

Abstract :

The object of this work is to propose a simulator under EPKS Honeywell DCS, for a 120 t/H BOILER in Arzew Refinery, offering a real ability for gas consumption optimization.

Knowing that good boiler efficiency is mainly based on the correction of gas combustion according to the analysis of oxygen in the flue gas and based on the mathematical model of combustion, we can deduce the optimal operating parameters to reduce the consumption of gas combustion respecting the curve (ratio AIR / GAS - O₂) and any real drift in measurement of oxygen in the flue gas can be detected in time, then allow to verify the reliability of the O₂ analyzer.

Through the evolution of computers sciences and with the introduction of virtual machines, we are able to create simulators that represents exactly the industrial reality, with better flexibility, in addition, the simulator presented offers the advantage of being performed under a Honeywell DCS virtualized environment and validated from a real process.

The simulator that we present incorporates a boiler as the main equipment witch it is fully modeled and all systems (combustion control, BMS, ESD) that manages this process, are integrated into the simulation database, this simulator is also being used for operator training and development.

The Strength benefits of this work are :

- Customized boiler simulator / Based on true interpolates process values
- Experimental simulator / not mathematical only
- Validate results (% linear interpolation error negligible by increasing number of sample on model building)
- Include a boiler / increase the operator knowledge on STARTUP/SHUTDOWN procedures = Real training)
- If changes in existing system are to be made, the effects of the changes should be tested on process simulator prior to implementation
- Customized boiler simulator allows to test various scenarios and gas consumption optimization logics in few minutes with very low cost
- Optimized combustion = low NO_x emissions

Problematic:

The natural gas consumption in boilers real production machines for power in refinery process continues to grow due to the exponentially demand for refined products derived from petroleum, a rationalization of this consumption must first go through optimization of combustion control in order to reduce the air / gas ratio based on the analysis of oxygen in the flue gases, this objective has been achieved at the Arzew Sonatrach refinery by the development of a dynamic, personalized and dedicated boiler simulator for improved combustion efficiency, it is based on mathematical model inspired by the theory of combustion and linear interpolation models for process parameters modelling .

The main constraint to achieve this project was the complexity of the boiler process and control , with high combined control loops.

The starting of the work was by studying the boiler combustion theory and collect of all live data for 2 years , it was the data base for the modelling.

Why simulation ?

In this context, simulation is arguably one of the most common techniques for flow analysis in production systems as well as for the design of a suitable control policy. It is a powerful tool by its flexibility and its ability to represent virtually any system.

By definition the simulation is the imitation of a real process or system during specified time. The act of simulating requires that a model must be developed; this model represents the key characteristics of the selected physical abstract system or process. It represents the system itself, whereas the simulation represents the operation on this system.

From this definition we can understand that the simulation consists to:

- Develop a model of the real system studied
- Conduct experiments on this model (not calculations)
- Interpret the observations provided by the model and make decisions on the system.

The objective may be to understand the dynamic compartment of the system, compare configurations, to evaluate different control strategies, and optimize performance.

For our work the simulation was applied on production systems (boiler) , by building a software model of it.

The simulated boiler 31H3 :

This is the main Arzew Refinery boiler with 120 T/h production of 50 Kg/cm² steam , power of 4.5 MW electrical generator and for all motor turbines for this refinery .

The process around this boiler:

The steam unit includes three boilers 31H1/H2/H3, two boilers 31H1/31H2 are identical capacity (55 T/h) whereas the main boiler 31H3, is 120 T/h capacity, the boilers demineralized feed water pass through 31D101 deaerator and must be pumped to boilers at 60 kg/cm² and 120°C temperature.

Our simulator is based on the main boiler 31H3, which is able to guarantee, the production of HP steam (50 kg/cm²) for the refinery units (topping + lube oil)

The HP Steam 50 Kg/cm² is the steam driving of the electrical turbine generator 31K1 (for 4,5 MW 5,5 KV production).

the pressure reducing steam from 50kg/cm² to medium pressure 25 kg/cm² is controlled by the automatic valve 31PRC11V and from 25 kg/cm² to 3kg/cm² by the automatic valve 31PRC10AV.

