Cairo University
Faculty of Engineering
Mech. Power Department

دبلوم تطبيقات التحكم الأوتوماتيكى
فى نظم القوى الميكانيكية

MEP 599 Diploma Design Project- Summer Term 2015

SIMULATION AND CALCULATION OF WATER TUBE BOILER PROGRAM

by

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ABSTRACT

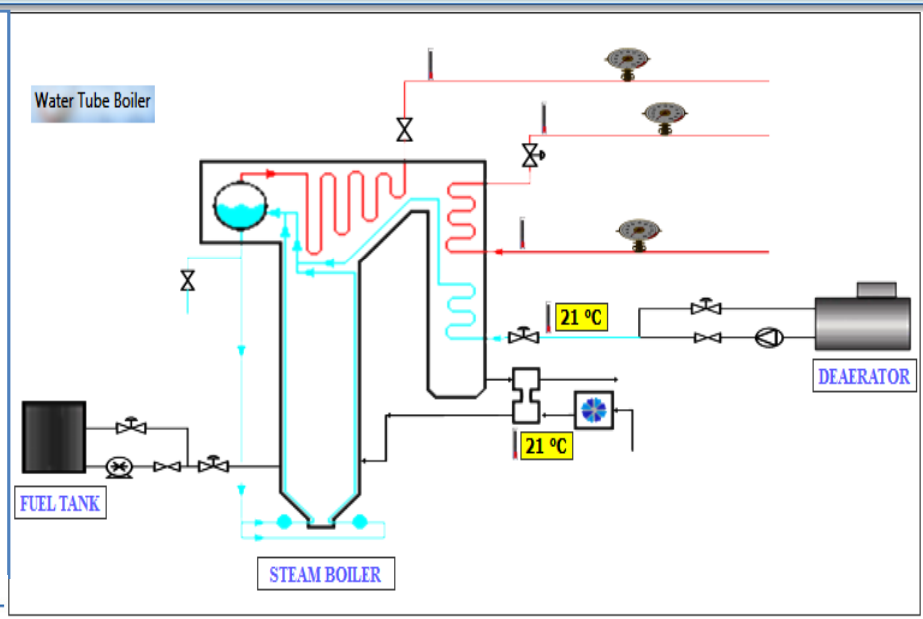
Boilers are pressure vessels designed to heat water or produce steam, which can then be used to provide space heating and/or service water heating to a building. In most commercial building heating applications, the heating source in the boiler is a natural gas fired burner. Oil fired burners and electric resistance heaters can be used as well. Steam is preferred over hot water in some applications, including absorption cooling, kitchens, laundries, sterilizers, and steam driven equipment.

Two principal types of boilers are used for industrial applications:

1. Fire tube boilers-Products of combustion pass through tubes surrounded by water.
2. Water tube boilers- Products of combustion pass around the tubes containing water. The tubes are interconnected to common channels or headers and eventually to a steam outlet for distribution to the plant system

The steam plants of today are a combination of complex engineered systems that work to produce steam in the most efficient manner that is economically feasible. Whether the end product of this steam is electricity, heat, or a steam.

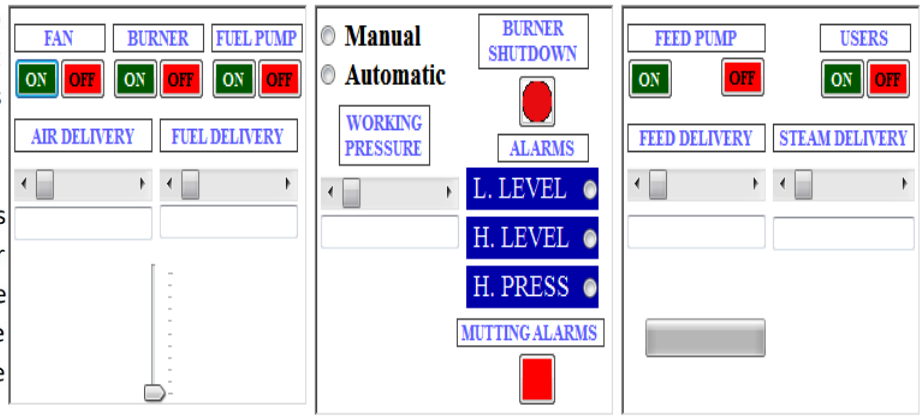
The aim of this project is to establish a program that can simulate the water tube boiler and calculate the needed data for getting more efficient steam generator.



