Loop Volume, Rate of Change in Load or Flow Rate (5/13)

These three items all affect the magnitude of capacity transients on the chiller. Because they all affect the chiller's performance in the same way, they will be discussed together here. All three relate to the time it takes the chilled water to cycle through the complete chilled water loop from the chiller to the load and back again. In order to understand how changing each parameter effects the chiller's operation, a simple chilled water loop system diagram is useful. (See Figure 2)

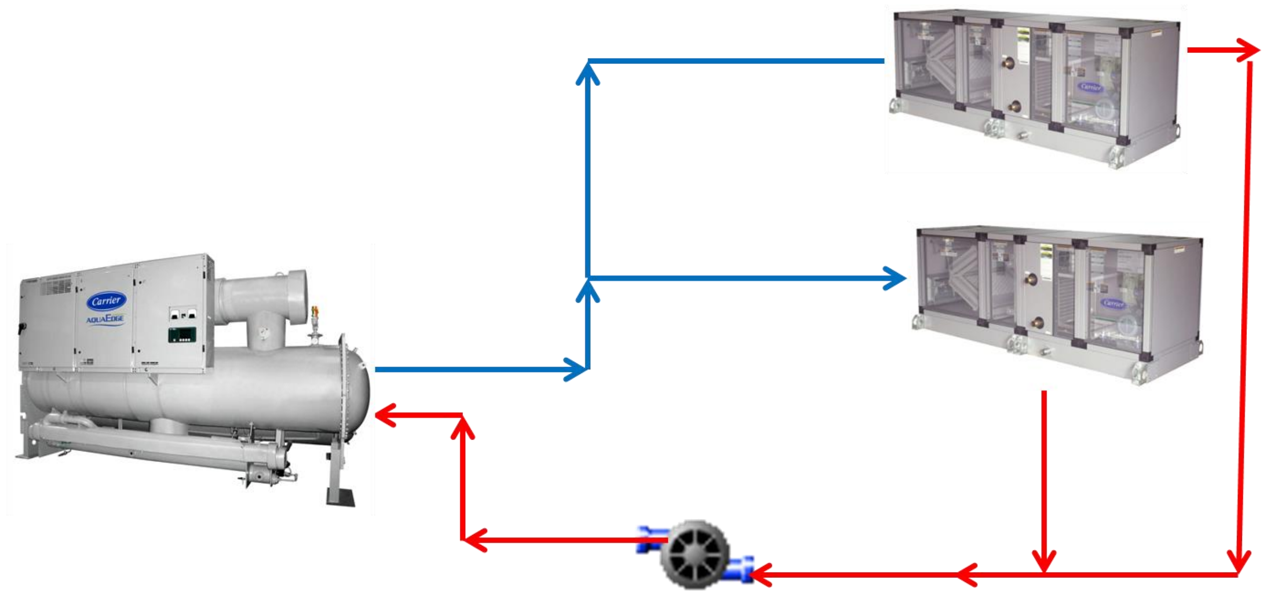

Figure 2- Simple Chilled Water Loop

Loop Volume

The amount of water in the chilled water loop has a significant impact on chiller performance. A small loop volume serves to magnify the impact of plant transients, while a large loop volume tends to act as an insulator. Consider a reduction in load when the loop volume is very small. As the space warms up slower than before (a load reduction), the water leaving the fan coil/air handler is cooler than it used to be. If this water quickly reaches the chiller, the chiller will not have the time to react to the difference in entering chilled water. Subsequently the leaving chilled water will be colder. This decreasing temperature cycle will continue until the chiller can react to the decreasing load via speed reduction. If the chiller cannot stabilize the leaving chilled water temperature fast enough, the chilled water will get close to the freeze protection set point and may shut down the chiller.

Once the chiller can reduce its speed, the compressor will work less hard. This decrease in work of the compressor re-equilibrates the rate of boiling vs. the rate of refrigerant removal of the compressor. This equilibrium is designed to settle out at the programmed chilled water set point. The 23XRV has no moving slide valves or guide vanes, so its reaction time to changes in load is very fast. This means there is less need for the buffering effects of larger loop volumes.

