DRIP DISTRIBUTION SOIL PERFORMANCE AND OPERATIONS IN A NORTHERN CLIMATE

by

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A thesis submitted in partial fulfillment of

the requirements for the degree of

Master of Science

(Agricultural Engineering)

at the

UNIVERSITY OF WISCONSIN-MADISON

2000

2.6.1 Energy in the Soil System

The energy in the soil system is an important concept in order to understand the processes of soil freezing. The temperature of the soil depends on the ratio of energy absorbed into the soil to that being lost (Brady, 1990). The specific heat of the soil is one of the most important properties in understanding soil temperatures. The specific heat of a dry soil is much lower than that of water, which means that a dry soil will heat up much more easily than a wet one (Brady, 1990). If the water contained in a wet soil does not drain, it may evaporate, which is a very energy-consuming process and has the potential to cool the surrounding soil (Brady, 1990).

When the soil water begins to change its phase from liquid to ice, the heat that is liberated is known as the latent heat of fusion or "frost heat" (Jumikis, 1977). This is what contributes to the chilling effect caused by large amounts of ice on the temperature of the surrounding soil (Jumikis, 1977). The latent heat is calculated based on the amount of the frozen soil water rather than the entire soil moisture content. In coarse textured soils, almost all of the soil water freezes at 0 C (32 F), but in fine textured soils, part of the soil water will remain unfrozen at temperatures below this (Jumikis, 1977). The lower freezing point in fine textured soils is due to many physical and chemical factors, including the amount of fines, stress on the soil water, ionic charge density over the surface of the soil particles and electrolytes present in the soil water (Jumikis, 1977).

2.6.2 Definitions of Freezing Soil

The concept of soil freezing is difficult to define. There are many factors that can influence the frost action in a particular soil system. Some of these include the soil type, organic matter content, moisture content and chemistry of soil solution, as well as the insulating effects from a vegetative or snow cover. The air temperature and initial soil temperature are also factors in the frost action in soils. In order to confidently state the extent of freezing in a particular soil, these, and many more, factors must be measured. Rather than measuring each of these parameters the criteria for soil freezing in a particular study can be defined. Jumikis (1977) presents the following definitions in reference to freezing soils.

> Frost-prone soils are soils in which, when subjected to freezing, ice lenses are formed.
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> Frost occurs when the air temperature is below the freezing point of water.
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> Freezing temperature of the ground is the temperature at which the available soil water transforms into ice (depending upon soluble salts in water and pressure conditions).
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> Freezing soils are those in which ice crystallization of free soil water takes place at a given instant
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> Frozen soil consists of all soils at negative or 0 C (32 F) temperatures which contain voids completely or partially filled with ice. Besides ice, there may also be some unfrozen water present.
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> Frosty soils are soils at 0 C (32 F) or negative temperature containing no ice inclusions.

2.7.2 Climate of Wisconsin

Wisconsin is located in the cold climate region of the United States. Average annual temperatures vary from 4 C (39 F) in the north to about 10 C (50 F) in the south (Wisconsin State Climatology Office web-site). Temperatures drop to -40 C (-40 F) during more than half the winters, with temperatures of -34 C (-30 F) or colder being reported by northern stations almost every winter. The first autumn freeze typically occurs in late August to early September in the northern and central lowlands, and early October along the Lake Michigan coast. The last spring freeze ranges from early May along the coast and in the southern portion of the state, to early June in the northern regions. During the summer months, temperatures may rise above 32 C (90 F) in the summer for 2-4 days in the north to about 14 days in the south.

About one-third of the annual precipitation in Wisconsin falls during the winter. The average seasonal snowfall ranges from about 75 cm (30 inches) in the south to more than 250 cm (100 inches) in the north. The first measurable snowfall typically occurs in early November to early December. The average annual duration of snow cover varies from approximately 85 days in the south to more than 140 days in the north along Lake Superior.

For some time, it was thought that drip systems could only be installed in wooded areas, which have plenty of ground cover, or on seasonal properties which are shut down for the winter. However, snow can be a very good insulator, and thus can protect the buried, or surface, driplines from freezing even during a harsh winter. More research needs to be done to determine the fate of these systems in a cold climate, with little or no snow cover.

2.7.3 Soil Temperature Measurements

A precise and convenient method for measuring soil, liquid and air temperatures is by the use of thermocouples. A thermocouple is made from the junction of two dissimilar homogeneous metals. When this junction undergoes a temperature change, an electromotive force (emf) is created (Lenk, 1967). These emfs can easily be measured by means of a millivoltmeter or a potentiometer (Lenk, 1967). If one end of the junction is kept at a constant, or known temperature, the value of the emf at the other end is proportional to the temperature difference (Lenk, 1967). The relationship between temperature and emf are not linear, so a temperature-emf reference table must be used to convert the generated emf to its equivalent temperature.

