



# Fundamentals of Chiller Plant Design



*The keys to superior Chiller Plant Design*



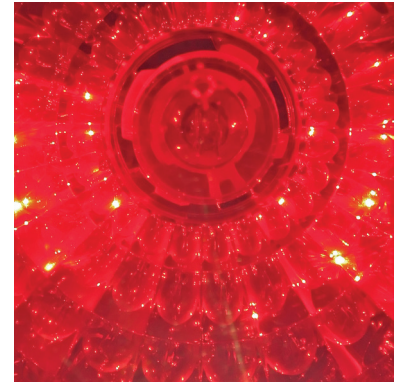
# 2

## Pumps

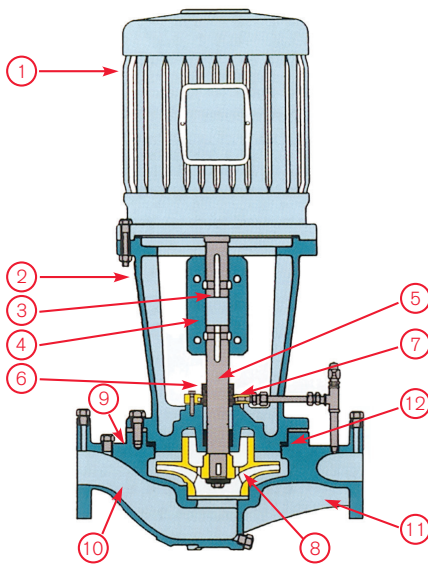
Pumps are used in hydronic systems to force fluid flow throughout the distribution system. For HVAC applications, pumps range in size from a few US GPM to more than 20,000 US GPM requiring 1500 horsepower. Centrifugal pumps are the type most commonly used in the HVAC industry. They are dynamic type, similar to fans and centrifugal compressors. They convert velocity pressure into static pressure. Since their flow is continuous, they have higher flow rates without pulsations which minimizes vibration.



**Figure 2.1**  
Pumps for a Central Chiller Plant



### Centrifugal Pump Basics



Courtesy of S.A. Armstrong Ltd

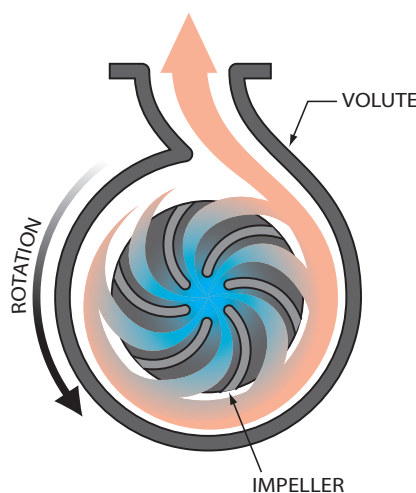
**Figure 2.2**  
Single Inlet Centrifugal Pump Components

# Pumps

Increasing impeller diameter will increase head. Increasing impeller width will increase flow. Increasing impeller rpm will increase head and flow.

**Figure 2.2** shows a typical pump. The impeller (8) is mounted on the pump shaft (5) with roller bearings (7) in either overhung or center hung arrangement. The impeller discharges radially into the **volute** or diffuser (11), which is built into the pump casing. The pump shaft enters the pump casing at the **stuffing box** (6) where some form of seal is used to stop leaks. Smaller pumps may use packing to provide a shaft seal; larger pumps use a mechanical seal. Wear rings are used between the casing and the impeller inlet to provide a seal between the low and high pressure sides of the pump.

The prime mover is usually a motor (1). For 60 Hz applications they can be 1200 (expensive), 1800 or 3600 (noise issues) rpm with 1800 rpm being the most common. Small pumps can be close coupled to the motor. Larger pumps have the motor shaft joined to the pump shaft with a coupling (4).

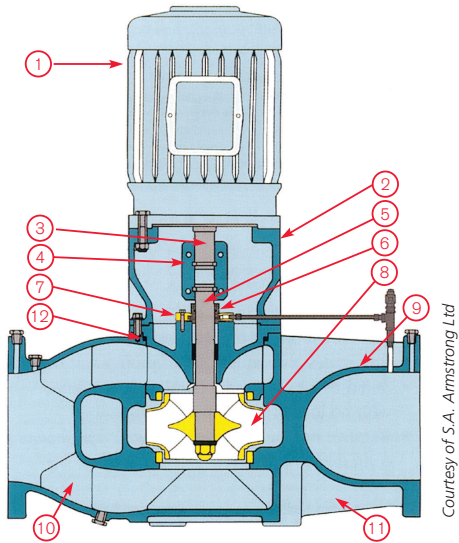


**Figure 2.3**  
Centrifugal Pump Flow

Referring to **Figure 2.3**, fluid enters the impeller inlet. The impeller shape and its radial vanes direct the fluid radially to the shaft. The increasing impeller diameter in the radial direction accelerates the fluid. The accelerating process adds a significant amount of energy in the form of velocity pressure to the fluid. The fluid exits the impeller radially and enters the volute or diffuser. Volute (more common) discharge fluid perpendicular to the shaft while diffusers discharge the fluid parallel to the shaft. Either allows the flow to slow, converting velocity pressure into static pressure. Generally, the larger the diameter, the more pressure (head) the pump can develop. The wider the impeller, the more flow it can produce. If the speed is increased, both flow and head will increase.