Smaller loop volumes can reduce total installed cost and possibly eliminate the need for a chilled water storage tank. As an example, a one (1) ft section of 8" diameter pipe should hold 2.6 gallons of water. For a chilled water loop with 3000 gallons, this would mean an equivalent distance of approximately 1150 ft. If the loop volume is shrunk to 1500 gallons, but the equivalent feet are constant, (1150 ft) then the pipe diameter could be reduced to 6". The reduction in cost for this change would vary by location, but could be a savings of up to ***45% in piping costs!***

The easiest way to examine the affect of a change in loop volume is to consider the effects of an identical transient on two systems whose only difference is loop volume.

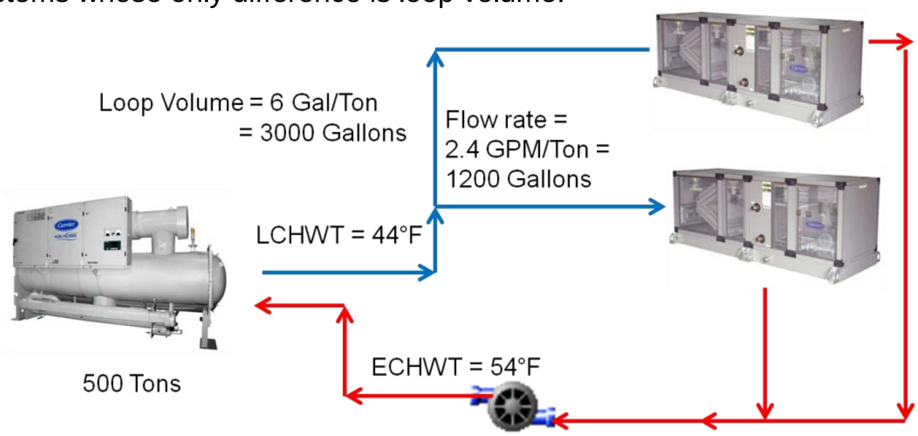

Figure 3 - Large Loop Volume System during Transient

The amount of time it takes the chilled water to complete one cycle is determined by how much water is in the loop, as well as the flow rate.

$$Loop\ Transit\ Time = \frac{1\ Minute}{1200\ Gallons} * 3000\ Gallons = 2\ min, 30\ seconds$$

During a load reduction transient, the ECHWT decreases, and until the chiller can unload, it will be matched by a corresponding reduction in LCHWT. If the chiller doesn't unload in time, it will get close to its freeze protection trip points. A smaller loop volume amplifies this affect, because the colder LCHWT makes its way BACK to the chiller more quickly, the cycle then progress at a faster pace. Consider the loop transit time if the loop volume is halved to 3 GPM/Ton.

$$Loop\ Transit\ Time = \frac{1\ Minute}{1200\ Gallons} * 1500\ Gallons = 1\ min, 15\ seconds.$$

Under these circumstances, the chiller designed for a small chilled water loop must be able to unload faster than the chiller designed for the larger loop volume to ensure the reliability desired.

Large Rate of Change of Flow

The effect of a large rate of change of load is the same as a reduction in loop volume. Consider our simple system where the chilled water flow rate very quickly goes from 100% down to 50%. Because capacity is a function of both flow and ∆T, as the flow-rate decreases, the ∆T across the chiller will increase. This will create a cycle where the leaving chilled water temperature will continue to decrease until the chiller can sense the condition and take action to control the leaving chilled water temperature. If the chiller cannot perform such action fast enough, the risk exists of freezing evaporator tubes, or shutting a centrifugal down on surge prevention. However, because the 23XRV has no slide valves, no guide vanes nor port unloaders, it is able to respond to these changing conditions very quickly. It is why the 23XRV is rated for a 70% reduction in flow per minute, far beyond the capability of any centrifugal on the market.

