WELL GROUTING

Introduction

Grouting is the placement of a sealing material such as neat cement or bentonite into the annular space between a well casing and the borehole created during well construction. Grouting is an effective and necessary measure for the protection of public health and ground water quality. The DNRE has identified several cases where improper grouting or lack of grouting in both consolidated and unconsolidated formations is suspected of causing leakage of contaminants downward along the well casing into potable water aquifers.

In some areas in Michigan bedrock either outcrops or is very close to the surface. Wells drilled in these areas are extremely vulnerable to contamination from surface water or near-surface water contaminated by sewage systems that are installed in the thin glacial drift. Proper grouting of the casing into the bedrock to a point below the upper fractured zone prevents contaminants from flowing into the well. Grouting with neat cement is required in areas where bedrock is close to the surface (less than 25 feet from surface) and in situations where upper bedrock formations produce water of unsuitable quality. Wells constructed with methods that produce a borehole larger than the casing (rotary, spiral auger, bored) must be grouted from the bottom of the annular space to the ground surface. Driven wells or those drilled by cable tool or hollow rod, where the casing is driven into the smaller diameter borehole, should be grouted by placing dry granular bentonite around the well casing as it is being driven. In some instances (e.g., drilling through a known contaminated formation using cable tool or similar methods) it is necessary to install a larger temporary conductor pipe, which will be removed during the grouting operation,

Purpose of Grouting

1. Provides sanitary protection for the water supply from surface or near-surface contamination sources.
2. Protects the water bearing formation by preventing movement of water between aquifers.
3. Seals off a formation which is known to have been contaminated or which produces water of undesirable quality.
4. Preserves the hydraulic characteristics of the aquifer and provides a seal against loss of artesian pressure.
5. Increases the life of the well casing by protecting it from corrosion in areas of acid soils or where other corrosive conditions exist.
6. Provides structural support for casing when neat cement is used for grouting PVC plastic well casing.

Grouting Rules

Rule 133a

- No devices to suspend grout.
- No inducing collapse of the borehole wall.
- Grout from bottom to top in a continuous operation.
- Density of grout shall be consistent.
- Borehole shall be at least 2 inches larger than the casing size.
- Borehole shall be at least 2 7/8 inches larger than the casing when a grout pipe outside the casing is used.
- An annular space between a permanent casing and temporary casing shall be grouted during temporary casing removal by pumping neat cement or bentonite grout,

or by pouring bentonite chips, bentonite pellets, or granular bentonite, into the annular space. Granular bentonite shall not be poured into an annular space that contains drilling fluid or water.
- Neat cement shall be allowed to set a minimum of 24 hours. If bentonite is added, the grout shall set a minimum of 48 hours.

Rule 134a Oversized borehole.
- Grout the entire length of the casing for a standard well installation.
- Grout not less than 10 feet above the top of the screen in a gravel-pack well to the level of the pitless adapter.
- The depth of grouting may be increased or decreased by the health officer.

Rule 135 Driven casing
- Maintain dry granular bentonite around the permanent well casing at all times that it is being driven.
- Where a temporary casing or temporary borehole is used, the borehole or temporary casing shall be at least 3 inches larger than the permanent casing and extend not less than 25 feet below the ground surface or into a confining layer identified by the health officer. Grouting of the annular space between the permanent casing and the temporary casing or borehole shall comply with the provisions of Rule 133a.

Rule 137 Bedrock wells.
- Where bedrock is encountered within 25 feet of the ground surface, an oversized borehole shall be drilled and the casing shall be grouted with neat cement for a minimum depth of 25 feet.

Rule 137a Verification of well grouting.
Contractor may be asked to excavate the well head for inspection if:
- Visible open annular space.
- Failure to detect grout 2 feet or more below the water service line.
- Dye detected in the well water after testing.
- Well log indicates that the well has not been grouted or lacks information or contains incomplete information.

Rule 138 Flowing artesian wells.
Shall be grouted to:
- Protect the artesian aquifer from loss of artesian head
- Prevent erosion of the borehole or the area in the vicinity of the well
- Confine the flow to within the casing

Prevent mixing of previously distinct aquifers below grade

Grouting Materials
Neat cement and bentonite are the two main materials used for making grout slurries.

Portland Cement, ASTM Type I or API Class A & B - Portland cement is a mixture of lime, alumina, magnesia, and sulfur trioxide. The components are combined and heated, and the resulting "clinker' is ground up and mixed with gypsum to make various types of cement. Type I cement is used in neat cement grout and concrete grout mixtures. Neat cement slurry is superior to bentonite as a grouting material in high bedrock situations, especially fractured limestone. It forms a hard rock-like seal around the casing which will not wash out from ground water flow in the formation. A curing time of 24 hours is required before resuming drilling.

As the water to cement ratio increases, the compressive strength of the cement will decrease and shrinkage during curing and permeability of the cement will increase. When cement is mixed with water, a number of chemical reactions take place. As the mixture cures and changes from a liquid to a solid, heat is given off. This is referred to as the "heat of hydration" and will result in an increase of the temperature of the casing and the surrounding soil. The amount of heat given off is dependent upon several factors, such as cement composition, use of additives, and thickness of the grout envelope. The American Petroleum Institute (API) recommends a water to cement ratio of 0. 46 by weight or 5.2 gallons of water per 94 lb. sack of cement (5.2 gal. of water x 8.33 lb/gal. = 43.3 lb. divided by 94 lb. of cement = 0.46).

The maximum recommended water to cement ratio for neat cement is 0.53, or
6 gallons of water per 94 lb. sack of cement. Under certain conditions it may be necessary for the well drilling contractor, consulting engineer, or regulatory agency to increase the amount of water used in the grout mixture. Factors, such as temperature, type of geologic formations, extent of fracturing, use of additives, and water quality, will affect performance of the grout material and should be considered when planning the grouting operation.