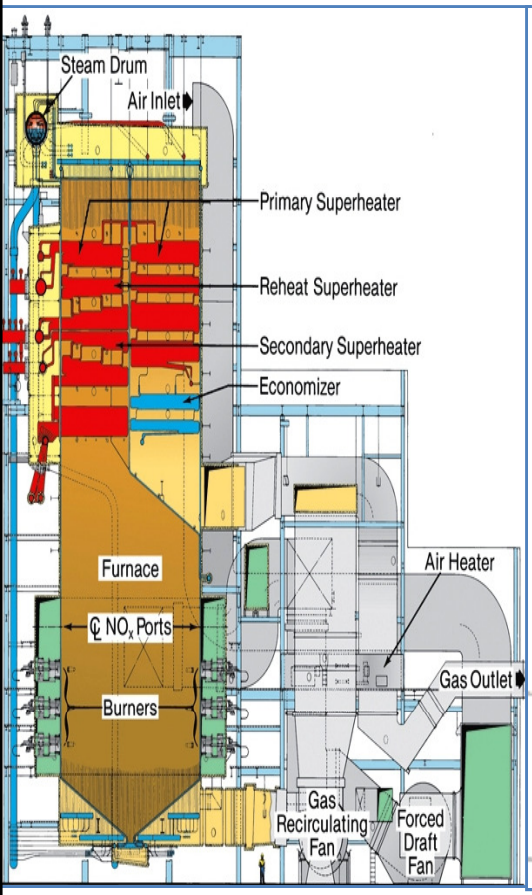
CONCLUSIONS

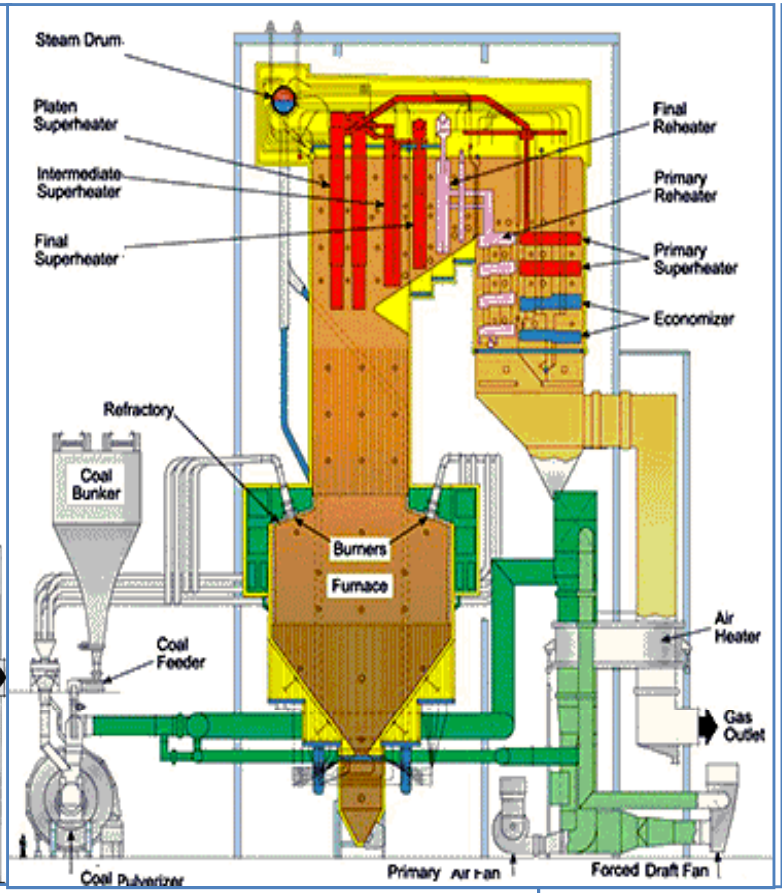
The steam plants of today are a combination of complex engineered systems that work to produce steam in the most efficient manner that is economically feasible. Whether the end product of this steam is electricity, heat, or a steam process required to develop a needed product such as electricity, the goal is to have that product produced at the lowest cost possible. The heat required to produce steam is a significant operating cost that affects ultimate cost of the end product.

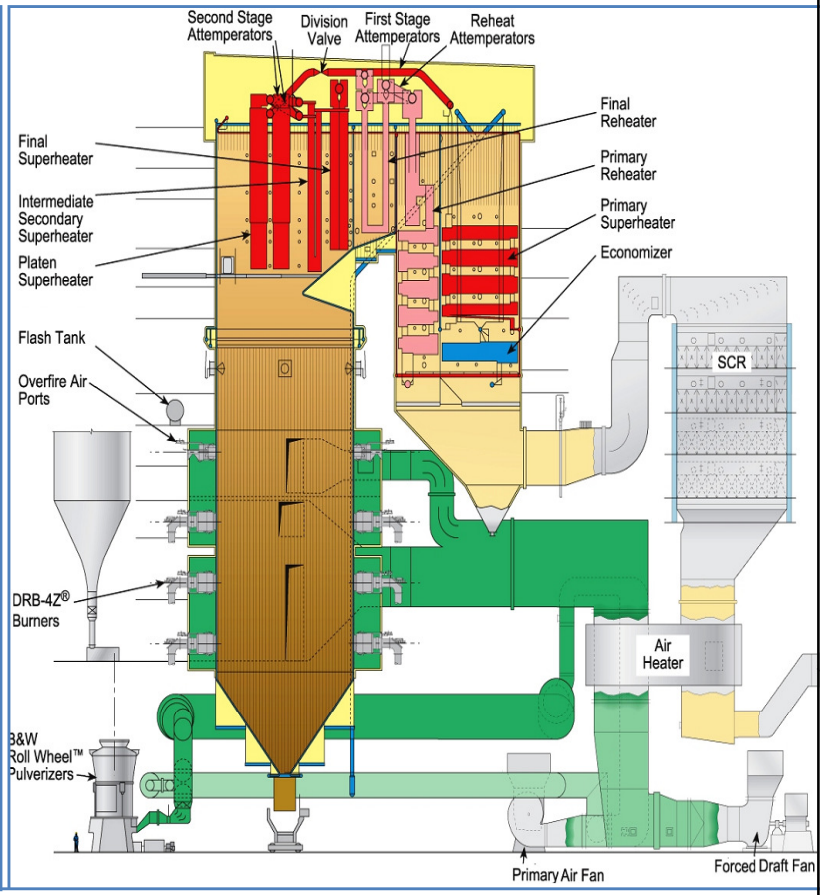
In this project we had establish a program that can simulate the water tube boiler works manually by the user or automatically to show the steps needed to operate the water tube boiler steps and we the program could give accurate results to a give inputs that the user give to the program this results could help building a more efficient boiler and give accurate results for the flue gases temperature across the boiler components and a heat balance for the boilers that shows the percentage of heat absorbed by each component.

