Thermal Grouting of Underground Transmission and Distribution Conduits

Guy Dickes, President, Constellation Group LLC guy@cgllc.us www.cgllc.us

ABSTRACT

Over the last several years, major advances in thermal grouting of underground power conduits have occurred. Distances up to 2000 feet have been successfully grouted using cementitious grouts. These grouts are designed to remove heat from the cables, allowing for better power transmission and improved insulation life.

KEYWORDS:

Thermal grout; Underground utilities; Transmission and Distribution; Conduit-in-casing;

INTRODUCTION

There are many reasons for installing transmission and distribution lines underground. This may be as simple as 'I don't want to see a tower in backyard'; or the maintenance issue of ice damage; environmental reasons; ask as many engineers and owners and you get as many different answers. Underground installation poses one major difference in cable environment than overhead lines- heat. Remove or minimize this heat and underground installation can become a very attractive alternative to overhead lines. There has been extensive study, testing, analysis and installation of underground lines with regards to heat removal/dissipation (www.geotherm.net). Until the last few years, few installations of long distance (over 500-2000 foot) horizontally drilled conduits-in-casing have been successfully installed and grouted. This paper will not discuss cut-and-cover installation. There have been two 2000 foot conduits-in-casing (Texas); two 950 foot (Colorado); several 500 foot (Colorado and Michigan); and numerous shorter successful grout installations, including jack and bore installations. With each installation new information and experience is gained. This is a rapidly advancing technology available to the power industry.

THERMAL GROUTING of UNDERGROUND UTILITIES

Thermal grouts are installed between the cable conduits in a cased or uncased borehole and the casing or bore. This grout's primary purpose is to remove heat generated by the electric current and dissipate this heat into the surrounding soil or rock. Heat removal serves two purposes- improved transmission of power (heat creates resistance) and improved insulation life. A 1% improvement in line efficiency can translate into huge savings for the power company. Extending the life of insulation is another major cost savings if cable lifespan can be extended.

Thermal grouting requires the same planning and execution as any other activity on a power construction project. Correct grout mix designs have to meet both the thermal requirements and constructability parameters to be successful. Coordination between the engineer and the contracting team is paramount. A mix design that works for thermal backfill (TBF) is not likely to work for conduit-in-casing grouting applications. A person understanding both sides of this issue plays an important role coordinating the best possible outcome. Executing the grouting program requires planning all aspects: technical, logistics and construction.

This paper does not discuss the thermal engineering aspects of underground utilities, but the correct construction of a thermal grouted installation. Thermal grouting starts with the thermal engineer's determination of heat generation; soil or rock conditions; and other engineering requirements. He will determine the necessary parameters for the thermal grout- how much heat must be dissipated by the grout. In general, this is thermal resistivity (or conversely, thermal conductivity).

Once the thermal requirements are understood, the correct grout mix must be designed for the application. It is at this point where differing requirements may be in conflict. The best materials (from cost/availability/thermal characteristics) for thermal dissipation and the best materials for grouting can be at different ends of the spectrum. Equilibrium must be reached between these two factors. By working with the thermal engineer, and understanding his requirements, Constellation Group LLC has worked with Geotherm, Inc. on a case by case basis to develop grouts that meet the thermal and constructability requirements of the project.

In general, cementitious thermal grouts consist of cement, aggregate(s), and water. It is the ratio of these products that determine the thermal characteristics of the grout. The lower the thermal resistivity, the better the thermal performance. In simple terms, cement has a moderately low thermal resistivity (TR), silica sand a low TR; water a high TR and air an extremely high TR. Increasing sand, and reducing cement, water and air content will improve the thermal characteristics. This does not create a good grout from a constructability standpoint. Hence, the need for equilibrium.

One concept must be understood- a flowable grout is not necessarily a pumpable and stable grout. A contractor or engineer seeing grout flow down the chute of a ready mix truck into a cut and cover installation should understand this grout may not be pumpable. Often it is not. A pumpable grout must be stable (in the hose, grout line, and casing) and not segregate or separate under the loads of a pumping operation. Adding water to a flowable grout does not make it pumpable and may make it worse.

In many thermal grout designs, using locally available materials is the most cost effective solution. This has been a satisfactory solution for shorter casing lengths (under 200 feet). As the lengths increase, the use of specialized trucked-in materials may become necessary. Grout samples must be tried and tested for pumping and thermal characteristics. Often as many as one to two dozen mix designs are necessary to reach this equilibrium. The use of chemical admixtures can improve both the constructability and thermal characteristics of the grout tested. There is no standard mix design; there are too many variables.