Portland Cement ASTM Type III or API Class C - This is referred to as high-early strength cement. The cement clinker is finely ground to provide smaller particle size than Type I cement. This increases surface area and provides high-early strength with a faster curing rate. A 24-hour curing time is required before resuming drilling when using either of these. For Class C cement, API recommends a water to cement ratio of 0.56, or 6.3 gallons of water per sack. For Type III cement, the water to cement ratio may range from 0.53 (6 gal./sack) to 0.62 (7 gal,/sack). Bentonite is commonly used as an additive (1-2%) with these types of cement. The amount of water necessary to hydrate the slurry properly increases with addition of bentonite.

Bentonite - Sodium bentonite is the principle ingredient in drilling mud or fluid used in rotary drilling. It is hydrous silicate of alumina and is comprised mainly of the clay mineral montmorillonite. The suitability of sodium bentonite as a grouting material comes from its ability to swell up to 15 times its dry volume when hydrated. It will maintain a gel-like seal around the casing if moisture is retained. Natural clays found in Michigan generally do not have the swelling properties to make them suitable as grouting material. Most bentonite used in the drilling industry is mined in the western United States. Bentonite used in Michigan shall be at least 85 percent montmorillonite and meet API specifications standard 13A. A slurry consisting of bentonite and water may be used as a grouting material if it has a minimum weight of 9.4 lbs/gal. Field experience has shown that settling of solids frequently occurs, resulting in an open upper annulus and need for the well drilling contractor to regrout.

In recent years several new bentonite products have been marketed that are specifically designed for grouting. These grouts have a solids content of over 20 percent by weight and settling problems are greatly reduced. Therefore, these high solids bentonite grouts are recommended. Slurry weight of 9.4 lbs/gal as measured with a mud scale is required. Bentonite grouts should not be used in some porous formations, such as fractured limestone, where the bentonite may be washed away from the casing due to excessive ground water movement.

Grout Additives

Bentonite - This is added to cement to increase set volume, reduce shrinkage, decrease density, and decrease water loss from the cement. Up to 5 percent bentonite by weight may be added to cement slurries, although 1-2% is the more commonly used, preferred amount.

Calcium chloride ($CaCl_2$) - This accelerator is added to cement to speed up the setting time and increase early strength. Two percent $CaCl_2$ by volume added to cement will result in a compressive strength after 24 hours approximately equal to that of cement without $CaCl_2$ after 48 hours. Calcium chloride is useful when grouting in cold weather since it will speed cement curing. The use of $CaCl_2$ or other accelerators should be avoided when PVC well casing is used. The more rapid hydration of the cement will also be reflected in a rapid increase in temperature of the cement. This may result in deformation of plastic well casing.

Grouting Methods

Most water well grouting methods were developed by the oil well drilling industry. As water well drillers and public health officials became aware of the benefits of grouting, oil well grouting techniques were adapted for the water well industry. Several firms specializing in oil and gas well cementing can provide assistance to the water well driller when a large volume of cement grout is required.

Grout slurries must be placed into the annular space from the bottom of the zone to be sealed, upward to the surface in one continuous operation. Pouring grout directly into the annulus from the surface is not approved since it may result in bridging and prevent the grout from reaching the bottom. Several methods discussed below will provide for placement of grout from the bottom of the annular space.

Cement grout must be adequately mixed and free of lumps prior placement. Equipment to be used for mixing grout may range from a wheelbarrow and shovel to specially designed hoppers and jet-type mixing pumps. The grouting method and amount of grout required for a particular job will dictate the type of equipment to be used. Pumping equipment must be able to handle a viscous slurry, develop high pressures (100-300 pounds per square inch [psi]), and have an adequate capacity. Diaphragm, piston, worm gear, or helical type pumps are best suited for pumping cement slurries, but heavy duty open-vane centrifugal pumps can also be used under some conditions.

It is important that the drilling contractor demonstrate complete organization in his grouting procedure. A successful grouting job requires a sequence of events to occur without mechanical failure of cement mixing and pumping equipment. The contractor must also be prepared by having enough cement on site to complete the grouting without interruption and enough water for grout mixing and cleanup.

Centering guides should be used on the casing to assure centering of the casing within the borehole and complete encasement within the grout envelope. Prior to placement of the grout, the annular space should be checked to make sure that bridging or caving of material from the borehole wall has not occurred. When cement is used as a grouting material, adequate time must be allowed for cement curing prior to resuming drilling operations.

<u>The following grouting methods are visually shown in the Well Construction Code book on page 56</u>:

> **Displacement Method-**In this method a borehole at least 2 inches larger than the nominal casing size is drilled. In caving formations, a temporary conductor casing (or surface casing) is installed to keep the borehole open during the grouting operation. The estimated volume of grout required is placed directly into the bottom of the borehole by shoveling, pouring or the use of a dump bailer after the temporary surface casing is in place. The permanent casing with a drillable plug (a wooden plug is often used) is lowered into the borehole to displace the grout. The plug also prevents grout from entering the inside of the permanent casing. In some cases the weight of the casing alone is not sufficient to displace the grout and the casing must be filled with water and forced into the hole by the pull-down mechanism on the rig. As the casing is lowered, the grout moves up the annular space from the bottom of the borehole toward the surface. The surface casing is removed promptly to expose the grout to the borehole wall. After the required curing time**,** the plug is drilled out and the drilling operations resume. This is one of the simplest grouting methods and is suitable for situations where the bottom of the borehole can be visually inspected prior to grouting (25 - 40 feet deep) and where little or no water is present in the borehole.