In addition to the temperature difference, the emf generated is also dependent on the metallurgical composition of the wires (Lenk, 1967). One of the more popular metals is copper constantan, which consists of a pure copper wire for the positive conductor and a copper-nickel alloy, known as constantan, for the negative conductor (Lenk, 1967). This alloy combination consists of about 55 percent copper and 45 percent nickel and is used in place of pure nickel because nickel becomes brittle upon oxidation (ANSI, 1982). This variety of thermocouple, known as Type T, is exceptional for use with sub-zero temperatures due to its high resistance to corrosion from atmospheric moisture or moisture condensation (Lenk, 1967). These are more accurate than most other commercially available thermocouples for the temperature range of -184 to 149 C (-300 to 300 F) (Lenk, 1967).

2.7.4 System Performance in Wisconsin

In 1995, thermocouples were installed at an on-site drip distribution system serving a residence in Rock County, Wisconsin. The driplines at this site were installed at varying depths for each zone. The nominal depths were 15, 25, 40, 60, and 75 cm (6, 10, 16, 24 and 30 inches) below the ground surface. Temperatures were monitored at each of these depths along with ambient air temperatures. The only zone receiving effluent during this time was at the 15 cm (6 inch) depth. During the winter of 1995-1996, the air temperatures fell to a minimum temperature of -36 C (-3 F) and remained below 0 C (32 F) for two separate periods of 34 days at a time. Negative temperatures (Celsius) in the soil reached a depth of 75 cm (30 inches) below the zones that were not active. The soil beneath the active zone only reached below 0 C (32 F) temperatures a few times throughout the winter season. The winter of 1996-1997 was slightly warmer with air temperatures reaching a minimum of -25 C (-13 F), with below 0 C (32 F) temperatures maintained continuously for two periods of 39-40 days and three other periods of more than 20 consecutive days (Converse, 1997b). The soil beneath both the active and inactive zones approached negative temperatures (Celsius), but only dropped below 0 C (32 F) a few times at all of the depths. The winter of 1997-1998 was slightly warmer than both previous years, experiencing air temperatures of -21 C (-6 F).

Negative air temperatures (Celsius) were maintained for a period of 40 consecutive days. Despite these cold temperatures, the soil did not experience any negative temperatures (Celsius) during this winter season, even at a depth just below the soil surface. With these cold temperatures throughout these three years of study, there were no occurrences of operational problems of the drip systems.

During the winter of 1997-1998, the temperatures were monitored in a simialr manner at a site in Jackson County, Wisconsin. This site experienced temperatures down to -10 C (14 F) with negative temperatures (Celsius) remaining for several weeks (Converse, 1998). These low temperatures did lead to some freezing problems at this site. Temperatures of -3.6 C (26 F) were found at the depth of the dripline, extending down to -1.7 C (29 F) at a depth 30 cm (12 inches) below the dripline. There are two possibilities for the problems that occurred at this site. The driplines were not installed at a continuous depth, causing hills and valleys along the length of the tubing. This may have resulted in some of the wastewater remaining in the tubes at all times. This, combined with the fact that some of these locations had a very shallow soil cover of approximately 5 cm (2 inches), made the system prone to freezing. Following that winter season, approximately 15 cm (4 inches) of additional soil cover was placed over the system. The distribution network is in an area with some trees, however it is beneath a manicured lawn. An un-mowed lawn or forest litter on the ground surface, this may have provided some insulating effects on the distribution network.

2.7.5 System Performance in Other Cold Climates

Research has been done with drip distribution systems installed in Minnesota. The climate of Minnesota is similar to that of Wisconsin, with mean annual temperatures of 7 C (45 F) in Minneapolis to 4 C (39 F) in Duluth (Midwest Climate Center Web-site). However, snowfall amounts are typically greater in Minnesota than in much of Wisconsin, with mean annual snowfall amounts of 143 cm (57 inches) in Minneapolis to 193 cm (77 inches) in Duluth (Midwest Climate Center Web-site).

McCarthy et al. (1998, 1999) have been monitoring several systems for cold weather performance in Duluth, Minnesota. During the winter of 1996, the system was temporarily shut down as a result of freezing problems thought to be associated with the controller and its associating piping (McCarthy et al., 1998). During the winter of 1998-1999, the dripline buried 15 cm (6 inches) froze. All other depths (30, 45 and 60 cm; 12, 18 and 24 inches) were able to withstand freezing temperatures. These same results occurred during the winter of 1999-2000.

Freezing was also a concern for drip systems installed in Colorado. However, despite the occasional conditions of no insulating snow cover, no malfunctioning was experienced (Church, 1997).