Often overlooked is one behavior of cementitious grouts- heat of hydration. The cement-water reaction creates heat, and often in sufficient amounts to melt plastic conduits. Heat of hydration of any given grout should be tested and planned for in the grouting operation. Tearing out melted pipe or replacing an entire bore is a very expensive proposition. Proper grout design and operational planning is required. All that may be necessary to mitigate heat of hydration is filling the conduits with water. This author has personally tested simple grouts that have reached over 101 degrees C.

Once a satisfactory grout mix has been designed, operational planning becomes the next step. Almost always, the logistics of grout delivery on-site is the critical path. There is no point of planning a grouting operation until a commitment from the local supplier is determined. In the case of the Austin/Davenport, grout was mixed on site in rented ready trucks. It was determined we could mix 50 to 60 cubic yards per day. The entire operation was planned around capacity. In Detroit, the supplier was also the general contractor and had a batch plant located a mile away. He was able to deliver 7 cubic yards every 20 minutes. We pumped 154 cubic yards in 12 hours. In Colorado (first project) we could not get grout until 1:00 PM, so we planned around this restriction. The point is made- determine grout availability before planning a grouting operation.

Once a grout mix design and availability are determined, a grouting operational plan can be implemented. This can include pumping operations, staggered grout pipe installation in long bores, traffic control, spoils control and other operational necessities. It is imperative to keep within the established plan. In the case of Colorado (third project) the increased availability (over that previously planned) of grout allowed for an accelerated program. Multiple casings were in involved, so the schedule was moved up to the next available pour, saving a day in a week long schedule.

Once an operational plan is implemented, Quality Control becomes paramount. In many cases, the cost of an HDD conduit-in-casing installation can run into the millions of dollars. To quote NASA/Apollo XIII, 'Failure is not an option'. Grouting must be done right the first time- period. Grout needs to be tested from every truck. Rejecting a truck load of grout is a small cost compared to ruining a 1000 foot bore. Generally, once a mix design is established, all that needs to be tested is Specific Gravity and Flow (efflux). Often air content can be tested as well.

RECENT SUCCESSFUL CASE HISTORIES:

Austin/Davenport, Texas:	Two 2000 foot conduits-in-casing; 360 cubic yards of grout; HDD
Colorado Springs #1:	One 950 foot conduit-in-casing; 170 cubic yards; HDD
Detroit, Michigan:	Two 450 foot conduits-in-casing; 154 cubic yards; Jack and Bore
Longmont, Colorado:	Seven (various length 100-205 foot); 189 cubic yards; Jack and Bore
Colorado Springs #2:	Four (400, 500, 600, 950 foot) conduits-in-casing; 380 cubic yards; HDD

Of utmost importance, when using new materials or mix design, is the execution of a full scale mock-up. This was performed first at Austin/Davenport. One thousand feet of 3" HDPE was laid out on the ground. A fifty foot full scale mock-up of the conduit-in-casing was buried with one end into the ground. Forty engineers and interested parties were on hand. After a truck load (7 CY) was mixed, quality control testing was performed. It was determined the grout was slightly heavy (higher specific gravity) with a slightly slower efflux (ASTM C939). Ten gallons of water was added to the truck. The S/G and efflux were now in compliance. The grout was introduced into the grout pump. The initial hopper of grout had some additional water added (called slicking) to help wet the grout hose and line. After several minutes of slow pumping, grout exited the 1000 foot grout pipe. At this point the grout pipe was attached to the mock-up section and grouting continued until grout exited the mock-up. This test passed- but more importantly, gave everyone- from the Owner to the Engineer to the Contractor the comfort level that we could and would be successful. This was the first successful long-bore grouting project- and it was done twice (two 2000 foot bores).

In Longmont, because a substantially different mix design was being used, the mock-up was again used to test the mix design. In this case, a two hundred foot section of 3" PVC pipe was laid out. The grout was easily pumped this distance.

Upcoming projects include a 3000 foot uncased bore in Canada. Constellation Group LLC has been involved on the engineering team in this particular case. There have been numerous cases of failed grouting in uncased bores (last being in the mid-eastern United States) and we want to ensure this does not happen in Canada. We use our collective experiences to plan each project. Using a similar mix design in Colorado Springs (#2) as planned for in Canada, we know the grout will pump the distance. What were encountered in Colorado Springs were casings filled with water from a local storm event. The grout easily displaced the water reducing concerns about displacing drill mud in the uncased bore. A major part of the Canadian project is a full scale mock-up: pumping through 1500 feet of grout pipe and then into a 150 deep hole filled with the planned drill mud. Instrumentation will include temperature pressure sensors along the grout pipe and into the drill hole.