> **Grout Pipe Method (Gravity)-**In this method the grout is placed in the annular space by gravity through a funnel attached to a grout pipe (or tremie) that is suspended in the annular space. A 1 inch or 1¼ inch rigid pipe is used as the grout pipe. The borehole diameter must be large enough to accommodate the grout pipe. A two inch or larger annular space will usually be sufficient, which requires a borehole that is 4-5 inches larger than nominal size of the casing. The use of welded casing aids in providing maximum annular space for grouting. The grout pipe is extended down between the permanent casing and conductor casing. The grout is placed through the funnel & tremie in one continuous operation, beginning at the bottom of the zone being sealed. The bottom end of the grout pipe should be kept full of grout and remain submerged in grout during the operation. The grout pipe is gradually withdrawn as the grout fills the annular space. This is accomplished by disjointing it in typically 10 foot sections. The conductor pipe should be removed as the grout is being placed in the annulus. Grout should be added until it appears at ground surface. Where a pitless adapter is to be installed, grout may be terminated a few feet below surface. Drilling is resumed after curing of the cement.

Grout Pipe/External Placement Method (Pumping) – *This is the most commonly used grouting method.* The same procedure as described above is followed except that the grouting material is placed in the annulus with the aid of a grout pump rather than by gravity flow alone. Screening the cement before it is placed into the mixing hopper will help to prevent clogs and interruption of the grout pumping procedure. The grouting procedure begins with the tremie pipe being lowered to the bottom of the annulus. As the grout material is placed by pumping, the tremie pipe should be sequentially raised to prevent it from becoming stuck in the annulus. Typically, thin cement grout appears initially at the surface. Grouting may stop when consistently thick cement grout is observed. A grout scale is useful in determining adequacy of the grout weight. A slurry of neat cement grout, mixed at a ratio of 6 gallons of water to one 94 pound sack of Portland cement will weigh approximately 15 pounds per gallon.

Pressure Cap Method-In this method, the grout is placed through a grout pipe that is inside the permanent casing. An airtight pressure cap is placed in top of the casing with the grout pipe extending through it to the bottom of the casing. The casing is suspended off the bottom of the borehole. A valve on the pressure cap allows water or drilling mud to be circulated down the grout pipe and out through the pressure cap, filling the casing and annulus. The valve is then closed to keep the casing filled with water or drilling mud, without an interruption in pumping, cement is substituted for water or drilling mud and is injected down the grout pipe until the grout appears at the surface. The water or mud in the casing prevents the grout from entering the open casing bottom. After the grout appears at the surface, just enough water or mud is pumped through the grout pipe to flush cement from it. The grout pipe is then pulled back through the pressure cap to raise the end out of the cement and prevent it from being cemented in. Pressure is maintained in the well casing until the grout has cured. Drilling is resumed after the required setting time.

Grout Shoe Method-This method involves pumping the grout through a grout pipe inside the casing, which is fitted with a drillable cementing shoe (or float shoe), and raised above the bottom of the borehole. The cementing shoe has a backpressure valve, which prevents grout from backing up into the casing when the grout pipe is removed. The grout is forced around the bottom of the casing and upward in the annular space until it appears at the surface. The grout pipe is then detached from the cementing shoe and raised to the surface. After the required setting time, the cementing shoe is drilled out and the work on the well continued.

Displacement Plug Method- This method involves pumping the grout directly down the permanent well casing, which is raised off the bottom of the borehole. Grout is forced upward in the annular space to the surface and displaces drilling mud or water that has been circulated prior to grouting. The volume of grout required for the job is pumped into the casing. A displacement plug (or separator plug) is placed on top of the grout column in the casing. The plug is made of a drillable material such as plastic, rubber or wood. A measured volume of water equal to the volume of the casing is pumped into the casing, forcing the plug to the bottom of the casing and expelling the grout into the annular space. Pumping continues until grout appears at the surface. The water in the casing is maintained under pressure until the cement has set. In this method, a zone of weak cement may exist at the interface of the grout and drilling mud if all of the drilling mud is not wasted at the surface. However upon completion this zone will be located at the upper end of the annulus rather than at the critical location at the bottom of the casing. If additional grout is added, this weak cement may be pumped onto the ground surface. In this method, it is critical that volumes of grout and displacement water be accurate.

Grouting Wells – Volume Calculations

The chart below may be used to estimate the total volume of grout slurry required to fill the annular space between the permanent well casing and the borehole. The bags of grout required can be determined by dividing volume listed in the table below by the grout manufacturers suggested yield per bag. Be sure the yield per bag is in cubic feet (ft) for this calculation. If not, recall that 1 cubic foot of water = 7.48 gallons. An amount equal to 20 percent of the calculated volume may have to be added to allow for borehole irregularities.

ANNUAL SPACE VOLUME (Cubic Feet) DIAMETER IN INCHES											
WEL CASING DEPTH IN FT.	CASING	2	2	4	4	5	5	6	6	6	8	8
	HOLE	4	6	6	8	8	10	8	10	12	10	12
	25	1.4	4.1	2.1	6.0	4.5	9.4	2.7	7.6	12.6	3.5	9.5
	50	2.8	8.3	4.3	11.9	9.0	18.8	5.5	15.3	27.3	7.0	19.0
	75	4.2	12.4	6.4	17.9	13.5	28.2	8.2	22.9	40.9	10.5	28.5
	100	5.6	16.5	8.6	23.8	18.0	37.6	11.0	30.6	54.6	14.0	37.9
	125	7.2	20.7	10.8	29.8	22.5	47.1	13.7	38.3	68.2	17.5	47.4
	150	8.5	24.8	12.9	35.8	27.0	56.5	16.4	45.9	81.8	20.9	56.9
	175	9.9	29.0	15.1	41.8	31.5	65.9	19.2	53.6	95.5	24.4	66.4
	200	11.3	33.1	17.2	47.7	36.0	75.3	21.9	61.2	109.1	27.9	75.9

Grouting Wells – Neat Cement Requirements

The chart, *'Grouting Wells - Neat Cement Volume Requirements'* may be used for estimating the number of bags of cement required for grouting the annular space between the permanent well casing and the borehole. These figures are based on a mixture of one bag (94 lbs.) of cement to 6.0 gallons of clean water, which yields a volume of 1.28 cubic feet. The quantity of cement is calculated for a clean borehole. It is a common practice to add an amount equal to 20 percent of the calculated volume to allow for borehole irregularities and severely fractured formations.

