Heat Pump Design for 100% Outdoor Air Systems

INTRODUCTION

This technical bulletin will review the basics of water source heating and cooling loops, and the technology used by HVAC equipment to use the earth's energy efficiently. This bulletin will focus on how a 100% outdoor air dehumidifier can use such a loop to provide highly efficient heating in the winter, while also enhancing its ability to dehumidify in the summer and deliver treated ventilation air to the space. Different types of refrigerant designs will be reviewed and compared.

Many hybrid loops are being developed to help reduce the length of piping installed in the ground. The earth handles the majority of the load, but a boiler is installed to lend support during peak heating times, and a cooling tower or chiller is installed to assist during maximum cooling times. (Refer to Figure 2.)

BACKGROUND ON LOOPS

According to the EPA, by 2010 millions of buildings will use a basic ground source heating and cooling loop. Running an HVAC system is a major factor in the operating budget of any building. Harnessing the energy of the earth significantly reduces energy costs. Experts see this as the driving force behind the enormous increase in the use of loops over the next 10 years. In addition, this type of loop allows the mechanical engineer the flexibility to simultaneously address the heating and cooling demands in different parts of a building.

A hydronic loop is installed in such a manner that it links all of the HVAC equipment to the temperature-stable mass of the earth. Ground water temperatures are very stable year round, but they vary geographically. The ground acts as a heat sink when there is an excess of heat (typically the summer) and as a source of heat in the winter. The loop can be designed in four basic ways. (Refer to Figures 1 and 2.)

1.) Ground Loop - A well 200-300 feet deep (closed or open).

2.) Surface Loop - Trench 4-6 feet below the surface, with a total running length in excess of 600 feet.

3.) Lagoon Loop - Coil in lagoon or lake deeper than 10 feet.

4.) Ground Loop (Hybrid) - Boiler/tower water loop system. - (Figure 2)

