4725.3050 GROUTING.

Subpart 1. ***Grouting materials.*** *The following grout materials as listed in part 4725.0100 are approved for filling an annular space between unconsolidated material or bedrock and a casing:*

"**Grout**" means a material used to fill the annular space around a casing, or to seal a well or boring. The purposes of grout are to: protect a well, boring, and aquifer from contamination; prevent interaquifer flow; prevent uncontrolled flowing wells or borings; preserve different aquifer chemistries; protect casing from corrosion; and prevent casing failure from deformation.

Approved grouts are neat-cement grout, cement-sand grout, and bentonite grout.

Treatment chemicals used to condition water for mixing grouts must meet the standards for drilling additives, ANSI/NSF Standard 60-2003e.

A. neat-cement grout, except that rapid setting cement must not be used with plastic casing;

"**Neat-cement grout**" means a mixture in the proportion of 94 pounds of Portland cement and not more than 6 gallons of water. Bentonite up to 5 percent by weight of cement (4.7 pounds of bentonite per 94 pounds of Portland cement) may be used to reduce shrinkage. Additives to reduce permeability or control setting time must meet ASTM Standard C494/C494M-04. Additional information is found under the definition of "neat cement" in Minnesota Rules, part 4725.0100.

NEAT-CEMENT GROUT FORMULA

- 94 pounds of Portland cement; and
- Not more than 6 gallons of water.
- Up to 5 percent of bentonite (4.7 pounds per 94 pounds of Portland cement) may be added.

Some manufacturers are supplying Portland cement in 42 kilogram (92.6 pound bags). The formula for neat-cement grout remains: not more than 6 gallons of water to 94 pounds of Portland cement. The formula for the 42 kilogram bags is:

- Not more than 5 gallons and 117 fluid ounces of water (11 ounces less than a gallon), and
- 42 kilograms (92.6 pounds) of Portland cement.
- Not more than 5 percent cement bentonite (4.6 pounds) may be added.

Neat-cement grout made with 5.4 gallons of water instead of 6 gallons will result in a grout that has less shrinkage and is less permeable.

"**Rapid setting cement**" means a Type III Portland cement as designated in ASTM Standard C150-04a, or any Portland cement containing an accelerated admixture. "Rapid-setting cement" must be mixed in the proportion of 94 pounds of Portland cement and not more than 6 gallons of water. Additional information is found under the definition of "rapid-setting cement" in Minnesota Rules, part 4725.0100

One cubic yard of neat-cement grout contains 1993 pounds of Portland cement and not more than 127 gallons of water.

The following is a table of cement/water ratios and the resultant minimum density of the mixture when weighed with a mud scale:

If bentonite is added to neat cement, additional water may be added according to the following table:

NEAT-CEMENT AND BENTONITE GROUT WATER RATIOS AND DENSITIES

MIXTURE	WATER RATIO (gal./bag of cement)	MINIMUM DENSITY (lbs./gal.)
Neat cement	6.0	15.0
Neat cement & 1% Bentonite	6.0	15.0
Neat cement & 2% Bentonite	6.5	14.7
Neat cement & 3% Bentonite	7.2	14.4
Neat cement & 4% Bentonite	7.8	14.1
Neat cement & 5% Bentonite	8.5	13.8

B. cement-sand grout; and

"**Cement-sand grout**" means a mixture of Portland cement, sand, and water in the proportion of 94 pounds of Portland cement, not more than 1.0 cubic foot of dry sand, and not more than 6 gallons of water. Admixtures to reduce permeability or control setting time must meet ASTM Standard C494/494M-04.

CEMENT-SAND GROUT FORMULA

- 94 pounds of Portland cement;
- Not more than 6 gallons of water.
- 1.0 cubic feet of sand (approximately 105 pounds)

ONE CUBIC YARD OF CEMENT-SAND GROUT

	BY VOLUME	BY WEIGHT (lbs.)
Portland Cement	13.5 (94 lbs.) bags	1269
Washed Sand	13.5 cubic feet	1418
Water	81 gallons	676
Yield	1 cubic yard	3363 lbs.

C. bentonite grout when used in unconsolidated materials.

Bentonite grout may only be used in unconsolidated formations, not in rock. Unconsolidated materials includes glacial drift (glacial till and glacial outwash), clay, silt, sand, gravel, and cobbles. Cretaceous age formations, found mainly in southwestern Minnesota, are also considered as unconsolidated materials for the purposes of these rules.

"**Bentonite grout**" means:

- Water and a minimum of 15 percent by weight of bentonite, with no additives to promote temporary viscosity.
- An additional 15 percent by weight of either washed sand, cuttings taken from the bore hole, or granular bentonite may be added.

Bentonite used for grout must either be natural-mined montmorillonite clay without additives or be a bentonite meeting ANSI/NSF Standard 60. The bentonite must be designed by the manufacturer as a grout and must be mixed to manufacturer's specifications and the minimum standards of these rules. A grout designed by the manufacturer to be 10 percent bentonite solids may not be used since it does not meet the 15 percent minimum. A 30 percent solids bentonite grout may not be diluted to a 15 percent solids mixture.

BENTONITE GROUT FORMULA

- 50 pounds of bentonite; and
- 34 gallons of water.
- An additional 50 pounds of washed sand, cuttings, or granular bentonite may be added.

Bentonite is commonly sold in 50 pound sacks.

Thirty-four gallons of water weighs approximately 283 pounds.

Fifty pounds of washed sand or cuttings are approximately equal to 1/2 cubic foot, 3.2 gallons, or 2/3 of a 5 gallon pail.

Higher percentages of bentonite may be used and are encouraged.

High-yield drilling fluid bentonites that are not designed by the manufacturer for use as grout are not allowed for use as grout. High yield drilling fluid bentonites, particularly when they are mixed using with a high shear pump or mixing system, may be difficult or impossible to mix to the required bentonite content. Bentonite grouts tend to be either coarser-grind bentonites, lower-yielding bentonites, or bentonites containing additives to slow wetting and expansion.

Contractors have reported success mixing up a slurry of 10 percent bentonite and water, and then paddle mixing in 5 or more percent of granular bentonite to the point that the granular bentonite is dispersed but not completely mixed. This "Ohio" mixture has the consistency of cottage cheese. Since the bentonite has not fully hydrated, working times are typically less than 30 minutes until the mixture becomes too thick to pump.

Contractors have also reported success by adding granular bentonite into the mud box near the mud pump suction intake and drawing into the suction hose a mixture of bentonite grout and granular bentonite. This mixture is then immediately pumped into the well or boring through the drill rods. Tests on the resultant grout have indicated that this practice can result in a legal grout. However, this method has potential problems including plugging of the suction hose, inconsistent mixtures, and dilution. If this method is used, caution must be taken to assure that the resultant grout meets the minimum specification, is verifiable, and is not diluted.

The approximate density (weight) of 15 percent solids bentonite grout without the addition of sand or cuttings is 9.1 lbs./gallon.

Bentonite grout (or other grout) mixtures can be verified to meet the rules by the use of a mud balance. A specified quantity of the grout is weighed, which results in a bulk density. Approximate densities are as follows:

Fluid	Density
Water	- 8.3 lbs./gal.
Drilling mud (6 percent bentonite and water)	- 8.6 lbs./gal.
15 percent bentonite and water	- 9.1 lbs./gal.
30 percent bentonite and water	- 9.9 lbs./gal.

