COMMERCIAL HVAC SYSTEMS

Water Source Heat Pump Systems

Technical Development Program
Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.

This TDP module will provide an understanding of the components in water source heat pump systems, configuration options, system benefits, and many applications associated with the overall system. WSHP systems have become a very popular choice for use in commercial buildings where individual zones of control are required to maintain comfort conditions. Building types that exhibit a simultaneous cooling and heating load are ideal candidates. WSHP systems have other desirable characteristics like zoning capability, ease of design, and reliability so that buildings where little or no reclaim will take place are often still considered for using a WSHP system.

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Introduction

Water source heat pump (WSHP) systems have become a popular choice for commercial buildings where multiple zones of control are desired. They can also be applied successfully in smaller installations like residences. This TDP module will discuss both applications, but will concentrate on the commercial applications. The usage of WSHP systems breaks down to roughly 60 percent new construction and 40 percent retrofit and replacement.

In this TDP module, we will learn about the various types of water source heat pump units that can be used to comprise a HVAC system. The internal components in a typical WSHP unit and the function of each will be explained. This will allow the reader to understand how the WSHP units operate when connected to a system water loop. System components will be then discussed. These include boilers, towers, pumps, piping, and controls. See Figure 1.

There are many overall variations for WSHP systems. They may be categorized into two main groups. The first system type is a standard closed-loop system where the loop piping runs inside the building. This system typically includes a boiler (also called a heat adder), a cooling tower (also called a heat rejecter), pumps, and controls as shown in Figure 1.

The second type of WSHP system uses the Earth’s resources as a heat sink. These systems are called geothermal systems. A lake, river, well, or the ground itself is used to add or remove heat to maintain an operable water temperature. Some of these systems are closed-loop and some are open loop. Open-loop means the water is used in a once-thru configuration. A separate section on geothermal systems is included in this TDP.

Commercial WSHP systems are popular because they can supply simultaneous heating and cooling. This leads to comfortable conditions in zones that have different requirements. A WSHP system typically requires a dedicated outdoor air unit to maintain required ventilation levels as specified by ASHRAE (American Society of Heating, Refrigerating, and Air Conditioning Engineers) Standard 62.1. This TDP module will examine the various ways to deliver ventilation air.

Control of the individual units, the water loop temperature, and other components in the system are also covered in this TDP. Recommendations on proper application of units to minimize radiated sound along with the required maintenance considerations are included.
This TDP module is meant to complement the Carrier System Design Guide on Water Source Heat Pumps. In this TDP we will reference the Design Guide in several areas, the most notable being the design process and layout of an example building. The Design Guide can be used for a step-by-step approach to selecting and designing an entire WSHP system including an operating cost analysis comparison to other systems.

After reading this TDP, the reader will understand how WSHP units and systems work, and why they are a popular, reliable, and versatile alternative to other air-conditioning systems.

Water Source Heat Pump Unit Operation

A water source heat pump is a mechanical reverse cycle device that is used to transfer heat from one medium to another. A water source heat pump extracts heat from the water when in the heating mode and rejects heat to the water when in the cooling mode. The water supply may be a recirculating closed loop or a once-thru system using water from a well, a pond, or a stream. Water for closed-loop heat pumps is usually circulated at 2.25 to 3.00 gpm per ton of unit cooling capacity. A once-thru groundwater heat pump can operate with a lower water flow, but the same range is still recommended.

The WSHP refrigeration circuit consists of a refrigerant-to-water heat exchanger, compressor, refrigerant metering device, refrigerant-to-air heat exchanger (or refrigerant-to-air coil), fan, reversing valve, and controls. Heat is transferred from one medium to the other by a hermetic refrigerant circuit.

The most common design configurations for packaged WSHPs are horizontal units, which are positioned above a dropped ceiling; vertical units, which are usually located in basements, utility closets, or equipment rooms; and console units, which are designed for under window mounting in the conditioned space. We will discuss all the types of units in detail later in the TDP.

The feature that most distinguishes a heat pump from the typical refrigeration system is that it is reversible. This allows the unit to provide cooling in summer and heating in winter at a relatively efficient level. In a WSHP unit a reversing valve switches the compressor discharge from the refrigerant-to-water heat exchanger for cooling to the refrigerant-to-air exchanger for heating.

