifting other than grout leaks are sometimes readily discernible, and where structures are involved damage may be substantial. When structures are present grouting should be accomplished without any lifting, and if lifting takes place grouting should be stopped immediately. It is important, therefore, to recognize signs or clues that lifting may be occurring. The inspector should watch for changes in the behavior of the hole each time pressure is raised. After the initial rupture of the rock, it may be noted that the pump labors less, the gage pressure may drop a few pounds, and the injection rate may increase. All these signs may occur simultaneously. If lifting takes place at a depth of several feet and is caused by cleaving of bedding planes, the hole may have a relatively high back pressure. This is a result of the rock pushing back on the grout. It can be checked by closing the valve between the grout line and the hole. The gage will then reflect the pressure of the grout in the hole. If it is nearly the same as the injection pressure and does not fall at a readily visible rate, it should suggest the possibility of lifting. If it falls rapidly it is pump pressure that is dissipating. Unfortunately, these signs and clues are not infallible. Some of the clues can be produced by grouting at least one other subsurface condition. During the grouting of solution channels or cavities compartmented by muck, a hole may show most of the indications of lifting without having any lifting involved. If grout breaks

from one compartment to another, it will quickly enlarge its channel in the soft filling, causing a pressure drop and an injection rate increase.

6. GROUTING IN FLOWING WATER. A channel carrying flowing water encountered during grouting operations should be closed by excavation and backfill if feasible. If at depth, this can sometimes be accomplished through large-diameter drill holes. Portland- cement grout is not usually effective at sealing voids filled with rapidly moving water. If the movement of water is caused by dewatering or other pumping activities, it is likely that such operations will have to be suspended before grouting can be successful. In the case of fairly large underground channels filled with naturally flowing water discovered by drilling for grouting, the flow must be essentially stopped before attempting to fill the channels with cement grout. As much information as possible on the size and shape of the channel should be obtained. The borehole television camera can be used to augment information from drilling and sounding. It may be possible to construct a barrier across the channel by drilling and backfilling cased 6 -in. or larger holes, one at a time, spaced so that intermediate holes will overlap the primary holes. Since the casings would be left in place, they should be something other than steel so that they can be readily cut with a drill. A barrier may be created by introducing an inflatable bag attached to an injection pipe into the water-filled channel through a 6-in. hole. Grout or mortar is then pumped into the bag through the pipe to inflate it against the walls of the cavity. After the flow of water is stopped, grout can be pumped into the channel upstream from the barrier until it is filled sufficiently to satisfy the requirements of the project.

7. CLEANING GROUT HOLES. The injection of grout is only one of the subsurface operations that can result in lifting and damage to rock. Lifting can be done by water during drilling operations, and it can be done by compressed air used to blow sludge and cuttings out of grout holes. The best way to clean grout holes after drilling is completed is by washing them through the drill rods with the drill raised just above the bottom of the hole. Washing should be continued until the water returning to the surface is clear. If the hole has been stopped because of water loss, the washing should be continued for approximately 5 min unless it is certain that the drill water was lost into a large cavity. No washing is needed in that event. If air is used to clean the hole, the injection pipe should not have a diameter greater than half the diameter of the hole. If the annular space around the pipe is small, it may become clogged with debris ejected by the compressed air causing full compressor pressure to be exerted against the walls of the hole. Lifting is almost certain to take place if the compressor pressure greatly exceeds the load of overlying rock and soil. This risk also exists for percussion drilling when air is used to remove the cuttings.

8. SAFETY. Some of the dangers that attend pressure grouting with cement grout are briefly described here. An important thing to keep in mind is the

"pressure" part of pressure grouting. Cement is composed of jagged rock-like particles of matter that are very abrasive without pressure. Under pressure, cement grout can damage the skin or cause severe injury to the eyes. It is important that grout pipes and hoses be in good condition and all connections be properly made. If a grout line breaks while grouting at high pressure, grout can be ejected many feet with great force. If necessary for personnel to be exposed to cement dust, goggles should be worn to protect the eyes. If the weather is windy and dust conditions are severe, exposed portions of the skin should also be protected to avoid cement "burn." Waste grout should be discarded away from the work area as a good housekeeping practice and to eliminate splashing hazards.