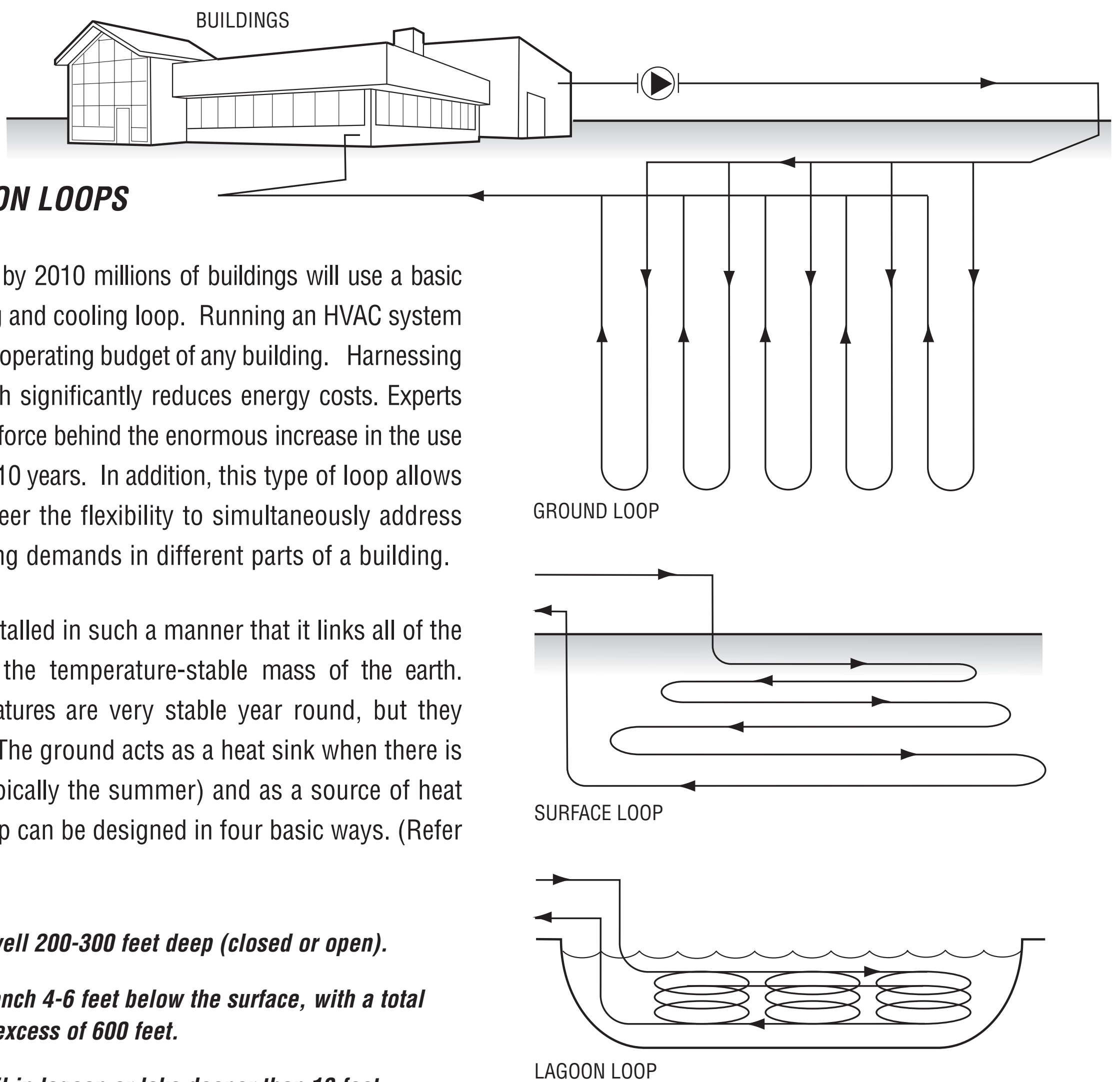

Figure 1 - Ground Source Loop

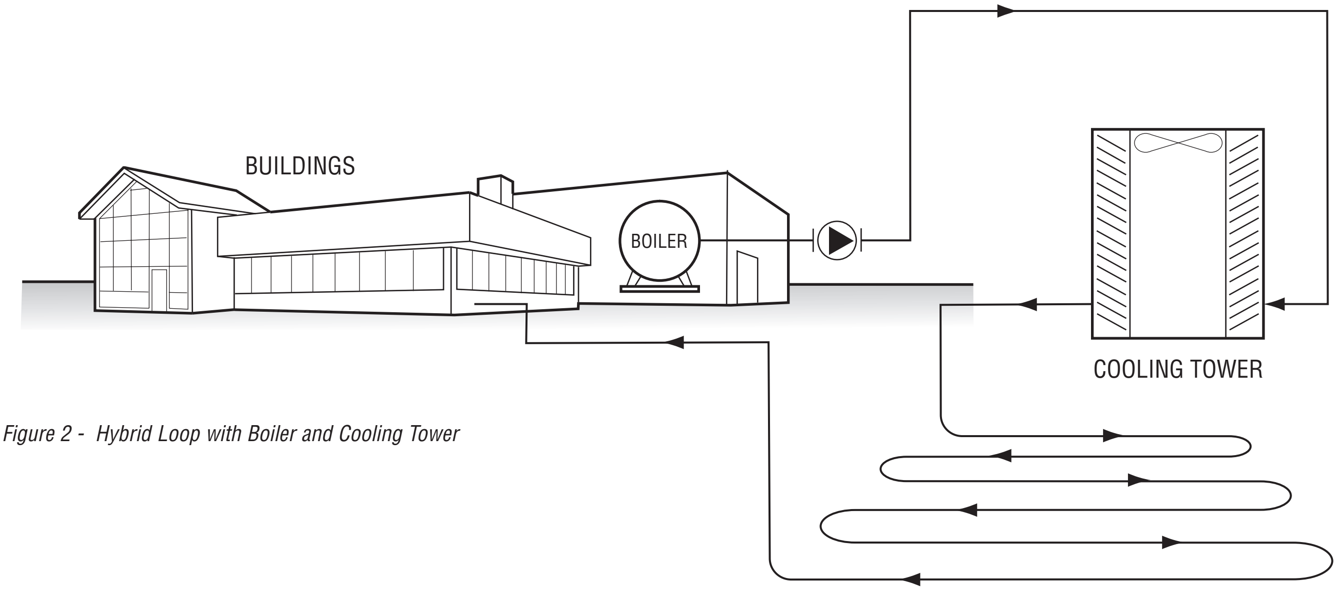

Figure 2 - Hybrid Loop with Boiler and Cooling Tower

HEAT PUMP PRINCIPLES

A heat pump essentially performs just as its name implies, by "pumping" energy from a hot source to a cold source. For HVAC applications, this process must also pump energy from a cold source to a hot source in order to achieve cooling. When this device is in the heating mode it draws energy from the water and transfers it to the air. In the cooling mode the reverse must occur, thus, heat from the air is transferred to the water.

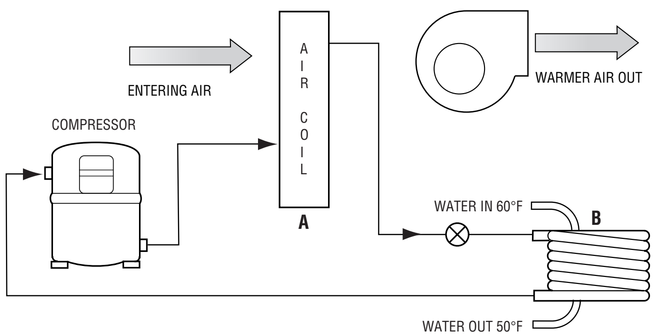

Figure 3 - Typical Water Source Heat Pump in Heating Mode

This energy transfer takes place through a refrigeration system with the compressor acting as the energy pump. In the heating mode, the water coil accepts cold refrigerant gas from the TXV valve. The ground source water is significantly warmer and transfers heat from the water to the refrigerant. The refrigerant then circulates to the compressor, picks up the heat of compression and becomes a hot