Subp. 2. ***Grouting requirements and methods.*** *The following general requirements apply to the grouting of wells and borings.*

A. Grouting must start immediately on completion of drilling and be completed before placing a well or boring in service.

If the drilling machine is removed from the well or boring and no more hole will be advanced, drilling is completed and grouting must begin immediately.

B. The annular space to be grouted must be protected from collapse and the introduction of materials other than grout.

Collapse must be prevented, and also the introduction of materials, including cuttings, into any annular space that is required to be grouted.

C. A steel plate, or a nontoxic metal, rubber, or plastic grout basket may be attached to the casing within ten feet of the bottom. Wood, burlap, or other organic material must not be used.

These are sometimes referred to as “formation packers” or “shale traps.”

The grout basket must be within the aquifer and must not be within an overlying aquifer or confining layer. If a well is cased with plastic casing only 5 feet into bedrock, a grout basket may not be used.

D. Grout must be pumped under pressure into the annular space from the bottom up to the established ground surface or base of the pitless adapter or unit. Grout must be pumped through the casing or through a tremie pipe placed within ten feet of the bottom of the space to be grouted. The tremie pipe may be retracted as grouting proceeds; however, the bottom of the tremie pipe must remain submerged in grout while grouting.

Pumping of grout in the annular space may be accomplished by using any type of pumping pressure including mechanical, air, or human powered pumps. Typical pumps used include mechanical pumps such as piston pumps, drill rig mud pumps, Moyno-type rotor pumps, air pressure pumps such as a Wilden pump, or various hand pumps.

A tremie pipe, also referred to as a grout pipe, is a small diameter pipe, hose or tube used to convey grout. The pipe is commonly steel or plastic, but may be a flexible hose, and even copper has been used. Flexible pipe, and at times rigid pipe, can be loosely fastened to, or installed with the casing. The tremie pipe is usually installed between the casing and hole, but in some methods it is installed inside the casing, and may be connected to (as a "stinger") a float or grout shoe attached to the bottom of the casing.

The **tremie pipe must be set to within 10 feet** of the bottom of the annular space to be grouted.

The casing may also be used to install the grout, through use of one or more plugs (Halliburton method), Bradenhead, or casing fitting method.

In addition to grouting through a tremie pipe, grouting may also be completed by use of the displacement method. The displacement method allows placement of grout in the bore hole and then setting the casing with a bottom plug into the grout-filled bore hole.

The appendix contains tables of bore hole and annular volumes.

E. Grout flowing out of the annular space at the surface must meet the minimum specifications and densities in this chapter before grouting may stop.

The grout must be pumped until the **entire annular space** to be grouted is filled with grout material meeting the minimum specifications. The first grout which appears at the surface is often thinned by formation water. The density of the grout should be measured before it is pumped and then pumped until the same density appears at the surface.

F. Dumping of grout is not allowed except when the depth of the space to be grouted is less than ten feet.

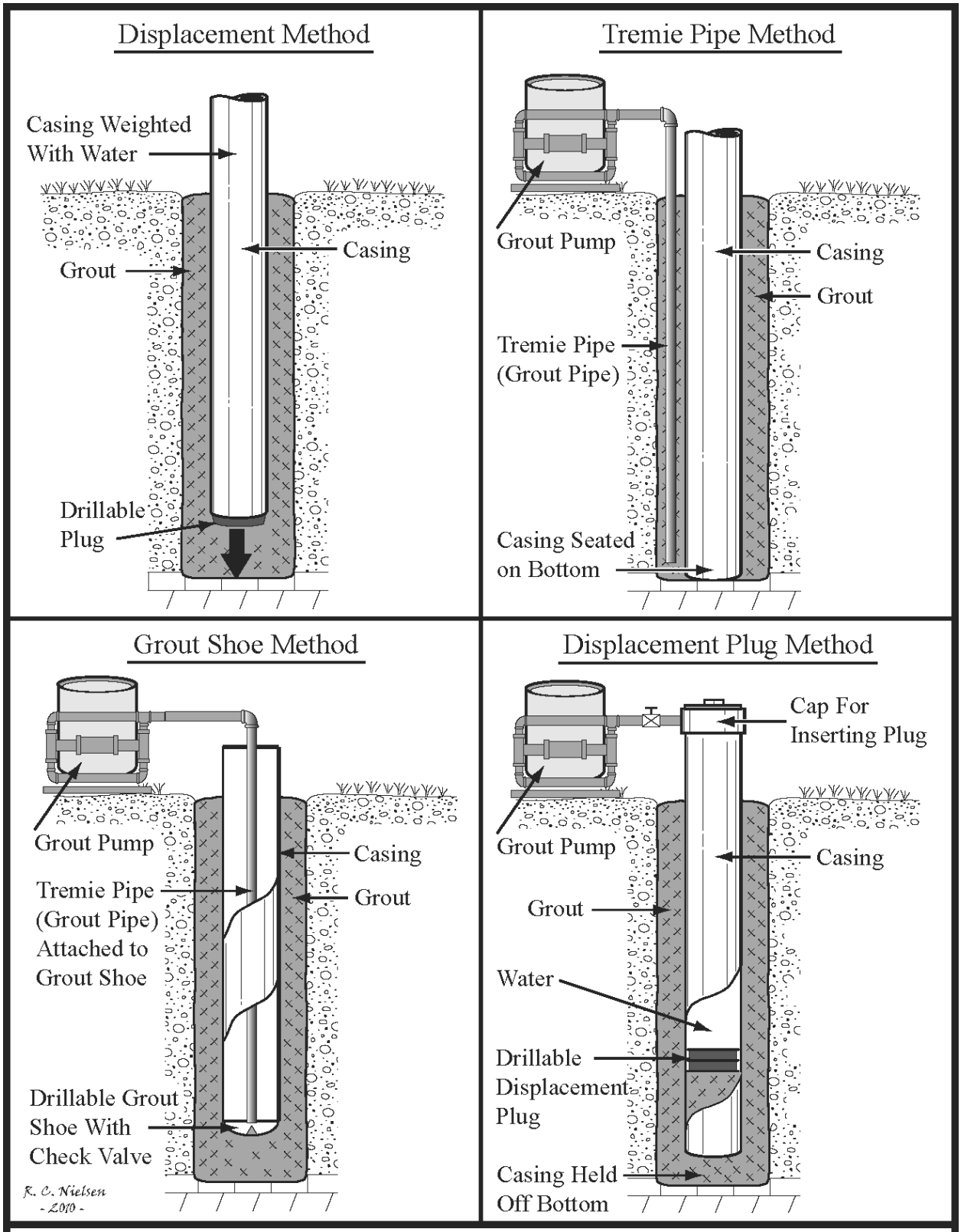


Figure 13. Grouting Methods

Subp. 2a. ***Wait on cement.*** *Neat-cement grout or cement-sand grout must be allowed to set a minimum of 24 hours. Rapid setting cement must be allowed to set a minimum of 12 hours. Drilling, development, or pump operation is prohibited during the time the cement is setting.*

The prohibition of pump operation during the time the cement is setting does not prohibit the pumping of a flowing well during the grouting process in order to grout.