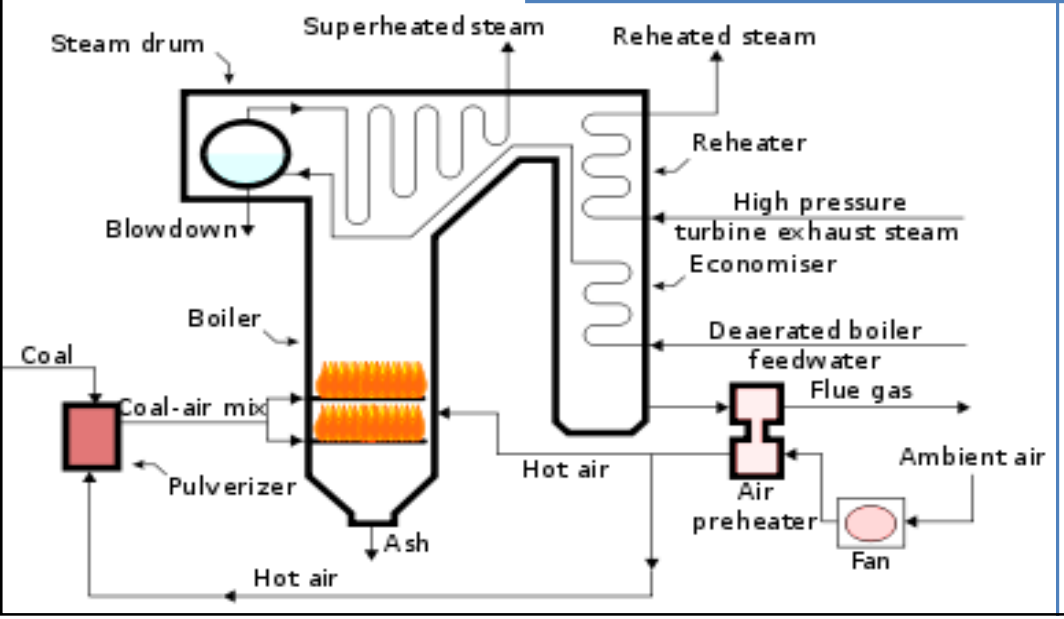


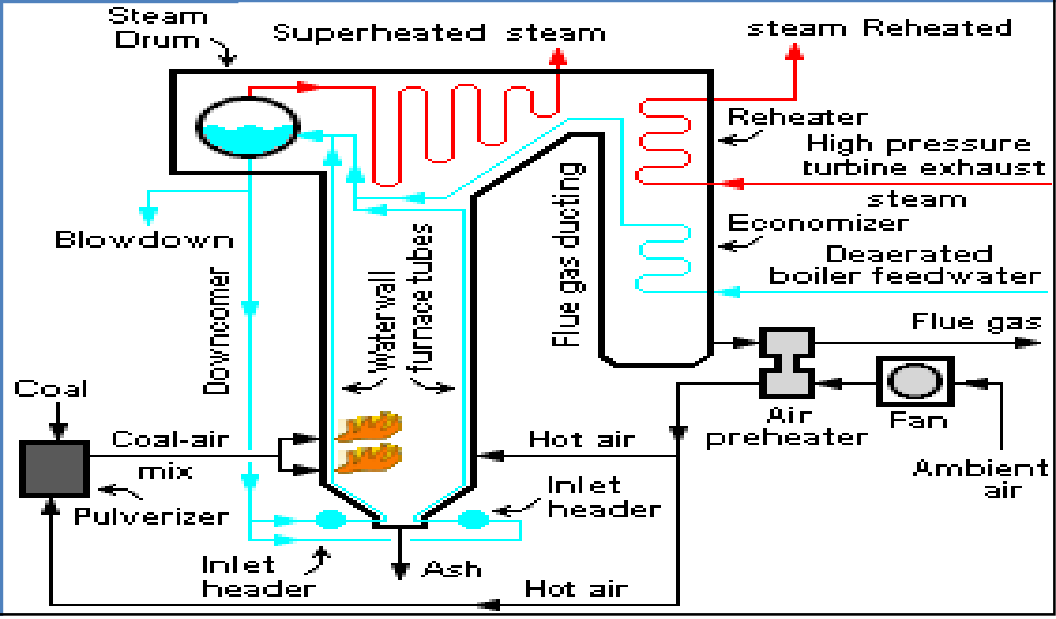
Different Designs of Water Tube Boilers for various types of fuels

