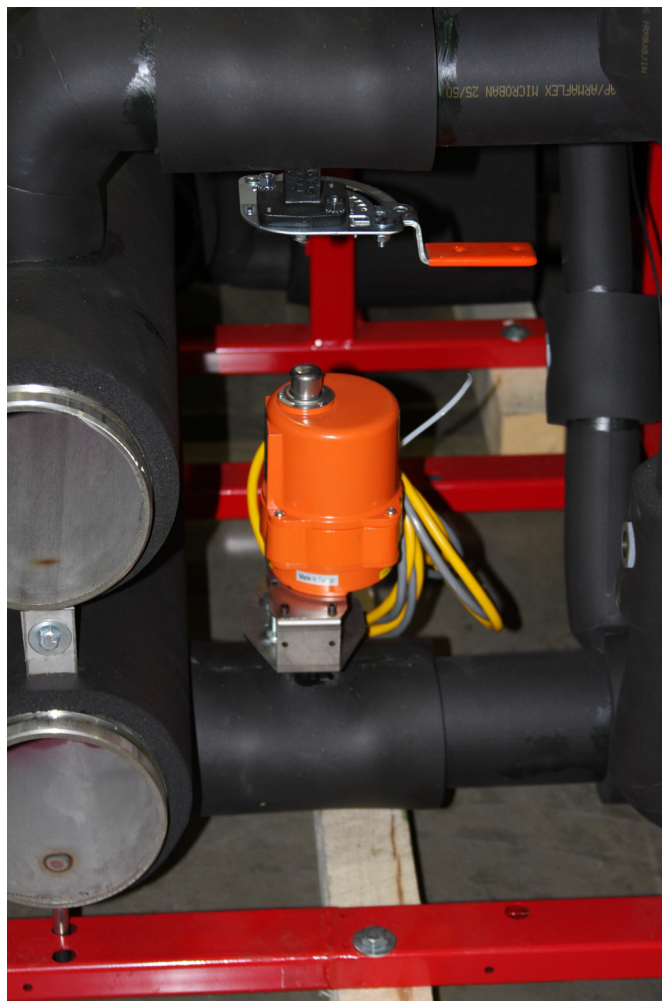


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Multistack Variable Primary Flow Control Capabilities Screw and Scroll Compressor Modules



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Multistack Modular Chillers and Variable Primary Flow Pumping Systems

The Multistack Modular Chiller design offers some unique advantages when used in a variable primary chilled water flow system. No other chiller system has the potential for greater turndown than the modular design of Multistack Chillers. Its high part-load efficiency and inherent redundancy make Multistack Modular Chillers ideal for most HVAC and Industrial Process applications.

Significantly different from a conventional chiller system, Multistack Modular Chillers must be properly understood and applied in a variable primary chilled water flow environment in order to take full advantage of its unique capabilities. This document will provide a good basis for understanding the application of a Multistack Modular Water Chiller in a variable flow system in such an environment. Certainly, specific application requirements may override the design approach suggested here.

When applying the Multistack Modular Chiller in such a system there are two important factors to consider.

- 1. Minimum flow requirement at low load**
- 2. Minimum flow requirement at full load**

With proper design consideration, managing these conditions is simple. We will outline the basic recommendations for employing a variable primary flow pumping system with a Multistack Modular Chiller first, then address flow requirements.

BASIC SYSTEM RECOMMENDATIONS

When applied in variable primary chilled water flow systems, the Multistack Chiller is unique in its operation compared to conventional systems. The application of the Multistack Chiller in these systems may require a different control approach when compared to conventional systems due to the multiple independent circuits employed by Multistack. When applying the Multistack Chiller in a variable flow environment, each unit incorporates its own modulating chilled water control valve and the individual compressor circuits often times do not unload (as is the case of the scroll compressor chillers). Finally, we must take into account the fact that most Multistack Chillers operate with capacity control logic based on return chilled water temperature.

A Multistack Chiller wants relatively constant PER CIRCUIT flow--variable primary flow is then achieved by "stepping" the chilled water flow up and down based on the number of operating circuits. For example, in the case of a 10-circuit modular chiller, we can theoretically operate the chiller in ten 10% steps. Similarly, in a 5-circuit modular chiller, we can theoretically operate the chiller in five 20% steps. At each of these steps, the variable flow system will operate to maintain a constant pressure differential across the chiller, however the flow at that constant pressure differential will vary based on the number of circuits operating (or, to say it in another way, how many of the modulating control valves are open).