Subp. 3. ***Grouting depth requirement.*** *When constructing a well or boring with a method such as mud or air rotary, auger, or jetting that creates an open annular space or drills a bore hole larger than the casing or casing couplings outside diameter, a grouting material specified in subpart 1 and the grouting methods specified in subpart 2 must be used to fill the annular space between the casing and the bore hole.*

The rules require the **top 50 feet** to be grouted in a well or boring that is constructed with a method which creates an annular space. An annular space is created when (1) a well or boring is drilled with an auger, bucket auger, rotary, jetting, hollow rod, or similar method and the casing is installed after the hole is drilled; or (2) a method is used that has cuttings return up the annular space between a casing or drill stem and the bore hole; or (3) a temporary outer casing is installed around a permanent inner casing and the other casing is removed. The annular space must be grouted through the casing or a tremie pipe. Bentonite grout may be used in unconsolidated formations. Neat-cement or cement-sand grout may be used in any formation. If the hole collapses, it will be necessary to clean the annulus by driving an outer casing, overdrilling, or removing the casing and enlarging the hole. The practice of jetting in a single tremie pipe and grouting the jetted hole is not allowed.

A. If the depth of the casing is 50 feet or less, the grout must extend from the bottom of the casing, top of the bentonite seal as specified in subpart 8, or top of the gravel pack, to the established ground surface, or the base of the pitless adapter or unit.

The 50-foot distance is measured from the land surface.

B. If the depth of the casing is more than 50 feet, the annular space below 50 feet must be filled with grout, except that the portion of the well or boring in an unconsolidated formation below 50 feet in depth may be filled with cuttings. The cuttings must be placed without bridging, and must be the unconsolidated materials taken from the bore hole. The annular space above 50 feet must be filled from:

(1) a depth of at least 50 feet to the established ground surface or the base of a pitless adapter or unit; or

(2) the top of the bentonite seal as specified in subpart 8 or the top of the gravel pack to the established ground surface or the base of a pitless adapter or unit.

This allows the use of **cuttings** taken from the bore hole to fill the annular space in unconsolidated materials below 50 feet. This does not allow the use of any other fill material such as sand, bentonite chips, or soil. If cuttings are not used to fill the annular space below 50 feet, or if the cuttings do not entirely fill the annular space from the top of the gravel pack to a depth of 50 feet, the annular space from the top of the gravel pack or above the cuttings must be grouted through a tremie pipe to the established ground surface or the base of a pitless adapter or unit. Cuttings must be emplaced so that bridging and bore hole collapse do not occur.

The MDH recommends that grout be used instead of cuttings. Settling of improperly placed cuttings can cause excessive settling of the grout placed above the cuttings and compromise the seal in the annular space of the well, the water quality in the aquifer, and the quality of a well owner's drinking water.

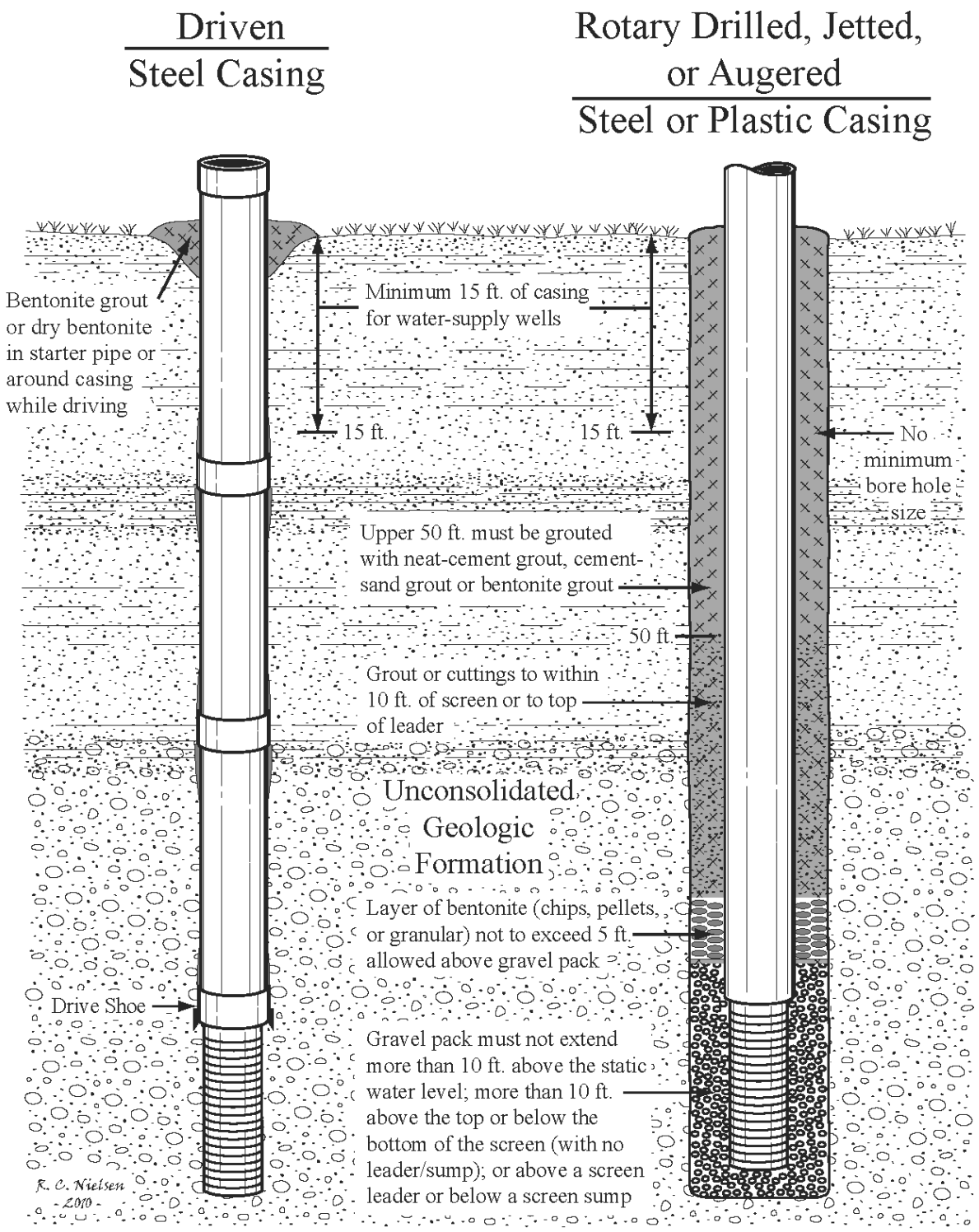
The **tremie pipe** must be installed to within 10 feet of the top of the cuttings or gravel pack.

This applies to any well or boring where an annular space is created between the casing and bore hole, which includes outer casings (or surface casings) on multiple-cased wells or borings and surface casing in unconsolidated materials if the casing is, intentionally or unintentionally, left in place.

It is recommended that wells or borings in which "**temporary**" **outer casing** is installed in unconsolidated materials be grouted around the outer casing in accordance with subpart 3 of this part with bentonite prior to drilling the bore hole below the surface casing. This will allow the contractor to retrieve the casing and will not result in a violation if the outer casing cannot be removed. If the outer casing is not grouted in place, at a minimum, the contractor should not allow cuttings to wash down the annular space between the outside of the surface casing and bore hole because the cuttings may inhibit the removal of the surface casing.