NEAT CEMENT VOLUME
NUMBER OF BAGS OF CEMENT

(Based on 6 gallons of water per bag of cement that yields 1.28 cu. ft. or 9.5 gallons)

CASING	2	2	2	4	4	4	5	5	5	6	6	6	8	8	8
HOLE	4	5	6	6	7	8	7	8	9	8	9	10	10	11	12
25	1.1	2.1	3.3	1.7	3.1	4.7	2.0	3.5	5.4	2.2	4.0	6.0	2.7	5.0	7.5
30	1.3	2.5	3.9	2.0	3.6	5.6	2.4	4.2	6.5	2.6	4.8	7.2	3.3	6.0	9.0
40	1.8	3.2	5.2	2.7	4.9	7.5	3.2	5.6	8.7	3.5	6.4	9.6	4.4	8.0	12.0
50	2.2	4.1	6.5	3.4	6.2	9.4	4.0	7.0	10.9	4.3	8.0	12.0	5.5	10.0	14.9
60	2.7	5.0	7.8	4.1	7.4	11.3	4.8	8.4	13.1	5.2	9.6	14.5	6.6	12.0	17.9
70	3.1	5.8	9.1	4.7	8.6	13.2	5.6	9.9	15.3	6.0	11.2	16.9	7.7	14.0	20.9
80	3.6	6.6	10.4	5.4	9.9	15.0	6.4	11.3	17.4	6.9	12.3	19.3	8.8	16.0	23.9
90	4.0	7.5	11.7	6.1	11.1	16.9	7.2	12.7	19.6	7.8	14.3	21.7	9.9	18.0	26.9
100	4.4	8.3	13.0	6.8	12.3	18.8	8.1	14.1	21.8	8.6	15.9	24.1	11.0	20.0	29.9
120	5.4	10.0	15.6	8.1	14.8	22.5	9.7	16.9	26.2	10.4	19.1	28.9	13.2	24.0	35.9
140	6.3	11.6	18.3	9.5	17.3	26.3	11.3	19.7	30.5	12.1	22.3	33.7	15.4	28.0	41.9
160	7.1	13.3	20.9	10.8	19.8	30.1	12.9	22.5	34.9	13.8	25.5	38.6	17.6	32.0	47.8
180	8.0	15.0	23.5	12.2	22.2	33.8	14.5	25.3	39.2	15.5	28.7	4..4	19.8	36.0	53.8
200	8.9	16.6	26.1	13.5	24.7	37.6	16.1	28.1	43.6	17.3	31.9	48.2	22.0	40.0	59.8
220	9.8	18.3	28.7	14.9	27.2	41.3	17.7	31.0	48.0	19.0	35.1	53.0	24.2	44.0	65.8
240	10.7	20.0	31.3	16.2	29.6	45.1	19.3	33.8	52.3	20.7	38.3	57.8	26.4	48.0	71.7
260	11.5	21.6	33.9	17.6	32.1	48.9	20.9	36.6	56.7	22.5	41.4	62.7	28.6	52.0	77.7
280	12.4	23.3	36.5	18.9	34.6	52.6	22.5	39.4	61.0	24.2	44.6	67.5	30.8	56.1	83.7
300	13.3	25.0	39.1	20.3	37.0	56.4	24.2	42.2	65.4	25.9	47.8	72.3	33.0	60.1	89.7

These figures are based on a clean borehole, Due to borehole irregularities and other factors, the actual required volume is usually greater. It is a sound practice to have 20 percent to 50 percent more material at the job site.

For additional information on grouting wells refer to *"Michigan Water Well Grouting Manual*,**"** MDPH, 1988

EVALUATION OF GROUTING

During Well Construction

1. What grouting method and material and mix recipe is being used? Is it in compliance with the well construction code and any permit specifications?

2. Check for suitable grouting equipment (pump, mixer, grout pipe).

3. Determine volume of grout expected to complete the job. Allow for 15-20% loss to the formation. Is there enough grout on job site?

4. Use grout scale (mud balance) to weigh slurry before it is pumped into annulus. Grout scales may be obtained from the sources listed.

5. Observe grout return to surface. Initial return will be a thin, watery consistency. Once the slurry visibly appears like the slurry being pumped into the well, weigh the return to verify that the weight out equals the weight being pumped in.

6. Record the amount of grout used and other grouting-related details needed to complete grouting section of the water well drilling or plugging record.

Office Review of Water Well Record

When reviewing the section concerning grouting of the annulus on the water well record, the following may be indicators that the well has not been properly grouted:

1. The section has not been completed.
2. The section indicates that the annulus was not grouted as required by the well construction code, (i.e., the entire casing length or to within 10 feet of the bottom of the casing for screened wells.)
3. The number of bags of grout used, is not sufficient to fill the estimated volume of the annulus. By calculating the volume of the annulus, and comparing that to the amount of grout used, a determination can be made as to whether or not a sufficient volume of grout was used to seal the annulus. The previous charts show annular space volumes and neat cement volume requirements. Bentonite grout volumes vary by manufacturer. If needed, LHDs should be able to calculate the annular space volume to determine if the amount of grout used was appropriate.

