The use of ethylene glycol solutions in heating systems

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TECHNICAL NOTE

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PREPARED FOR inquiry reply

SUBJECT THE USE OF ETHYLENE GLYCOL SOLUTIONS IN HEATING SYSTEMS

The primary purpose of using ethylene glycol solutions as a substitute for water in a heating system is to provide protection from damage due to freezing. This protection may be required for a snow melting system so that it can be operated on a periodic basis during the winter or to provide protection from damage due to freezing for a building heating system located in a cold weather area, in the event that a failure should occur in the system. Although a heating system for a building must be protected against the lowest anticipated ambient air temperature, the snow melting system only requires protection from the lowest anticipated ground temperature, which is much more moderate. In addition, the normal operating temperature of the building heating system may be considerably higher than that of a snow melting system. These and other differences are such that although it is practical to use ethylene glycol in snow melting systems it is not practical to do so in a building heating system except under unusual circumstances.

The ethylene-glycol antifreezes currently available on the market contain about 2 per cent of additives which serve as corrosion inhibitors and have negligible effects on other physical properties of pure ethylene glycol. Ethylene glycol is not initially corrosive; like most organic chemicals, however, it slowly deteriorates with use.

Two factors that have significant effects on the deterioration of ethylene glycol are heat and oxygen. Thermal decomposition of ethylene glycol is very slow at moderate temperatures but at about 325°F there is a rapid increase in its rate of decomposition. When oxygen is present in the antifreeze solution, in addition to the normal oxidation process very corrosive acidic products are formed when the ethylene glycol decomposes. Because of this thermal decomposition a maximum temperature of 250°F is recommended for systems where aeration is not likely to occur and a maximum temperature of 150°F where it may occur. Because of the high local temperatures which may occur, the use of a direct-fired heating exchanger is not recommended.

To prevent corrosion of the heating system, various inhibitors are added to the ethylene glycol. Each inhibitor provides protection for different metals. Other substances are also added as anti-foaming agents or adsorptive inhibitors. To provide for long service life the antifreeze should be designed for the particular operating characteristic of the system and the materials with which it will be in contact. The use in a heating system of an antifreeze designed for use in automotive engines will not have the same service life as an antifreeze specially compounded for heating systems.

Because of the acidic nature of the products of thermal decomposition, inhibitors are added which will provide the antifreeze with a "reserve alkalinity." Borax is such an inhibitor, but antifreeze containing borax should not be used in a system where galvanized iron is used, as the corrosion of zinc in solutions of ethylene glycol containing borax actually increases with decreasing temperature.

Some loss of antifreeze will occur during normal operation, but the strength of the glycol-water mixture can be maintained by adding the necessary amounts of antifreeze and water. It is also possible to extend the life of the antifreeze by replenishing the additives. The antifreeze can be tested for additive strength by sending samples to the manufacturer. Since information on additives is considered a trade secret, only the original manufacturer can provide the proper inhibitor and advise on the amount to be added to the system. Different brands of antifreeze should not be mixed due to the possibility of interaction between the different additives. When it is considered necessary to drain the system and refill it with a fresh charge of antifreeze, it may be possible to reduce the cost by reclaiming the ethylene glycol from the old solution. The heating system may be equipped with filters, but active clay and other absorbent filters should not be used as they may remove the additives from the solution. Before charging or recharging the system with antifreeze, it may be advisable to clean the system, using a suitable cleaner, but care must be taken to see that the system is thoroughly flushed after cleaning.

Ethylene glycol is not considered toxic under normal conditions. The undiluted material will cause slight discomfort to the eyes but is non-irritating to the skin except when in contact with it for long periods or if the skin is bruised. It can be poisonous if swallowed in large quantities. To prevent the possibility of contaminating the water supply, there should be no direct connection to the water system such as an automatic water make-up arrangement. Filling the system and topping up can be accomplished by using a temporary hose connection. An expansion tank with sight glass is, therefore, a necessity.

Although pure ethylene glycol is flammable, solutions of 60 per cent or less are effective fire-extinguishing agents. The National Fire Prevention Association permits the use of glycol solutions to protect wet sprinkler systems from damage due to freezing.

The freezing temperature of different concentrations of ethylene glycol in water is well defined, except in the range of 58 to 80 per cent ethylene glycol content. Generally, the optimum concentration of ethylene glycol in water is considered to be in the range of 60 to 65 per cent, which has a freezing point of -62 to -65°F. In lesser concentrations of ethylene glycol in water, ice crystals separate out on cooling to form a slush. These solutions continue to expand as the temperature drops to -54°F, apparently because of the continuous formation of ice crystals. It can be seen that as long as the solution is in the non-rigid stage, excessive pressures due to expansion on freezing cannot build up. Because of this, most snow melting systems when not in use are protected from damage at temperatures well below the freezing point of the solution. Where the solution must circulate at low temperatures, however, the freezing point of the solution must be below the minimum anticipated system temperature. It is also suggested that to ensure an adequate concentration of additives, the minimum concentration of ethylene glycol should be about 25 per cent. If it is desired to use a lower concentration, the possibility of adding additional inhibitors should be investigated.