The rules require a casing to be surrounded with grout, or cuttings in unconsolidated formations below 50 feet, or undisturbed formation in the case of driven casings. The practice of installing **multiple casings in a single bore hole** with gravel pack surrounding screened intervals set at different depths does not meet the standards of the rules. Each casing must be in a separate bore hole.

Additional grouting requirements exist for confining layers, rock, flowing wells or borings, dewatering wells, monitoring wells, vertical heat exchangers, and elevator borings.



* Note: See additional requirements or exemptions for confining layers, rock, limestone or dolomite, flowing wells and borings, dewatering wells, monitoring wells, vertical heat exchangers, and elevator borings.

Figure 14. Wells and Borings in Unconsolidated Formations*

Subp. 4. ***Grouting between casings.*** *The annular space between an inner and outer casing, must be filled with neat-cement grout or cement-sand grout according to subpart 2.*

Minnesota Rules, part 4725.2250, subpart 8 requires that the inside diameter of an outer casing must be at least **3.0 inches larger** than the outside diameter of the inner casing, couplings or bell end, whichever is larger, for inner casings with 12 inches inside diameter and smaller. The inside diameter of an outer casing must be at least **3.5 inches larger** than the outside diameter of the inner casing, couplings or bell end, whichever is larger, for inner casings larger than 12 inches inside diameter and greater than 100 feet deep. The annular space between an inner casing and an outer casing must be grouted for its entire length by pumping neat-cement or cement-sand grout through a tremie pipe or through the casing as specified in Minnesota Rules, part 4725.3050. The inner casing must extend above the established ground surface at least 12 inches.

Neat-cement grout or cement-sand grout are the only types of grouts allowed between two casings.

A table of annular space volumes is included in the appendix.

Subp. 5. ***Driving casing.*** *When driving casing in an unconsolidated formation, a cone-shaped depression or temporary outer casing filled with bentonite grout, bentonite powder, or granular bentonite, must be maintained around the outside of the casing. The bottom of driven casing, except for a drive point, temporary casing, or outer casing that has a neat-cement or cement-sand grouted inner casing must be equipped with a drive shoe in accordance with part 4725.2250, subpart 15. Casing may only be driven through;*

A. an unconsolidated formation;

B. sandstone bedrock including the St. Peter, Jordan, Franconia, Ironton-Galesville, Mt. Simon, Hinckley, or Fond du Lac formations;

C. ten feet or less of limestone or dolomite bedrock including the Cedar Valley through Galena groups, the Platteville formation, or the Prairie du Chien group;

D. ten feet or less of the St. Lawrence or Eau Claire confining layers; and

E. two feet or less of the Decorah or Glenwood confining layers.

The cone-shaped depression or annular space between the temporary outer casing and the casing being driven must be kept filled with bentonite grout, bentonite powder, or granular bentonite, at all times during the advancement of the casing. Typically, 1 pound of dry granular bentonite is needed per foot of casing if driving 2-inch casing, and 2-1/2 pounds of dry granular bentonite is needed per foot of casing if driving 4-inch casing (one sack of bentonite for each 20-foot-casing section).

When using dry powdered or granular bentonite, care must be taken to keep the bentonite dry in order to facilitate the movement of the bentonite down around the casing as the casing is driven. The use of a temporary outer casing appears to be a more effective method than a cone-shaped depression at delivering the bentonite around the driven casing.

A cone-shaped depression or temporary outer casing is not required if the only time the casing is driven is to seat the casing into a rock unit (driven 10 feet or less). For information on driving casing more than 10 feet into a sandstone formation see subpart 7, item B, of this part.

A **drive shoe** is not required on a temporary casing, or on a lighter-weight outer casing in unconsolidated formations which is cement grouted with an inner casing. However, contractors are cautioned that they are responsible for deformation of the casing, failure of the well or boring, or collapse due to light-weight casing or the lack of a drive shoe. A well or boring which is not properly grouted or completed must be corrected or properly sealed by the contractor. Correction may include perforation, removal of casing, or overdrilling.

Subp. 6. ***Sealing bore hole below screen.*** *If a bore hole extends more than ten feet below the bottom of a screen, the bore hole must be filled with grout from the bottom of the bore hole to within ten feet or less of the screen.*

The purpose of this rule is to prevent permeable materials (sand, gravel pack) from filling a bore hole below the bottom of the screen. This is of particular importance in situations where collapsing sand, gravel, or gravel pack may penetrate a confining layer. If a hole is drilled deeper than the interval in which the screen will be set, the bore hole below the screen must be grouted. It is not permissible to allow the hole to collapse or fill the hole with gavel pack.

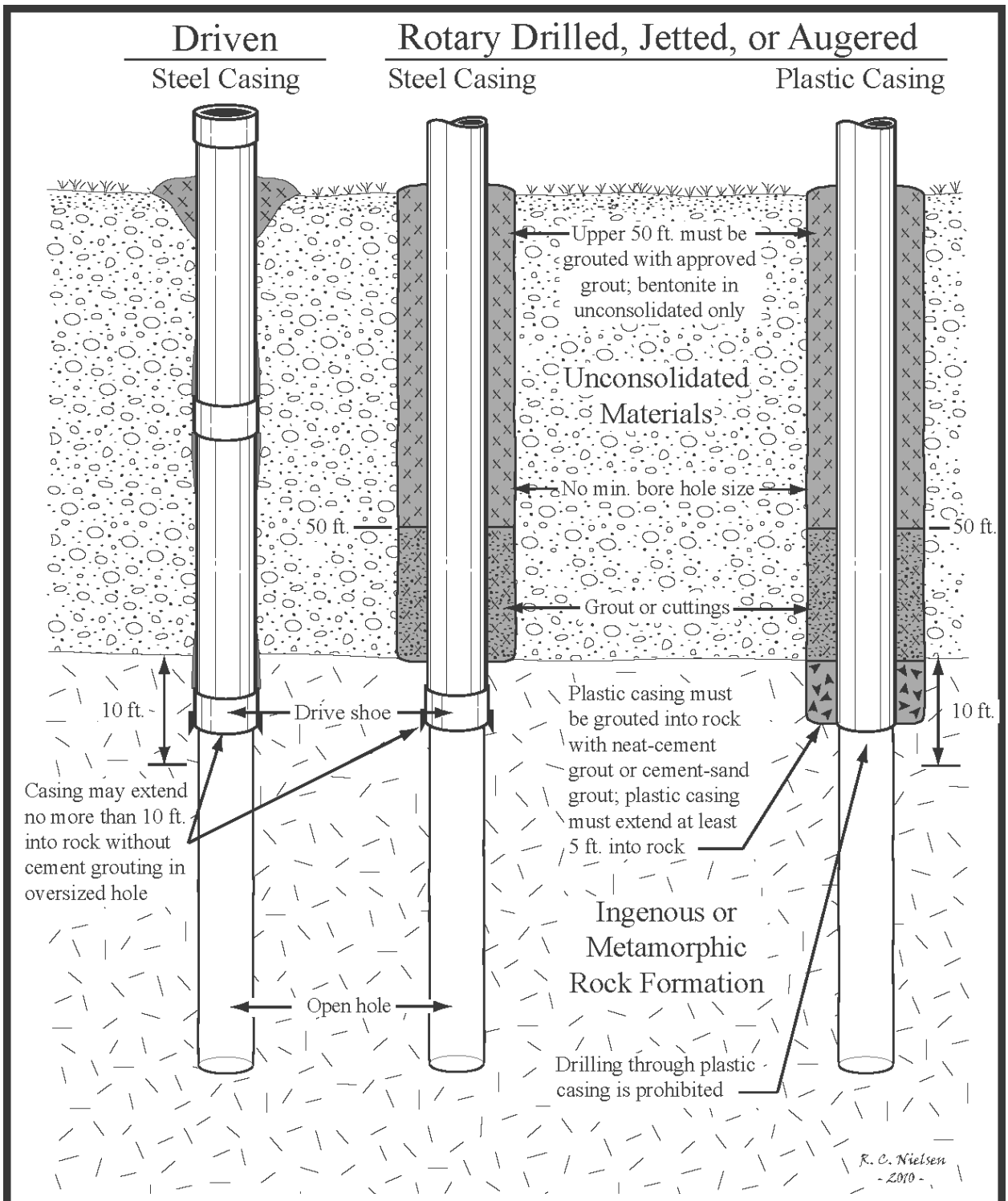
"Filling" (partial sealing) of the bore hole must be done in accordance with Minnesota Rules, part 4725.3850 which requires grout to be pumped through a tremie pipe from the bottom of the hole upward. Neat-cement or cement-sand grout must be used in rock, and neat-cement, cement-sand, or bentonite grout may be used in unconsolidated materials. Sealing the lower portion of a bore hole without sealing the target formation, and doing so with grout that is capable of supporting further well construction (i.e., neat-cement grout or cement-sand grout) presents several potential problems. Considering these problems, it may be advisable to seal the entire bore hole and start a new well or boring.

