



North American Society for Trenchless Technology (NASTT)
NASTT's 2013 No-Dig Show



Sacramento, California
March 3-7, 2013

Paper MM-T2-03

Record Setting Installation of 1.2 mile 115kV Electrical Transmission Line Under Intracoastal Waterway – Case Study on HDD and Thermal Grout Considerations

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ABSTRACT: PowerSouth's Wolf Bay Crossing in Orange Beach, AL was a challenging and innovative HDD crossing involving the complex installation of large-scale electrical transmission lines with thermal grouting. The project involved installing 6,200-feet of 36-inch steel casing by HDD using the Pilot Hole Intersect method under an Intracoastal Waterway with depths of 110 feet. This paper provides owners, engineers, and contractors with valuable insight into the limitations and challenges involved in completing the bore which is now the longest of its kind in the United States, doubling the record for thermal grouting with HDD, and setting the record for longest installation of continuous cross-linked polyethylene insulated (XLPE) cable rated at 115-121kV and 300MVA.

Once the 36-inch steel casing was installed, multiple HDPE pipes were bundled and pulled into the casing (five 10-inch and one 8-inch pipe) with stainless steel bands spaced throughout the length of the bundle. The conduit pipes were used to house XLPE cable pulled through the conduits. Thermal grout was installed around the conduits to dissipate heat caused by high voltage power transmission. While the science of thermal grouting has an established history, it has only recently been successfully used on long HDD bores. Ultimately, an innovative design resulted in a highly fluid material that was easily pumped and distributed throughout the 6,200-feet of casing pipe, effectively interacting with the transmission line while satisfying specified strength and thermal resistivity parameters.

1. PROJECT BACKGROUND

As economic growth and expansion in the Orange Beach and Gulf Shores areas continue, PowerSouth Energy Cooperative's transmission system was nearing capacity. During the planning phase, there were six substations located south of the Intracoastal Waterway in Baldwin County, served by two transmission line feeds. A reliability study determined that a single point of failure along the transmission system serving Orange Beach could cause multiple outages with potentially long restoration times. The solution to potential reliability problems in the Orange Beach area was to bring a third transmission line feed onto the system south of the very deep Intracoastal Waterway within Wolf Bay.

PowerSouth employees developed a plan for a transmission line of 6 miles, which included 4.9 miles overhead work (above ground) and an approximate 1.2 mile (6,200-feet) segment to be directionally bored under water. A great deal of preliminary work was completed before boring the line under the bay, including feasibility studies, environmental reviews, routing, soil testing, land surveys and unique hydrographic surveys of the work site. Waldemar S. Nelson & Company served as the lead project consultant, handling the detailed engineering and design, material procurement and construction management. Southeast Directional Drilling won the award for construction and HDD services as a prime contractor. The Constellation Group was retained as an expert thermal

grouting consultant by Southeast in order to complete the thermal grouting scope in-house. The project was completed over a six-month period ending in April 2012. See Image 1 for project overview and area.



Image 1 - Project overview and aerial photograph of the project area.

2. HDD AND PIPE FABRICATION

A. Preliminary Work and Conductor Barrel Casing.

For the bay crossing, Southeast Directional Drilling mobilized two HDD rig spreads. Both drill rigs were modified American Augers machines with pullback capacities of 1,100,000 and 625,000 pounds. Each rig spread included mud systems, mud pumps, drill pipe, tooling, and other support equipment. Fabrication of steel casing and HDPE conduits that would later go in the casing were performed concurrently with drilling operations by Energy Services South (ESS) and M&M Pipeline Services.

Before HDD could begin, approximately 220-feet of 60-inch diameter, steel conductor barrel casing was proposed and used by Southeast to protect the active Florida Ave. substation at the south end of the crossing from impacts of the HDD process. After the conductor casing was installed, the substation would not need to be de-energized for the duration of the HDD work scope including the installation of the 36-inch steel casing and HDPE conduit bundle installation to follow.

The conductor barrel casing installed by pneumatic hammer was sized so that its 220-foot length would extend through the limits of the substation and its 60-inch diameter size would allow the largest down hole tool, a 48-inch reamer, to pass through. The conductor casing remained in place after completion of the HDD segment.