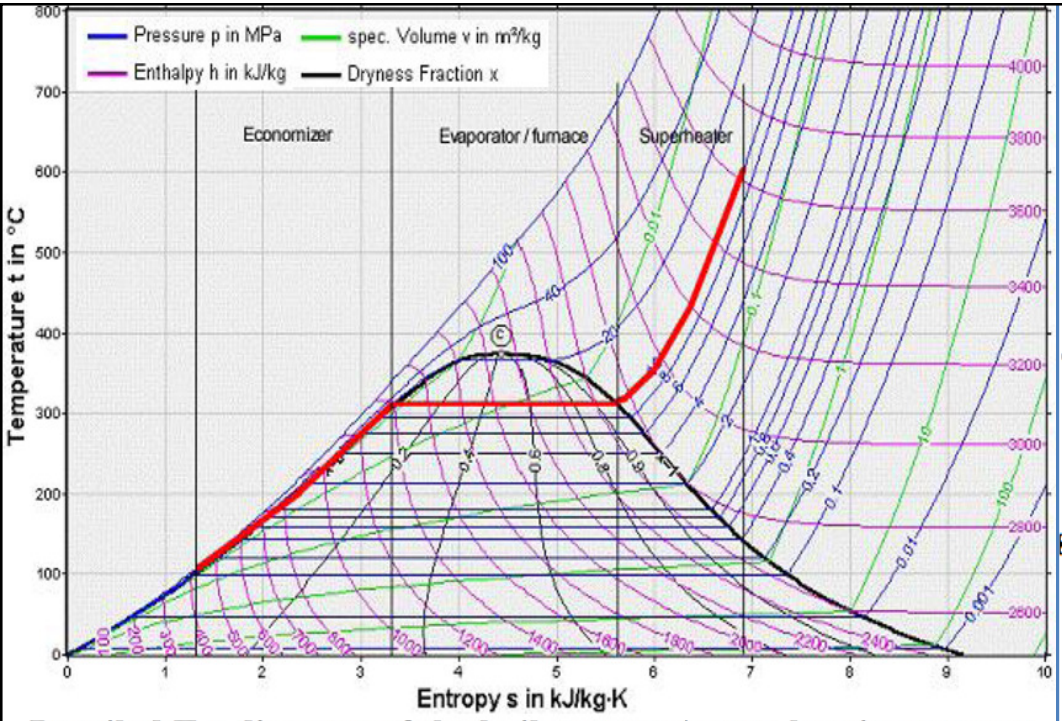




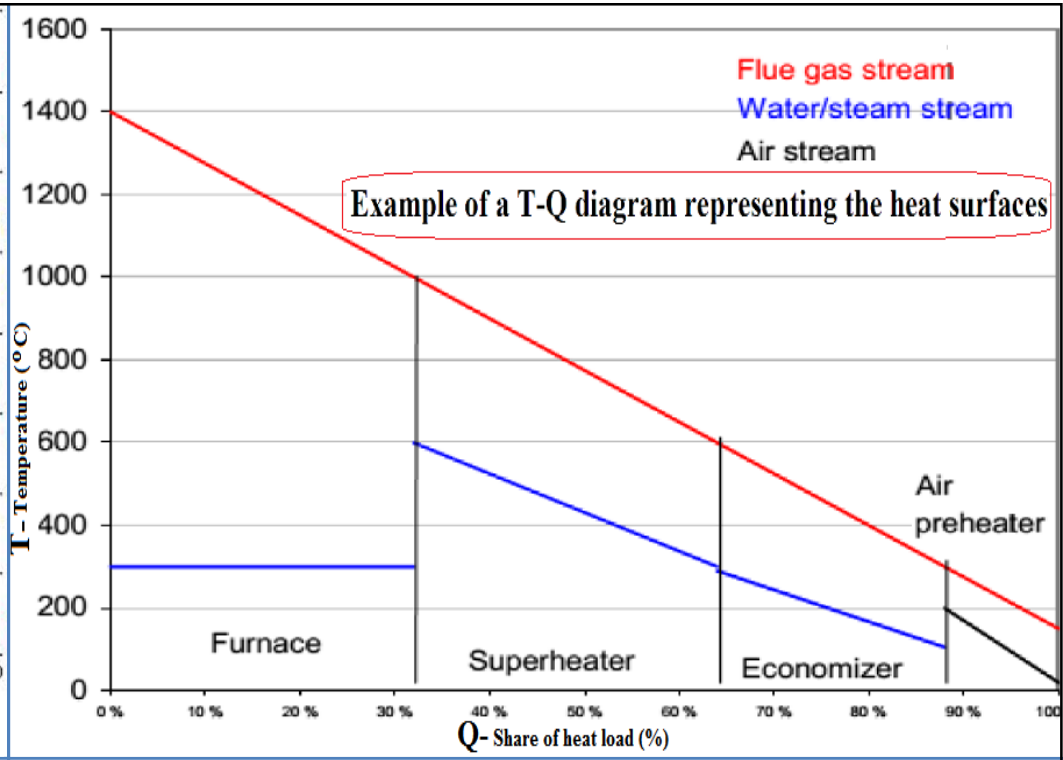


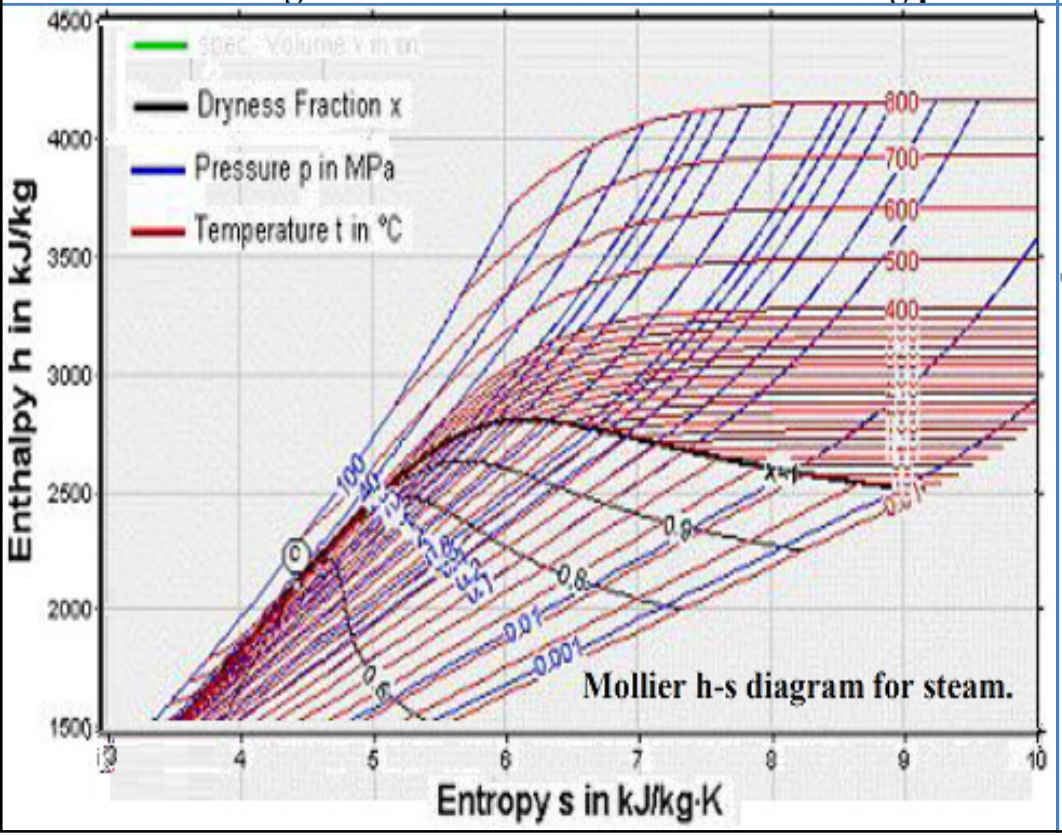


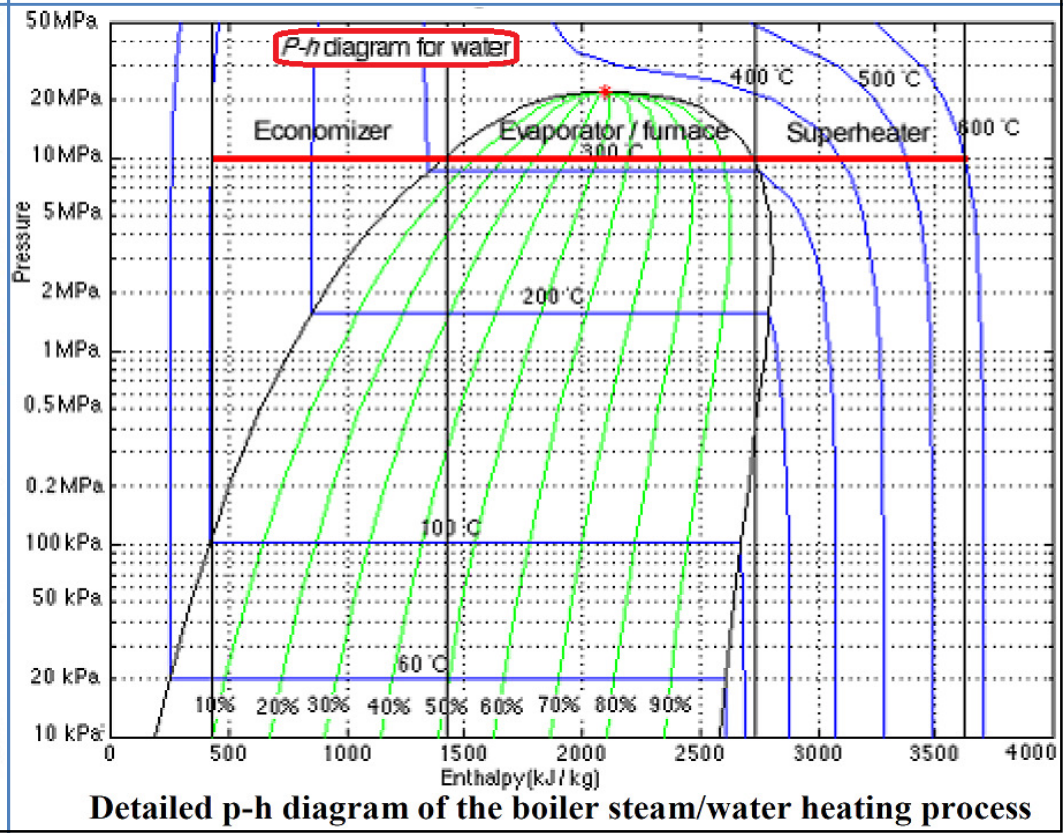




Detailed T-s diagram of the boiler steam/water heating process







Detailed p-h diagram of the boiler steam/water heating process

1. Calculations of Boiler Heat values and Efficiency:

To establish the actual-real and accurate heat balance of a boiler it is necessary to effectuate particular steaming tests (i.e., perform effective runs) during which you have to detect all the magnitudes related to the calculation of the heat balance itself. Every magnitude is determined in its average value of a series of measures effectuated with maximum exactitude time at equal intervals, during the test time, that vary from 5 to 8 hours. The tests are to be effectuated at the different load rating of the boiler.

From a didactic or an educational point of view it is enough to effectuate only one detection of the interested magnitudes.

As an example, the following procedure is proposed for the heat balance calculation:

After having executed the beginning or starting selections of the generator and after switching or to commute in automatic mode according to the instructions given previously (see page 9). Print both the diagnostic page and the heat balance page.

The magnitudes or the values necessary for the heat balance calculation are:

- Quantity of available heat in the fuel Qd;
- Quantity of heat used in the economizer Qe;
- Quantity of heat used in the generator tubes Qg;
- Quantity of heat used in the superheater Qs;
- Quantity of heat used in the re-superheater Qrs;
- Quantity of heat lost in the funnel for fumes Qf;
- Quantity of heat lost for radiation and unburned Qi.

As previously exposed when we have defined the calorific power the quantity of heat per hour available will be: $Qd = Pcs * Pg$

where

Pcs = 42.070 kJ/kg fuel superior calorific power

Pg = fuel mass delivery

The heat quantity per hour transferred into the economizer to the water will be:

$$Qe = Pv * (h_e - h_l)$$

where remembering the definition of specific heat and the heat energy concept you will have:

$h_e - h_l = c_m * (T_e - T_l)$ Heat energy kept in one kg of water

c_m = 4,270 kJ/kg °K average specific heat of water

Pv = Mass delivery of water or of steam (at stabilized plant are equal)

The heat quantity per hour transferred in the generator tubes will be: $Qg = Pv * (h_v - h_e)$

Where, h_v = Heat energy kept in one kg of saturated steam at the exercise pressure

Note: to calculate h_v at the absolute pressure of (relative pressure +1) bar read the value of the enthalpy on the superior limit curve into the Mollier diagram of the steam

The heat quantity per hour transferred into the superheater will be: $Qs = Pv * (h_s - h_v)$

Where, h_s = Heat energy of the superheated steam

Note: to calculate h_s read the value of the enthalpy at the intersection of the overheating isobaric with the overheating isotherm into the steam Mollier diagram.

The heat quantity per hour transferred into the re-superheater will be: $Qs = Pv * (h_{ru} - h_{re})$

where h_{re} = heat energy of the re-superheated steam at the entrance.

h_{ru} = heat energy of the re-superheated steam at the exit.

The quantity of heat lost in the funnel for fumes is obtained, remembering always the definition of specific heat: $Qf = (Pa * \beta + Pg) * c_{mf} * (T_f - T_a)$

where β = 1,225 kg/m^3 Air volume mass

c_{mf} = 1,025 kJ/kg °K fumes average specific heat

Pa = Air volume delivery

The heat quantity lost for radiation and unburned is obtained for difference:

$$Qi = Qd - Qe - Qg - Qs - Qrs - Qf$$

System Operation: A.1 Program steps

1) The main water tube boiler program window is shown in Figure A1; it allows the user to choose operating method from manual to automatic and gives the user text boxes to insert working conditions.

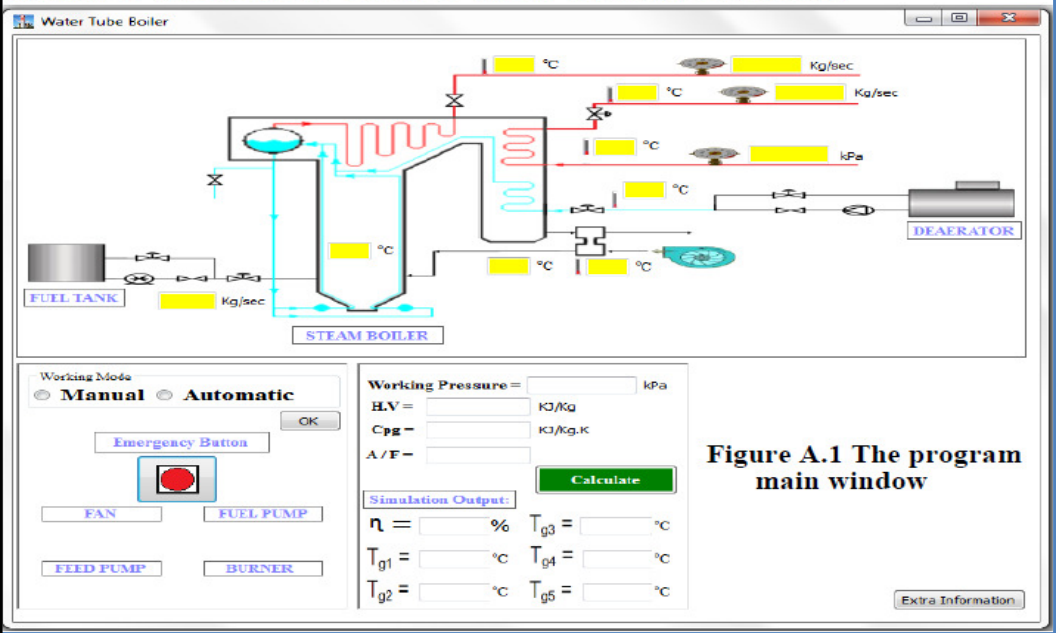


Figure A.1 The program main window

2) The user selects the manual working mode to operate the water tube boiler simulator the fan button will show up, as shown in Figure A.2.