Subp. 7. ***Grouting in bedrock.*** *The additional requirements in items A to C apply to grouting a well or boring in bedrock.*

"**Bedrock**" includes shale, sandstone, limestone, dolomite, granite, basalt, quartzite, taconite, slate and other sedimentary, igneous, and metamorphic rocks. "Bedrock" also includes materials sometimes referred to as "slaterock," "ledgerock," or "traprock."

For the purpose of these rules, "bedrock" does not include sediment of recent or glacial origin, regolith where the original cementaceous material has been weathered to the point that it no longer binds the matrix, or deposits of Cretaceous age.

A. When bedrock is encountered in the construction of a well or boring, the casing must be equipped with a drive shoe driven firmly into stable bedrock or the casing must be grouted with neat-cement grout, or cement-sand grout from the bottom of the casing to the top of the bedrock.



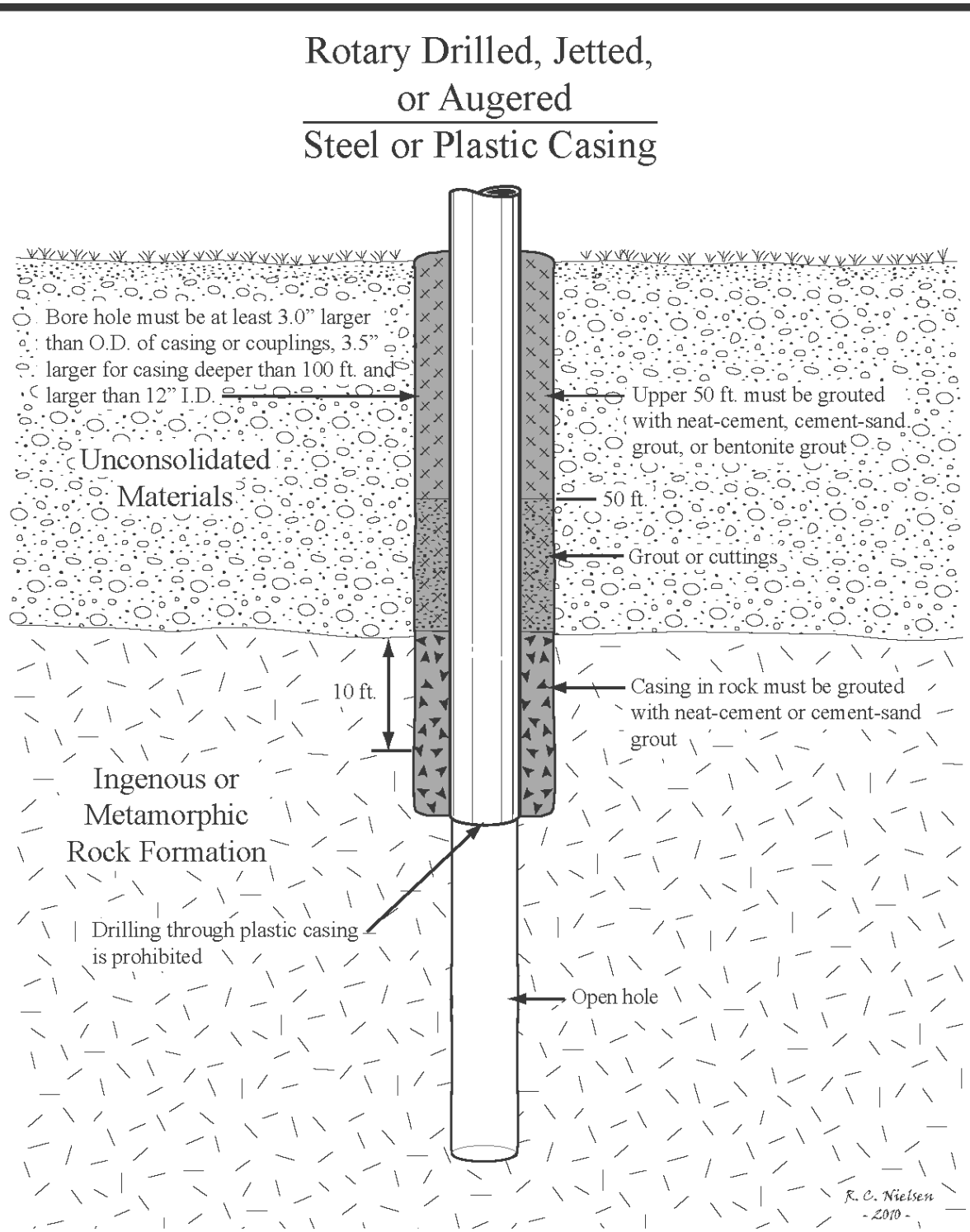
* Note: See additional requirements or exemptions for casing more than 10 feet into rock, confining layers, limestone or dolomite, sandstone, flowing wells or borings, monitoring wells, vertical heat exchangers, and elevator borings.

Figure 15. Wells and Borings in Rock With Casing Less Than 10 Feet Into Rock*

B. When the casing of a well or boring extends more than ten feet into bedrock, or extends through any portion of a bedrock confining layer, the casing must be installed in a bore hole 3.0 inches larger, or 3.5 inches larger for casings deeper than 100 feet and larger than 12 inches inside diameter, than the outside diameter of the casing or couplings, whichever is larger, and the annular space in bedrock must be grouted with neat-cement grout or cement-sand grout, except that steel casing may be driven more than ten feet in a sandstone formation.