Many of the other components required for a heat pump are the same as for a traditional air-conditioning unit. However, in the heat pump, the function of the heat exchangers can be reversed, so that they each must function as an evaporator and condenser.

Unlike a traditional air-conditioning unit, in a heat pump, the function of the heat exchangers can be reversed.
Cooling Mode

In the cooling mode, the WSHP unit’s refrigerant-to-water heat exchanger acts as a condenser and its refrigerant-to-air heat exchanger acts as an evaporator. The reversing valve is energized for cooling.

During the cooling mode, heat is extracted from the air by evaporating the refrigerant in the refrigerant-to-air heat exchanger. This extracted heat plus the compressor heat is rejected into the water loop. This is called the heat of rejection. Hot gas from the compressor discharge is directed by the reversing valve to the refrigerant-to-water heat exchanger. Here the hot gas is condensed into liquid as the gas gives up heat to the colder water passed through the exchanger. Liquid refrigerant then passes through a metering device that causes a drop in its pressure and temperature. The cold liquid-vapor mixture then enters the refrigerant-to-air heat exchanger where it evaporates. The indoor air is cooled to condition the space. Cool refrigerant vapor then is drawn into the compressor where its temperature and pressure are increased so the cycle can be repeated. See Figure 2.

Heating Mode

In the heating mode, the WSHP unit’s refrigerant-to-water heat exchanger acts as an evaporator and its refrigerant-to-air coil acts as a condenser. The reversing valve is deenergized for heating.

The hot compressor discharge gas is directed by the reversing valve to the refrigerant-to-air heat exchanger, which will act as a condenser. Air is then heated as it passes over the refrigerant-to-air heat exchanger as it condenses the refrigerant and heats the space. Liquid refrigerant flows through the metering device to the refrigerant-to-water heat exchanger that acts as the evaporator. Heat is extracted from the water loop as it passes through the refrigerant-to-water heat exchanger and the cold liquid refrigerant evaporates. The cold vapor then is drawn into the compressor and the cycle repeats. See Figure 3. The heat that is extracted is known as the heat of absorption.
Mode Changeover

The reversing valve in the unit’s refrigeration circuit is located on the compressor discharge. The reversing valve causes the changeover from cooling to heating mode and from heating to cooling mode. In a reversible system, some of the traditional components must have special features to allow for reverse flow. For example, the metering device must be capable of metering flow in both directions. This type of metering device is usually called bi-directional.

In addition to the reversing valve and metering device, there are other design considerations that make the heat pump different from the conventional air-conditioning unit. The compressor is specially designed to operate over the wide range of compression ratios encountered in the heating mode. Both the air and water heat exchangers are specially designed for WSHP use because they must both evaporate and condense refrigerant. For example, the refrigerant-to-air heat exchanger, when acting as a condenser in the heating cycle, must have adequate surface area to keep the condensing temperature and pressure at reasonable levels.

WSHP System Operation

A typical closed loop system as shown in Figure 4 consists of a number of WSHP units, a closed circuit cooling tower, a boiler, a common piping loop comprised of a supply and return line, and a water-circulating pump with a standby. Standard hydronic accessories are also required such as an expansion tank, air separator, and piping vents.

Notice the arrangement of the components with the loop flow passing through the heat rejecter (tower), then through the heat adder (boiler), expansion tank, pump, and then out to the heat pump system. The piping is almost always a reverse return system as shown in Figure 4. In a reverse return system, the combined supply and return length of water piping through each unit is essentially the same. This results in a system that is more self-balanced than a direct return system. For a complete discussion on reverse return piping, see TDP-502, Water Piping and Pumps.

There are several variations of this standard closed loop configuration, which we will discuss later. Closed loop systems use recirculated water. Open loop ground source systems use a once-thru (non-recirculating) design.

Water circulating in the loop acts as a heat source for WSHP units operating in the heating mode and as a heat rejection sink for those units operating in the cooling mode. Thus, heat may be transferred from building zones that need cooling to zones that need heat. This reclamation of heat is one of the major advantages of the WSHP system. The circulating loop temperature is maintained between 60° F and 90° F. When more zones require heating than cooling, the loop temperature drops (approaching 60° F) and the boiler is activated to make up the heat deficit.