Typical Thermal Grout Requirements:

1. Low thermal resistivity; to transmit heat to the surrounding rock from the electrical transmission lines- to be determined by the thermal engineer
2. High Flow (low efflux) so the grout would flow around interstitial spaces and spacers; and would require low pumping pressures to avoid crushing the conduits
3. Low heat of hydration — high cure temperatures can soften HDPE or PVC conduits
4. Long set times — it may take all day to place 50-75 CY of grout
5. The grout had to be homogenous — it cannot separate and be pumpable
6. Low shrinkage — the engineers have to ensure complete filling of the pipeline or bore

Efflux of very extremely fine aggregate grouts should be tested with a standard ASTM C939 flow cone; as in Austin and Colorado Springs. Slump testing was necessary in Longmont due to the coarser aggregate used. A standard oil field mud balance or digital scale with calibrated cup can be used for Specific Gravity testing.

Heat of hydration can be tested prior to actual installation. Heat of hydration can be addressed using chemical admixtures, use of specific aggregates, and static filling or continuous flushing of conduits.

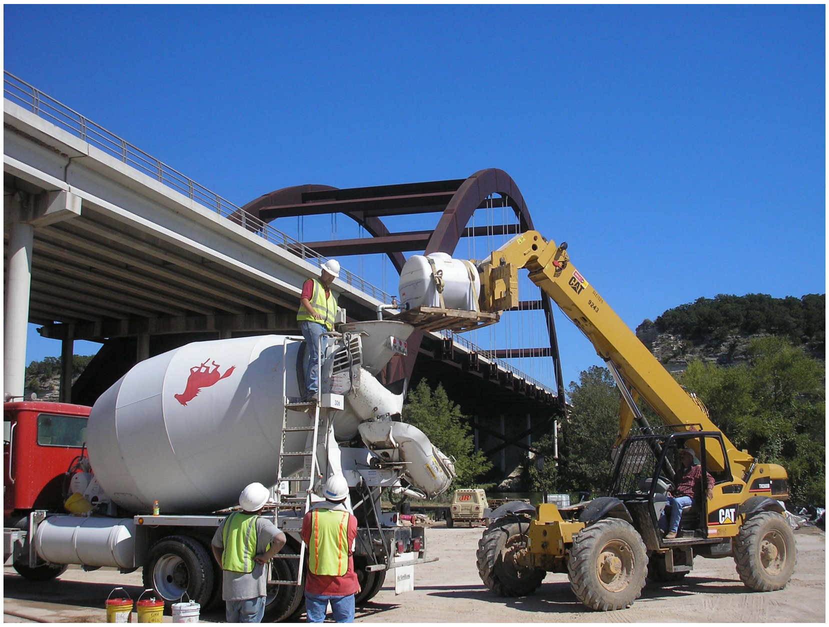
Cement based grouts can generate a considerable amount of heat and can melt PVC conduits used in underground installations.

Pumping pressures have to be determined and maintained to prevent crushing of conduits deep in the bore. By using high-flow stable grouts, this pressure is minimized, making pumping easy and minimizing crush issues.

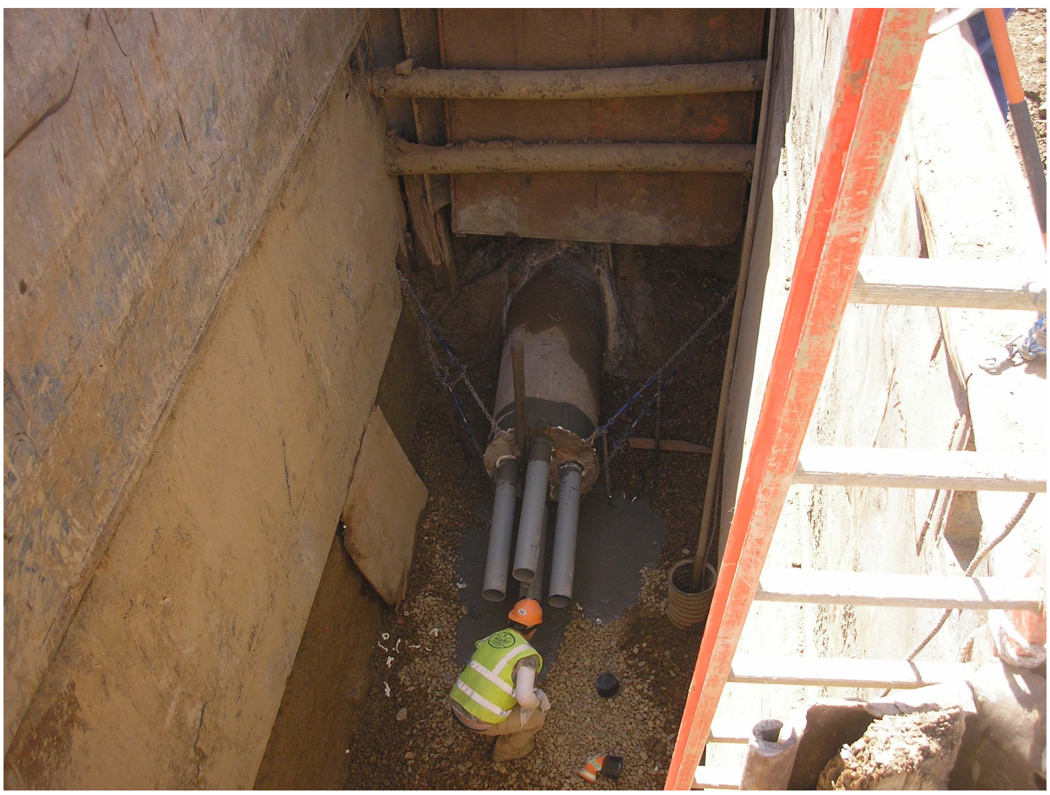
The photos attached show various aspects of a thermal grout operation, including what happens when an inexperienced contractor performs beyond his ability or understanding.