When an office review of a water well record discloses that a well may not have been properly grouted, investigate the violation by field inspection and/or consultation with the well drilling contractor, and order correction as needed.

Field Evaluation of Grouting Upon Well Completion
Two methods of the field evaluation of grouting are generally used: Visual Observation and Probing.

Visual Observation
The initial effectiveness of visual observation of grouting is limited to what can be observed at the ground surface. Any of the listed conditions may lead to the drilling contractor being required to excavate around the casing using a backhoe to allow more complete evaluation of the grout job. Some examples of visual observation include:

1. Look for the presence or absence of grout material laying on the ground surface in the vicinity of the well casing. During the grouting procedure, the well drilling contractor is required to pump the grout material to the bottom of the well using a grout pipe, force the grout upward through the annulus and finish with the grout material appearing at the ground surface. The grouting procedure may stop when the consistency of the grout material at the ground surface is the same as the consistency of the grout material in the grout mixer (i.e., pumped in equals flowing out). There often is thin or access grout visible in the vicinity of the well when the driller is finished grouting. However, a visual evaluation can be limited in effectiveness if the area around the casing has been disturbed since the well was completed, such as when the pitless adapter was installed, when general site grading was conducted, or due to site clean-up in the area around the casing.

2. Soil collapse around the casing may indicate improper grouting. This may suggest that the annulus was not properly sealed and that soil from around the well casing may have collapsed into the open portion of the annulus.

3. Solution channels or washouts that are visible around the well casing may indicate problems with grouting. They suggest that surface water may be flowing downward around the outside of the well casing. The water may be flowing from the surface into a near surface aquifer or all the way down to the bottom of the well. In any case, borehole erosion can occur, resulting in a pathway for surface water-carried contaminants to get into the well.

4. You may be able to see unapproved grout materials in the vicinity of the well, such as bentonite slurry residue, when neat cement was required.

5. You may observe empty bags of an unapproved grout material left lying around the drilling site.

6. You may obtain information from the owner, neighbors, other contractors, or other persons who may have visually observed an improper grouting procedure. For example, the owner may relay to you that they observed the well drilling contractor shoveling cuttings into the annulus or pouring dry granular bentonite from the surface along the side of the well casing.

Use of Soil Probes

IMPORTANT: To reduce the risk of electrocution, it is recommended that probes be used for occasional field checks and to focus on wells that the local health department has reason to believe may not have been grouted. The DNRE advises that probing be limited to installations where the pump has not yet been installed. Lock Out/Tag Out procedures, on the electrical box, pursuant under MIOSHA regulations must be followed when probing after the pump is installed.

Sanitarians are advised to use the following precautions when grout probing:

- Do not probe around wells located beneath overhead electrical lines.
- Have the property owner shut off the power to the submersible pump before you probe.
- Do not use excessive force when an obstruction is encountered. Obstructions are usually rocks, tree roots, pitless adapter clamps, or casing couplings, but you may also encounter electrical or gas lines.
- Use insulated handles on the augers or probes.
- Do not probe around flowing artesian wells. You may cause a break-out of flow around the outside of the casing.
- Use proper lifting techniques when pulling probes out of the hole to avoid back injury.

A small diameter, hollow-core soil probe with extensions is an effective tool for evaluating water well grouting after a well has been completed. Samples of the grouting material can be recovered for identification.

As part of normal well completion practice, grout will be removed from the upper few feet of a well casing during installation of the pitless adapter. We recommend that grouting evaluation begin about 2 feet below the pitless adapter/water service line connection. Taking normal excavation depths into account, you would not expect to find any grout above this level.

The grout probe is used to evaluate the presence of approved grout material, without damaging the seal provided by the grout.

1. Method

Probing should be done on the side of the casing away from the dwelling and offset 90 degrees from the electrical service connection. This will reduce the chances of hitting either the water service line or the electrical power supply wire. Probe carefully in the upper 4 feet until you have determined that you have gotten past these two potential danger/damage possibilities. Note that you may also encounter a pitless adapter U-bolt or a casing coupling within this zone. Once past this zone it is less likely that you will encounter hazards. It may take several tries to get the probe past the pitless adapter or casing couplings.

It may be advantageous to use a shovel or a standard 4 inch diameter bucket soil auger start the grout probe hole. This facilitates getting the end of the probe past the pitless adapter. However, be cautious to avoid cutting or wrapping the power supply electrical wires around the auger.

The probe is guided down along side of the well casing in a vertical position to a point below the pitless adapter. Once the probe is below the pitless adapter, it should be removed and the probe barrel cleared of any soil material. The probe is then reinserted and a sample of any material found below the pitless adapter is collected for evaluation. Again clear the probe barrel, and reinsert the probe to obtain another sample. This process is continued until a good quality grout material has been located. Threaded extension pipes can be used to increase the depth of probing. When an open annulus or material with little resistance has been encountered, use caution when adding extensions to avoid losing the probe string down the hole.

Normally, once a good quality grout material has been found using the probe, it is not necessary to probe any deeper into the annulus. The probe is generally not extended more than 3 feet into the good quality grout material.

Where an open annular space exists or where drilling mud or cuttings were used to seal the annulus, the probe may fall freely or with little effort. Open annular spaces are frequently detected where grout slurries have failed, where formation materials have collapsed creating a bridge, or below bridged grout that was poured into the annulus from the surface.