The piping system should contain as few joints as possible since ethylene glycol will leak through joints that are watertight. Welded or soldered joints are preferred as are steel or wrought-iron pipe or copper tubing. Plastic pipe may also be used, provided its other limitations are considered.

Air vents should be kept to a minimum since these may permit the entry of air into the system. Snow melting systems and hot water heating systems using only a single air stripper connected to the expansion tank have proved successful although they do not conform to the usual practice. Since no permanent connection should be made to the potable water supply, it is suggested that the system should be an open system using a vented tank which can also be used for charging the system with both water and antifreeze. The whole system should be designed to reduce the possibility of aeration through cavitation and in other ways because of the effect of oxygen on the antifreeze.

When designing a system using ethylene glycol solutions as a heating medium, it is probably easier to use the available design data for a water system and then to make adjustments depending on the strength of the glycol solution. The two main characteristics of the system that will be affected by such a change are pipe friction and heat transfer.

At high temperatures the viscosity of glycol is nearly that of water but as the temperature drops, the viscosity of glycol increases at a greater rate. Since the friction head can be expressed as an exponential function of the viscosity, the new friction head can be determined by multiplying the water friction head by the exponential ratio of the kinematic viscosities of the water and the antifreeze solution. For snow melting systems Adlam (1) has found that using the fourth root of the ratio of viscosities gives satisfactory results.

The kinematic viscosity in centistokes is equal to the absolute viscosity in centipoise divided by the density in grams per cubic centimeter. For water at 68°F the absolute viscosity is one, the density is one and the kinematic viscosity is one, so that the kinematic viscosity can be expressed as the absolute viscosity divided by the specific gravity. Values for these characteristics are available in tables provided by the antifreeze manufacturer but the use of values for pure glycol-water solutions found in other reference books should prove satisfactory.

Calculations based on Adlam's correction for viscosity indicate that the pump head may have to be increased as much as 30 to 100 per cent which will cause a proportionate increase in pumping costs. An alternative to increasing the pump head is to reduce the friction head of the system by increasing the size of piping. For a snow melting system that is operated only when snow is falling or forecast the hours of operation are few and an increase in the cost of pumping would probably not be significant. This would not be the case, however, for a building heating system operating in a cold climate. In this case, the difference in capital and operating costs for each design must be carefully calculated as they will certainly influence the final selection of the heating system.

If the system is to be allowed to cool to low temperatures, then the selection of the type of pump requires special consideration. With snow-melting systems, provided the antifreeze solution is still liquid at the minimum design temperatures, the normal choice of a centrifugal pump will be acceptable. If it is possible that the antifreeze solution may be practically all slush, however, then a positive displacement-gear-type pump may be required to provide the high pressures required to start circulation.

The change in the rate of heat transfer when a glycol solution is used in place of water must also be considered. Glycol-water solutions have a lower specific heat, a slightly higher density, a higher viscosity and a lower heat conductivity than pure water. The net result of these factors in a given system will be to reduce the heat transfer rate below that for water. The precise effect will, however, depend largely on the type and design of the system. In snow-melting systems where the pipes are embedded in concrete or ground, characteristics of the material surrounding the pipe are responsible for the major portion of the resistance to heat flow and the effect of changing the heating medium from water to antifreeze solution may not be important. In a building heating system, the effect will be more pronounced depending on the particular heating units involved, since for the same flow rate the temperature drop will increase. In many cases the reduction in heat capacity may be offset by a moderate increase in the operating temperature of the system. In liquid-to-liquid heat exchangers the change to a glycol solution may be much more serious, due to the increased film resistance on the glycol side. A 60 per cent glycol solution may require a heat exchanger twice as large as that required when water is used. Here again, the design of the heat exchanger itself will have a significant effect and the matter should be discussed with the manufacturer of the heat exchanger.

In order to calculate the required increase in the capacity of the heat exchanger, Adlam (1) suggests the following equation:

$$\frac{H_w}{H_s} = \left(\frac{K_w}{K_s}\right)^{0.6} \times \left(\frac{C_w}{C_s}\right)^{0.4} \times \left(\frac{U_s}{U_w}\right)^{0.4}$$

where

H = heat transfer, Btu/(hr) (sq ft) (°F)
K = thermal conductivity of liquid, Btu/(hr) (sq ft) (°F) per inch
C = specific heat of liquid, Btu/(lb) (°F)
U = absolute viscosity of liquid, centipoise
w = water
s = glycol solution

The change to ethylene glycol solution as a heating medium will always tend to increase the cost of the heating equipment and probably also the cost of operation and maintenance of the system. The cost of ethylene glycol itself will, of course, vary with the quantity required and the shipping charges. Current prices in Ontario (excluding sales tax but including freight) vary from about $1.80 per gallon in bulk to $2.30 per gallon in 45-gallon drums. Maintenance of the system will be increased by the necessity for testing the strength of the antifreeze and the condition of the additives. Because of the cost of the antifreeze, regular inspections for leaks must be made and subsequent topping up carried out. It may also be necessary in some cases to provide protection against theft of antifreeze. The importance of these and other factors will depend on the particular heating system, the conditions under which it must operate and the economics of providing the required protection.

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