After driving the casing to the desired length of approximately 220-feet, it was augered out with 42-inch diameter auger segments connected directly to the drilling rig's drill stem. Once the final soil material was removed from the conductor casing, a 16-inch diameter centralizer pipe was installed to center the drill stem while completing the pilot hole and ream passes.

B. 36" Steel Casing Installation

Next, the 36-inch diameter steel casing pipe was installed by HDD throughout the 6,200-foot long crossing by using Pilot Hole Intersect Method. This method involved two drilling rigs boring simultaneously from opposite ends of the long crossing until they reached a point of intersection near the center of the crossing approximately 3,100-feet away from each rig. At that point, the secondary rig retracted drill pipe while the primary rig's drill pipe followed it up the borehole without deviation from the planned path. Special tracking software was required in conjunction with the hole intersect method, which made the length of installation technically feasible.

Throughout the drilling process, SEDD monitored operations, including drill times, pull and push pressures, rotary torque, rpm, differential, soils removed, drilling fluid pressures and other fluid data, and flow rate being pumped. The disposal of drill cuttings and spoils and displaced drilling fluid complied with applicable regulations.



Image 2 - HDD rig performing Pilot Hole Intersect Method

Once the pilot hole was complete, Southeast completed the reaming operation in two ream passes. The reaming strategy was subject to change depending on the types of soil encountered during drilling the pilot hole and each ream pass. The reaming progression used after these observations consisted of a 36-inch diameter initial ream pass followed by a 48-inch final ream pass. The 48-inch ream pass was followed by a mud or swab pass immediately prior to pulling in the 36-inch steel casing pipe. The drill stem was connected to the pulling assembly consisting of a tapered ball reamer, swivel, shackle, and pulling head for the 36-inch steel casing pipe. The pullback operation was a continuous operation once started until completion.

Pullback installation of the 36-inch steel casing was successful, albeit longer in duration than anticipated. Southeast estimated about 20 continuous hours to install the casing as compared to the 68 continuous hours it actually required. The challenges faced were apparent after the initial pullback attempt as the geological formation continuously allowed the drill stem to become key-seated in the bottom of the borehole, creating a challenge to keep the reamer, which is located directly in front of the pulling assembly, from rotating freely.

In order to overcome these challenges during the pullback, Southeast delayed pumping ballast water during the initial stages of the pullback in an effort to use the buoyancy forces on the 36-inch steel casing to assist with the rotation of the reamer. Southeast also used a pneumatic hammer located at the north end of the pipeline to assist in breaking the frictional forces throughout the pullback.

C. HDPE Fusion and Bundle Installation

HDPE fusing and bundle assembly activities were performed concurrent to the HDD operation. Once the 36-inch steel casing was installed, multiple HDPE pipes (five 10 inch and one 8 inch pipe) needed to be bundled and ready to be pulled together into the casing. Two inch wide and 0.44-inches thick stainless steel banding spaced at eight foot intervals throughout the length of the bundle held the bundle together as it was installed.

The HDPE fusion and lay-down area was on the north side of the crossing along the right-of-way and adjacent to the 36-inch steel pipe fabrication area as shown in Image 4 below. HDPE fusion occurred in one location with the conduits extended in length until each respective conduit pipe string was complete. Each conduit was initially pulled along rollers during fabrication until the fusion process was completed. Once all conduit strings had been fused to final lengths, the conduits were removed from the rollers and placed on the ground for preliminary hydrostatic testing. Once the test was performed with successful results, the water from each conduit was removed by passing a foam pig through each conduit with air pressure. Once all conduits were dry, they were placed back onto the rollers bundled, and finally pulled into the 36-inch steel casing.

The conduit pipes in the bundle were designed to house XLPE cable specially imported from Japan, to be pulled through the installed conduits by a cable contractor upon completion of Southeast's scope of work. However, before Southeast could turn over the pipeline installation to others, a completed bore path profile was generated and used in developing a strategy for the final thermal grouting activity required by design requirements. This last activity was also under Southeast's scope of work and the thermal grout design, production, and QA/QC process included finding suitable suppliers for the necessary materials and adapting production capabilities to the highly specialized process. The next section of this paper will provide insight into the thermal grouting activities and process.