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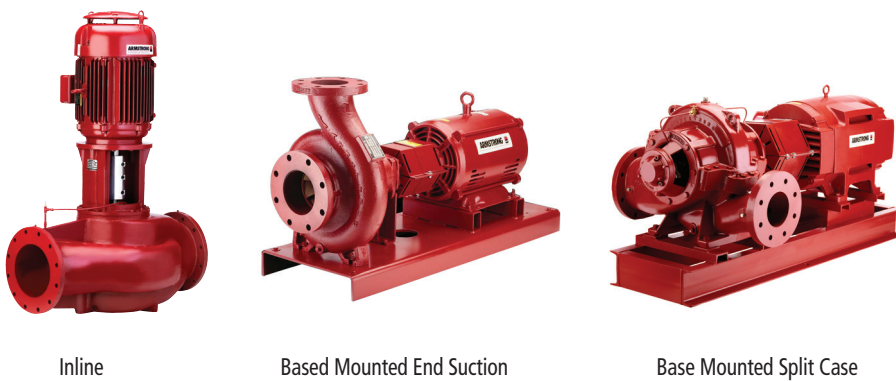
Pumps



**Figure 2.4**  
Double Inlet Pump Components

**Single inlet impellers** are used on smaller sizes. The larger the single inlet impeller, the larger the axial force on the bearings. Larger pumps are **double inlet**. These look like two single inlet impellers (8) back to back, discharging into a common volute (11). Double inlet impellers have balanced axial forces on the bearings.

Double suction pumps are considered hydraulically balanced since the axial forces cancel each other.



**Figure 2.5**  
Centrifugal Pump Configurations

# Pumps

Pumps can be *inline, base mounted end suction or split case*. Small, close coupled inline (sometimes called *circulator*) pumps are meant to be mounted right in the pipe, either horizontally or vertically. Large vertical inline pumps have horizontal connections and can be single or double inlet type.

Based mounted end suction pumps have a steel base under both the motor and the pump. They are installed on a concrete pad. Fluid enters the pump horizontally, parallel to the shaft, and discharges vertically.

Base mounted split case pumps have a steel base under both the motor and the pump. They are installed on a concrete pad. Fluid enters the pump horizontally, perpendicular to the shaft, going to a double suction impeller and discharging horizontally, perpendicular to the shaft. The split casing allows access to the impeller and bearings.

## Radial Thrust Loads

Radial thrust loads are at right angles to the pump shaft. The forces are caused by accelerating the fluid in a radial direction from the impeller into the diffuser or volute. Typically these are balanced because the flow is even in all radial directions. However, at reduced flow the forces become imbalanced, leading to severe strain on the bearings and pump shaft. The forces are nearly balanced at the Best Efficiency Point (BEP) and most imbalanced near shut off head. The imbalanced radial forces drop considerably at reduced rpm. To avoid undue strain on the bearings and pump shaft, the pump should be selected between 70 and 120% of BEP flow. Alternatively, using a double suction pump (more flow with lower rpm) will also reduce the thrust load.

## Head vs. Pressure

As mentioned in Chapter 1, it is customary to describe the pressure a pump can provide as *head* rather than in units of pressure. Head is measured in *feet (meters) of water column* or *ft w.c. (m w.c.)*. It is the difference in head between the suction and discharge of the pump. Head can be converted to pressure by the following;

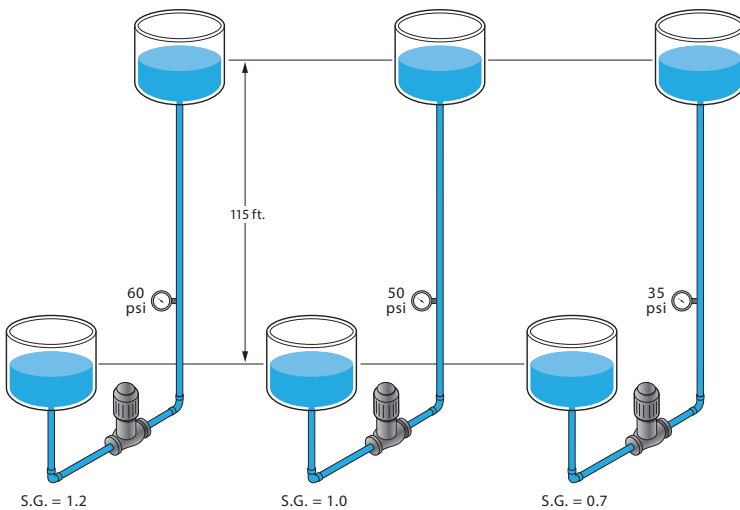
$$\text{Head (ft water column)} = (\text{Pressure (psi)} \times 2.31) / \text{SG}$$

Where

SG = Specific Gravity, the density of fluid divided by density of water (water = 1.0)

## 2

## Pumps



**Figure 2.6**

Pump Head vs. Discharge Pressure

The main reason to describe pump pressure as head is shown in **Figure 2.6**. Here, three different fluids are all acted on by the same pump. In each case, the fluid is lifted the same amount. However, each fluid has a different specific gravity, so the pressure is different. By describing the pump performance in terms of head, only one set of performance curves is required. Pressure can be calculated using the equation above and knowing the Specific Gravity of the fluid being pumped. If pressure were used, each fluid would need its own set of performance curves. For HVAC systems, water is the most common fluid. Some systems require antifreeze, which will change the system characteristics.