2. Grout Material Evaluation

The following descriptions are useful for identifying grout samples collected with the soil probe:

a. *Bentonite grout* - An acceptable bentonite grout seal will appear as a pliable clay with a gelatin, oatmeal, or peanut butter consistency, tan to gray in color. If granular bentonite or coarse grade bentonite was used, the individual particle configuration may be recognized. If coarse grade bentonite was poured into the annulus and remained nonhydrated, it will usually be difficult to penetrate with the probe. An unacceptable bentonite drilling mud slurry or drilling mud/cuttings slurry will appear as a thin, watery clay mixture tan to gray in color.

b. *Neat cement grout* - An acceptable neat cement or cement/bentonite grout will be a hard rock-like material, gray to greenish-gray in color that can be penetrated with the probe only for the first few hours after completion of the grouting. After the cement sets, the probe is only useful for identifying the top of the grout.

There may be instances where the use of the hollow core sampler is not practical due to the presence of rocks or other obstructions. In these cases, it may be possible to use a solid rod tile probe to evaluate the presence or absence of an open annulus around a well casing. Most tile probes have a threaded end that the point is threaded on to. Probe extension rods are available. The main drawback of using a tile probe is that you cannot collect samples of material for examination.

After evaluating for the presence of grout using a probe, fill in the hole in the grout that is created by the probe. Pour granular bentonite into the hole and periodically tamp it with the probe. Since the probe generally does not penetrate into the grout material more than 1 to 2 feet, a large quantity of bentonite is generally not needed. When a standard 4 inch diameter bucket soil auger is used along the upper portion of the annulus (above the pitless adapter), the parent material removed from that portion of the hole may be used to fill the hole.

A pair of wrenches is useful for disassembling the probe extensions and a screwdriver comes in handy for clearing the soil or grout material from the probe core. A wire brush and a can of WD 40 or equivalent are useful for cleaning the threads on the probe extensions and to assure that you can get the sections apart when you are done.

NOTE: Extreme caution must be used to avoid contact with overhead utility lines. Where overhead lines are present, be careful when extracting the probe because you didn't have to worry about it when you were assembling the sections one-by-one at ground level. However, once placed down the annulus it may be 25 feet or more long. When you go to pull it out the probe is now one tall piece! Use common sense and remember safety first.

If using a soil probe where a submersible pump has been installed, be cautious of unprotected buried electrical wires that may be near the well casing. Although you would expect the electrical wire to extend toward the building and away from the well casing the contractor may have looped excess electrical wire around the back side of the casing. Be extremely careful when resistance to the probe is encountered. Treat all wires as "live" and don't take chances by forcing probes through or around them. Always keep probe handles wrapped with electrical tape or non-conductive handle wraps.

3. Interpretation of Grout Probing Results

When a field evaluation determines that a well has not been properly grouted, the sanitarian shall contact the well drilling contractor and order correction of the violation using the following guideline:

a. Condition. Grout not observed directly below pitless. Annulus open part way. Grout found with probe at some distance down hole.

Grout is not observed just below the pitless adapter, and a clean, dry, open annulus is present around the casing. Probing the annulus reveals that approved grout material is present, but is more than a few feet below the pitless adapter. There are no liquids in the open annulus, and the annulus has no obstructions (side wall collapse, bridged material, etc.).

Corrective measures.

Option #1 - Extend a tremie pipe to the depth that the grout was found, and pressure grout from that point back to the ground surface. Neat cement or an approved bentonite grout may be used.

Option #2 - If the grout is within 10 feet of the pitless adapter, pouring grout from the surface is an acceptable corrective measure. Slowly pour coarse grade or granular bentonite into the annulus, tamping with a length of pipe as needed to prevent bridging. Continue this sealing method until the grout material reaches the pitless adapter or the ground surface.

b. Condition. Grout not observed with probe. Annulus contains water. No bridging observed.

Grout is not observed at the pitless adapter, and the annulus around the casing is open. The annulus contains muddy water or what appears to be a watery bentonite material that has not set-up. Probing the annulus deeper reveals that thicker grout material has settled 25 feet down the annulus. No bridging was found in the upper 25 feet of annulus.

Corrective measure. Extend a tremie pipe to the depth that the grout was found, and pressure grout from that point back to the ground surface or to a point just below the pitless connection. Neat cement or an approved bentonite slurry grout may be used.

c. Condition. Grout not observed. Annulus open. Probing does not find grout.

Grout is not observed at the pitless adapter, and an open annulus is present around the casing. Probing the annulus fails to locate any grout material, but the probing does reveal that the annulus to the depth probed is open (i.e., there is no bridging, sand, or any other material in the annulus.) Muddy water may or may not be present in the annulus.

Corrective measure. The well has not been properly grouted. The well drilling contractor must be contacted to discuss the violation. The contractor has two options:

Option #1 - Meet with the sanitarian at the site, and demonstrate to the satisfaction of the sanitarian that the well was in fact grouted, but that the grout material has settled to a point below where the sanitarian had probed. Generally, the contractor will place a tremie pipe in the annulus and extend the tremie down to the apparent bottom of the open annulus. Through jetting action or other means, it is best if a grout sample can be obtained to demonstrate that grout is present and that the borehole has not simply collapsed. Once that determination is made, the contractor can be authorized to pressure grout from the bottom of the annulus back to the ground surface or level of the pitless adapter. Neat cement or an approved bentonite grout may be used.

Option #2 – Properly plug the deficient well and annulus, then construct a new well. Plugging of the ungrouted well is not an easy task, since the annulus around the casing has not been properly sealed. Sealing the inside of the casing only does not protect the aquifer from surface contamination, since contaminants from the surface may still enter the aquifer through the unsealed annulus. The sealing of this open annulus must be addressed during the abandonment process and may require the removal or perforation of the casing if there is no other way to properly seal the annulus.

d. Condition. Annulus partially plugged with sand, cuttings, etc. Some grout found with probe.