gas. In this state, it is directed to the air coil where it gives up heat to the cold air stream. The refrigerant quickly returns back to a cool, saturated vapor and the process is repeated. (Refer to Figure 3.)

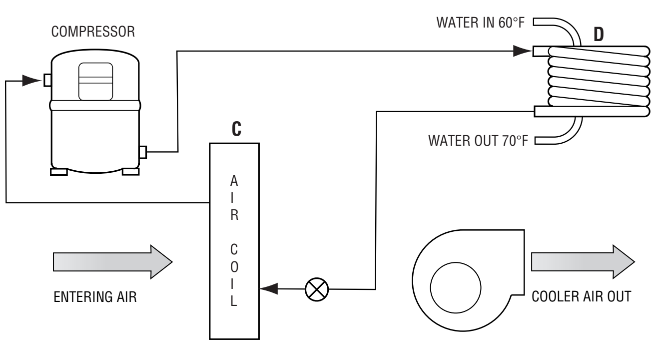

Figure 4 - Typical Water Source Heat Pump in Cooling Mode

In the cooling mode, the cold gas from the TXV valve is directed to the air coil. The refrigerant cools the air to its dewpoint and water condenses, giving up more energy. The refrigerant once again flows through the compressor and ends up in the water condenser where it gives up heat to the ground source loop. (Refer to Figure 4.)

REVERSE CYCLE HEAT PUMP - OLD DESIGN

A 100% outdoor air heat pump dehumidifier must operate in both the heating and dehumidification/cooling modes to handle a wide range of outdoor ambient conditions. The most conventional method is to add a reversing valve to the two-element refrigeration loop to allow the energy flow to go in either direction. The valve is reversed when the outdoor air reaches its set point (dew point or dry bulb temperature). (Refer to Figures 5 and 6.)