Images 3 & 4 - Bundle pull-in (left) and layout of 36" steel casing with HDPE conduits prior to respective installations (right)

3. THERMAL GROUTING

Grout Requirements; Mix Design and TR Testing

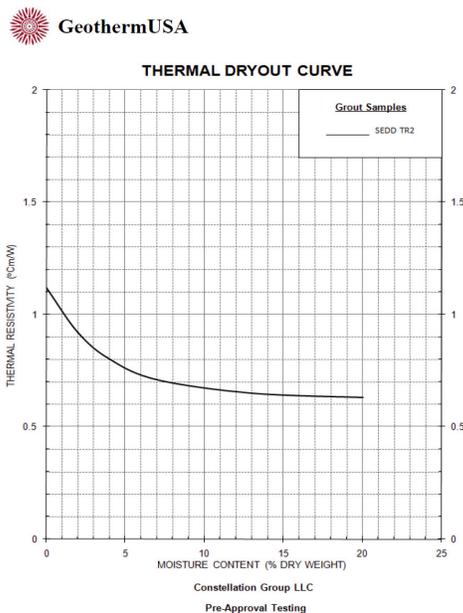
Waldemar E. Nelson, New Orleans, LA was the design engineer on this project. Based on a. their limited prior experience with thermal grouts in horizontal directional drilling (HDD) applications and b. operational needs of the Owner, they took a very conservative approach to their grouting requirements for the project. In summary, the thermal grout:

- Thermal resistivity (TR or rho) of 1.5⁰C-m/W at 0% moisture
- Sufficient grout to lock the conduit bundle into the casing (it was not a project requirement to fill the casing 100%)

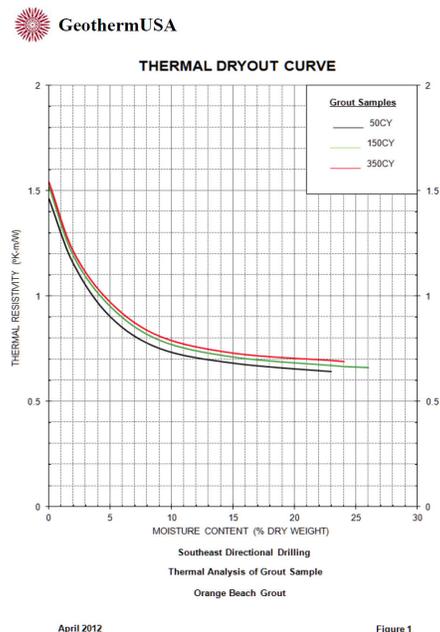
Southeast Directional Drilling (SEDD) and Constellation Group LLC (CGLLC) took it upon themselves to fully grout the casing. Prior to grouting on site, a mix design needed to be developed to meet the needs of the client and the operational requirements of the project.

CGLLC undertook this portion of the project. Working with SEDD to locate a ready-mix supplier was the first step in the process. As each ready-mix supplier uses both different cement and admixtures, it is imperative to develop grouts from locally sourced materials, and have the grouts tested using these materials. Similar mix designs, using different dry materials and different admixtures, may result in significantly different TR values. A mix design in New Orleans is likely to produce different results in New York.

Initial samples produced, using the materials to be used in production, resulted in very good characteristics. The basic materials for thermal grout are 1. Cement, 2. Silica, 3. Water, 4. Admixtures. By varying percentages, significantly different grouts can be produced. Small amounts of water can alter the thermal resistivity. In the results shown below, a reduction of dry specific gravity of only 2.7% has a noticeable impact. The ready mix supplier (Baldwin Concrete) uses Euclid Chemical admixtures, thus the local representative was contacted and consulted, to provide the necessary admixes and technical support for the project.