Grout is not observed immediately below the pitless adapter but the annulus around the casing is not open. The annulus contains sand, cuttings, or other consolidated material and some grout. Deeper probing of the annulus reveals that uniform, approved grout material is present 25 feet down hole, but apparently settled in the annulus, above which the wall of the annulus apparently collapsed.

Corrective measure.

Option #1 - Reestablish a clean, open annulus by flushing the annulus (jetting) with water or drilling fluid, and then regrouting the upper 25 feet of now open annulus. Field experience has demonstrated that cleaning material out of a filled annulus to reestablish the open annulus is a difficult and time consuming procedure which is seldom successful. However, it is the well driller's option to pursue this corrective measure, if he/she so chooses.

Option #2 - Plug the well, and drill a new well. Casing removal or perforation is required as part of the sealing procedure to assure that the ungrouted annulus is properly plugged.

e. Condition. Annulus plugged with sand, cuttings, etc. Grout not found.

Grout is not observed just below the pitless adapter. Probing the annulus fails to locate any grout material, and the probing reveals that the annulus contains sand, drill cuttings, or other material that has filled the annulus.

Corrective measure. The well has not been properly grouted, and there is no practical way to reestablish an open annulus along the entire casing length for regrouting purposes. Section R 325.1669(2) of the Rules for Part 127, Act 368, PA 1978, states "If a health officer or the department determines that a registered well drilling contractor has improperly located or constructed a well, the well drilling contractor shall be responsible for plugging the well." The well drilling contractor must be contacted and ordered to plug the well. As noted above, casing removal or perforation is required as part of the sealing procedure to assure that the ungrouted annulus is properly plugged.

Common Problems Associated With Grouting

Bentonite Grout Problems

1. Using too much water. Each bentonite grout product has a specific maximum amount of water to use in the mixing of each bag of the grout. It is extremely important that bentonite grout is mixed according to the manufacture's specifications. Exceeding this maximum amount will lead to the following problems:

   a. Reduction in the percentage of solids in the grout. Instead of the grout having a solids content of 20 to 30 percent, the solids content may be as low as 5 percent.

   b. Reduction in the weight per gallon of the grout. Bentonite grout must meet the manufacturers minimum required weigh, but in no case shall it be less than 9.4 pounds per gallon with 15 percent solids. Some high solids bentonite grouts will exceed this weight.

   c. Preventing the proper "set" or "curing" of the grout material. The grout will remain in a "soupy" consistency, instead of turning into a "peanut butter like" consistency.

   When a bentonite grout with too much water has been placed in the annulus, the bentonite solids will settle to the bottom of the annular space, and excess water is absorbed by the vadose zone of the soil, leaving a long column of open annulus above the solids.

2. Bentonite grout "setting up" before being pumped into the annulus. This may occur because of one of the following reasons:

   a. Taking an excessive amount of time between mixing of the grout and pumping it into the annulus. Each bentonite grout product differs in the time required before "setting" or "curing" starts, ranging from a few minutes to 30 minutes. If pumping is delayed until "setting" has started, the pump may not be able to move the grout because of the high head conditions, or the grout may not flow to the pump intake.

   b. Excessive mixing temperatures. If mix water is warm, the time before "setting" of the grout starts is significantly speeded up because of the more rapid hydration (absorption of water) of the bentonite.

   c. "Sheering" of the bentonite during mixing. Some pumping or mixing methods tend to sheer (grind into smaller particles) the bentonite. This allows the bentonite to hydrate at a rate faster than intended, causing the bentonite grout to set up in a shorter period of time. Use of centrifugal pumps or jet mixers are common causes of sheering.

3. Grout mixture not "setting" properly after being placed in the annulus. This leads to settling of the bentonite solids to the bottom of the annulus, leaving an open annulus around the upper portion of the casing. Causes for grouts not setting properly include:

a. Using too much water in mixing the grout.

b. Excessive chlorine in the mix water (above 50 parts per million).

c. The pH of the mix water is too low. The pH of the mix water should be 8.5 to 9.0.

d. The mix water has hardness (calcium carbonate), which interferes with the hydration of the bentonite. Mix water must be free of hardness. Mix water should be treated with soda ash to remove hardness before being mixed with the dry bentonite.

e. Tannins or excessive salts (greater than 7,000 ppm) in the mix water. Tannins and salt break down the bentonite.

4. Failure to remove drilling mud and cuttings from the annulus prior to grouting. When using the "tremie pipe down the annulus" method of grouting, drilling mud and cuttings must be flushed out of the annulus using clean water prior to grouting.

If only clean water is in the annulus at the beginning of the grouting operation, the water, being lighter than the grout, is pushed up the annulus ahead of the grout as the grout is pumped into the bottom of the annulus.

A drilling mud/cuttings mixture can be heavier than bentonite grout. If it is left in the annulus, the bentonite grout will channel up around the outside of the tremie pipe instead of pushing the column of the drilling mud/cuttings up and out of the hole. When this occurs, a quantity of the cuttings and drilling fluid is left in the annulus. These solids settle to the bottom of the annulus, leaving a water filled or open space where the drilling mud/cuttings once stood. The heavier grout material above the open space then recedes into the opening, leaving an open annulus at the top of the casing.

