TYPE 751: SIMPLE BOILER WITH EFFICIENCY FROM DATA FILE

General Description

Type751 models a simple steam boiler. According to ASHRAE, a boiler is defined by its overall efficiency (output/input) and by its combustion efficiency ((input energy-stack energy)/input energy). In this model, the boiler efficiency and the combustion efficiency are read from an external data file in which they are provided as a function of entering liquid temperature and device part load ratio. A version of this component exists (Type700) in which the combustion and boiler efficiency values are specified as inputs to the model instead of in an external data file.

Nomenclature

Cp_{fluid}	[kJ/kg.K]	Specific heat of the liquid stream
$\dot{Q}_{need}$	[kJ/hr]	Energy required to heat the liquid from its entering condition to the set point temperature.
$\dot{Q}_{\max}$	[kJ/hr]	The device capacity. The maximum rate at which energy can be delivered to the liquid.
$\dot{Q}_{fluid}$	[kJ/hr]	The energy delivered to the liquid stream.
$\dot{Q}_{fuel}$	[kJ/hr]	The rate at which fuel energy is consumed.
$\dot{Q}_{loss}$	[kJ/hr]	The rate at which energy is lost from the device due to combustion process inefficiency.
$\dot{Q}_{exhaust}$	[kJ/hr]	The rate at which energy is exhausted from the boiler through the combustion stack or chimney.
$\dot{m}_{fluid}$	[kg/hr]	The mass flow rate of liquid flowing through the boiler.
T_{in}	[ºC]	The temperature of liquid entering the boiler.
T_{out}	[ºC]	The temperature of liquid exiting the boiler.
T_{set}	[ºC]	The boiler set point temperature.
PLR	[0..1]	The boiler part load ratio.
$\eta_{combustion}$	[0..1]	The boiler's combustion efficiency.
η_{boiler}	[0..1]	The boiler's overall efficiency.

Detailed Description

Type751 uses a simple efficiency equation to predict the energy requirement of heating a liquid to its set point temperature. The heater is capacity limited and in these two regards, is quite similar to standard TRNSYS Type6. Where Type751 differs from Type6 is that it reads overall device efficiency and also a combustion efficiency as functions of device part load ratio and entering liquid temperature. Type751 reports the energy lost during the combustion process and the energy exhausted from the boiler combustion stack. Type751 does not account for any phase changes in the boiler; fluid is assumed to exit from the device as a pure liquid, not as a vapor and not as a liquid vapor mixture.

No Flow Condition

If the flow of liquid through the Type751 boiler is zero, the model sets the output temperature equal to the input temperature and sets the output flow rate to zero. It further sets the energy transferred to the fluid, the energy lost during the combustion process, the energy exhausted through the boiler stack, the

amount of fuel consumed and the device part load ratio all equal to zero. The no flow condition supercedes the device control signal meaning that if the input flow rate to the boiler is zero, the model ignores the value of the control signal. Consequently, the boiler may be ON (control signal set to 1) and yet not be meeting the requested set point temperature.

Boiler OFF Condition

If there is flow of liquid through the Type751 boiler but the boiler control signal is zero (OFF), the model sets the output temperature equal to the input temperature and sets the output flow rate equal to the input flow rate. As with the no flow case, Type751sets the energy transferred to the fluid, the energy lost during the combustion process, the energy exhausted through the boiler stack, the amount of fuel consumed and the device part load ratio all equal to zero.

Boiler ON Condition

If there is flow of liquid through the Type751 boiler and the boiler control signal is set to 1 (ON), the model first calculates the energy required to elevate the temperature of the liquid from its inlet value to the set point value the using equation 751.1

$$\dot{Q}_{need} = \dot{m}_{fluid} Cp_{fluid} \left(T_{set} - T_{in}\right) \qquad \text{(Eq. 751.1)}$$

The required energy input is limited by the device capacity (specified as a parameter) and 0. Thus the device will not calculate a negative value of Q_{need} if the inlet temperature exceeds the set point temperature and the boiler control signal is ON. If Q_{need} does not exceed device capacity, the energy transferred to the liquid stream Q_{fluid} is set equal to Q_{need}; the device is assumed to be internally controlled in such a way that it delivers only the required amount of energy to the liquid stream. The outlet temperature is set equal to the set point temperature and the part load ratio (PLR) is set according to equation 751.2

$$PLR = \frac{\dot{Q}_{need}}{\dot{Q}_{\max}} \qquad \text{(Eq. 751.2)}$$

If the boiler is capacity limited because the required energy exceeds device capacity, the energy transferred to the fluid (Q_{fluid}) is set to the device capacity (Q_{max}), the PLR is set to 1 and the outlet fluid temperature is set according to equation 751.3

$$T_{out} = T_{in} + \frac{\dot{Q}_{\max}}{\dot{m}_{fluid} Cp_{fluid}} \qquad \text{(Eq. 700.3)}$$