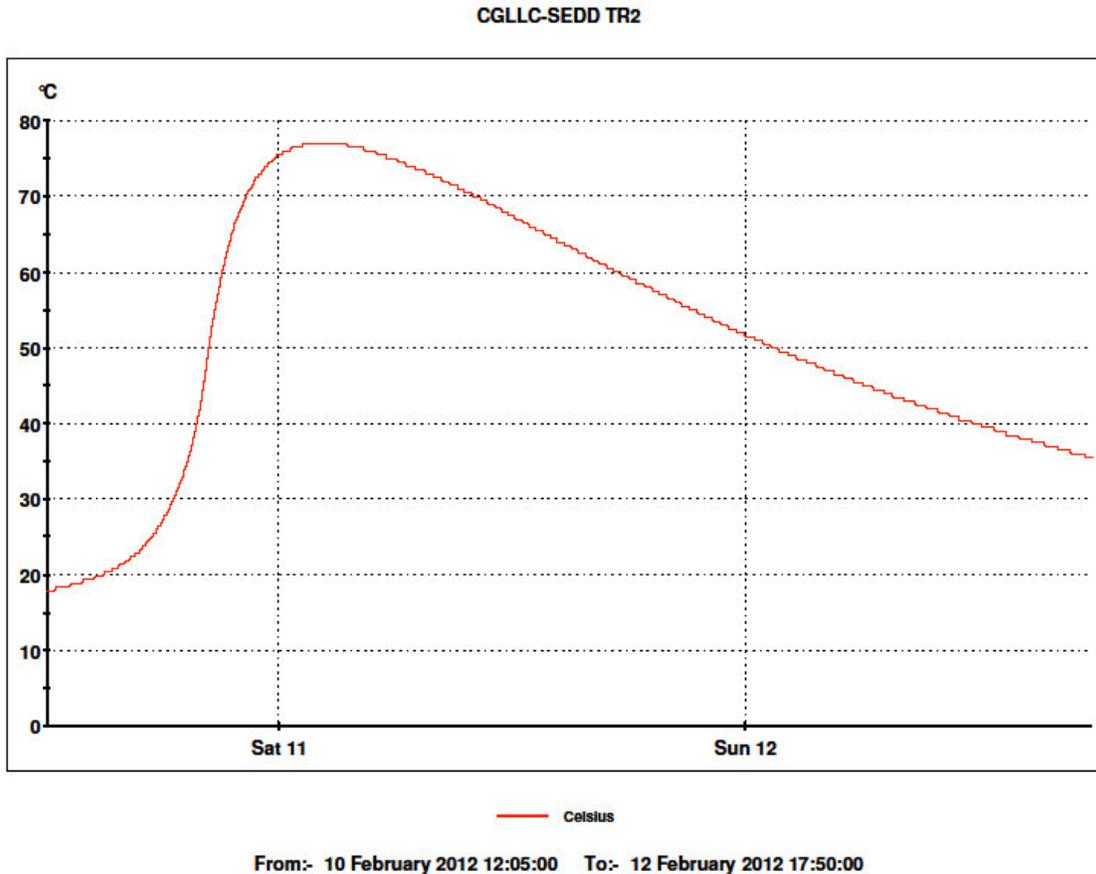


Graph 1 TR Results from Initial Testing



Graph 2 TR Results from Field Samples

A representative sample was tested for Heat of Hydration. It is imperative when working with cementitious grouts to be aware of the rise in temperature caused by the chemical reaction of cement and water. Admixtures can be used to control and modify the chemical process. See Graph 3. Maximum temperature reached 76.6°C or 170°F; sufficient to damage or melt PVC. Care must be exercised when using any cementitious grout.



Graph 3 Heat of Hydration Test

Planning:

This is perhaps the hardest part of grouting. There is a myriad of details that must be addressed and adhered to during grout production and construction. From diameter and location of sacrificial grouts, to marking those pipes; to schedule; to having the right connections and pressure gauges for those grout pipes. Quality control procedures must be developed and maintained. Driving times from the grout mix location to pump location must be taken into account. Specialty admixtures and dosing equipment has to be available. Pump and operator needs to be contracted and scheduled.

Once a mix design is finalized, the simplest and most effective Quality Control technique used in the field to ensure consistent batches is Specific Gravity(S/G). If the is correct, then the proportions of water to dry materials are correct. Encountered at another project, a batch of 7 cubic meters had an S/G of 2030 kg/m³; where correct S/G was 2080 kg/m³. A return to the mix station and the addition of one metric tonne of dry material brought the grout into specification. A digital scale and calibrated canister are what is necessary. An oilfield mud balance works as well.

