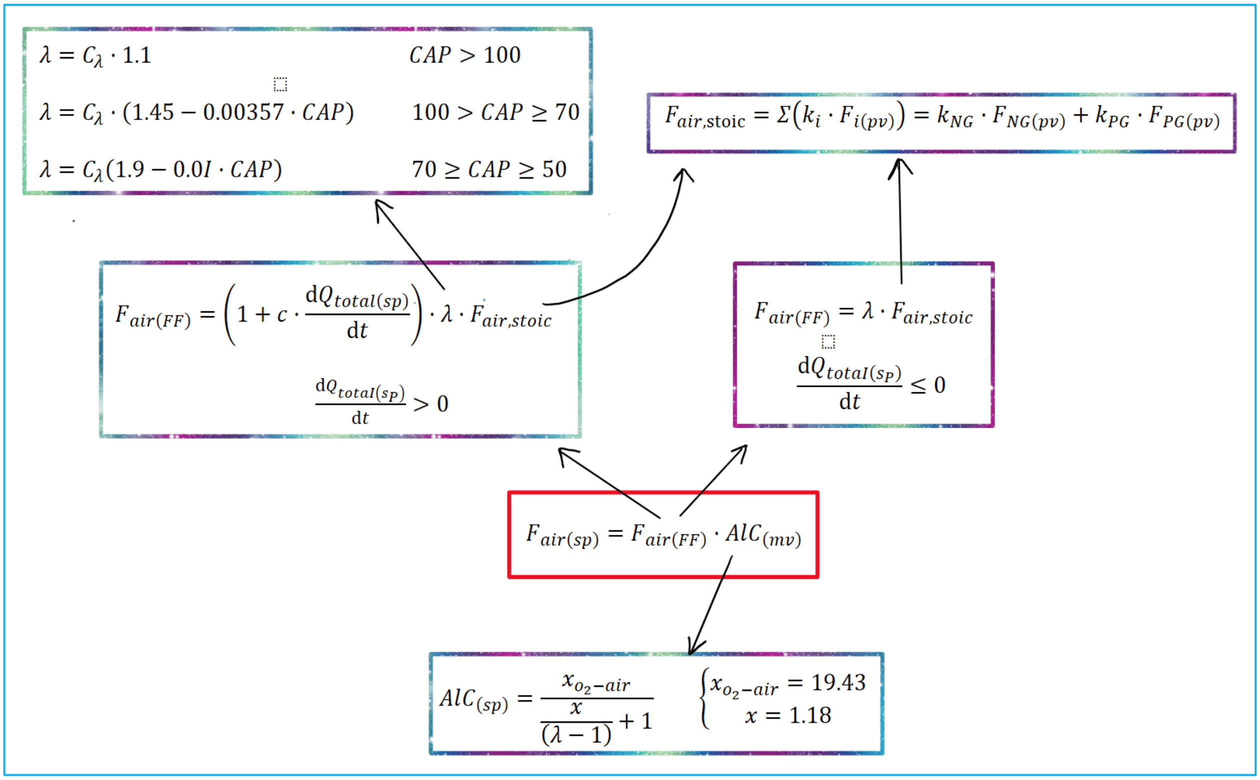
Educational Institute for Equipment and Process Design

Fired Heater Process Control

Combustion air flow

The combustion air control is based on a calculated air demand and on the measured oxygen content in the flue gas from the radiant section. A combined feed forward and feedback strategy is applied for the flow of combustion air.



Notes:

$F_{air,\,stoic}$ = Air demand for stoichiometric combustion. K_i being the air demand for fuel i.

$\frac{dQ_{total(sp)}}{dt}$ = a lead function that is added to avoid firing with deficit of air at a load increase caused by the time delay for the air system. When the load is decreased, the lead function is set to unity. The result is that the time delay will cause an increased excess air ratio, which is acceptable. The lead function has a value between 1.0 and 1.2.

