Colmac Cx Series Sequence of Operations

Summary of heat pump water heater operation:

Colmac's Cx series heat pump water heaters are designed to operate on their own, or in arrays of multiple heat pumps. They will communicate in a master-slave configuration via ethernet to balance run hours and coordinate lead/lag and staging.

The following logic is based off stratified storage, meaning there is cold water in the bottom of the tank, hot water in the top, and a *stratification layer* between the two. A stratification layer is simply the transition point between hot and cold water in the tank. With a defining layer between hot and cold water, we can look at the tank capacity as a volume of hot water remaining, rather than a uniform temperature.

When there is a draw from the building, hot water leaves the top of the stratified storage tank and cold makeup water enters the bottom of the tank. As the hot water is depleted, the cold-water level rises, and the stratification layer rises along with it. A temperature sensor in the side of the tank will see a dramatic drop in temperature when the stratification layer (and the cold water below it) reaches the sensor location. As an example, if the sensor is halfway up the side of a 100-gallon tank, roughly 50 gallons of hot water will have been drawn from the tank when the temperature sensor sees a dramatic temperature drop. For this reason, the location of the temperature sensor in the side of the tank is paramount. Our sizing simulations usually assume a 20-25% storage draw before the heat pumps turn on.

When the master heat pump sees a temperature drop via the factory-provided tank temperature sensor, it will tell the heat pump with the least amount of run hours to turn on. Once the heat pump turns on, it will push hot water into the top of the tank, pushing the stratification layer and cold-water column down.

If the temperature sensor continues to see a temperature drop after the first heat pump has started, that means the building is drawing more hot water than the heat pump can produce. If there are multiple heat pumps, this event would trigger another heat pump to turn on. The second heat pump's call to turn on would be driven by stage 2's setpoints.

At this point, neither heat pump will turn off until warm water enters the heat pump inlet. Since the heat pumps are pulling cold water from the bottom of the stratified storage tank, an increase in heat pump inlet temperature means the cold water has depleted and the hot water has filled the entire tank.

On the following page is a simple sequence of operation that shows settings for a multi-stage heat pump system. The system can be configured in multiple stages to lengthen heat pump run time, or it can have a single stage with one or more heat pumps turning on after the initial tank temperature drop.

Sequence of Operation:

Stage 1:

- Monitor tank temperature sensor
- If tank temperature <= DELAY SETPOINT, start count down.
- If tank temperature stays below DELAY SETPOINT temperature for specified amount of time (DELAY TIME), turn on specified quantity (# TO RUN) of heat pumps.
- Heat pump produces specific water temperature (usually 140°F)
- Run until Entering heat pump inlet temperature > MAX POTABLE ENTERING TEMPERATURE.
    - The max EWT setpoint drives required pipe sizing because it drives the minimum TD through the heat pump. The lower the minimum TD (due to higher inlet temperature and fixed outlet temperature), the higher flow rate the heat pump will produce.

Stage 2:

- Repeat stage 1 with new set of setpoints.

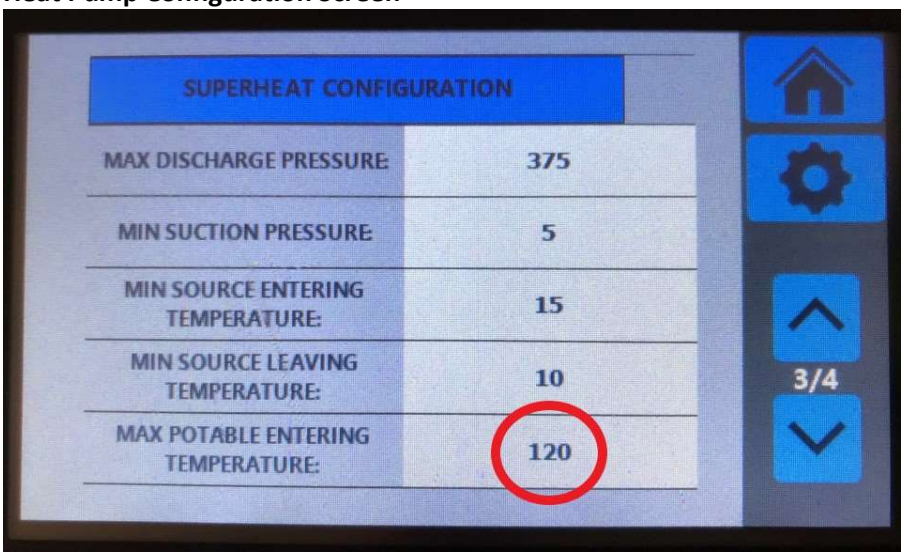
A few remarks:

- Each stage can have one or more heat pumps assigned to it.
- Once max entering water temperature is reached, all heat pumps will turn off. All heat pumps that have been triggered, regardless of which stage, will run until the max entering water temperature is reached on any of the heat pumps. The heat pumps should be piped in parallel, so the entering water temperatures should be near equal on all heat pumps.
- Each stage uses its own temperature setpoint and can reference a different sensor than the stage before it.
- If a BMS is used that will forego the staging system, it can simply tell the master how many heat pumps to run and the master will look at run-hours to determine which specific heat pumps to run.

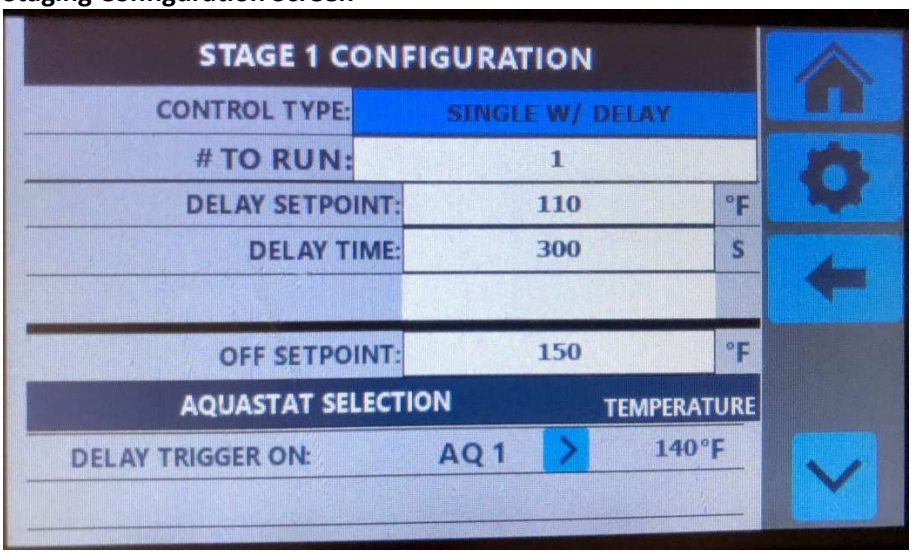
Configuration Screens

Below are screenshots of the staging configuration screen, and the heat pump configuration screen. For the purpose of staging, the only important setting on the heat pump configuration screen is the max potable entering temperature.

Heat Pump Configuration Screen



Staging Configuration Screen



Variables not covered in sequence of operations:

OFF SETPOINT: This is a redundant off point that can be used for more advanced staging controls. For basic staging purposes, this can be set 10F higher than the heat pump outlet temperature.

DELAY TRIGGER ON: In a system with multiple temperature sensors, you can choose which temperature sensor the stage looks at to turn heat pumps on. The corresponding temperature is the current temperature of the sensor you have selected.