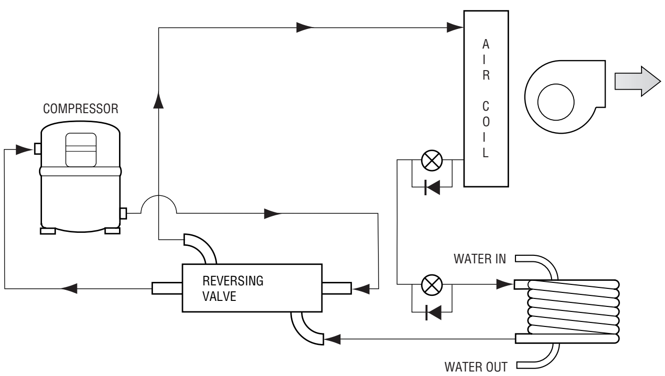

Figure 5 - Typical 100% O/A Reverse Cycle Heat Pump in Heating Mode

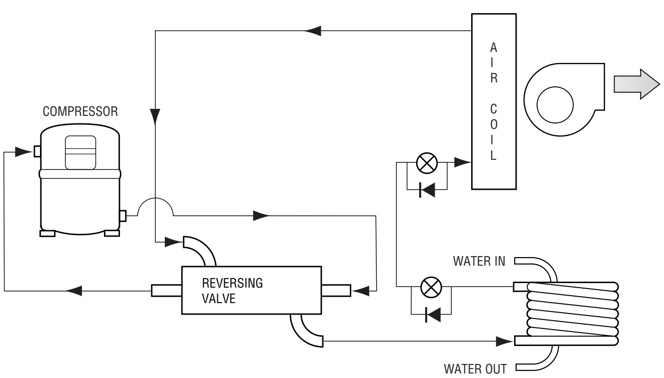

Figure 6 - Typical 100% O/A Reverse Cycle Heat Pump in Cooling Mode

Several design issues must be considered when applying a reverse cycle system to a 100% outdoor air application. For instance, one must consider the range of conditions that the coil will be exposed to. Plus, it is important to remember that the air-side and water-side exchangers must function efficiently as evaporators and condensing coils. Bi-directional flow is a very difficult refrigeration design that must accept significant performance degradation in order to operate in all modes under all ambient conditions.

For example, consider a typical air-side coil functioning as a condenser. The majority of the refrigerant passing through its tubes exists either as a superheated vapor or a low quality liquid/vapor mixture. This mixture must flow with a velocity sufficient to "sweep" refrigeration oil back to the compressor to ensure proper lubrication. When the system reverses and this same coil functions as an evaporator, the pressure drop of the refrigerant in the coil becomes much higher. This happens because the majority of the refrigerant passing through its tubes now exists as a sub-cooled liquid or high quality liquid/vapor mixture.

Unfortunately, high evaporator pressure reduces the cooling capacity of a heat pump because its compressor must work harder to overcome the friction between the liquid refrigerant and the tube walls of the evaporator coil. Although one can design a coil to reduce its refrigerant pressure losses when it functions as an evaporator, this same coil may not function well as a condenser. Its refrigerant velocity may then be insufficient to sweep lubricating oil back to the compressor.

The second major design consideration is the amount of variable heat required to adjust the temperature of outdoor air to the designated space temperature. Only a part of the energy in the heat pump loop is needed to reheat the air, therefore, a second condenser in series with the first is required to reject the total heat of rejection of the system. This further complicates the refrigeration balance and creates the risk of oil returning to the compressor. The basic reverse-cycle system does not control the leaving air temperature.

Q-PUMP™ - 100% OUTDOOR AIR SYSTEM

Desert Aire's Q-Pump system uses a four-element refrigeration system to overcome the typical problems of a two-element reverse cycle system, including:

1.) *Reduced efficiency and performance.*

2.) *High cost of oversized refrigeration valves.*

3.) *Potential for liquid slugging and need for accumulators.*

4.) *Refrigerant suddenly flashing into vapor, violently expanding and damaging pipes.*

Desert Aire's Q-Pump dehumidifier uses a unique method of heating 100% outdoor winter air without the need for a separate auxiliary heat source such as gas. Our basic system is effective down to 15°F winter design temperature without additional auxiliary heat. With an optional enthalpy wheel, the system is effective down to -10°F, again, without additional auxiliary heat.

The key difference between Desert Aire's Q-Pump option and prior solutions is the use of two independent water condensers. One acts as the true condenser for the balance of the total heat of rejection (THR) of the system and the other is the evaporator in the reverse cycle heating mode.

