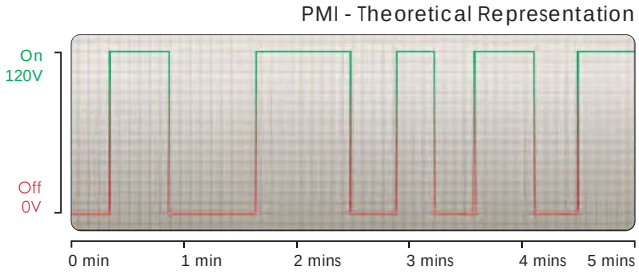
Pulsed Modulated Injection Theory (PMI)

PMI uses all 3 (proportional, integral, derivative) functions of a PID Control algorithm to open and close 1 of 2 relays housed within the CPU-1000. The control can choose to use PMI on either a pump (PMIp) terminals 26, 27 & 28 or a valve (PMIv) terminals 15 & 16.

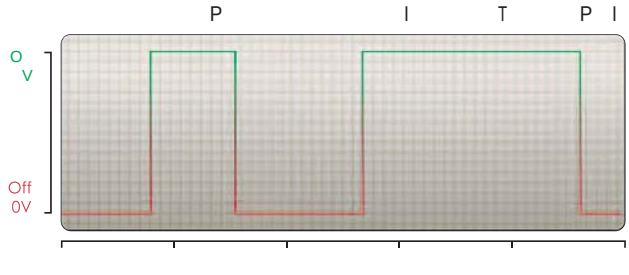
In the example of a pump, the PMI logic will determine how long the pump needs to be ON for and how long to be OFF for to maintain adequate injection rates to stabilize the target temperature in the mixed (radiant) heat emitter. In the case of pump injection, the pump is being held on (pulsed on) e.g. full speed, for a calculated period of time and then held off (pulsed off) e.g. zero speed, for again a calculated period of time. The ON pulse and the OFF pulse, time is continuously being monitored and compensated for by the Controls internal algorithm using PID application theory.

*** It is important to view this as a long on pulse or off pulse as opposed to a rapid series of pulses. The duration of each pulse will likely be several seconds or even minutes before the beginning of a new cycle length. It is also important to recognize that this control principle cycles the device on and off more frequently than is customary. This has been taken into consideration and several safety features are built into the Control to alleviate any potential adverse effects on the Control, the electrical environment, pump motors and valve coils.**

A. Typical Short Cycle Runtime



B. Typical Long Cycle Runtime



*** In both examples, actual cycle time may be longer or shorter then shown**

In the case of PMIv or valve injection the theory is exactly the same. With regard to the slower and varying response time of the valve the control PID will compensate and respond with timing changes accordingly.

HBX has tested this injection principle both in the lab and in extensive customer site locations with a variety of manufacturers' valves and pumps with exceptional control characteristics and no detrimental effects on either valve motors/coils or pump motors etc.

The main advantages to employing this control strategy with mixing are:

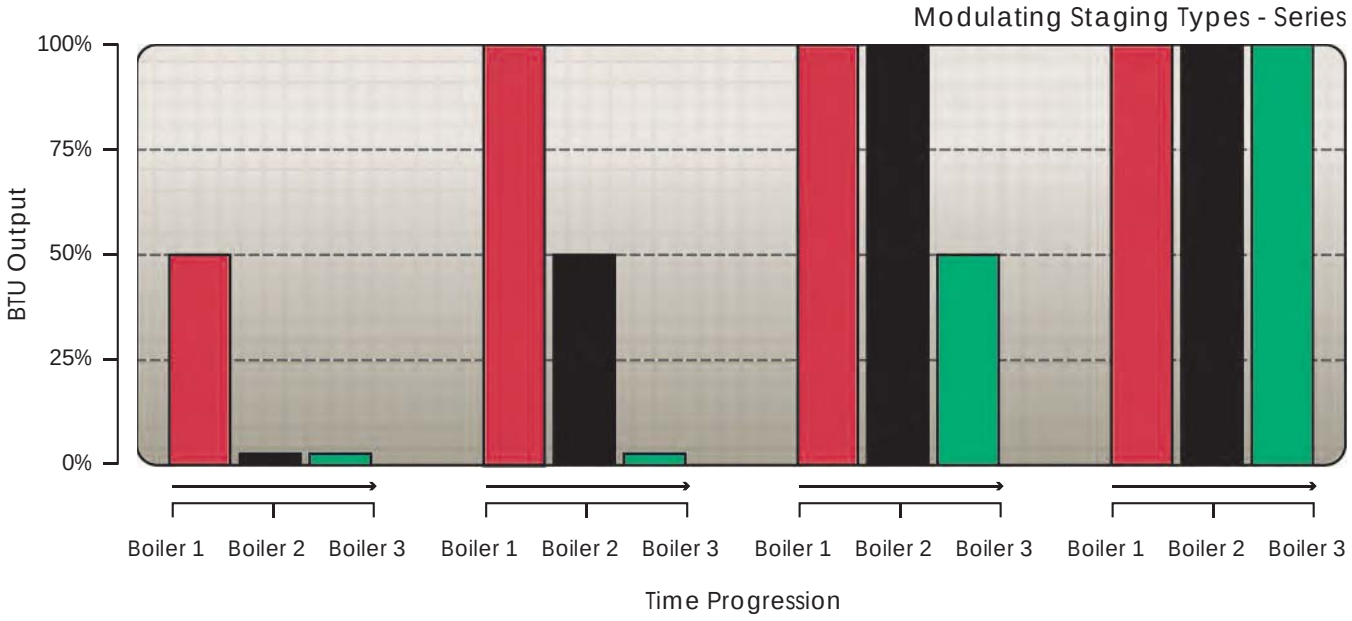
- **i.** Single Phase pumps up to 10 amps (1HP, 120VAC) can be used for injection
- **ii.** Extra Controls do not need to be wired into the main Control
- **iii.** The option exists for future mechanical system upgrades or modifications without changing your primary controller
- **iv.** Greater injection control using valves

PMIp is not recommended with split-phase motors. Premature failure of the start winding and/or centrifugal starting contacts may occur.

MODULATION TYPE: SERIES

The Series method of modulating boilers is based on a simple but effective algorithm. Underlying theory causes boiler 1 to fire when there is a load; modulating from the start percent (designated by the installer within the modulating options of the Control) to 100%. If the heat demand has not been satisfied at this point boiler 2 will then begin to modulate from the start percent to 100% (if required). This process will continue for each installed modulating boiler in the system to a maximum of five.