Because of this unique operational characteristic of the Multistack Chiller, we recommend controlling the system bypass valve based on the pressure differential across the chiller (Drawing 1). So, as the pump VFD operates to maintain a pressure set point, the system bypass valve will modulate to maintain minimum pressure across the chiller at all operating conditions.

Since the distribution units (AHU, FCU, etc.) are modulating their control valves in response to system load and the chiller also operates in response to the same system load, the distribution units and the chiller should always require similar flow. However, the inherent control lag and differing response times in these two systems will cause, at any given time, the flow needs of the distribution system and the chiller to be out of synch. These control lags, which are the most difficult part of controlling most variable flow systems, are inevitable and easy to manage in the properly engineered Multistack Variable Flow system.

Further, since chilled water distribution systems handle transient flow fluctuations much better than conventional or modular chillers, positive control of the flow through the chiller is necessary. Unlike conventional chiller systems, a unique characteristic of the Variable Flow Multistack Modular System is that the flow requirements of the chiller are easily measurable and controllable—and directly correlate to the pressure differential across the chiller at all load conditions. For that reason, we also recommend that Pump Speed is controlled based on the pressure differential across the chiller because the chiller control system is continually measuring and responding to the system load. A unique characteristic of modular chillers is that although the flow changes as it opens and closes its valves, the pressure differential across the chiller remains relatively constant (that is, the modular chiller is variable flow, but constant differential pressure). So, by controlling the variable speed pump to a differential pressure set point across the chiller the pump still responds to the system load. With a modular chiller, since the chiller is always more susceptible to operational issues due to flow, it is much more reliable to control flow based on chiller requirements than based on a pressure set point in the system.

NOTE: *In this system it is still acceptable to control to a system pressure set point, which is the traditional method of Variable Speed Pump Control. The disadvantage of this traditional control method in a modular variable flow system is that in those transient periods when the distribution system is asking for more flow than the chiller requires, you will pump more water, and consume more energy than if you were to control to the differential pressure across the chiller. And, since this condition is transient, and it is inevitable that the chiller will sense the increase in load being indicated by the distribution system (and therefore increase its flow and capacity output), that this temporary condition of the distribution system requiring more flow than the chiller will be rectified in relatively short order.*

Using the Multistack design control method coupled with the recommendations in the rest of this document will yield a reliable and efficient variable primary system that, in most cases, can turn down significantly lower than conventional variable flow systems, and is much easier to design, commission, operate and maintain.

MINIMUM FLOW REQUIREMENTS AT LIGHT LOAD

Multistack provides automatic flow control valves at each chiller evaporator in order to achieve maximum flow turndown. In most systems, this is achieved by the use of modulating two-way valves in each module allowing each valve to control the leaving water from its module to the system's leaving water set point.

In order to insure proper operation at all load points, the system must maintain a minimum pressure differential across the chiller. By maintaining this minimum pressure, we insure that there will be sufficient flow at all load conditions. In addition, as is unique to the modular variable flow design, the minimum flow required by the chiller will differ at any given load point—which is easily measurable.

In conventional chillers, a low chilled water flow condition will cause a system safety and take the chiller off line. In a Multistack Chiller variable flow system, the most common indication of a flow problem is a chilled water freeze protection safety alarm. Since each individual Multistack chilled water evaporator has its own freeze protection safety, any time an individual evaporator sees a significant reduction in flow, that individual circuit may lockout on a freeze protection safety.

Because the internal header system of Multistack Modular Chillers tie together the system evaporators in a parallel flow arrangement, the differential pressure across the system can be directly correlated to the flow across all active evaporators (evaporators with their individual flow control valves open). The Multistack control system will insure that the lead circuit (which is normally rotated each day) will never fully close its modulating valve, insuring that the pumping system will not be “dead-headed” by the chiller under a no-load condition.

