One Cure for the Common Cold

Frozen ground can easily freeze the workload for petroleum equipment contractors. Sue Meekhof describes how ground heaters help contractors “heat up” cold weather construction projects—even in Prudhoe Bay, Alaska.

Ground Thawing:

Hydronic heat, supplied by an E140 Ground Heater, was used to thaw a gasoline pipeline at a Newberry, Michigan service station. A vapor barrier and insulation blankets contained the heat, and hay bales secured these layers, protecting them from gusting winter winds

When temperatures drop and the ground begins to freeze, petroleum equipment contractors in colder climates often face challenges that can range from thawing frozen pipelines to curing concrete for a dispenser island. Their concerns turn to how to best manage cold weather and, in some cases, extend their construction season. Hydronic heat is a relatively new tool available to contractors that can help them accomplish both.

Ground thawing 101

To address the problem that frozen ground poses to contractors, one must first understand the properties of soil and why ground freezes.

• Lesson One: Soil doesn’t freeze. It is not the soil, but water in the soil that freezes. Dry soil will not cake together and solidify into frozen ground. In order for the ground to freeze, water must be present. Ice then binds soil particles together. Because all soil types contain some degree of moisture, the focus must be on the real problem—water.

• Lesson Two: Know your soil. To assess the demands of a particular thawing application, contractors should first understand basic types of soil and their abilities to retain moisture (see Figure 1).

Civil engineers classify soil in four categories: gravel, sand, clay and silt. Gravel is a coarse soil that contains a mixture of small-to-large stone and sand particles. Though gravel contains only a small percentage of water (five percent), it freezes deeper and faster than other soil types. This is because the gravel’s coarse makeup allows water to penetrate quickly to greater depths.

Every cubic foot of frozen gravel contains five to seven pounds of ice. Silt, on the other hand, is a fine soil that consists of uniform, small-rounded particles. Silt has a tendency to draw water up from the water table below to form ice lenses or layers of pure ice within the soil. With this capacity for absorbing moisture, a cubic foot of silt can contain anywhere from 15 to 52 pounds of ice. Knowledge of a thaw area’s soil type and the amount of recent rainfall will be two critical factors for determining the length of time needed to thaw the ground.

Figure 1: Ice contents of frozen soils; Courtesy of Ground Heaters, Inc.

• Lesson Three: Know your heat. The effectiveness of a heating method to thaw frozen ground is assessed by how that method delivers its heat to the thaw site. Hot air heaters use air. Hydronic heaters utilize liquids to deliver their heat. The more density the delivery method has, the more heat it can transport. Water is 968 times more dense than air and can therefore carry much more heat than air (One pint of water can deliver 140 BTUs of usable heat, while one pint of air can deliver .021 BTUs of usable heat). Obviously, basic physics proves hydronic heat is much more effective than hot air.

• Lesson Four: Heat is necessary for thawing. To thaw frozen ground, heat must be transferred to the soil to melt the ice. Changing ice to water is a phase change that requires 143 BTUs of heat energy per pound of ice.

Battling frozen ground

Frozen ground has long been a challenge for contractors who work with pipelines and refueling stations. In the past, the arrival of the winter season in northern regions effectively signaled an end to excavation. Though still possible, excavation could proceed only with much “wear and tear” on the excavation equipment, particularly to the bucket and teeth, joints and hydraulic system. Because the process was also more time-consuming, costs increased and workers were exposed to lower temperatures for a longer period of time.

Another significant challenge to contractors working in cold weather was the difficulty of working with the temperature-sensitive process of pouring concrete needed in the wake of repairs. Thus, in many cases, excavation and pouring concrete virtually ended until the spring thaw.

However, contractors do not often have the luxury of waiting for spring. Frozen and broken pipelines that involve either loss of product or potential harm to the environment cannot wait for repair. With increased equipment repairs and the desire to extend the construction season, thawing frozen ground has become a key objective within the industry.

Figure 2: Heat loss with hot air system using propane heaters for ground thawing

Traditional technology

The logical alternative has been to take heating methods already available and use them for thawing ground. In particular, propane air heaters had long been used for space heating and to keep the work environment tolerable **(see Figure 2).** On the surface, the concept of "throwing" hot air at frozen ground with these heaters seemed to be an answer. However, use of hot air heaters is relatively inefficient.

Because heat rises, hot air simply directed at the surface of frozen ground by propane heaters does little more than melt snow. Tents can be built to capture the escaping heat, but building and maintaining temporary tents is both time-consuming and expensive. At large work sites, tents need to be erected, dismantled and moved more than once. In addition, hot air heaters require a constant supply of fresh air to burn, which means only 15 percent of the heat is directed into the frozen ground; thus, 85 percent escapes ineffectually upward (and out) of the tent (based on R-factors of poly enclosures).[1]

Also, the cost of propane fuel for this inefficient heating process adds expense, particularly when multiple propane heaters are needed to thaw an effective work area. Use of propane heaters also exposes workers to potentially harmful levels of noise and noxious fumes within the enclosures. Finally, propane heaters cannot be used in potentially hazardous environments within the vicinity of flammable materials.