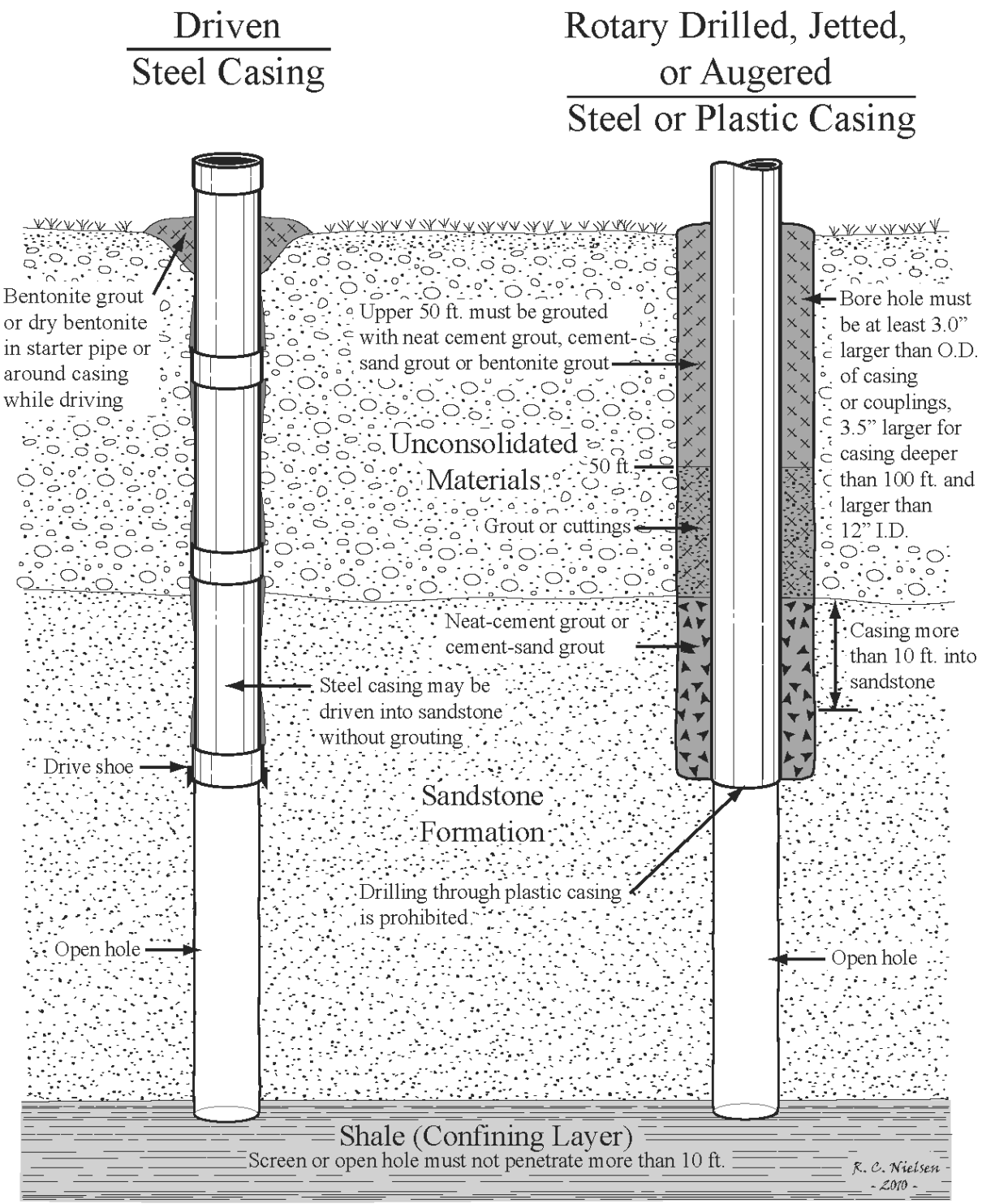
Steel casing may be driven **within** a sandstone formation to any depth without grouting. Driving casing in a sandstone (if the sandstone is the first rock unit) includes both driving the casing and drilling and driving the casing (drilling out ahead of the casing, by drilling through the casing, then driving the casing). A cone-shaped depression or temporary outer casing filled with bentonite as described in subpart 5 of this part is not required if the bore hole in the unconsolidated formation above the sandstone was drilled to produce an annular space and the annular space is grouted according to subparts 1 to 3 of this part.

A bore hole that is 3 inches (or 3.5 inches for 12-inch and larger casing) larger than the casing or couplings is often referred to as an “oversized” bore hole.



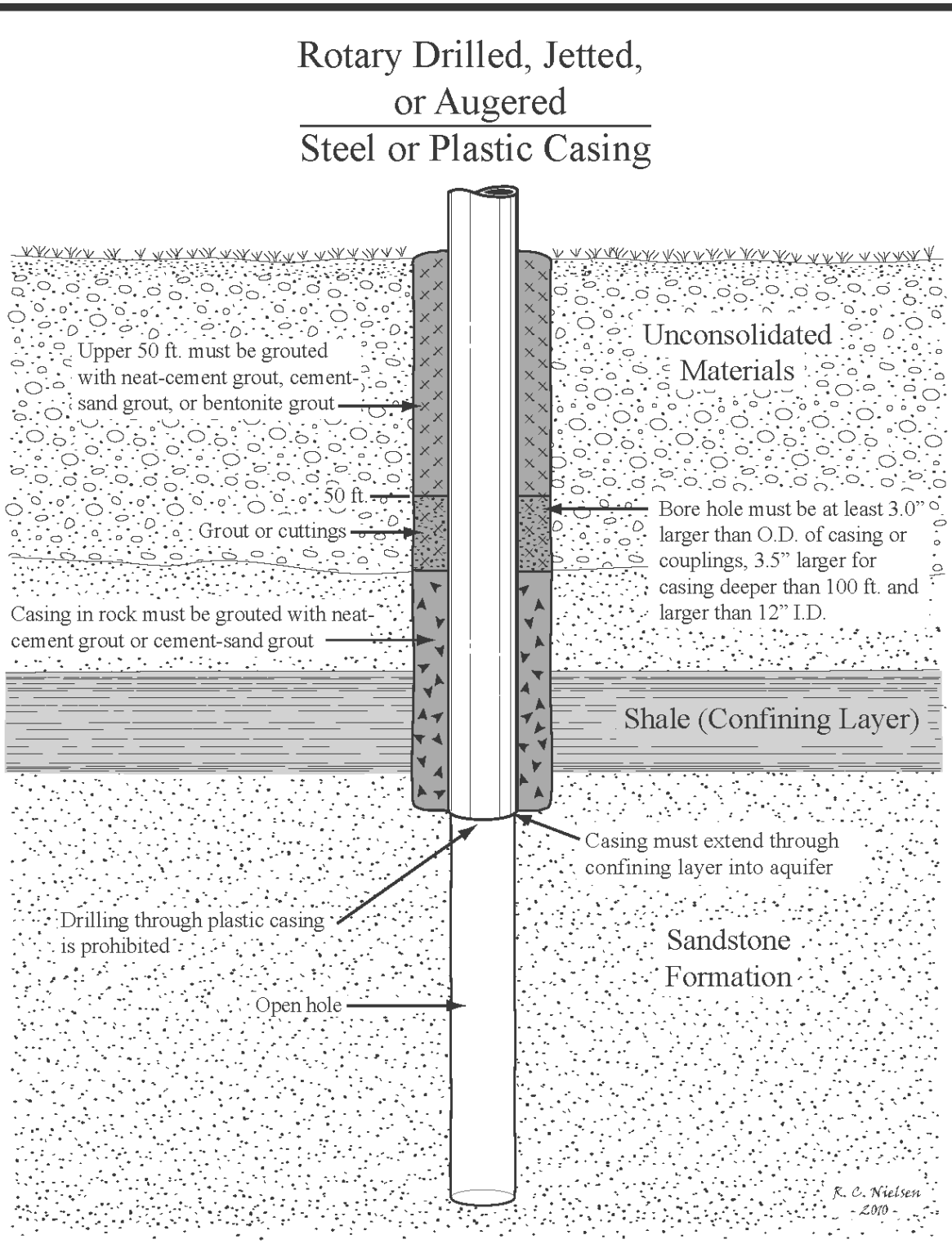
* Note: See additional requirements or exemptions for confining layers, limestone or dolomite, sandstone, flowing wells and borings, dewatering wells, monitoring wells, vertical heat exchangers, and elevator borings.