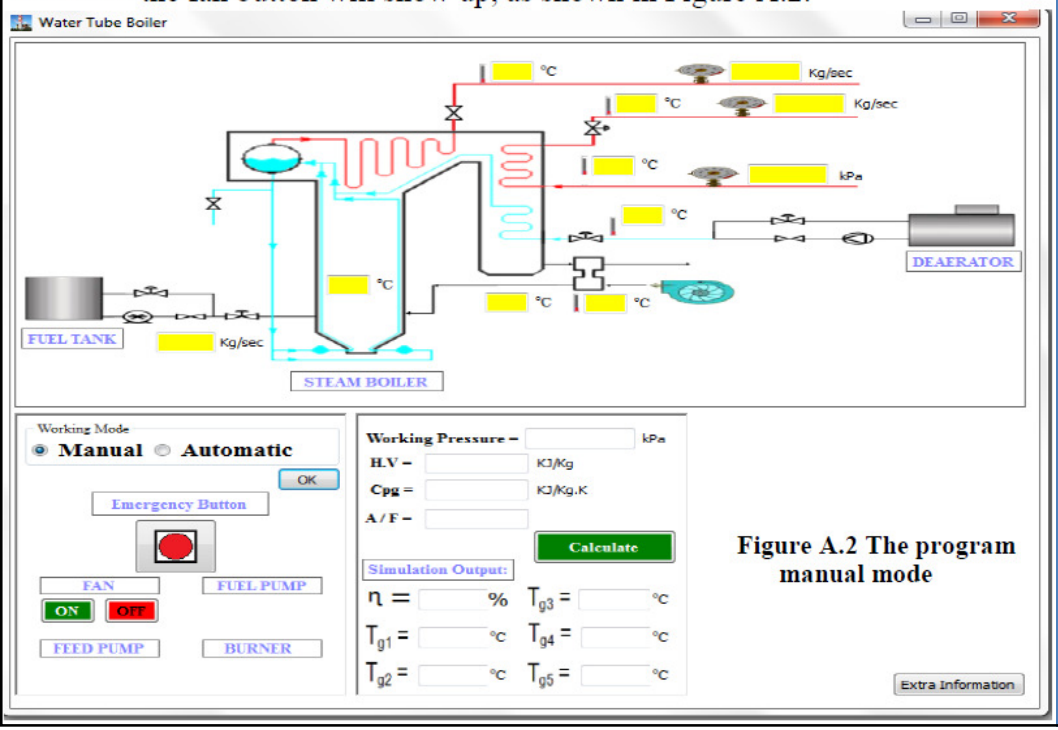


Figure A.2 The program manual mode

3) The user will now press the On button.

4) Now the fan is working and the fuel pump button will show up, as shown in Figure A.3.

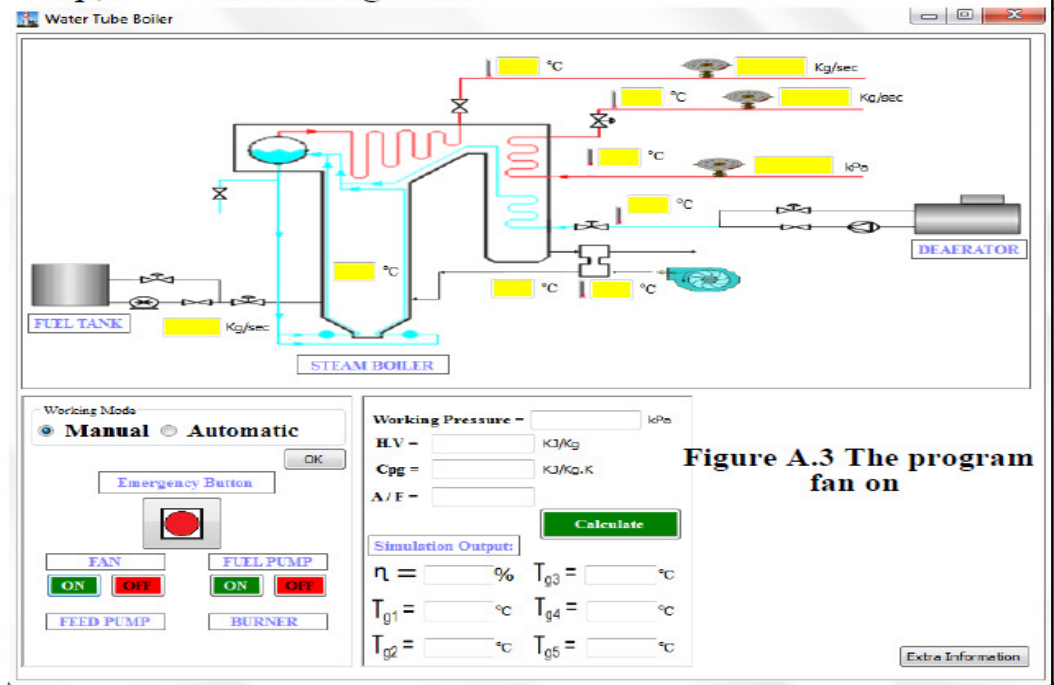


Figure A.3 The program fan on

5) The user will now press the On button.

6) Now fuel pump is working and the feed pump buttons will show up, as shown in Figure A.3.