Another ground-thawing alternative involves burning coal under metal culverts. Safety and environmental drawbacks to thawing ground with coal include the extreme fire hazard and dirty black smoke soiling the surrounding property, hazardous fumes and dangerous heat levels. In addition to these concerns, coal is extremely labor-intensive, inefficient for areas wider than a trench and costly.

Additionally, high-pressure steam heaters have been used to thaw frozen ground. Though generally effective, steam heaters require an operator to direct a wand that produces the high-pressured steam. Thus, the wand must be swept over every square inch of the thaw area. This is time-consuming and requires an operator to be exposed to winter conditions. Also, it is not uncommon for operators to be burned by the hot steam.

Hydronic heat alternative

Nearly five years ago, a Minnesota masonry contractor developed the idea that hydronic heat could be an effective way to thaw frozen ground and continue work throughout the winter. He approached a Michigan company that researched this initial concept with civil engineers, geologists and physicists—and the Ground Heater and Ground Heaters, Inc., were born. Basically defined, a hydronic heater is a system that transfers heat by circulating a fluid in a closed system of pipes or hoses. Though first developed in the 1940s, the basic hydronic heat transfer system had not been specifically applied to thawing frozen ground.

The major components of the original Ground Heater included a heater, pumps and hoses contained within a towable housing. With the hoses spread across the job site, the diesel-powered heater would heat a propylene glycol heat transfer fluid up to 185 degrees F. The pumps would then circulate the non-toxic propylene glycol fluid (similar to that of ethylene glycol, or common car antifreeze), through the length of hose and back to the heater. In the process, the heat from the hoses would directly conduct heat into the ground to thaw the frozen soil **(see Figures 3 and 4).** Since its initial development, additional models have been developed with extended thawing capabilities.

Figure 3: Heat loss with hydronic heat system using a Ground Heater for ground thawing.

Figure 4: Use of a vapor barrier and insulation blankets reduces heat loss when hydronic heat is applied to thaw frozen ground.

The method of heat application using hydronic heat with insulating layers vastly decreases heat loss and redirects heat downward to the frozen ground. To optimally retain heat, a poly vapor barrier is placed over the hoses. This is followed by insulation blankets, which trap excess heat energy caused by the phase change from ice to water and further accelerates thawing. As opposed to 15 percent of heat being directed into the ground using air heaters, 94 percent of the heat is conducted into the ground using hydronic heaters (based on R-factors of insulation blankets and use of a vapor barrier).

Hydronic heat can provide contractors with a cost-effective approach to thawing frozen ground. Ground Heaters, Inc. has developed a scenario to illustrate the cost and length of time needed to complete a typical thawing project using an E3000 Ground Heater, in contrast to hot air heat supplied by propane heaters. The objective is to thaw an area of ground (6,000 square feet), frozen to a depth of three feet. The type of soil is compacted gravel with six percent moisture content.

The equipment and labor needed to use the E3000 effectively in this instance would include: 6,000 square feet of a three-mil polyethylene vapor barrier; 80 R-6 insulation blankets; eight man-hours for laborers (estimated at $25/hr) to set up and take down the equipment; and 105 gallons of diesel fuel (estimated at $.85/gal). The estimated time to complete the thawing scenario would be three days. Total estimated cost for all materials, labor and fuel would be approximately $625, if a Ground Heater and insulation blankets are owned, and $1,450, if both are rented.[2]

In contrast, Ground Heaters' has estimated the costs to achieve the objective using hot air heat supplied by propane heaters. The equipment, materials and labor needed include the following: two propane heaters (500,000 BTU/hr per heater); enclosure materials for construction of a heat containment tent (two X four lumber for enclosure, six-mil polyethylene film; one X two lumber to hold film in place, nails and staples); 24 man-hours to construct and take down the enclosure (includes 18 man-hours for a carpenter; six man-hours for laborers); and propane fuel (estimated at 11 gal/hr X $.91/gal X 24 hrs X 25 days for a total cost $6,006). The estimated time to complete the job would be 25 days. Total estimated cost for all materials, labor and fuel would be approximately $8,883.

Putting hydronic heat to the test

Proving the value of Ground Heaters has been a matter of testing the equipment in the field. In both pipelines and service stations, varying sizes of Ground Heaters have been employed with success, often in unanticipated ways. The first major test of the hydronic heater occurred in Prudhoe Bay, Alaska. Located on the northern coast of Alaska, Prudhoe Bay’s oil fields provide 20 percent of the nation’s domestic oil supply, which is transported to Valdez, Alaska, through the TransAlaska pipeline. For pipeline inspection and maintenance purposes, more than 200 digs are required per year. Because of the fragility of vegetation and environmental concerns, all construction can only occur during the winter when the tundra is frozen. During a demonstration of the equipment, the heater was able to thaw six feet deep in five days **(see Figure 5).** This thaw is more impressive when one realizes that the frost depth at Prudhoe Bay penetrates more than 2,000 feet deep.