It is common for the Multistack Variable Flow Chiller to have minimum flow requirements less than 10% of full load design flow, even though the pumping system often requires a higher minimum flow than the Multistack Chiller. If this is the case, it is important to consider any possible requirement for a larger no-flow chiller bypass than is provided by the Multistack Chillers lead valve remaining open. Multistack can provide custom programming to open more than just the lead valve in a no-load and/or light load condition.

The minimum flow requirement of the Multistack Chiller will typically be the flow required for one half of one module because the turndown of most Multistack Chillers is 50% of the capacity of one module.

MINIMUM FLOW REQUIREMENT AT FULL LOAD

As discussed earlier in this document, there will always be some control lag between the load seen by the chilled water distribution system and the Multistack Chiller. Because of this, it is possible for the chiller to see a higher load than the air handler (or other terminal device) control valves. One such scenario could look like this: The chiller is operating at full load (perhaps in a pull down situation) and as the air handlers gain control of their load, they all simultaneously drive their chilled water control valves to their minimum positions (this can happen quite abruptly in some variable primary flow systems). As a result, the system flow begins to drop significantly as the pressure in the system rises. Sensing this rise the pump speed is reduced to compensate. At this point, the chiller (whose capacity is being controlled by chilled water temperature) has not yet seen a drop in required capacity at its system sensors due to the system water volume, and the time lag between a change in leaving temperature at the terminal devices and a change in temperature at the inlet header of the Multistack Chiller and remains fully loaded. So, if no other system action is taken, the result of this condition will be to significantly reduce the flow through the Multistack Chiller before the chiller has been able to sense a change in load and begin its unloading process. This could lead to a system lock-up on a freeze protection fault.

EXAMPLE: System Description

- Multistack Chiller System consisting of (5) MS50Z Modules @ total capacity of 250-tons
- Total refrigerant Circuits: 10
- Total System Design Flow: 600 GPM
- Minimum design flow at Light Load = 60 GPM
 - o 1/2 of the flow for 5 modules, or 1/10th of total system flow at full load
- Design Chilled Water Temperatures:
 - o Entering Chilled Water = 57°F
 - o Leaving Chilled Water = 45°F

Formula for determining Minimum Flow at Full Load:

- $GPM = (\text{System Capacity in tons}) / ((1/24) * ((\text{Design Return Water Temperature}) - 38^\circ\text{F}))$

Calculation for Example System

- $GPM = (250 \text{ Tons}) / ((1/24) * (57^\circ\text{F} - 38^\circ\text{F})) = 316 \text{ GPM}$

Notes:

1) From this calculation, we can conclude that the Minimum Pressure Differential allowable across the Multistack Chiller, at all load points, will equal the pressure drop of the chiller, operating at full load, with 316 GPM of total flow.

2) This formula uses 38° F as the minimum allowable leaving water temperature under any transient condition. This can be adjusted, but 38° F is the recommended minimum temperature

When sizing the system bypass, it is likely unnecessary to accommodate the full 316 GPM as calculated in the above example. If the minimum position of the chilled water control valves in the system is 30%, then you can take credit for this flow when sizing the bypass. So, if 30% of full load system flow is 180 GPM (as is the case in our example), then you can size the bypass for 316 GPM – 180 GPM, or 136 GPM. The minimum flow bypass should be located on the load side of the piping system (end-of-loop bypass), but may also be located in the equipment room on the load side of the system pump.

The modulating system bypass valve should be controlled based on pressure differential across the chiller. In order to get the widest control range and the lowest possible energy consumption from the pumping system, we recommend that the linear control algorithm follow this guideline:

1. Bypass Valve is Full Closed when DP across chiller \geq Pressure Differential Set Point
 - a. The Pressure Differential Set Point is the design Pressure Differential across the Multistack Chiller at full load with full design flow
2. Bypass Valve is Full Open when DP across chiller \leq Minimum Pressure Differential Set Point
 - a. This is the pressure drop across the Multistack Chiller when the system is operating at Minimum Flow at Full Load as described in this section

NO LOAD CHILLER BYPASS

The Minimum Flow Requirement at Light Load section discusses a unique capability of Multistack Variable Flow Chillers, the potential capability to require lower flow under light load conditions than the pumping system. That is, if each Multistack Module incorporates a chilled water control valve that closes flow whenever its corresponding circuit is off, then at a no-load condition, all chiller circuits will be shut down. If this occurs, without the provision for a NO LOAD CHILLER BYPASS, then the pumping system will be dead-headed.