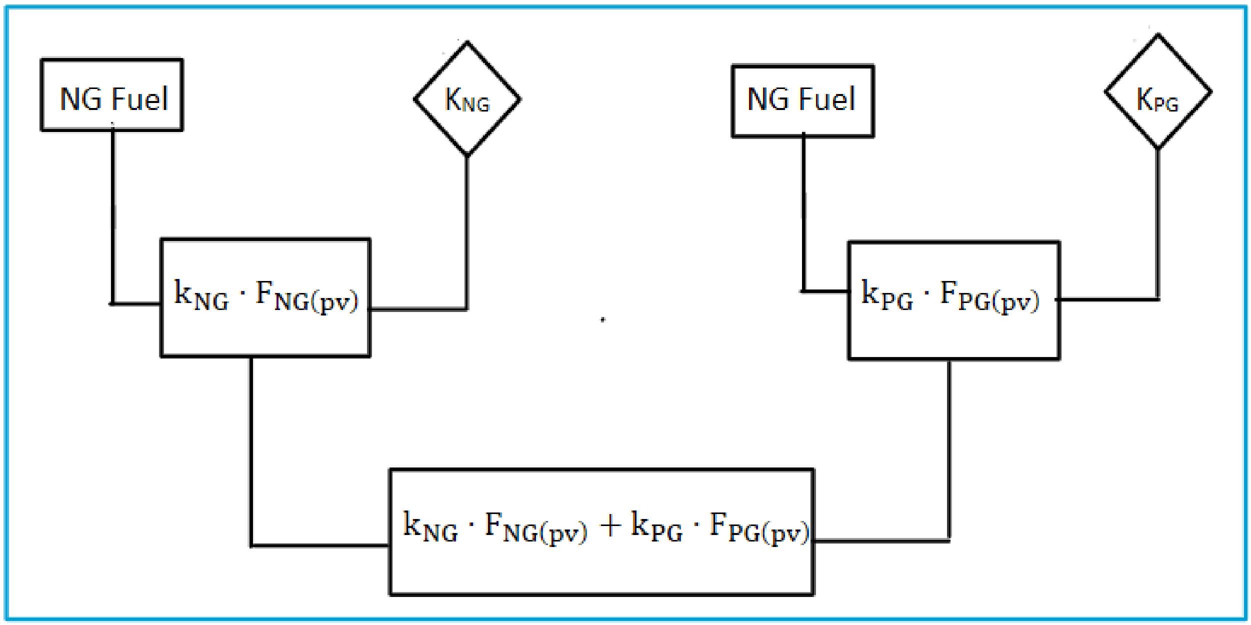
The output from AIC is a value between 0.95 and 1.05.

The stoichiometric air demand (k) of components is found in the following table:

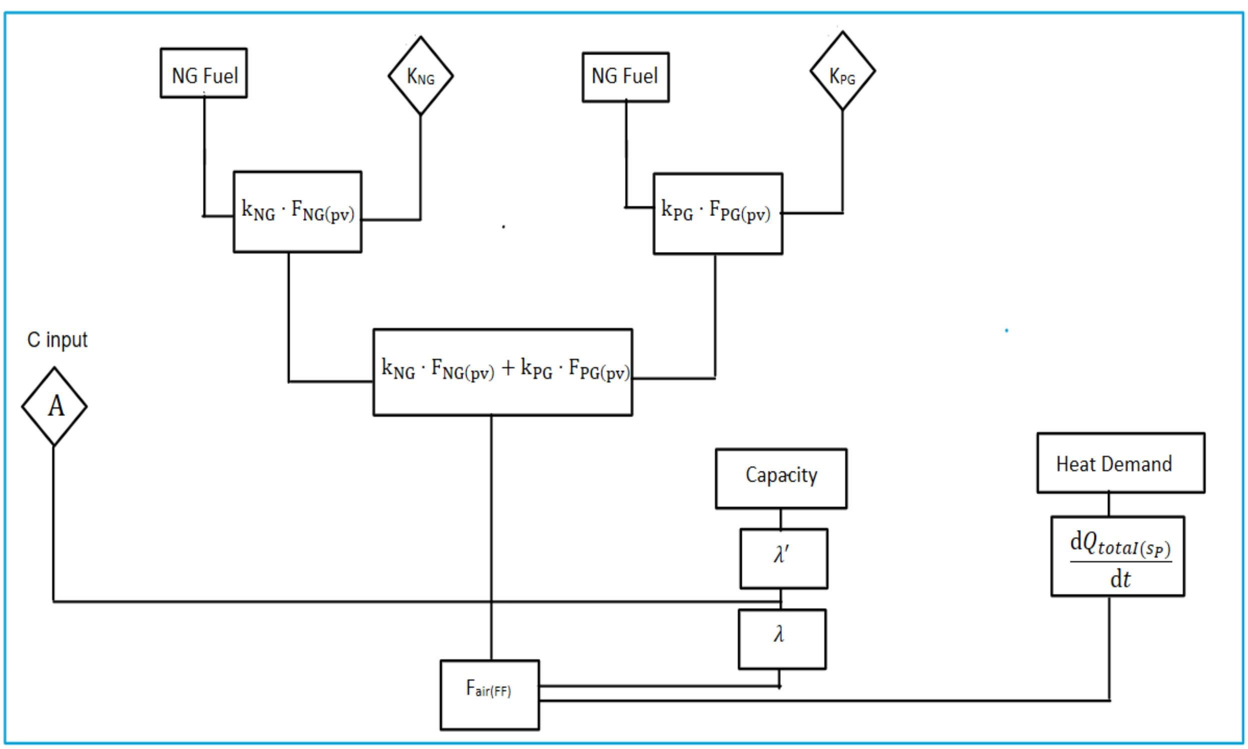
Component	Stoichiometric air demand[1], k_l Nm^3/Nm^3
Hydrogen, H_2	2.574
Carbon monoxide, CO	2.574
Methane, CH_4	10.295
Ethane, C_2H_6	18.016
Propane, C_3H_8	25.738
Butane, C_4H_{10}	33.459
Isobutane, C_4H_{10}	33.459
n-Pentane,C_5H_{12}	41.180
2-Methylbutane/3-Methylbutane,C_5H_{12}	41.180
Methanol, CH_3OH	7.721
Ethanol, C_2H_5OH	15.443
2-methyl-1-propanol,	30.885
Acetone	20.590
Methyl ethyl ketone	28.311
Methyl formate	10.295
Dimethyl ether	15.443

