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Grouting for Off-Shore Wind Electric Lines Land Approach

Off-Shore Wind Farms require Sub-Sea Cables to supply electrical energy generated by the Wind Turbines to the land. The electrical cables laid on the ocean floor have a sea-land transition for connection to the power grid. The electrical cables are encased by a conduit pipe, which is typically installed using a Horizontal Directional Drilling (HDD) method at the sea-land transition. Within the protective conduit pipe, the electrical cables require an engineered thermally resistive grout to aid in thermal energy dissipation produced by the electrical cable.

The designers of the electrical cable at the sea-land transition required a “pump-able” grout with a thermal resistivity of 1.0 m.C/Watt (0.58 BTU/hr.ft.°F thermal conductivity). BAROID IDP modified a current geothermal grout system, originally used for Ground Source Heat Pump geothermal loop installation grouting. The MAX-YIELD™ Grout System, utilizing a low-solids bentonite base (MAX-YIELD™ HP) and a graphite component (MAX-YIELD™ TCM), was designed to meet the specifications for the project. The requirements were to fill 955 meters (3,150 ft.) of a 16” OD X 12.23” ID HDPE pipe containing a nominal 4.25” OD electrical cable.

Grouting Objectives

Grouting Formulation & Design

- Grouting was tested at the BAROID IDP Laboratory in Houston, Texas
- Initial product testing specifications were as follows

Water	38.5 gallons	
MAX-YIELD™ HP	50 lbs	
MAX-YIELD™ TCM	13.5 lbs	
FANN 35A readings	**Low Shear**	**High Shear**
600 rpm	48	82
300 rpm	33	68
200 rpm	25	52
100 rpm	16	40
6 rpm	13	25
3 rpm	13	25

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Grouting methods traditionally require pumping via “tremie” lines, enabling the grout to be pumped through the “tremie” lines, and displacing and filling the pipe from one end back to the other end. This project required the grout to be pumped from the land to the ocean floor side, at depths (~ 20 ft.) below sea level without using “tremie” lines; therefore, a grout would have to maintain the ability to pump uniformly and flow through the 12.23” ID pipe, displacing seawater within the pipe. Additionally, the grout needed to have the capability of mixing in large volumes and pump continuously to displace the saline water from the conduit pipe at the ocean floor to a barge on the surface above. The grout needed to gel as a homogeneous mass, filling the conduit uniformly and surrounding the electric cables. Finally, the customized grout required a thermal resistivity of 1.0 m.C/Watt (0.58 BTU/hr.ft.°F thermal conductivity).

Project Site:
Land side conduit pipe with bulkhead supporting electric cable and grout line. Pipe extends 3,200 ft. beyond dunes to seafloor, 20 ft. below sea level. Picture taken from holding tank showing pump used to pump the grout.

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Jack-up barge at end of conduit pipe in 20 ft. of water approximately 2,000 ft. off the beach.
Grout plug pumped first and displaced to barge.l MAX-YIELD™ Grout System followed to fill the conduit and hold the electric cable. Cable-Boat in the distance laying the cable to Wind Turbines location 27 miles off the coast.

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After the Electric Cable is pulled from the ship through the conduit pipe to land, the Cable Boat continues laying the cable for 27 miles out to the Wind Farm Site off the coast.

The MAX-YIELD™ Grout System proved to meet the requirements for the project, including efficiently mixing in large volumes and maintaining thixotropic properties while mixing and storing with circulation. The MAX-YIELD™ Grout System was pumped with minimal pressure (25 PSI max) at 50 GPM. Once pumped into place and filling the conduit, the MAX-YIELD™ Grout System gelled to a yogurt consistency providing a homogeneous mass with the required thermal resistivity of 1.0 m.C/Watt (0.58 BTU/hr.ft.°F thermal conductivity).

The mix ratios guidelines for the MAX-YIELD™ Grout System was established at:

1. 1,000 gallons water
2. 25 bags (1,250 lbs.) MAX-YIELD™ HP
3. 6 bags (216 lbs.) MAX-YIELD™ TCM

Approximately 19,500 gallons of MAX-YIELD™ Grout System was mixed and maintained in a holding tank. A bentonite plug of MAX-YIELD™ HP (~ 1,500 gallons @ 25 bags/1,000 gallons) was pumped, displacing the saline water and filling the conduit. The displacement plug was immediately followed by the MAX-YIELD™ Grout System until the conduit was full and grout was detected on the barge. The conduit was filled with (~16,800 gallons) of MAX-YIELD™ Grout System.