As mentioned earlier, the standard Multistack Variable Flow Controller will insure that the chiller's lead circuit variable flow valve will always be open. This allows the flow required for one circuit through the chiller, so the issue of dead-heading through the chiller can be avoided. However, if the flow required for one chiller circuit is not adequate to maintain the minimum speed and/or minimum flow requirements of the Variable Flow Pumping System, then additional provisions for no-load chiller bypass must be made. There are many ways to handle this condition.

- Multistack can incorporate a no load chiller bypass into its chiller system
- Multistack can program its Variable Flow Controller to provide for more flow through the chiller under no-load or light-load conditions
- An external chiller bypass can be incorporated into the system design
 - o Note: This is a different chiller bypass than the "System Bypass" described above

If the minimum flow bypass is not provided within the Multistack Chiller System, and is incorporated into the system piping, here are some important design requirements.

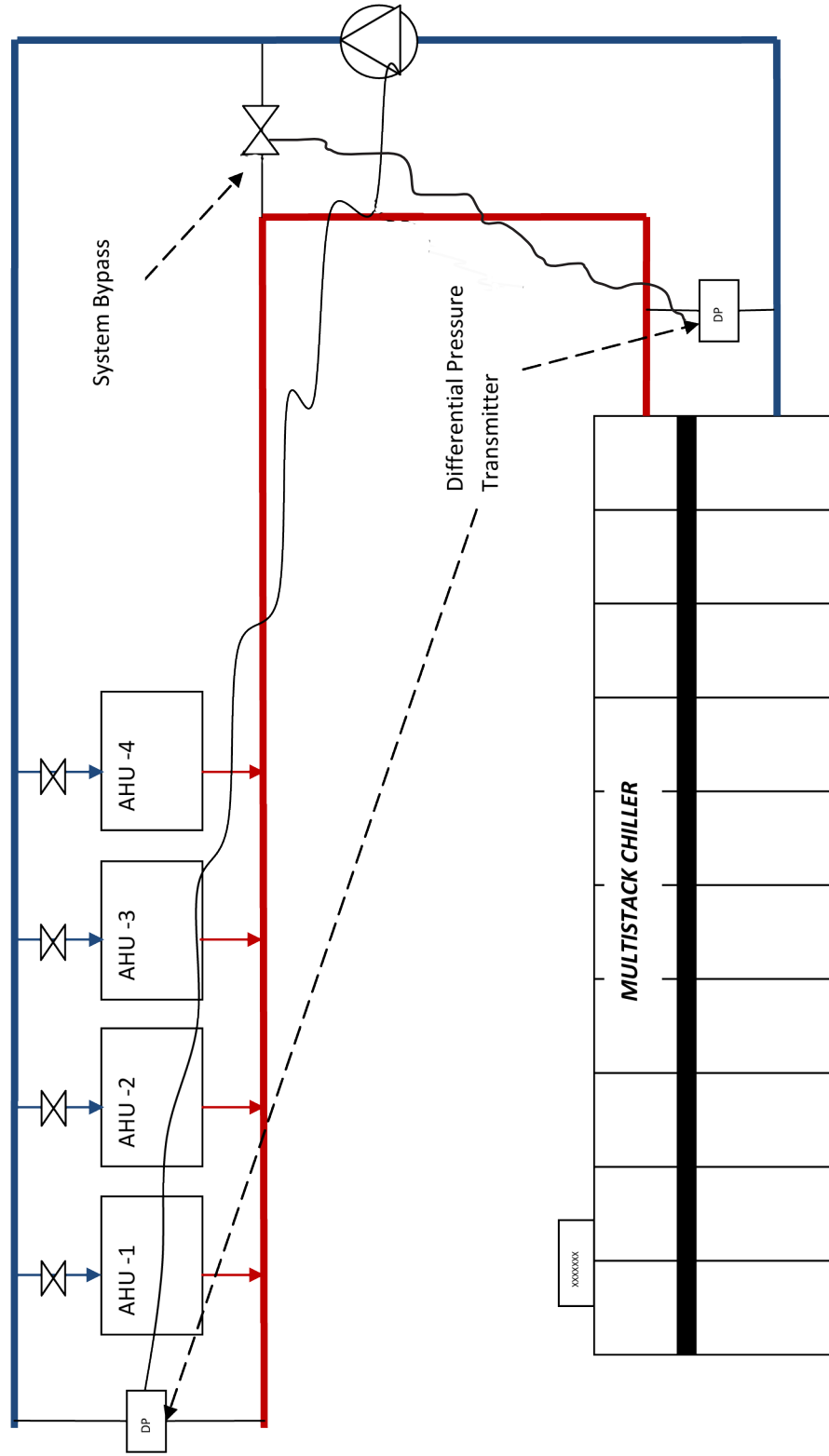
1. The bypass must open prior to, or simultaneously with, the last valve closing in the Multistack Chiller
2. The bypass must close once the Multistack Chiller has returned to its operating mode so as not to take needed flow from the chiller, and causing a freeze protection lockout
3. The bypass must be sized for the minimum requirements of the pump, VFD and the rest of the hydraulic system
4. Take into consideration the required flow/pressure needed at the inlet of the chiller when the first circuit starts.