Diagram

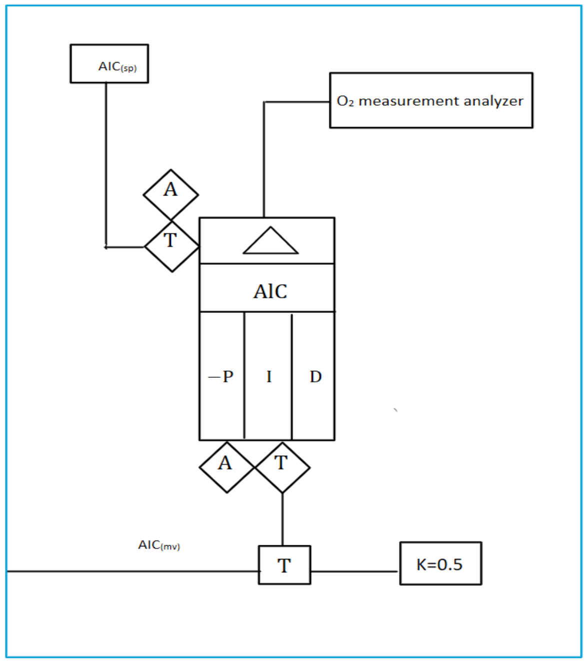
Step 1:



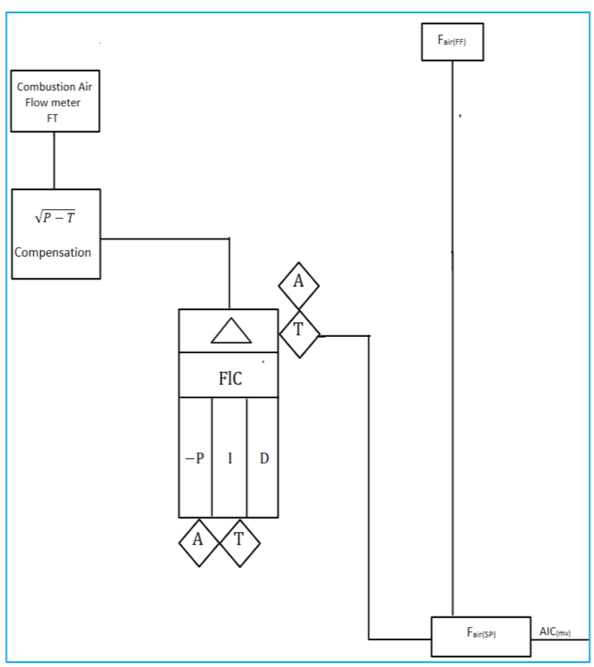
Step 2:



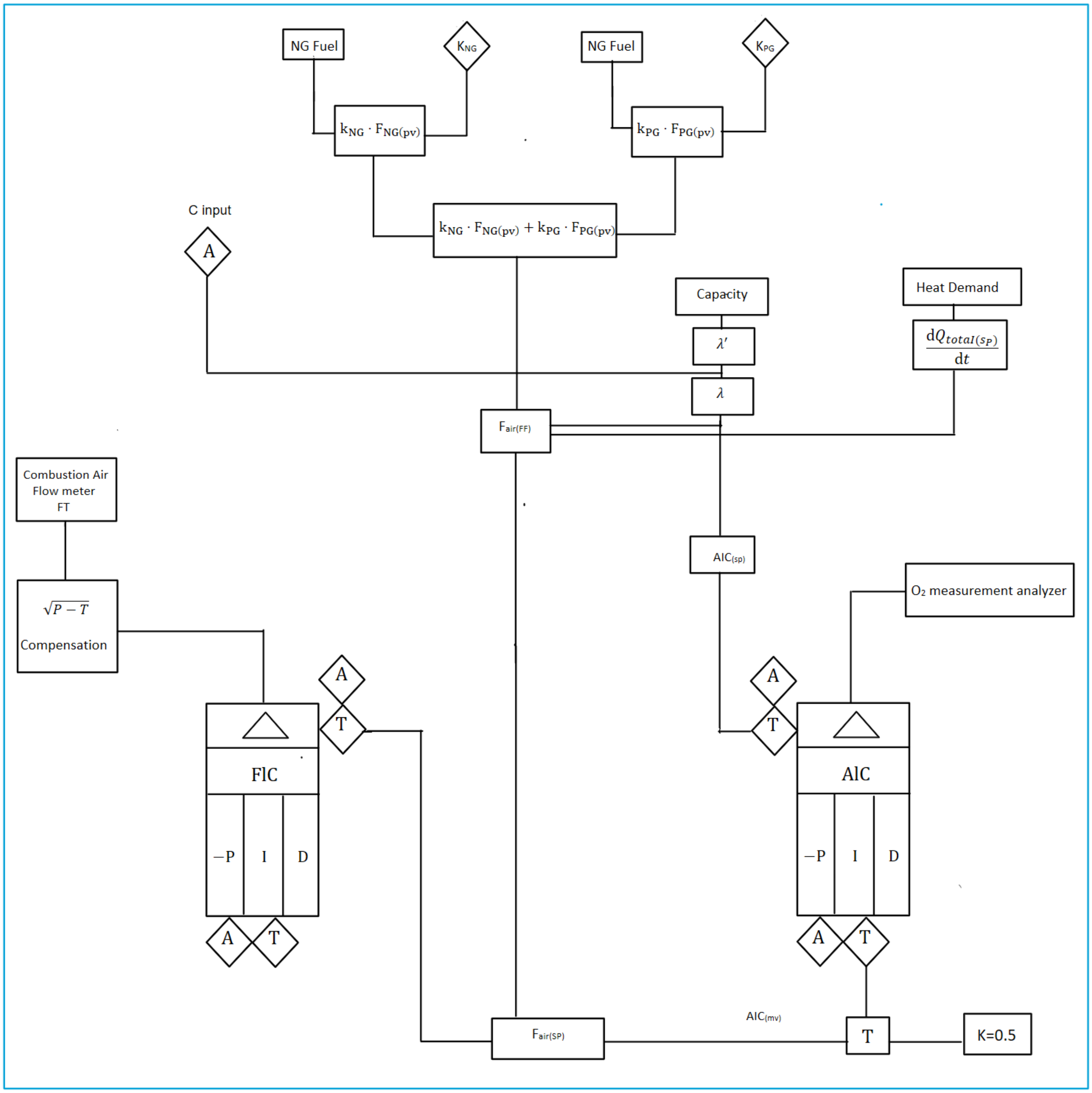
Step 3:


AIC(sp)
O2 measurement analyzer
A
T
AIC
−P
I
D
A
T
AIC(mv)
T
K=0.5

Step 4:

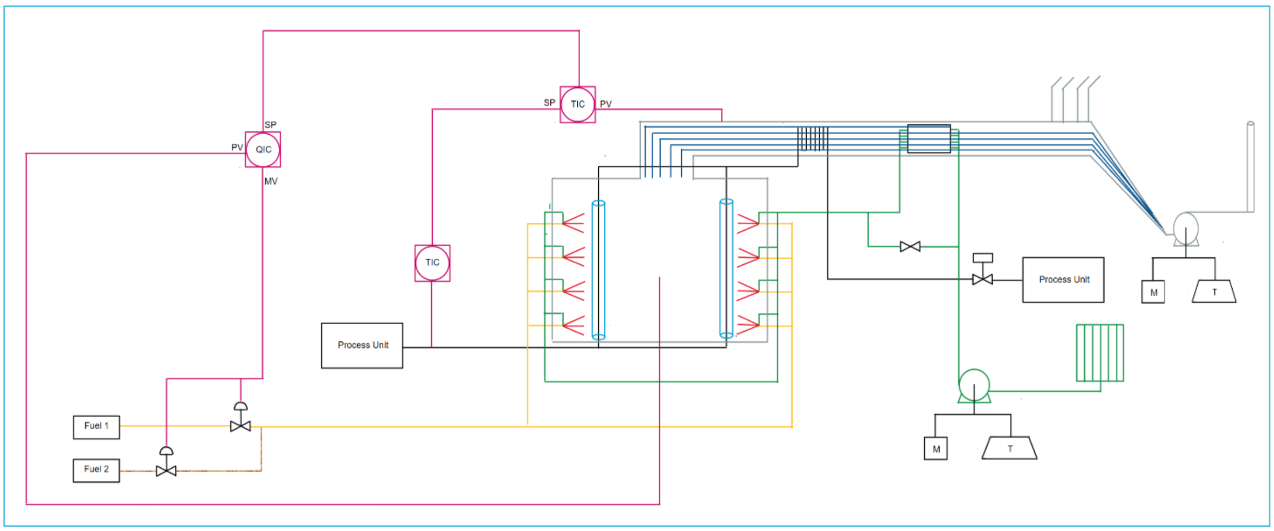

Fair(FF)
Combustion Air
Flow meter
FT
√P − T
Compensation
A
T
FIC
−P
I
D
A
T
Fair(SP)
AIC(mv)

Step 5:

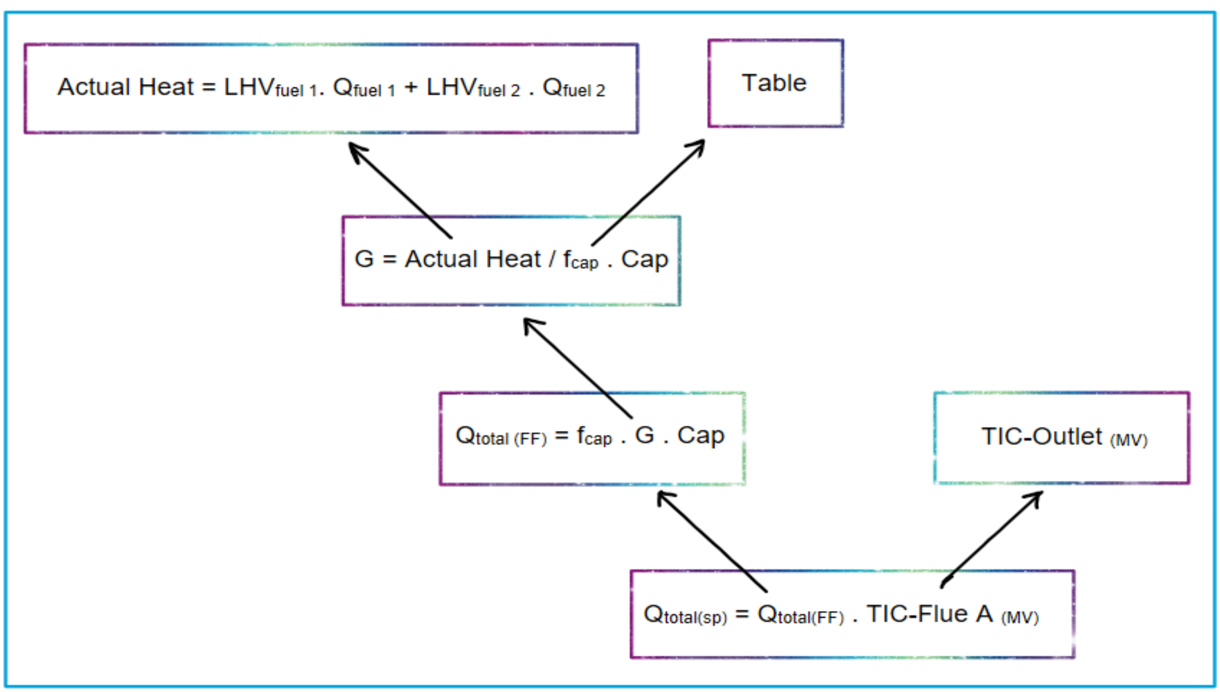

NG Fuel
K_NG
NG Fuel
K_PG
k_NG · F_NG(pv)
k_PG · F_PG(pv)
C input
A
k_NG · F_NG(pv) + k_PG · F_PG(pv)
Capacity
Heat Demand
λ'
dQ_total(SP) / dt
λ
F_air(FF)
Combustion Air Flow meter FT
AIC(sp)
O2 measurement analyzer
√P − T
Compensation
A
T
A
T
FIC
AIC
−P
I
D
−P
I
D
A
T
A
T
AIC(mv)
F_air(SP)
T
K=0.5

Reformer firing

The adjustment of reformer firing is done by changing the fuel flow to the burners to meet the required reformer outlet temperature.
The thermal behavior of the tubular reformer is dominated by a large time constant in the order of ten minutes. Because of the large time delay, a combined feed forward and feedback strategy is required for optimal control of the reformer outlet temperature.