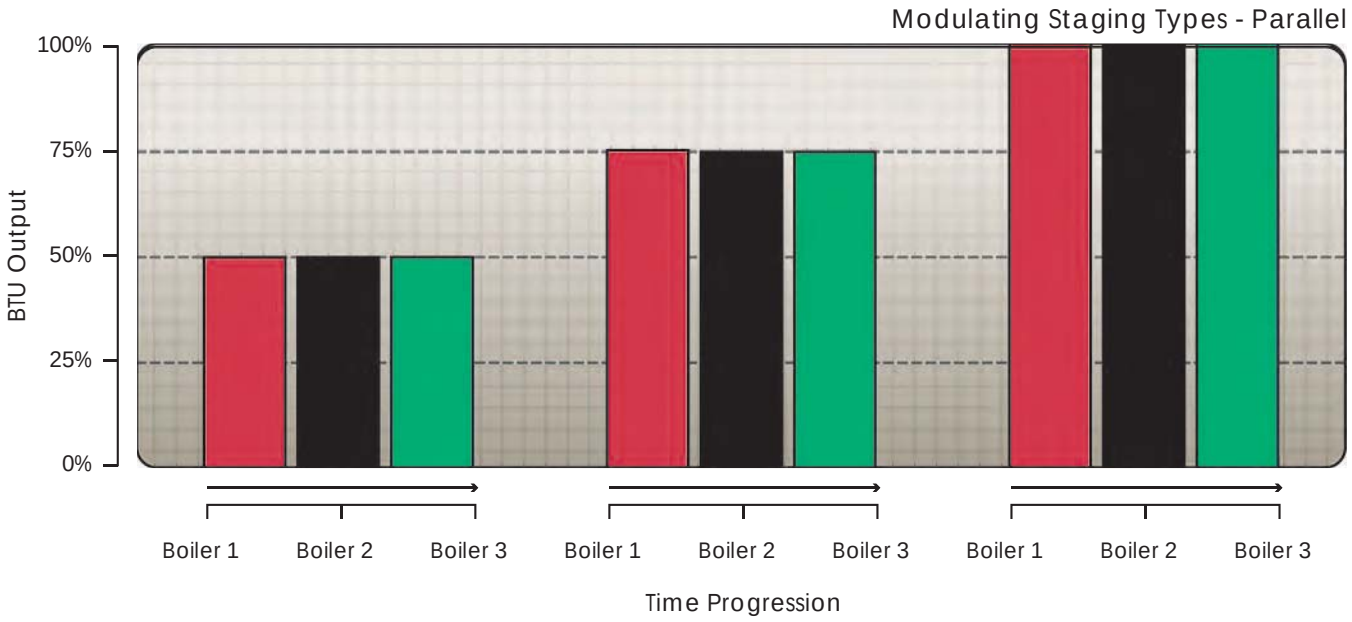
The process of modulating the boilers off works the same. When the last boiler in the system drops to the start percent it will then shut off that boiler. If the load continues to decrease then the Control will modulate down the second last boiler set up in the system. This will continue on until the lead boiler has dropped to the start percent. At this point the Control will allow the PID calculation to increase helping with boiler cycling. This will hold the lead boiler in the minimum fire (or start percent) position for longer, allowing the boiler to cycle less. As a result; system maintenance and system wear due to boiler cycling is decreased.



MODULATION TYPE: PARALLEL

The Parallel method of modulating boilers is the simplest of modulating algorithms. Underlying theory causes all of the installed boilers to simultaneously modulate from the start percent (designated by the installer within the modulating options of the Control) to 100% depending on the system load requirements. The maximum number of modulating boilers that the Control can handle is five.

The process of modulating the boilers off works in the same manner. When the load decreases, all of the boilers will modulate down until they are at the start percent . At this point, to help with boiler cycling, the Control will allow the PID calculation to increase. This will hold the lead boiler in the minimum fire position(or start percent) for longer allowing the modulating boiler to cycle less. As a result; system maintenance and system wear due to boiler cycling is decreased.



MODULATION TYPE: PROGRESSIVE

Progressive modulation is a complex algorithm for very precise control over modulating devices. HBX Controls has optimized the process to work effectively for multiple modulating boilers. This modulation algorithm is a combination of series and parallel modulation with additional benefits.

Underlying theory causes the first boiler to modulate from the start percent (designated by the installer within the modulating options in of the Control) to 80% modulation. If the load still requires more heat then boiler 1 decreases to 40%, and boiler 2 increases from 0% to 40% (maintaining 80% output with 2 modulating boilers now on). As the load increases both modulating boiler 1 and modulating boiler 2 will increase to 80%. If there is still a higher load requirement, both boiler 1 and boiler 2 will decrease to 55% and modulating boiler 3 will increase from 0% to 55%. All 3 modulating boilers now take on approximately the same load as the 2 modulating boilers at 80%. This process will continue on until all boilers set up in the system are firing. When all the modulating boilers are firing and a load is still required, all 3 boilers will modulate to 100% simultaneously.

As load decreases the modulating boilers will simultaneously modulate down to the start percent. The lag boiler will shut down and remaining modulating boilers will increase their modulating to split the remaining load in percent. At this point to help with boiler cycling the Control will allow the PID calculation to increase. This will hold the lead boiler in the minimum fire position for longer allowing the modulating boiler to cycle less. As a result; system maintenance and system wear due to boiler cycling is decreased.