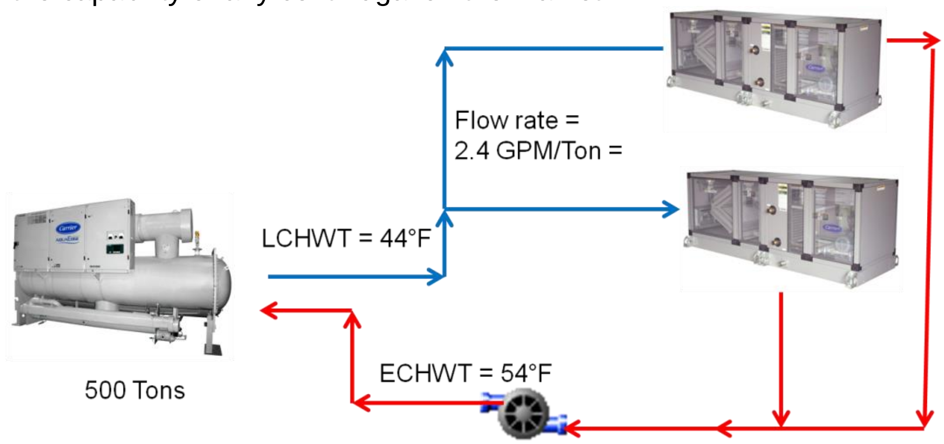

Figure 4 - Change in Flow before Transient

Shown is a 23XRV simple system at 100% load and design chilled water flow. If a flow reduction occurred, but the flow reduction was instantaneous, the system would appear as the below picture describes, until the chiller could unload.

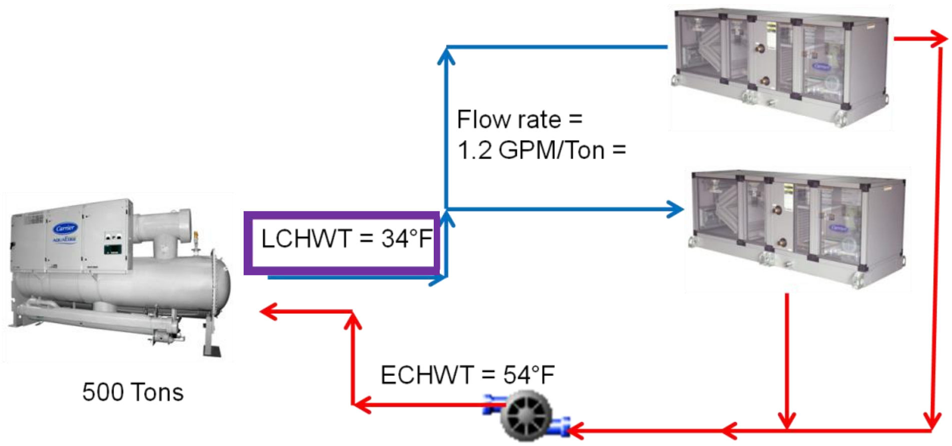

Figure 5 - Reduction in Flow Transient

In this diagram, the flow has decreased by 50%, but the load remains unchanged. The chiller must be able to unload quickly enough to reduce the evaporate ∆T and avoid tripping on a freeze protection set point.

Large Rate of Change of Load

The effect of a large, rapid change in load is very similar to the two transients previously discussed. A large reduction in load will reduce the temperature of the entering chilled water, and that temperature will continue to decrease until the chiller can unload. The faster the chiller is able to load up and un-load, the larger the change in plant load it can tolerate. Because the 23XRV has no slide valves, no guide vanes nor port unloaders, it is able to response to these changing conditions very quickly.