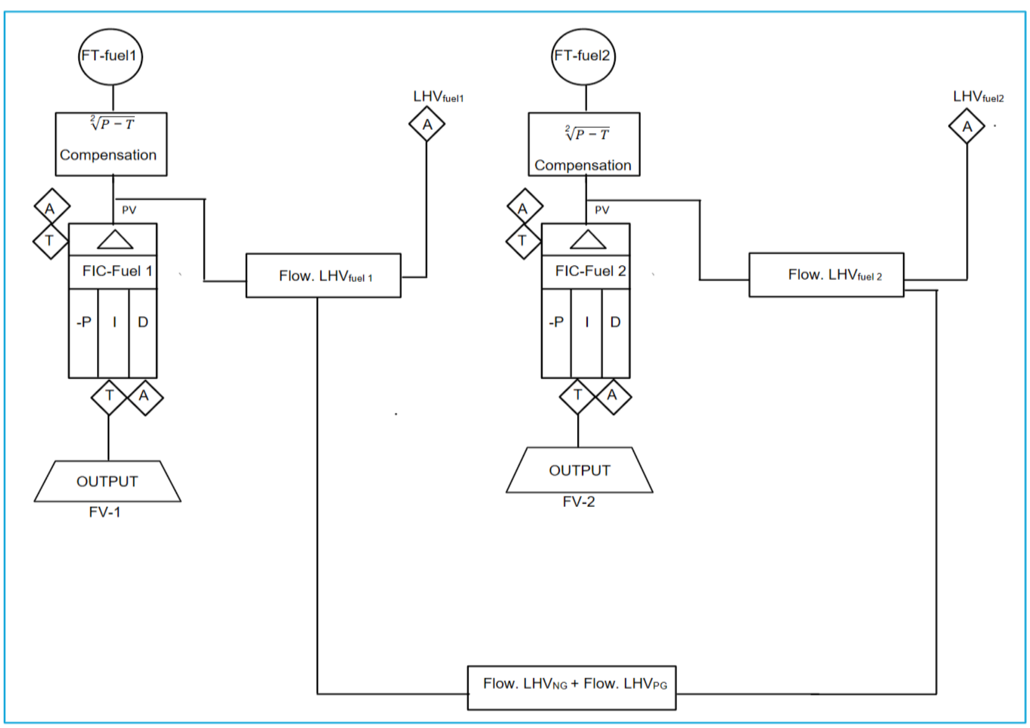
How it works in mathematical equations:



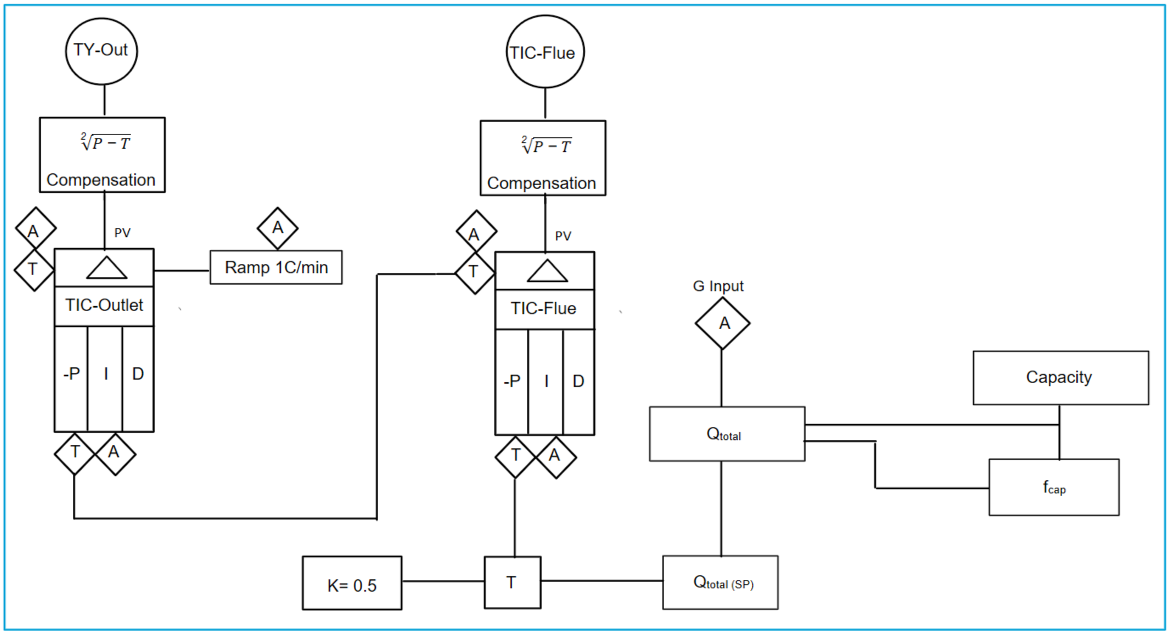
Capacity %	fcap
100	1.000
90	0.988
80	0.970
70	0.947
60	0.961