During grout production, particularly when using ready-mix companies is to ensure Batch One and every subsequent batch is repeated accurately. Repeatability is of greatest concern. If Batch One is off, it can be corrected, as long as the finalized batch is then repeated perfectly. This was performed very satisfactorily by Baldwin Concrete. Baldwin

Concrete is a subsidiary of Shelby Concrete. Charles Jones, from Shelby provided plant quality control and acted as liaison for Baldwin. As was the case at Orange Beach, specialized materials not carried by Baldwin, were required. This included certain admixtures and dry materials. Sufficient quantities need to be ordered and stockpiled prior to production.

Grout Supplier; Logistics

This may seem like a simple task, but it is not. In general, local concrete ready-mix suppliers are not enthusiastic about small orders of specialty grout. It takes them out of their daily routine, and ties up their equipment used to service their location clientele.

Fortunately for SEDD, Baldwin Concrete stepped up to the plate. The first ready mix supplier contacted seemed to have lost our phone numbers. By utilizing a local idled ready-mix plant, we were able to stockpile the necessary dry and wet materials without interrupting local concrete service. Roughly 40 percent of the dry materials came into the plant in ‘supersacks’; 2000 pound poly bags. With nearly 700 cubic yards of grout required for this project, this resulted in a large pile. Additionally, as this grout was roughly 60% cement, a local supply of cement was needed to restock the silos. The admixture supplier was Euclid Chemicals.

The supersacked materials were manually added to the ready mix trucks, utilizing a large excavator (Photo 1)

