TYPE 659: AUXILIARY FLUID HEATER WITH PROPORTIONAL CONTROL (PROPORTIONAL BOILER)

General Description

Type659 models an external, proportionally controlled fluid heater. External proportional control (an input signal between 0 and 1) is in effect as long as a fluid set point temperature is not exceeded. If the set point is exceeded, the proportional control is internally modified to limit the fluid outlet temperature to the set point as with Type6.

Nomenclature

T_{in}	[ºC]	Fluid inlet temperature
T_{out}	[ºC]	Fluid outlet temperature
T_{amb}	[ºC]	Ambient temperature
T_{ave}	[ºC]	Average temperature of fluid in the heater
$\dot{m}$	[kg/hr]	Fluid flow rate
Cp	[kJ/kg-K]	Fluid specific heat
UA	[kJ/hr]	Proportional boiler thermal loss coefficient
$\dot{Q}_{fluid}$	[kJ/hr]	Energy of the fluid
$\dot{Q}_{loss}$	[kJ/hr]	Energy lost by the heater to the ambient
$\dot{Q}_{aux}$	[kJ/hr]	Auxiliary energy added to the fluid by the heater
CAP_{htr}	[kJ/hr]	Heater capacity
γ_{htr}	[0..1]	Heater control signal
η_{htr}	[0..1]	Heater efficiency

Detailed Description

Type659 resolves the energy balance shown schematically in Figure 1 for the cases of no flow, flow with heater off and flow with heater on.

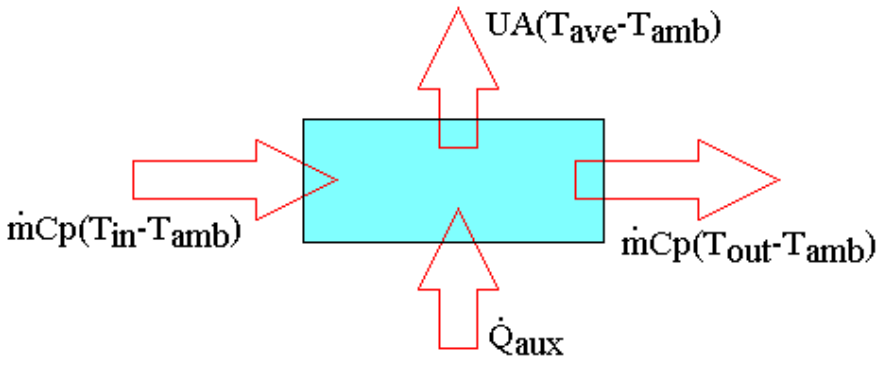


Figure 1: Fluid Heater Energy Balance

With flow through the device but the heater off, the energy balance can be written to solve for the fluid outlet temperature as shown in Equation 659.1.

$$T_{out} = \frac{\dot{m}CpT_{in} - UA\frac{T_{in}}{2} + UAT_{amb}}{\dot{m}Cp + \frac{UA}{2}} \quad \text{(Eq. 659.1)}$$

where the energy lost by the heater to the environment is given by equation 659.2 and the energy imparted to the fluid is given by equation 659.3

$$\dot{Q}_{loss} = UA\left(\frac{T_{out} - T_{in}}{2} - T_{amb}\right) \quad \text{(Eq. 659.2)}$$

$$\dot{Q}_{fluid} = \dot{m}Cp\left(T_{out} - T_{in}\right) \quad \text{(Eq. 659.3)}$$

With the heater on and fluid flowing through the device, the additional term for auxiliary energy is added into the energy balance. The outlet temperature is now given by equation 659.4

$$T_{out} = \frac{\dot{m}CpT_{in} - UA\frac{T_{in}}{2} + UAT_{amb} + \gamma_{htr}\eta_{htr}CAP_{htr}}{\dot{m}Cp + \frac{UA}{2}} \quad \text{(Eq. 659.4)}$$

Where γ_{htr} is the heater control signal having a value between 0 and 1, and η_{htr} is the heater efficiency. Because of the control signal and the heater capacity it is possible that the fluid outlet temperature will be lower than the desired set point. If equation 659.4 results in a fluid outlet temperature higher than the set point, internal controllers take over to limit the outlet temperature to the set point. The auxiliary energy imparted to the fluid by the heating element is given by equation 659.5.

$$\dot{Q}_{aux} = \frac{\dot{m}Cp\left(T_{out} - T_{in}\right) - UA\left(T_{ave} - T_{amb}\right)}{\eta_{htr}} \quad \text{(Eq. 659.5)}$$