How to show it

Step 1: Actual Heat Calculation

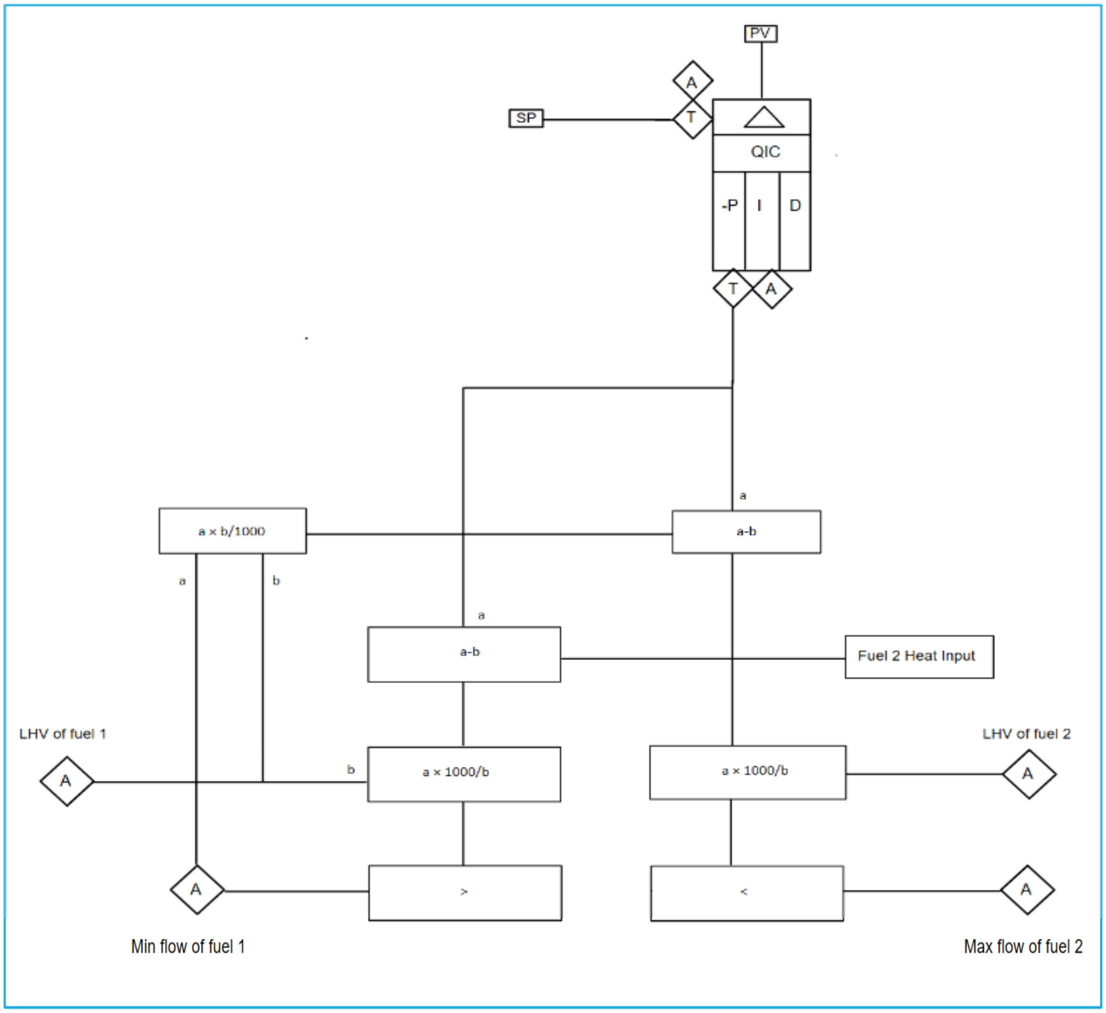


Step 2: Set point

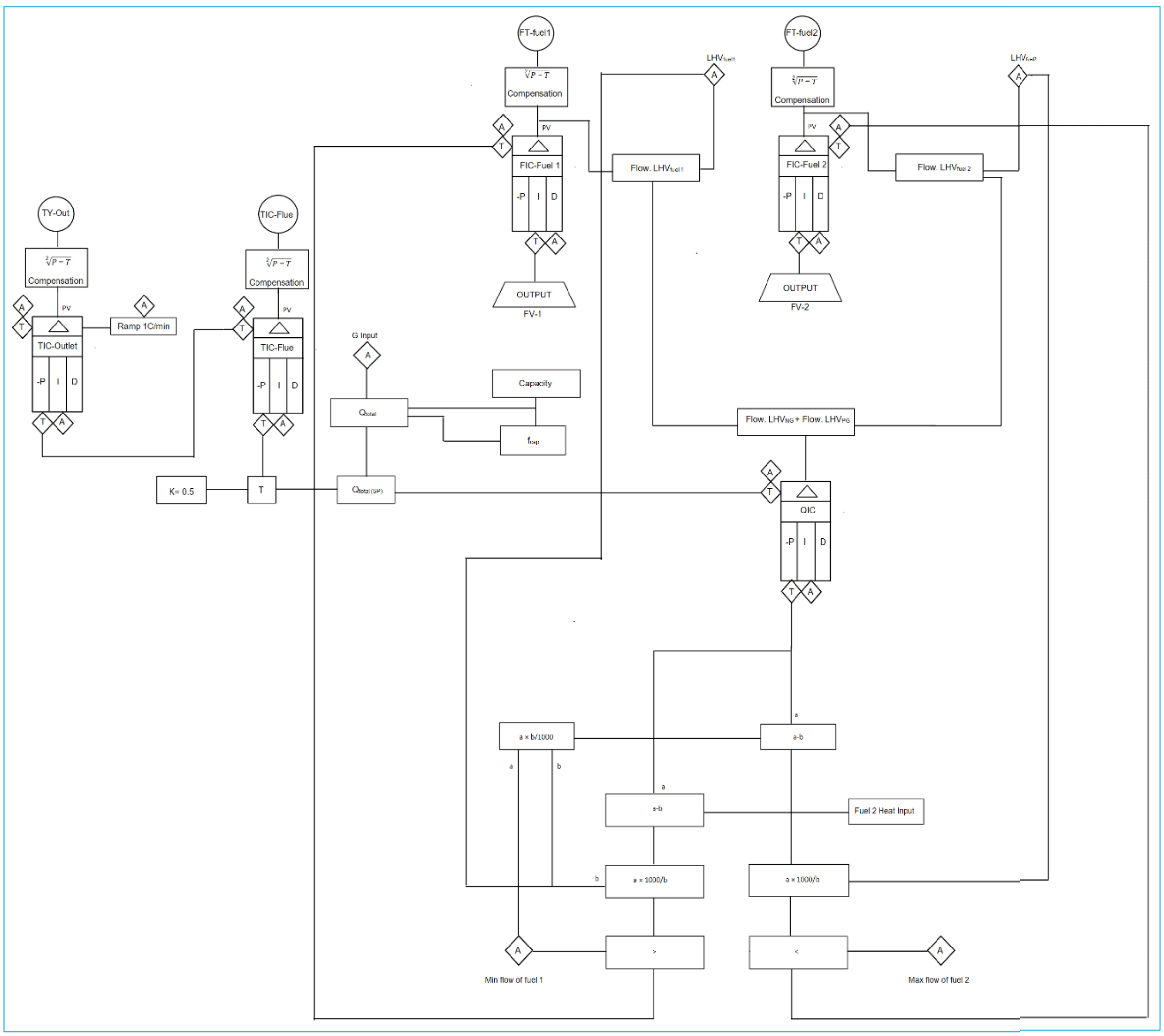


Step 3: Heat Distribution Between Fuel 1 and Fuel 2

The QIC receives the setpoint from the calculator $Q_{total(SP)}$ and compares it with actual heat input calculated in step 1; the difference is distributed over two fuels. Imagine we have two fuels, the first one being NG which exist and reliable and the second one being a mixture of CO and H_2 which are later produced in normal operation. Typical approach is that at least 10% of the total heat is supplied by NG to enhance the reliability whereas the rest of the heat is supplied by second fuel for optimization purposes. The minimum heat which is supplied by NG is calculated and sent to a calculation block. The error or a which is the total heat required is subtracted by the minimum heat and the rest heat shall be provided by fuel 2; to calculate its flow, the heat is divided by its LHV. Finally, the flow calculated is compared with max flow of second fuel. If it is less than max flow, then it is selected as setpoint for FV-2 but if it is more than max flow, then max flow is sent to the FV-2 as the setpoint. The heat which cannot be supplied by fuel 2 is now supplied by fuel 1 and its flow is increased.


PV
SP
A
T
QIC
-P
I
D
T
A
a
a × b/1000
a-b
a
b
a
a-b
Fuel 2 Heat Input
LHV of fuel 1
LHV of fuel 2
A
b
a × 1000/b
a × 1000/b
A
A
>
<
A
Min flow of fuel 1
Max flow of fuel 2

Step 4: Full Picture



Appendix

G: Specific fired heat requirement
fcap = Factor describing the relative thermal efficiency of the furnace as a function of the load.