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Samples taken during the pumping phase of the project established that the grout:

1. Mixed easily and uniformly
2. Maintained flow-ability (Thixotropic properties) while stored in large volumes
3. Pumped with minimum pressures
4. Consistently met the required thermal resistivity of 1.0 m.C/Watt (0.58 BTU/hr.ft.°F thermal conductivity).

Rheology of samples tested on the job site:

Sample gathered after pumping 10,000 gallons

MAX-YIELD™ Grout System	FANN Model 35 Viscometer
Mud Weight	9 ppg
600 rpm	51
300 rpm	48
200 rpm	46
100 rpm	46
6 rpm	55
3 rpm	54
10 sec	57
10 min	130
Funnel Viscosity	3m 40 sec / qt.
Filtrate	19.2 mL / 30 min
Thermal Resistivity	1.1 m.C/Watt

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MAX-YIELD™ HP and MAX-YIELD™ TCM added through mixing hopper. Mixed 1,500 gallon batches in a 3,000 gallon KEM-TRON Mud cleaning system. Mixed batches transferred to a 20,000 gallon tank
Per batch:
1,500 Gallons Water
38 Bags (1,900 lbs.)MAX-YIELD™ HP
9 Bags (324 lbs.) MAX-YIELD™ TCM

Bulkhead with Electric Cable pulled from the ocean side through the 3,200 ft. conduit. Grouting line and valves to allow grout to be pumped into the conduit for continuous filling of 16,800 gallons of MAX-YIELD™ Grout System.

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Electric Cable Bundle for electrical power generated from Wind Turbines (27 miles off the coast) to the power grid on land.

Grouting completed successfully with conduit filled and valves closed. MAX-YIELD™ Grout System pumped smoothly at 50 GPM and maximum pressure of 25 PSI.

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The MAX-YIELD™ Grout System proved to be an efficient cost effective grouting process for Electrical Cable grouting requirements. The MAX-YIELD™ Grout System can be mixed with basic mixing equipment in large volumes, and will remain thixotropic while stored and circulated in holding tanks. If gelation starts forming, with no or minimal movement of the mixed grout, the MAX-YIELD™ Grout System will resume thixotropic properties as mixing resumes. When the MAX-YIELD™ Grout System is placed in the pipe and pumping ceases, gelation begins within minutes. The MAX-YIELD™ Grout System forms a gelled mass that has a shear strength of 30 – 40 lbs./ 100 sq. ft., as measured with a FANN SHEAROMETER on a sample collected from the project.

MAX-YIELD™ Grout System sample gelled in SHEAROMETER cup. Grout sample aged 3 weeks. Sample taken from container and placed in SHEAROMETER cup. MAX-YIELD™ Grout System reformed (gelled) providing shear strength.

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Shear test performed using the SHEAROMETER of a sample taken from the time of filling the conduit. Sample allowed to set for 3 weeks:

1. After 1 minute: 40 lbs./ 100 sq. ft.
2. After 10 minutes: 40 lbs./ 100 sq. ft
3. After sitting on the grout for 1 hour: 30 lbs./ 100 sq. ft

SHEAROMETER reading of MAX-YIELD™ Grout System after shear tube set in grout 10 minutes:

40 lbs. / 100 sq.ft.

SHEAROMETER reading of MAX-YIELD™ Grout System after shear tube set in the grout for 1 Hour:

30 lbs. / 100 sq.ft.

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Advantages of the MAX-YIELD™ Grout System

BAROID Industrial Drilling Products (IDP) customized a grout to meet the challenges of the Off-Shore Wind Energy Transmission Market. Traditionally, grouts used for this application are a combination of sand, cement and bentonite; however, the equipment commonly used to mix, pump and tremie these traditional grouts for extended distances is expensive and labor intensive.

The BAROID IDP - MAX-YIELD™ Grout System is designed for easy mixing and pumping. The MAX-YIELD™ Grout System can fill the protective conduit pipe, stabilizing the electrical cables, without the use of tremie lines. The MAX-YIELD™ Grout System is able to displace the seawater within the conduit pipe, fully encasing the electrical cable.

The MAX-YIELD™ Grout System can be mixed and stored in large volumes and remain thixotropic with circulation. Mixing and pumping is performed with conventional equipment, supporting lower costs and enabling an efficient grouting operation. Once grout displacement is achieved, the MAX-YIELD™ Grout System gels to a homogeneous mass with the required thermal resistivity. In this application, a thermal resistivity of 1.0 m.C/Watt (0.58 BTU/hr.ft.°F thermal conductivity) was required.