Figure 16. Wells and Borings in Rock With Casing More Than 10 Feet Into Rock*



* Note: See additional requirements or exemptions for confining layers, rock, limestone or dolomite, flowing wells and borings, dewatering wells, monitoring wells, vertical heat exchangers, and elevator borings.

Figure 17. Wells and Borings in Sandstone With Casing More Than 10 Feet Into Sandstone*



*Note: See additional requirements or exemptions for confining layers, rock, limestone or dolomite, flowing wells and borings, dewatering wells, monitoring wells, vertical heat exchangers, and elevator borings.

Figure 18. Wells and Borings in Sandstone Below a Confining Layer*

C. If a cavern more than twice the diameter of the bore hole exists or the grout level fails to rise after insertion of either more than one cubic yard of grout or the quantity of grout necessary to fill ten vertical feet of hole, then the following grouting materials and methods may also be used in the portions where the conditions exist:

This subpart concerns all rock wells or borings (not just water-supply wells), and addresses cases of large grout loss due to caverns, large fractures, or blasted and bailed portions.

(1) pouring of a mixture of gravel or stone aggregate not larger than one-half inch in diameter while simultaneously pumping neat-cement grout or cement-sand grout through a tremie pipe in a ratio not to exceed five parts aggregate to one part grout;

Aggregate must be poured into the annular space at a rate slow enough to prevent bridging. If bridging occurs, the bridged aggregate must be knocked loose before proceeding with grouting of the annular space.

(2) pumping a mixture of gravel or stone aggregate not larger than one-half inch in diameter and cement-sand grout or neat-cement grout in a ratio not to exceed five parts gravel or aggregate to one part Portland cement; or

(3) pumping of alternate, equal thickness layers of cement-sand grout or neat-cement grout and pouring gravel or stone aggregate not larger than one-half inch in diameter. Individual layers of aggregate must not exceed ten feet in thickness. Aggregate must not be emplaced in a confining layer.

Neat-cement grout or cement-sand grout must be pumped through the casing or through a tremie pipe. The aggregate must be poured into the bore hole at a rate that prevents bridging.

This allows three alternative methods for filling large voids when **one of three** conditions occurs. The three conditions are: (1) if there is a cavern more than twice the diameter of the bore hole, (2) if the grout level fails to rise after insertion of more than one cubic yard of grout, or (3) if the grout level fails to rise after the insertion of the quantity of grout necessary to fill 10-vertical feet of hole. The three alternative methods for filling these large voids include: (1) pouring aggregate (pearock) while pumping cement, (2) mixing aggregate with cement and pumping the mixture, and (3) grouting a 10-foot layer of cement followed by a 10-foot layer of aggregate. The alternate materials may only be used where there is grout loss or large openings as detailed above.

Subp. 8. ***Bentonite seal between gravel pack and grout.*** *A layer of bentonite pellets, bentonite chips, or granular bentonite not to exceed five feet in thickness, is allowed between a gravel pack and grout. The bentonite pellets, bentonite chips, or granular bentonite must not extend into a confining layer or extend more than ten feet above the static water level, and must be poured without voids or bridging. A*

tremie pipe must be inserted to within ten feet of the top of the pellets, chips, or granular bentonite, and the annular space grouted to the established ground surface or base of the pitless unit or adapter.

This allows a bentonite seal on top of gravel pack for any type of well or boring. Previously, it was allowed only for monitoring wells and environmental bore holes. This is designed to prevent migration of grout into the gravel pack or screen. As an alternative, some contractors use a thin layer of finer gravel pack or sand on top of the gravel pack.

GROUT SETTLEMENT

A small amount of grout settlement is normal; however, MDH staff has documented excessive settlement problems with bentonite grout in annular seals, geothermal loop seals, and well and boring sealing – up to 90 percent settlement. Staff has seen heat loop borings drilled to 225 feet in which grout settled to 195 feet.

Manufacturers have told MDH that one-step, powdered bentonite grouts will settle 5 to 10 percent in an otherwise perfect hole – such as inside a well casing.

Some likely reasons for grout settlement include:

1. Using an inadequate grout product or mixture, must use a product manufactured for use as grout and mix this product in accordance with Minnesota Rules, Chapter 4725 and according to manufacturer specifications;
2. Poor mud wall or "filter cake" during drilling, cuttings and drill fluids trapped in washouts can mix with and dilute the grout;
3. An unstable grout "foundation," settlement of cuttings or collapse of bridged material;
4. Geologic variability, porous & permeable formations like sand & gravel can absorb the water phase of a grout mixture before the bentonite hydrates . . . and an inadequate mud wall makes it worse; and
5. Channeling of grout, if drilling fluid in the annular space or bore hole weighs more than the grout, the result will be grout channeling – typically up along the tremie line, dilution of grout takes place and loss of water from the drilling fluid remaining in the bore hole, drilling fluid in the annular space or boring must be thinned prior to grouting to prevent channeling.

It appears that in general, the granular bentonite products do a better job than the one-step grout products. These products almost always need to be used with an additive to retard hydration. It's very important not to over-mix grout. Mix only until the product is suspended, typically 15 to 60 seconds. The product should be lumpy and watery when pumped. Mix only enough to suspend the bentonite, and then pump. Let it hydrate in the hole.

Measure the <u>exact</u> amount of water needed for the product used. <u>Mark</u> this level on the shaft of the mixer, not the tank, which won't be accurate if the grouter isn't sitting level.

Water chemistry can have a big effect on grout performance. Soft water makes better grout. The hardness minerals calcium and magnesium retard bentonite hydration. Ideal make-up water should contain less than 100 mg/L calcium, have a pH between 8.5 and 9.5 (soda ash will correct hardness and adjust pH – usually only a few ounces of soda ash is all it takes to adjust the water for a batch of grout), and have less than 100 ppm chlorine. Test strips should be used to monitor the water chemistry.