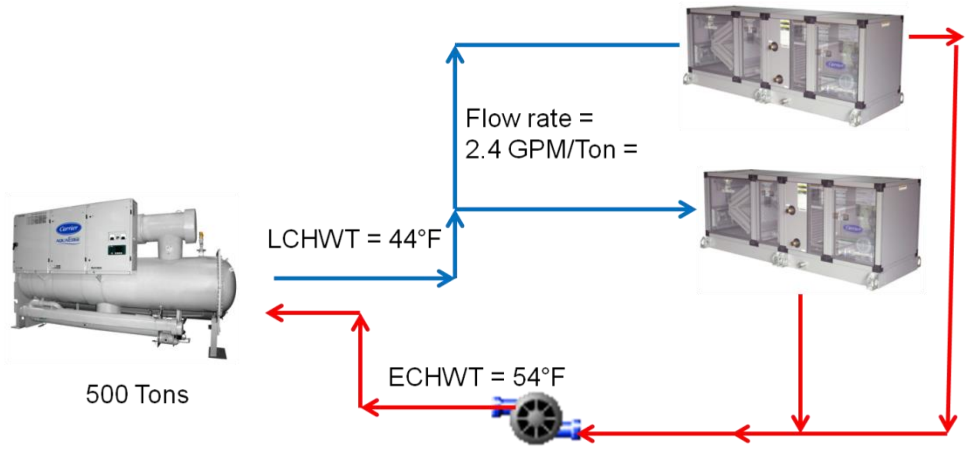

Figure 6 - Change in Load Before Transient

The above picture describes our simple system at steady state. When a large instantaneous reduction in load occurs, the ECHWT is lower, because the space is rejecting less heat to the chilled water loop. However, until the chiller can react, this will be matched by a corresponding reduction in LCHWT.

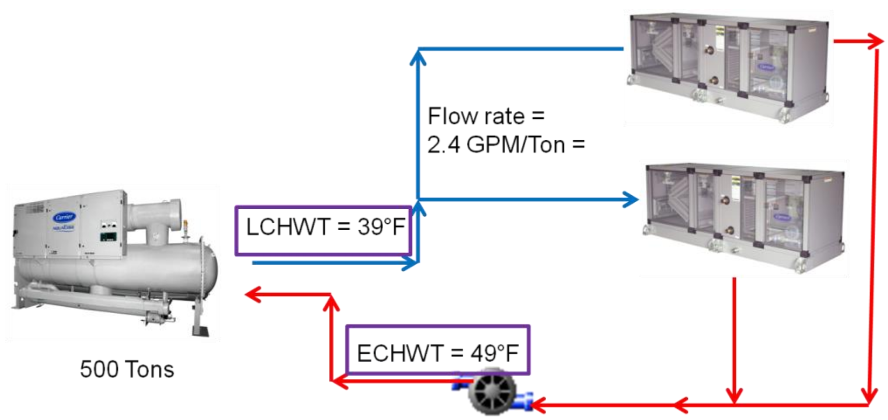

Figure 7 - Change in Load During Transient

The chiller will sense the reduction in ECHWT and begin unloading to return LCHWT to its intended set point. However, if the chiller cannot react fast enough, there is the potential to trip on a freeze protection set point.

	70% per Minute		10% per Minute	
Time after transient (minutes)	EChWT	LChWT	EChWT	LChWT
0	54	20.7 – Freeze Danger	54	44
1			54	42.9
2			54	41.5
3		The 23XRV can react fast enough to prevent This condition	54	39.7
4			54	37.3 – **Freeze Danger**
5			54	34 – **Freeze Danger**

Table 1- Large Change in Flow

Table 1 illustrates the changing temperatures for a flow transient where the chiller itself takes no action. After long enough, any chiller would trip on a freeze protection set point. A typical trip point for that parameter would be slightly higher than the freezing point of water, when using fresh water as the cooling medium. Knowing that, one can see how a 70% reduction in flow is problematic. However because speed control is the 23XRV's only method of capacity control, it CAN react fast enough to successfully navigate this transient. Inlet guide vanes are necessary on centrifugal chillers to control capacity when lift conditions (as opposed to load demand) determines impeller speed. The ideal fan laws do not improve with technology. All centrifugals will always require some method of capacity control beyond speed alone. Because the guide vanes cannot react as quickly as solid state electronics, the centrifugal chiller lags behind.