CONCLUSION

The Multistack Variable Flow Chiller can offer significant control and turn-down advantages in variable primary flow pumping systems that will both improve the energy profile of the system, and simplify the operation of the variable flow control system. Multistack has had extensive experience in variable flow pumping systems and is interested in being as involved as our customers would like us to be in the design process. Please contact us with any questions or concerns that you may have. We will listen, and do our best to support you in making your system the best it can be.

Diagram 1

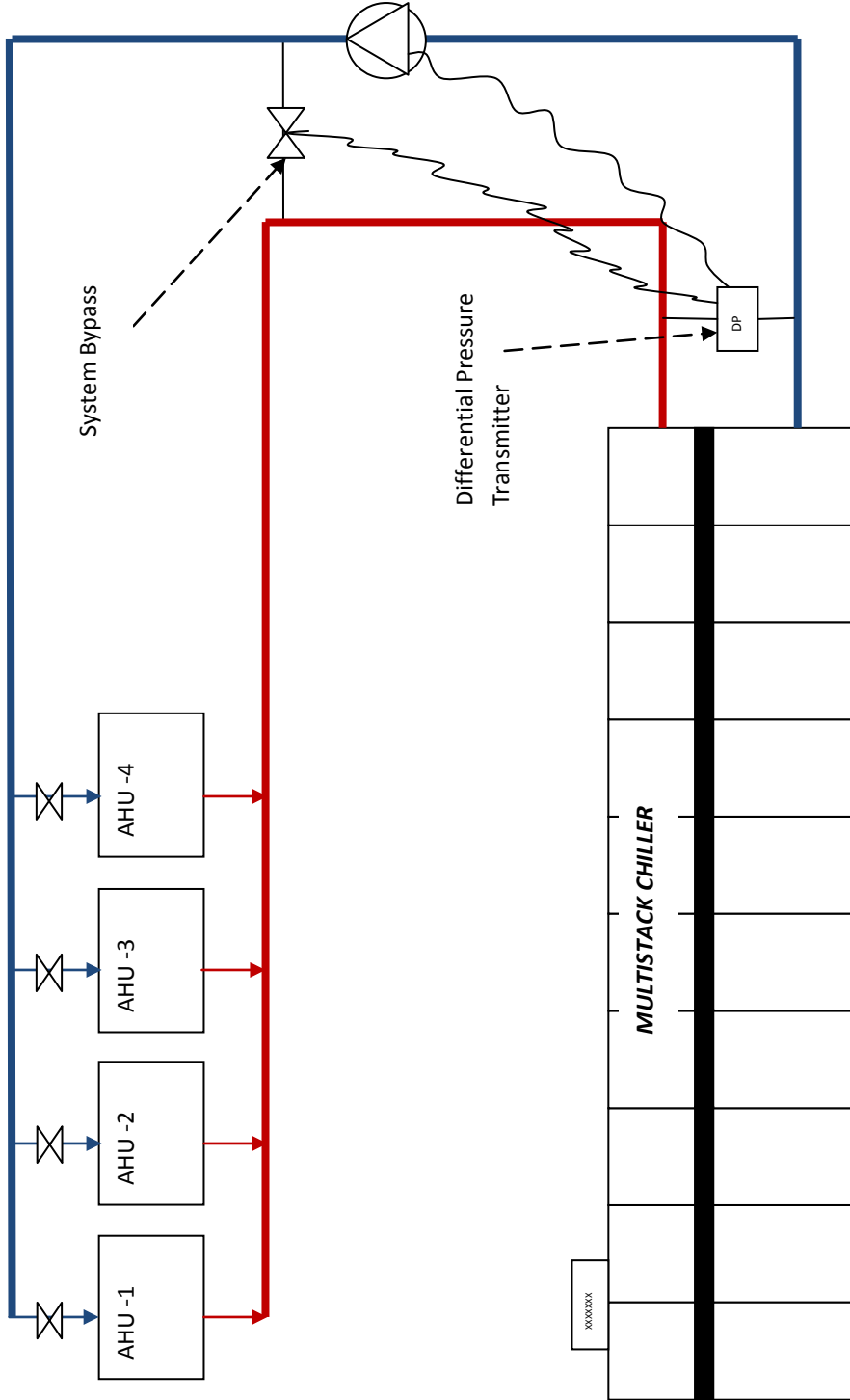
*Multistack Alternate Variable Flow Chiller Schematic
System Pressure Control*