Figure 5: Thawing ground in Prudhoe Bay, Alaska, with use of the E3000 Ground Heater. Personnel place a polyethylene vapor barrier over the hoses before covering with insulation blankets. Even in an arctic environment, thaw depths of 10 feet have been achieved

However, Alaska Petroleum Contractors (APC) performed an even more dramatic thaw. The company was responsible for construction and maintenance on the northern half of the TransAlaska pipeline. For one particular dig, APC needed to thaw a six-foot wide, 250 square-foot area, six feet deep, to install a 40-inch diameter pipeline casing under a road.

Once the Ground Heater was set up, the crew left with the intention of returning in six days to dig. During the thaw, a “big blow,” or wind storm, prevented the crew from getting back to the job site until 10 days later. When the crew was finally able to perform the dig, they found that although the ambient air temperatures remained below -15 degrees F, a thaw depth of 10 feet had been reached.

Since its uses in Alaska, other petroleum-related applications have surfaced. For instance, the Ground Heaters have been used to heat and prevent pipelines from freezing during pressure tests and to thaw frozen ground for industry-related construction applications. In fact, one petroleum company used a small Ground Heater to thaw a frozen gas line at a Newberry, Michigan service station without having to excavate (see Lead Photo).

“Concrete” solution for cold weather

In 1997, a contractor working on a construction site in Breckenridge, Colorado, purchased a Ground Heater for winter construction. After thawing up to seven feet of frost to begin installation of footers, the contractor decided to experiment with the hydronic heater to facilitate the temperature-sensitive process of concrete curing (see Figure 6). Not only did the hydronic heater effectively cure the concrete, but it did so at a fraction of the cost of using propane heaters (about $200/week versus $200/day, respectively).

Figure 6: Curing concrete footings in Breckenridge, Colorado. Hoses that contain the propylene glycol heat transfer fluid are draped over the forms to maintain a curing temperature range of 68-75 degrees F.

In addition to curing concrete, hydronic heat can be used to preheat the ground before pouring concrete slabs to speed both the setting and curing process. Hydronic heat has since been applied to "tilt-up" concrete construction in which a concrete casting slab creates a large heating pad for curing wall panels that are later tilted upward into place. Because concrete curing does not require as much heat as thawing frozen ground, Ground Heaters can cure twice as much area of concrete compared to thawing ground.

The Ground Heater

Currently, the four Ground Heater models available are the E140, E1700, E3000 and V60. Though all utilize the same basic hydronic heat principles, they differ in capabilities. All units are CSA-approved (Canadian Standards Association) and comply with all US DOT and Transport Canada regulations related to towable equipment.

The E140, which is fueled with 86 octane gasoline, is the smallest Ground Heater. With a heat output of 14,000 BTUs per hour, the E140 has a capacity to thaw 100 square feet, making it ideal for smaller ground thawing applications, such as thawing the frozen gasoline pipeline at the Michigan service station. The E1700 and E3000 Ground Heater models, both of which run on winter-blend diesel fuel, are intended for mid-size to large projects, respectively.

The E1700 includes 1,700 feet of hose that allows the unit to thaw up to 3,400 square feet of ground or cure up to 6,800 square feet of concrete. With a heat capacity of 300,000 BTUs/hr, the E3000 unit includes 3,000 feet of hose and can thaw up to 6,000 square feet of ground or cure up to 12,000 square feet of concrete. The largest Ground Heater unit is the V60, which was built based on the requests of the TransAlaska pipeline officials who observed the Prudhoe Bay application (see Figure 7). Complete with 6,000 feet of hose and a 400-gallon fuel tank, the V60 produces 405,000 BTUs/hr and can thaw up to 12,000 square feet or cure up to 24,000 square feet of concrete at a time.

The larger diesel tank allows for a 110-hour continuous run time between refuelings. The V60 also features a performance monitoring system and optional generator package. The future of hydronic heat The future of hydronic heat Hydronic heating poses minimal operator or environmental hazards and works much more efficiently and inexpensively than other ground thawing or concrete-curing options. As with any form of new technology, further refinements and capabilities are expected. In fact, since its inception five years ago, many changes have already been made to make this equipment more efficient, reliable, user-friendly and capable of multiple tasks. The current product offering is a far cry from the original unit that allowed a Minnesota masonry contractor to thaw frozen ground.

Figure 7: The V60 Ground Heater is used in large pipeline and large-scale construction applications

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