Once the PLR has been calculated, Type751 next queries the TRNSYS Data Reading routine with the inlet liquid temperature and the PLR value. The Data Reading routine returns values of boiler and combustion efficiency. The TRNSYS Data Reading routine is able to linearly interpolate in up to 4 dimensions of independent variables (in this case, two are provided: PLR and entering liquid temperature) but it is unable to extrapolate beyond the data range given in the external file. The value of one of the independent variables exceeds the range in the data file, the corresponding maximum or minimum value will be returned by the Data Reading routine and a warning will be printed to the TRNSYS list and simulation log files.

The Data Reading routine also expects the external data file to be in a certain format in order to read and interpolate it correctly. In the case of Type751, the first line of the data file must contain at least one value of entering liquid temperature, specified in degrees Celsius. The second line of the data file must contain at least one value of part load ratio (a value between 0 and 1). The subsequent lines of the data file must each contain two values, first a value of the combustion efficiency, then a value of the over all boiler efficiency. The boiler efficiency is defined as (output power / input power) and the combustion efficiency is defined as ((input energy-stack energy)/input energy). A sample data file has been provided in the \trnsys16\TESS Models\SampleCatalogData\Boilers\Fluid Boiler\ directory. The same file is reproduced at the end of this document for reference. The data is not taken from any actual device but is merely provided for syntactical reference.

Once the Data Routine returns the combustion and overall efficiency values, Type751 calculates the amount of fuel consumed by the boiler using equation 751.4.

$$\dot{Q}_{fuel} = \frac{\dot{Q}_{fluid}}{\eta_{boiler}} \qquad \text{(Eq. 751.4)}$$

The energy exhausted from the device is given by

$$\dot{Q}_{exhaust} = \dot{Q}_{fuel}\left(1 - \eta_{combustion}\right) \qquad \text{(Eq. 751.5)}$$

And the energy lost during the combustion process is given by

$$\dot{Q}_{loss} = \dot{Q}_{fuel} - \dot{Q}_{exhaust} \qquad \text{(Eq. 751.6)}$$

For reference, the data file for boiler efficiency data at two values of part load ratio and at eleven values of inlet liquid temperature might look like the following. Note that text appearing after the exclamation mark (!) is interpreted by the TRNSYS Data Routine as a comment and is ignored.

Sample Boiler Efficiency Data

```
4.444 15.556 26.667 37.778 48.889 60.000 71.111 82.222 93.333 104.444 115.556   !INLET TEMPERATURE (C)
0.000 1.000                                                                     !PART LOAD RATIO
 0.990   0.860  !combustion efficiency and boiler efficiency at 4.444, 0.000
 0.990   0.860  !combustion efficiency and boiler efficiency at 4.444, 1.000
 0.985   0.860  !combustion efficiency and boiler efficiency at 15.556, 0.000
 0.985   0.860  !combustion efficiency and boiler efficiency at 15.556, 1.000
 0.965   0.860  !combustion efficiency and boiler efficiency at 26.667, 0.000
 0.965   0.860  !combustion efficiency and boiler efficiency at 26.667, 1.000
 0.940   0.860  !combustion efficiency and boiler efficiency at 37.778, 0.000
 0.940   0.860  !combustion efficiency and boiler efficiency at 37.778, 1.000
 0.900   0.860  !combustion efficiency and boiler efficiency at 48.889, 0.000
 0.900   0.860  !combustion efficiency and boiler efficiency at 48.889, 1.000
 0.870   0.860  !combustion efficiency and boiler efficiency at 60.000, 0.000
 0.870   0.860  !combustion efficiency and boiler efficiency at 60.000, 1.000
 0.865   0.860  !combustion efficiency and boiler efficiency at 71.111, 0.000
 0.865   0.860  !combustion efficiency and boiler efficiency at 71.111, 1.000
 0.860   0.860  !combustion efficiency and boiler efficiency at 82.222, 0.000
 0.860   0.860  !combustion efficiency and boiler efficiency at 82.222, 1.000
 0.855   0.860  !combustion efficiency and boiler efficiency at 93.333, 0.000
 0.855   0.860  !combustion efficiency and boiler efficiency at 93.333, 1.000
 0.850   0.860  !combustion efficiency and boiler efficiency at 104.444, 0.000
 0.850   0.860  !combustion efficiency and boiler efficiency at 104.444, 1.000
 0.845   0.860  !combustion efficiency and boiler efficiency at 115.556, 0.000
 0.845   0.860  !combustion efficiency and boiler efficiency at 115.556, 1.000
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