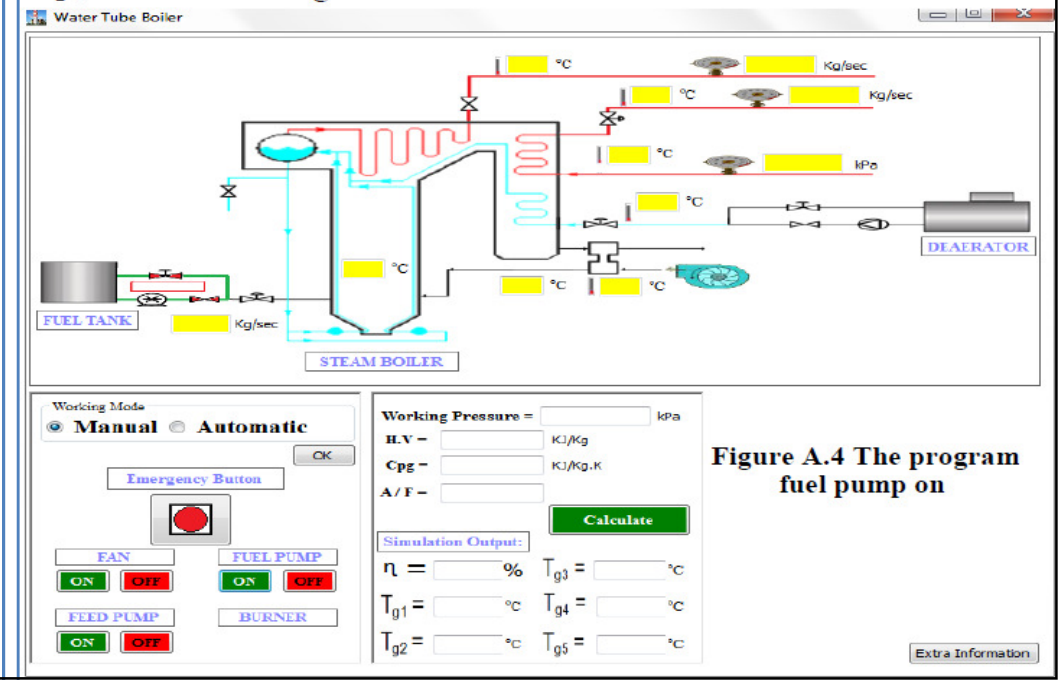


Figure A.4 The program fuel pump on

7) The user will now press the On button.
8) Now feed pump is working and the burner buttons will show up, as shown in Figure A.3.

