Series-Chiller Plants

System Description

Series chiller systems are easy to design and operate. They usually have two chillers. Chilled water flows through each chiller in a cascade arrangement. The chillers see different return water temperatures, so they have different loads.

Chilled Water Loop

The chilled water loop circulates throughout the building. Most traditional series chiller designs are constant flow with three-way valves at the terminal units.

Bypass lines around each chiller are sometimes provided to allow a chiller to be isolated for service.

System Parameters

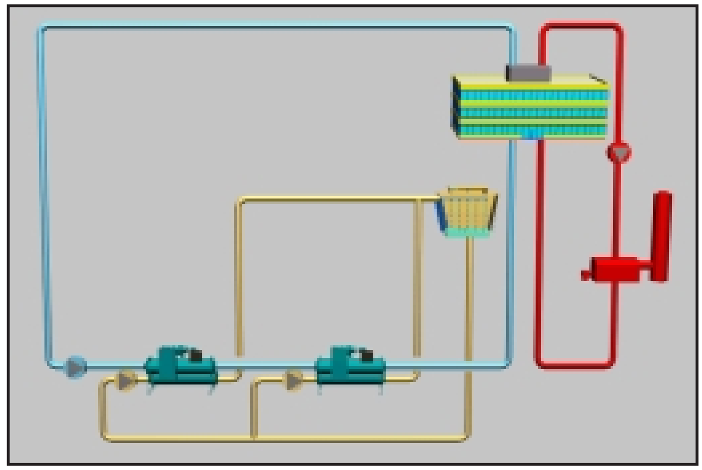
Series-chiller designs load the lead chiller first, then load the lag chiller. When the load is less than 40% of the design capacity, the lead chiller can meet the load.

Traditional control arrangements have both chiller water sensors downstream of the chillers and set at the required chilled water setpoint.

Modern controls allow the chillers to be digitally connected. If the chillers are identical, for loads less than 40% of design capacity, either chiller can operate. When both chillers are needed, the controllers evenly balance the power draw while meeting the load. This can improve system efficiency by about 2%. If the chillers are specifically selected to meet the two operating conditions, further operating savings are possible, but the lag chiller may not be able to operate as the lead chiller in an emergency.

Typical chilled water supply temperatures are 42 to 45°F, with 44°F being the most common. If a 10°F delta T is used, the chilled water flow is 2.4 U.S. g.p.m. per ton. Series-chiller design is a good choice for higher delta T systems.

Condenser water supply temperatures are 80 to 90°F, with 85°F being the most common. The condenser water delta T is typically 10°F, which equates to 3.0 U.S. g.p.m. per ton.



Chiller Selection and Sizing

Any kind of chiller can be used. Chillers can either be selected to meet the different operating conditions or have the same capacity. When selected with the same capacity, the lead chiller operates with a higher lift (it has to produce colder water) and provides about 40% of the system capacity, even though it has the same nominal capacity as the lag chiller.

When different chillers are used, the best performing chiller should be the lead chiller because it will be in the more demanding location. This is especially true when replacing a chiller in an existing series system.

Since all the chilled water flows through each chiller, water pressure drops must be added and can be an issue. Single pass shells are common.

Condenser Water Loops

Condenser water loops are needed for water-cooled chillers only. Each chiller gets its own condenser water pump sized to provide the correct flow for the chiller. Cooling towers are used to reject heat in the condenser water to ambient. Water-cooled chillers are more efficient than air-cooled chillers because they operate with a smaller compressor lift. A cooling tower may be matched to each chiller or a common tower plant can serve all the chillers.

Series-chillers can also have the condensers piped in series in the reverse flow to the chilled water. This is an excellent option for high delta T or low chilled water temperature systems.

System Pros

- Straightforward to design and operate.
- Good system for high chilled water delta T or low chilled water temperature applications.
- Multiple chillers provide redundancy.
- Chillers can be any size or type.

System Cons

- Extra piping may be needed to isolate chillers from the system for service.
- High-flow low chiller delta T can cause high water pressure drops in chillers. Chiller pressure drops must be added for pump sizing.

Energy Considerations

Series chillers can provide good performance particularly if the load is usually more than 50%. Series chillers also perform well in high delta T applications. Digitally linking the chillers for load balancing also optimizes the chiller plant performance. The following are some considerations outlined in ASHRAE Std 90.1-1999. The numbers in brackets refer to Std. 90.1-1999 sections.

- Energy efficiency tables for HVAC equipment. (6.2.1).
- Equipment must be scheduled off automatically during unoccupied hours. (6.2.3.1).
- Air- or water-side economizers are required. There are several exceptions to this rule, particularly when dealing with heat recovery (6.3.1).
- Reheat is allowed if at least 75% of the energy for reheat comes from on-site energy recovery (templifiers).
- Hydronic systems with a system pump power that exceeds 10 hp must employ variable flow and isolation valves at each terminal device. The system must be able to operate down to at least 50% of design flow. (6.3.4.1)
- Individual pumps over 50 hp and 100 ft. head must have VFDs and consume no more than 30% design power at 50% design flow (6.3.4.1).
- Supply temperature reset is required for hydronic systems larger than 300 mbh. Temperature reset is not required if it interferes with the proper operation of the system i.e. dehumidification (6.3.4.3).
- Fan motors larger than 7½ hp on cooling towers must either have VFDs or be two speed. A control system is required to minimize power usage (6.3.5).
- Hot gas bypass for refrigeration systems is permitted, but has strict limitations (6.3.9).

A thorough explanation of the Standard is beyond the scope of this document. The designer should have access to the Standard and a complete understanding of its contents. The ASHRAE 90.1-1999 Users Manual is also very helpful. ASHRAE considers Standard 90.1-1999 a high-profile standard and continuously updates it.

Typical Applications

Series systems are used in industrial applications requiring high system delta T or low chilled water temperatures. Since they are easy to design and operate, they are a good choice for small to medium applications.

Common applications include:

- Industrial
- Office Buildings
- Schools