5. Receding of the grout placed in the annulus, i.e., grout was pumped into the annulus from the bottom to the top, but was not present in the upper annulus a day later. This may be caused by any one or a combination of the following (most were discussed above):

a. Loss of water from the grout mixture into the vadose zone of the soil. The vadose zone is the dry portion of the soil above the saturated portion of the soil. When the grout is placed in the annulus, it has not yet set-up (hydrated). Normally, with time, the bentonite absorbs the water in the grout mix, and the grout solidifies to a peanut butter like consistency. If the water is removed from the grout before it can be absorbed into the bentonite, this hydration does not take place, and the bentonite falls to the bottom of the annulus or attaches to the sidewall of the annulus. Either way, only an open annulus remains.

b. Failure of the grout to properly hydrate (using too much water, poor mix water quality, etc).

c. Failure to remove drilling mud/cuttings from the annulus prior to grouting.

Neat Cement Grout Problems

1. Using too much water. A mixing ratio of not more than 6 gallons of water to one 94# bag of Type I or 1A cement must be used. Too much water will weaken the cement, reduce the solids content (minimum weight must be at least 15 pounds per gallon) and increase the likelihood of settling.

2. Insufficient mixing. The cement slurry must be sufficiently agitated to completely mix the cement with the water. If lumps of dry cement are in the grout when pumping begins, the lumps may plug the grout pump, the tremie pipe, or screens in the mixing tank. All lumps must be broken up or removed with a screen before entering the grout pump.

3. Failure to sufficiently clean equipment after grouting. Obviously, any residuals of the neat cement grout left in the grouting system will harden, causing equipment failure, plugged pipes, etc. Extreme care must be taken to remove all residuals of cement from grout pumps, mixing tanks, pipes, etc., after the grouting operation is completed.

Tremie Pipe Installation Problems

Installation of the tremie pipe to assure grout placement along the entire length of the casing may be a problem for some well drilling contractors. To meet minimum well construction code requirements, the tremie pipe must extend to the bottom of the space to be grouted. The following have proven to be effective methods of tremie pipe placement use by Michigan registered well drilling contractors:

1. Installing the tremie pipe to the bottom of the open bore hole prior to casing placement. Rigid (PVC, galvanized, etc.) tremie pipe is generally used.

2. Installing the tremie pipe at the same time the casing is being placed in the open borehole by attaching the tremie pipe to the bottom of the casing. The tremie pipe is taped to the bottom of the casing, and then tugged free after placement. Generally, polyethylene plastic pipe or collapsible vinyl pipe is used for this tremie pipe placement method.

3. Installing the tremie pipe down the inside of the casing, using draw down seals or a seal on top of the casing to prevent the grout from coming up into the casing.

4. Installing the tremie pipe after the casing has been installed by "fishing" rigid tremie pipe down the annulus. The use of this method is limited to shallower wells. For deep wells the end of the tremie pipe tends to get "hung up" on the side of the borehole, casing couplings, etc., preventing the tremie pipe from getting to the bottom of the casing.

PROPERTIES OF COMMON GROUTING MATERIALS

Material	Description	Attributes
Type I Cement	Most common type of cement used for grouting/plugging.	Forms good seal. Easier to mix and pump than bentonite. Required as grout where bedrock is encountered within 25 ft. of the surface and for plugging all wells terminated in bedrock.
Type III Cement	High early strength.	Not a common cement. Ground to finer particle size which increases surface area and provides faster curing rate.
Type IV Cement	Low heat of hydration.	Not a common cement. Used where the rate and amount of heat generated by cement must be kept to a minimum. Develops strength at a slower rate than Type I.
Type K Cement	Expansive cement.	Not a common cement. Basically Type I cement with additives to provide for rapid expansion. "Type K Komponent" is used for plugging abandoned wells.
Concrete	Neat cement with sand added. 50% sand by weight.	Less costly than neat cement. Provides a good seal. May not be poured from the surface through standing water due to separation problems. Can cause excessive pump wear.
Bentonite powder	Contain mixtures of sodium and calcium bentonite with other clays.	Drilling "gel." Various forms used in Michigan as the main component of most drilling muds.
Bentonite granular	Raw mined and particles are coarse granular (8 mesh is usual).	Intended for slurry applications to grout or plug wells. Low permeability. Slower water absorption and delayed swelling in comparison to powdered bentonite.
Bentonite chips	Large particle versions of granular products (.25-.75 in.).	Intended to be poured into a borehole or casing for plugging. Chips hydrate in place and swell to form a low permeability, highly stable seal. Water needs to be added above the water table.
Bentonite pellets	Powdered bentonite compressed into a pellet (.25-.75 in.).	Uniform in size. Same application as bentonite chips. Bridges easier and are more expensive than chips.

WATER WELL GROUTING MATERIALS SPECIFICATIONS

PRODUCT	WATER RATIO	WEIGHT/GAL.
Neat Cement	6.0 gallons max/sack of cement	15.0 pounds
	5.2 gallons recommended/sack of cement	15.6 pounds
Neat Cement & 1% Bentonite	6.0 gallons max/sack of cement	15.0 pounds
Neat Cement & 2% Bentonite	6.5 gallons max/ sack of cement	14.7 pounds
Neat Cement & 3% Bentonite	7.15 gallons max/sack of cement	14.4 pounds
Neat Cement & 4% Bentonite	7.8 gallons max/sack of cement	14.1 pounds
Neat Cement & 5% Bentonite	8.5 gallons max/sack of cement	13.8 pounds
Neat Cement & CaCl (accelerator)	6.0 gallons max/sack of cement CaCl - 2 to 4 lbs/sack of cement	15.0 pounds

Bentonite

Refer to the manufacturers specifications for water ratios and weights.
Refer to www.nsf.org/certified/PwsChemicals for National Sanitation Foundation (NSF) Certification

Concrete	1 sack of cement and an equal volume of sand per maximum 6 gallons water	17.5 pounds

*Calcium chloride accelerates the setting of cement. Rapid mixing and pumping of grout after adding calcium chloride is recommended.

NOTE: Neat cement is required in areas where bedrock is less than 25 feet from ground surface.