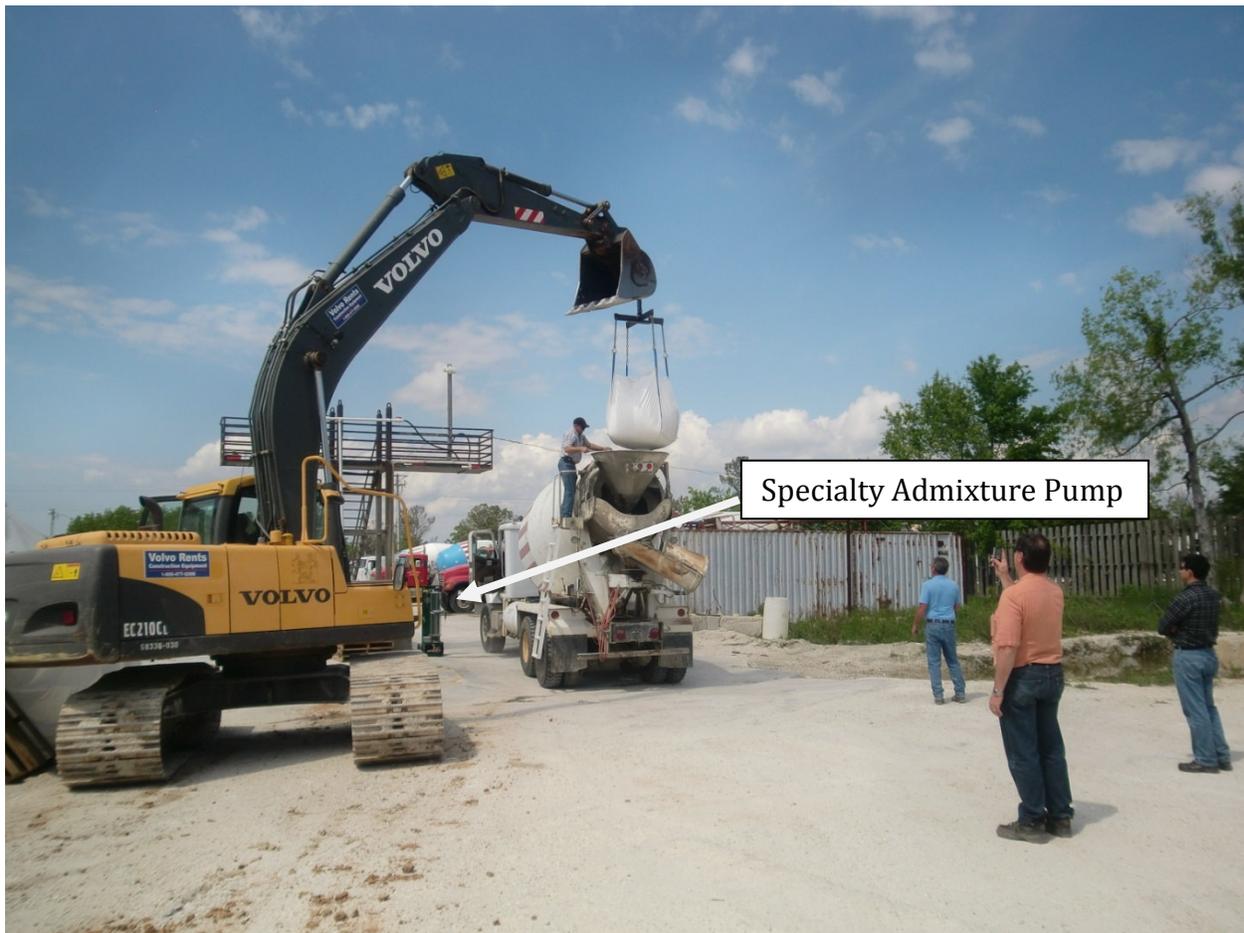


Image 5- Loading Dry Materials at Baldwin Concrete
This was a trial batch done prior to production grouting

Grout QC and Installation

This is easiest part of the thermal grouting process. If the mix design is correct, and the plant is delivering a consistent product (as was the case with Baldwin); the grouting process is just plain boring. A ready mix truck arrives, discharges and leaves; and the next truck arrives, etc. At 7 cubic yards per truck and 400 cubic yards the first day, it was repetitive. As the specifications and quality control program were not stringent in this case; samples were taken from the first third, second third and third of the daily delivery for TR testing. Specific gravity (or slurry density) tests were taken from nearly every truck. The ready-mix plant was extremely consistent, with very little variation from target specific gravity (119 pcf). One lesson learned from this project, and others, is that mix designs from the shop need to have their water content reduced in the field by about 5-10% to produce similar TR results. Moisture content in lab and field dry materials must be taken into account.



Image 6- Twenty Second Flow Grout (ASTM C939)

Strategically placed grout pipes (all 4 inch HDPE) were located at different locations along the conduit bundle. Although 10 grout pipes were installed, it was necessary to use only three for the entire project of 670 cubic yards. As grout was pumped, the water filled casing drained into retention ponds at either end of the bore. This required sump pumps frac tanks or vacuum trucks to be used to extract and contain the water. A truck mounted Schwing piston line pump never needed to go above idle to pump the entire HDD line. The line pressure shown in these photos show the 'on' and 'off' stroke pressures with grout being pumped at 25 cubic yards per hour through a 2100 foot 4 inch HDPE grout line.



Images 7 & 8- Grouting Pressure “Off” and “On” Stroke

Grouting Summary

Long distance thermal grouting has become a reality in underground electrical utility construction. Each project is unique. Specifications and requirements must be developed during the engineering phase of each project. Too often, this author has seen ‘cookie-cutter’ specifications and old mix designs that will not work as part of construction documents. Working with experienced contractors and engineers, the electrical utility industry can move their transmission and distribution lines safely underground, and at significant lengths. This record establishing grouted crossing of over 6,100 feet can easily be extended to greater lengths. Each project brings more experience and expertise to the industry.

7. CONCLUSION

The Wolf Bay Crossing Project presented unique challenges. These challenges were overcome by a combination of enhanced project management and technology utilization during HDD operations and use of personnel whose special expertise could help with the overall conduit bundle fabrication, conductor barrel casing, environmental regulations, and grouting supervision and logistics.

Working closely with selected vendors improves overall quality. As grouting lengths become greater, another variable in grout design becomes evident. With greater lengths comes longer grouting times, meaning grouts need to stay fluid longer. Although this factor did not impact our project, it was a variable not previously anticipated and could have had a direct effect on a project.

In line with the overall project strategy, thermal grouting was an engineered solution, not an afterthought, and involved a high level of collaboration among all parties. The outcome and considerations presented as a result of this project should help secure combined HDD and thermal grout design as a viable option in future planning of similar large scale underground transmission lines.