The Q-Pump is easily incorporated into Desert Aire's Total Aire systems by adding one water exchanger. The hot gas reheat coil is sized to warm up cold air to space conditions, e.g. from 15° to 75°F with 60°F water. During off-peak times, the unused heat of rejection boosts the water temperature before it is extracted from the loop. This added energy to the water loop increases the system's efficiency. In the summer mode the water evaporator is inactive and removed from the refrigeration loop by a solenoid valve. In the winter, the air evaporator coil is inactive and the water evaporator will pull energy from the slightly heated ground water loop. The evaporator reduces the water temperature by 5°- 6°F. Figures 7 and 8 provide a detailed schematic of our Q-Pump system and also show how it functions in the summer and winter modes.

CONCLUSION

If feasible, the installation of a heat pump into an HVAC application provides many advantages. First and foremost, this type of system provides such an efficient exchange of energy that a facility can expect an average of 50% savings in heating and cooling bills with respect to the 100% outside air dehumidifier.

While the concept of a heat pump is simple, the application requires precise, flawless engineering. Because Desert Aire's TotalAire dehumidifiers are specifically designed for energy recovery, a Q-Pump can be easily incorporated into the system. Our engineers have successfully incorporated Q-Pump technology into TotalAire units. Contact your local Desert Aire representative if you would like more information or assistance about incorporating a TotalAire dehumidifier and heat pump into your HVAC system.

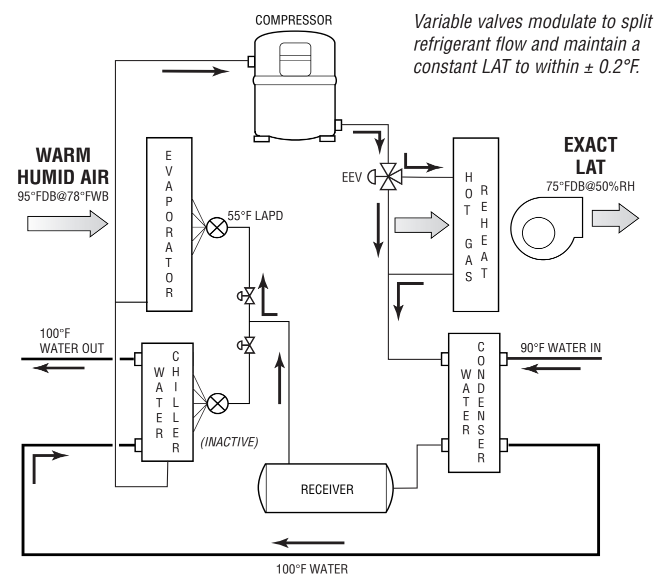

Figure 7 - Q-Pump Schematic with LAT Control: Cooling Mode

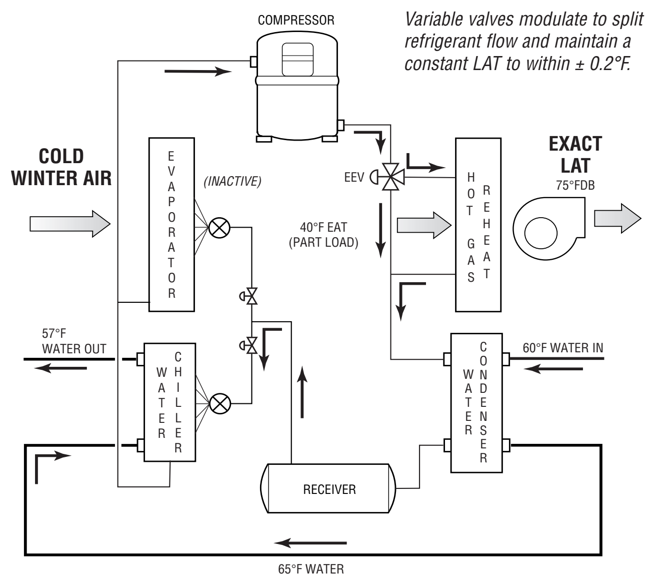

Figure 8 - Q-Pump Schematic with LAT Control: Heating Mode

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