Most pumps do a fair job pumping bentonite grout. One type of pump that doesn't work well with granular bentonite is the progressive cavity pump. These pumps cause excessive shear which results in almost-immediate hydration and that creates problems for pumping. Positive displacement pumps (piston pump) seem to be the most popular.

Don't thin the grout product to make it easier to pump. Don't add less than the correct amount of bentonite to the correct amount of water.

If you're having trouble pumping grout consider these problem areas:

- Mixing too long, delaying pumping;
- Shearing the product by using the wrong pump;
- Too small diameter of tremie line;
- Too much tremie line on the reel or on the ground;
- Splices, obstructions, or reductions in the pump discharge or tremie line; and
- Failure to run clean water through tremie line just prior to beginning to pump grout.

Successful Grouting tips:

- Drill a stable bore hole and try to avoid washouts.
- Thin down drilling fluid to help reduce channeling.
- Add cuttings slowly to avoid bridging, or consider full-length grouting.
- If using bentonite, use a granular bentonite product mixed to label requirements – at least 15 percent solids.
- Get the tremie all the way to the bottom and keep it submerged while pumping.
- Pump the bentonite grout fast to induce turbulent flow to remove drilling fluids.
- Use the largest tremie line possible.
- Drill a hole big enough to allow a tremie pipe that's big enough.
- Pump water through a tremie pipe prior to grouting. This does several things:
  - It cools the black poly down, which might be important if it's been out in the sun because heat speeds grout hydration;
  - It lubricates the inside of tremie; and
  - It verifies that the tremie isn't plugged.
- Use a rigid tailpipe if a flexible tremie pipe is used with the end cut at angle to help get past couplings or rocks, and drill holes in the side of the tremie near the bottom, just in case the bottom gets plugged.
- Remember: warm water speeds hydration.
- Pump until quality grout returns to surface.
- Save excess grout to top-off tremie displacement or settlement (Minnesota Rules, Chapter 4725 allows grout to be poured 10 feet – so keeping some on hand in a bucket lets you continue to top-off settling grout).
- The weight of the grout column can be very significant, particularly in deep wells or borings or where the static water level is low. Grouting in stages which allows the lifts to set before placing more grout, can sometimes reduce the settlement.
- Pump the grout at rates high enough to cause turbulent flow which removes drilling mud and cuttings left in the hole.

CONFINING LAYERS

In cases where the first bedrock encountered is one of the bedrock-confining layers (the Decorah, Glenwood, St. Lawrence, or Eau Claire confining layers) the well or boring may only be open to the formation for 10 feet (St. Lawrence or Eau Claire) or 2 feet (Decorah or Glenwood), and the well or boring may not be open to the underlying formation. If the well or boring is going to use an underlying formation, a bore hole 3.0 inches (3.5 for 12 inches and larger casings deeper than 100 feet) larger than the casing or coupling outside diameter must be drilled through the bedrock-confining layer and the annular space in the bedrock portion of the well must be grouted with neat-cement grout or cement-sand grout.

STEEL CASING

Steel casing equipped with a drive shoe may be driven into bedrock a maximum of 10 feet without drilling an oversized hole. If sandstone is the first bedrock unit, see subitem B above.

Steel casing without a drive shoe must be grouted with neat-cement or cement-sand grout for the entire length of casing in bedrock. If the casing extends mores than 10 feet into rock, an oversized bore hole is required.

PLASTIC CASING

Plastic casing must be cement grouted into bedrock. Plastic casing may not extend more than 5 feet into limestone or dolomite. Plastic casing must not be driven (Minnesota Rules, part 4725.2650). If the casing is installed more than 10 feet into bedrock, an oversized bore hole must be drilled.

SCREENING A CONTACT

In some environmental contamination situations, it may be necessary to monitor or remediate across the contact between an unconsolidated formation and bedrock. This typically involves gasoline or other hydrocarbons floating on the water surface which is near the drift/rock contact. Rules addressing this for remedial wells, monitoring wells, and environmental bore holes are contained in Minnesota Rules, parts 4725.6050, 4725.6650 and 4725.7450 respectively.

SUMMARY – GROUTING IS REQUIRED

CONFINING LAYERS.

- For any well or boring penetrating a bedrock confining layer.

MULTIPLE CASINGS.

- When an inner casing is placed inside an outer casing. The outer casing must be 3.0 (or 3.5 for 12-inch and larger casing) larger than the inner casing. Neat-cement grout or cement-sand grout must be used.

UNCONSOLIDATED FORMATIONS.

- For any well or boring drilled with a method which creates an annular space, from a depth of at least 50 feet or from the top of the gravel pack, whichever is less. A minimum bore hole size is not required. Bentonite grout, neat-cement grout, or cement-sand grout may be used in unconsolidated formations.
- When an annular space in unconsolidated formations below 50 feet is not filled with cuttings. A minimum bore hole size is not required. Bentonite grout, neat-cement grout, or cement-sand grout may be used in unconsolidated formations.

BEDROCK.

- For any well or boring with a bore hole larger than the casing O.D., and with casing more than 10 feet into bedrock. The top 50 feet must be grouted as explained above. The bedrock portion must be grouted with neat-cement grout or cement-sand grout. The bore hole in bedrock must be oversized.*
- For any plastic cased well, whether screened or open hole, in bedrock. The casing must extend a minimum of 5 feet into bedrock except that the casing must not extend more than 5 feet into limestone or dolomite. The bedrock portion must be grouted with neat-cement grout or cement-sand grout.
- For any steel cased well or boring finished in bedrock which does not have a drive shoe.

FLOWING WELLS AND BORINGS.

- For any well or boring which flows less than 70 g.p.m. or has less than 10 psi which is drilled by rotary, jetting, auger, or similar method. Neat-cement grout or cement-sand grout must be used.
- For any well or boring flowing more than 70 g.p.m. or which has more than 10 psi. Neat-cement grout or cement-sand grout must be used.

LIMESTONE OR DOLOMITE.

- For any water-supply well completed below limestone or dolomite that does not have 50 feet of surficial materials. The outer casing must be 3.0 (or 3.5 for 12-inch and larger casing) larger than the inner casing. Neat-cement grout or cement-sand grout must be used.
- For any water-supply well completed in limestone or dolomite if the static water level is less than 10 feet below the top of the limestone. The bore hole must be oversized. Neat-cement grout or cement-sand grout must be used.

MONITORING WELLS, ENVIRONMENTAL BORE HOLES, VERTICAL HEAT EXCHANGERS.

- For any monitoring well or cased environmental bore hole from the top of the gravel pack/bentonite seal or bottom of the casing to the surface; and
- For the entire depth of any vertical heat exchanger.

* An "oversized bore hole" is a drill hole that is 3.0 inches larger than the outside diameter of the casing, coupling, or bell end, whichever is larger; or 3.5 inches larger than the outside diameter of the casing, coupling, or bell end for casings 12 inches and larger and deeper than 100 feet.

STAT AUTH: MS s 103I.101; 103I.111; 103I.205; 103I.221; 103I.301; 103I.401; 103I.451; 103I.501; 103I.525; 103I.531; 103I.535; 103I.541; 103I.621; 144.05; 144.12; 144.383; 157.04; 157.08; 157.09; 157.13
HIST: 17 SR 2773; 33 SR 211

***4725.3100** [Repealed, 17 SR 2773]*

End
of
Grouting Section