1. Pressure Differential Set Point = _____ PSI
2. System Minimum Flow at Chiller Full Load = _____ GPM

Diagram 2

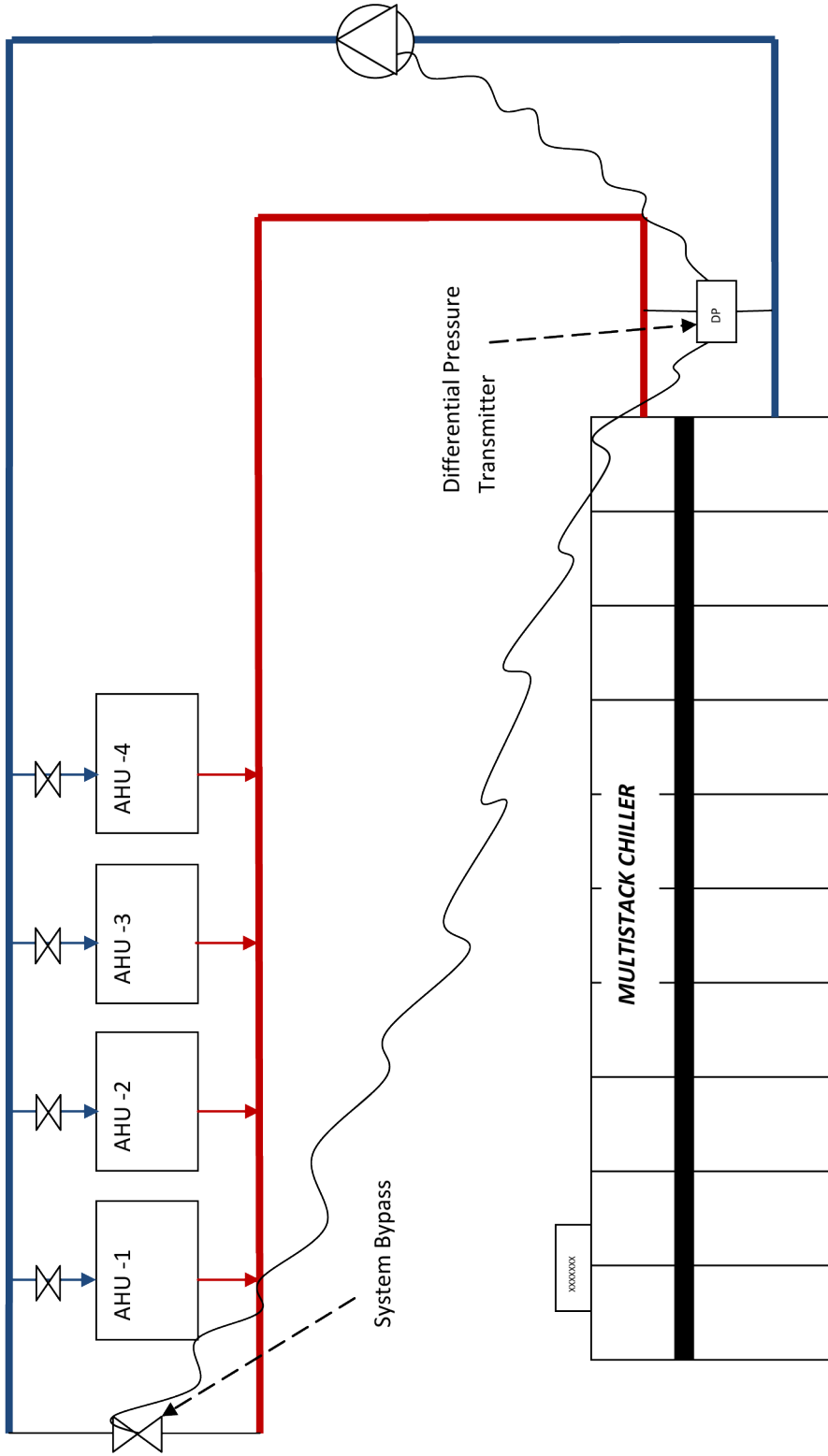
Multistack Variable Flow Chiller Schematic Equipment Room System Bypass