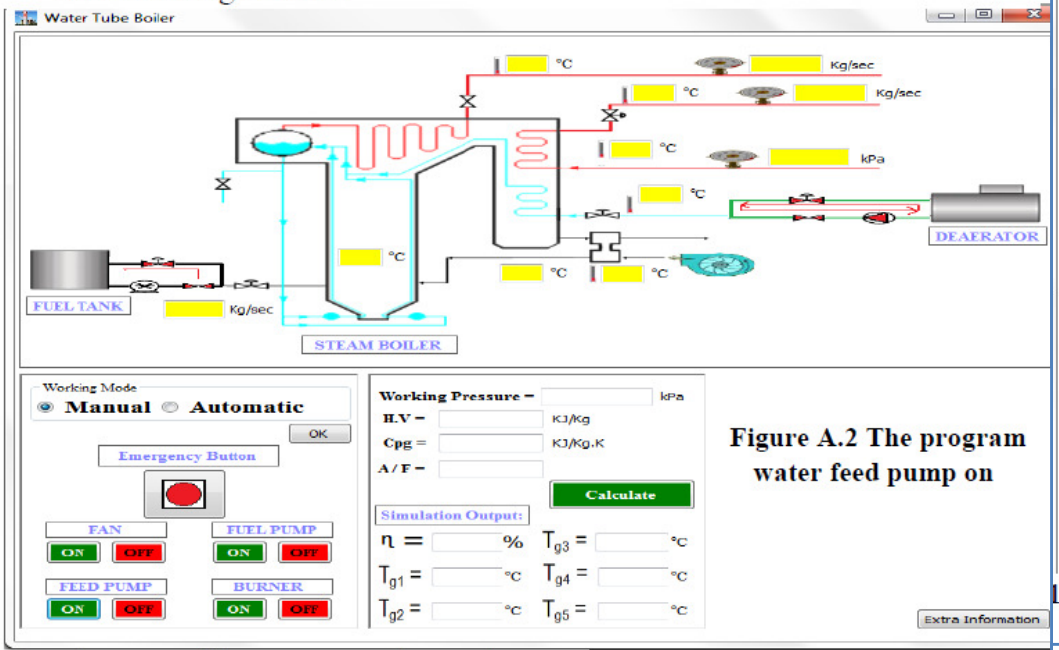


Figure A.2 The program water feed pump on

9) The user will now press the On button.
10) Now the burner is working

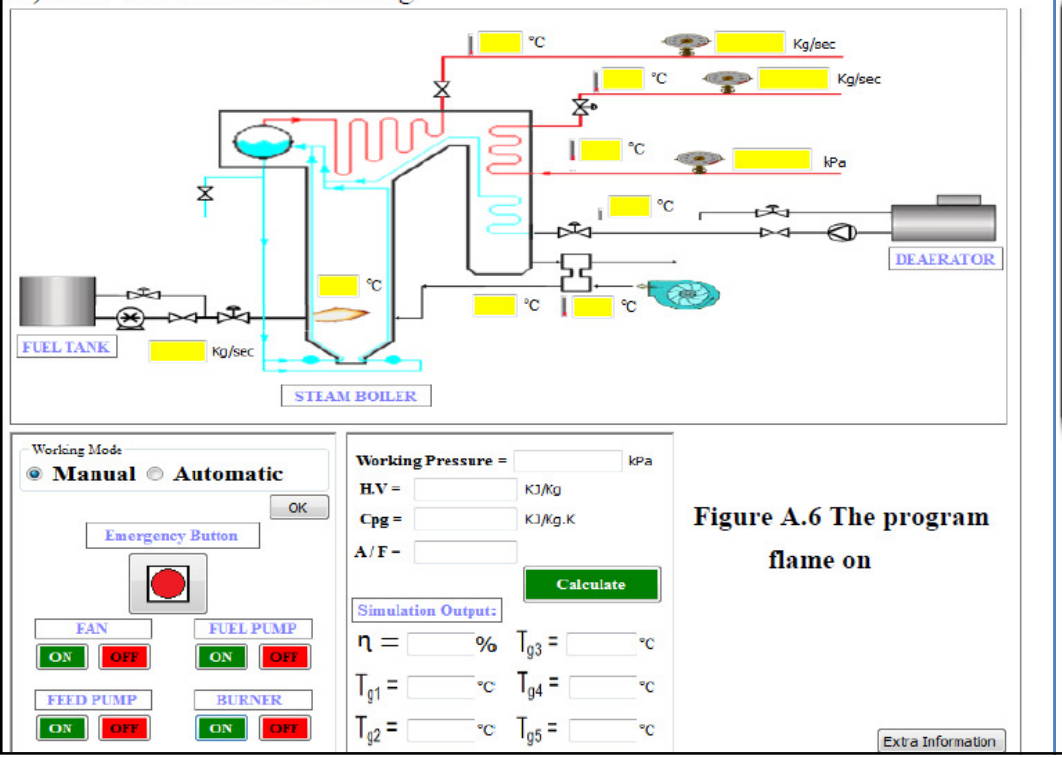


Figure A.6 The program flame on

11) After clicking calculates the program will show the results.

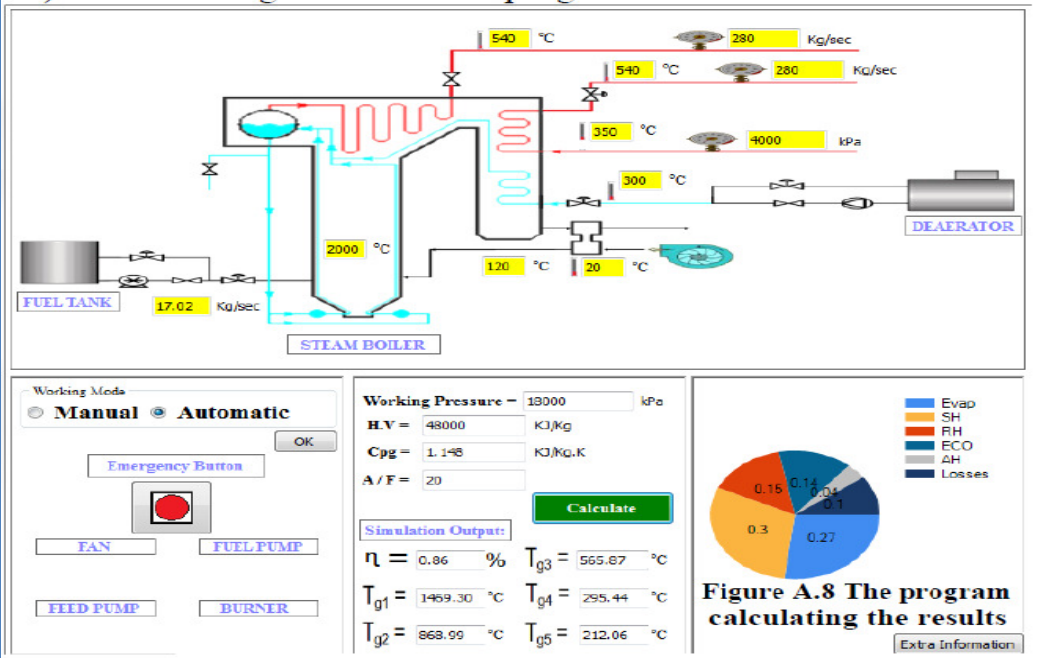
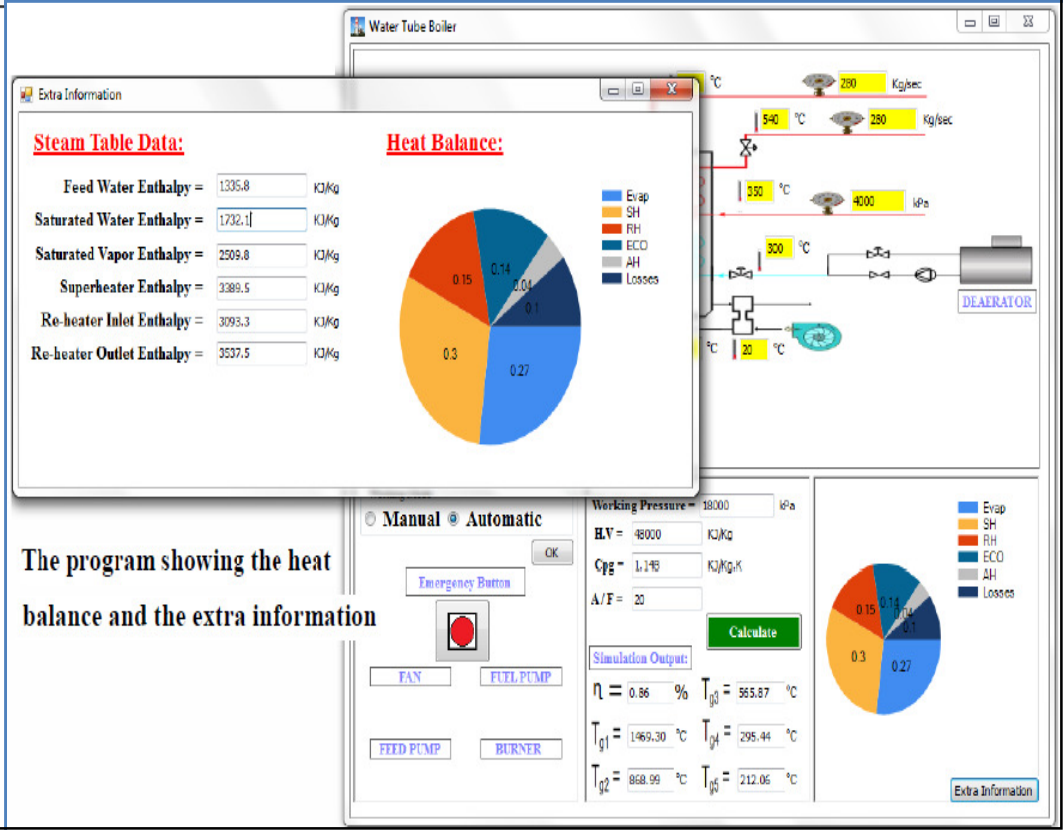


Figure A.8 The program calculating the results

12) For extra information the program will show the enthalpy and the heat balance of the boiler as shown in figure.



The program showing the heat balance and the extra information