Austin/Davenport Complete

One End of a Two Thousand Foot Casing

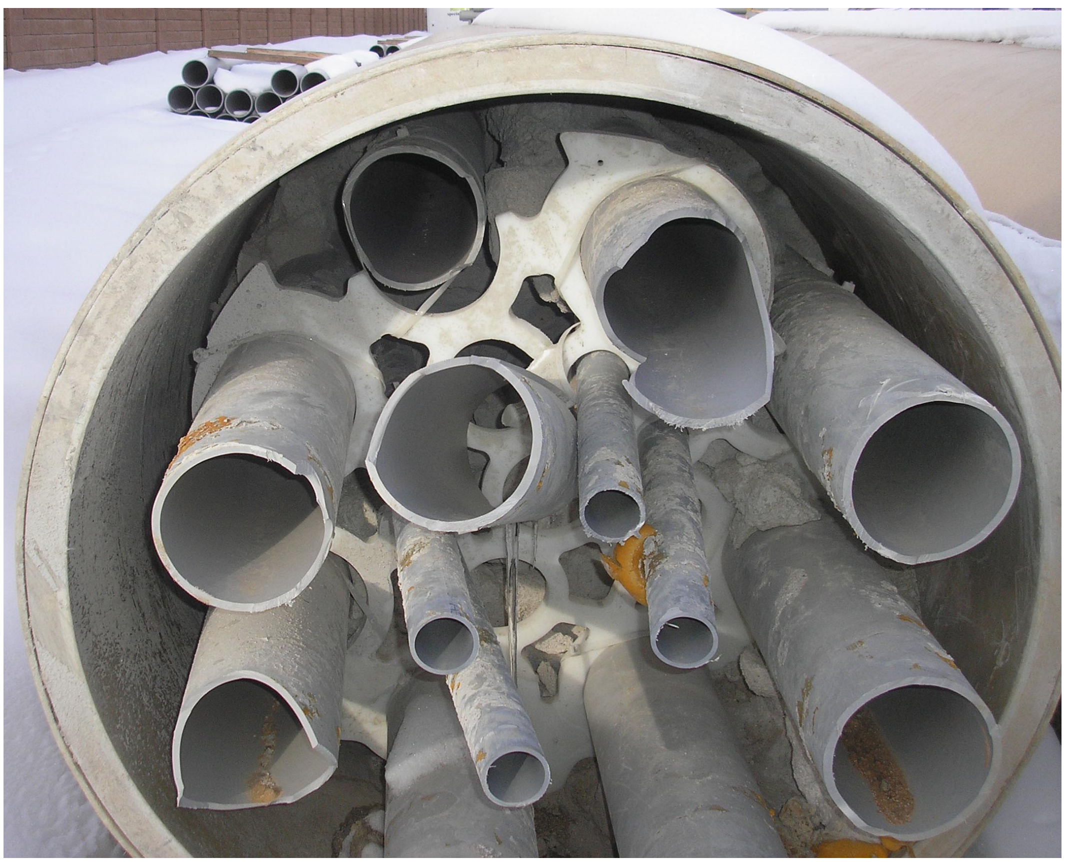


Adding Admixture in Texas



Jack and Bore in Colorado

Installing End Bulkhead in Colorado Springs



This was an Expensive 'Oops'   Don't Let This Happen to You!!

Thermal Grouting of Underground Electrical Utilities has come of age. Underground bores in the thousands of feet can be successfully grouted by the right team. Go Underground!!

Acknowledgements:

Deepak Parmar, Geotherm, Inc. (www.geotherm.net) for his support and expertise

Don McCoy, Underground Devices, Inc. (www.udevices.com) for his support and expertise