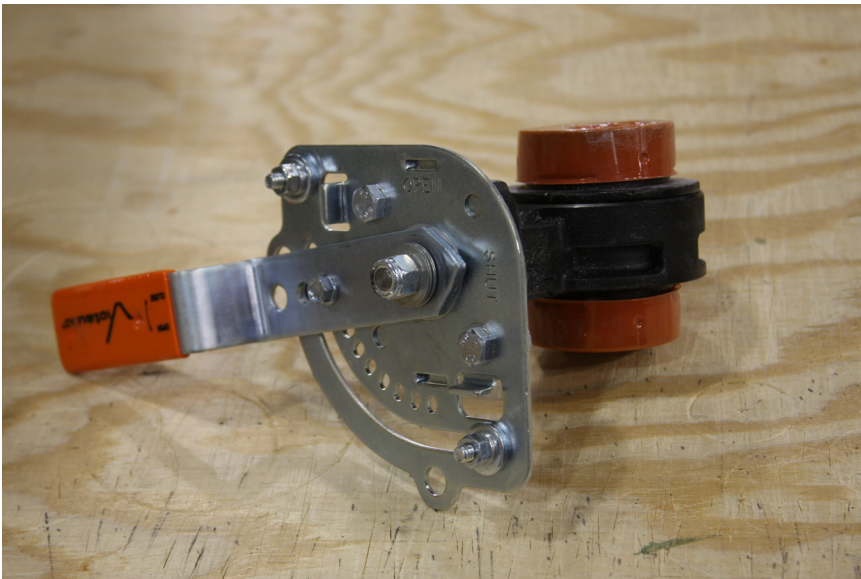
1. Pressure Differential Set Point = _____ PSI
2. System Minimum Flow at Chiller Full Load = _____ GPM
 - a. Chiller Pressure Differential at Minimum Flow = _____ PSI
3. System Bypass Maximum Flow = _____ GPM
4. Provide proportional control of Bypass Valve as follows:
 - a. Bypass Valve is fully closed when DP across chiller \geq Pressure Differential Set Point
 - b. Bypass valve is Fully Opened when DP across chiller \leq Chiller Pressure Differential at Minimum Flow

Diagram 3

**Multistack Variable Flow Chiller Schematic
Chilled Differential Pressure Control**



1. Pressure Differential Set Point = _____ PSI
2. System Minimum Flow at Chiller Full Load = _____ GPM
 - a. Chiller Pressure Differential at Minimum Flow = _____ PSI
3. System Bypass Maximum Flow = _____ GPM
4. Provide proportional control of Bypass Valve as follows:
 - a. Bypass Valve is fully closed when DP across chiller \geq Pressure Differential Set Point
 - b. Bypass valve is Fully Opened when DP across chiller \leq Chiller Pressure Differential at Minimum Flow



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