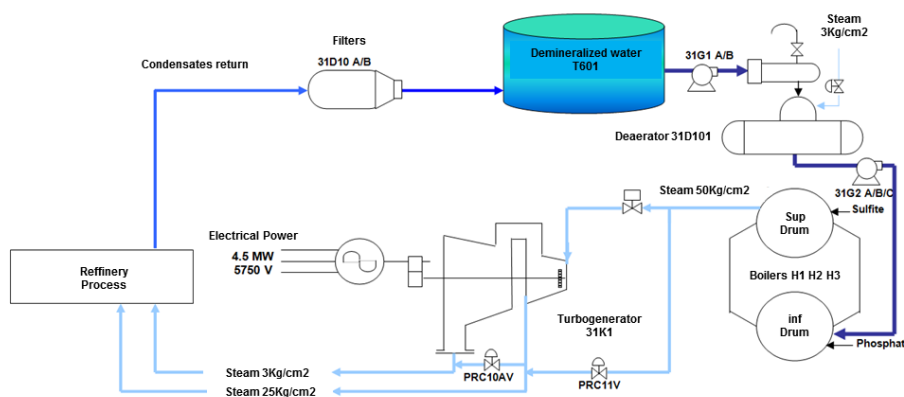


Fig 1

Hardware Platform used for the simulation:

The first aspect to be considered for this work was that the graphic and dynamic visualization of the model is a considerable asset to facilitate its verification and its validation.

At the present, we have very advanced tools of computer programming that facilitate the realization of our objective, but the reality of the industry is forcing us to be closer more and more of operator environment.

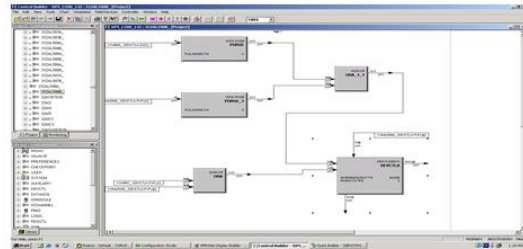
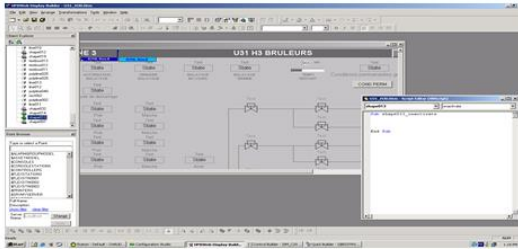
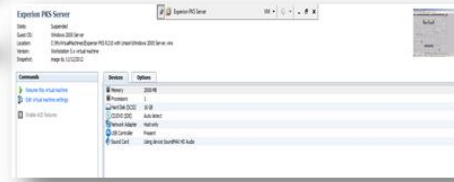
The ideal solution consists in using the virtual environment that VMWARE software, offer us.

A virtual machine is a software computer that, like a physical computer, execute the same operating system and applications, so from an DCS Honeywell Experion server, we clone a new virtual machine in order to have the same operator environment and all engineering tools (Control builder and HMI WEB)

Experion Server



VMWARE Virtual machine



Experion PKS Server

State: Suspended
Guest OS: Windows 2000 Server
Location: C:\MyVirtualMachines\Experion PKS R210 with Unison\Windows 2000 Server.vmx
Version: Workstation 5.x virtual machine
Snapshot: image du 11/12/2012

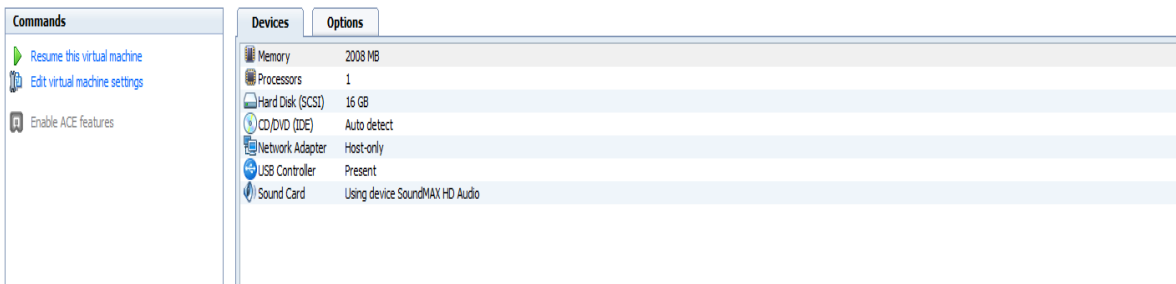
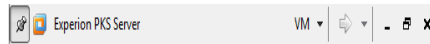


Fig 2

Engineering tools used for the simulator development:

1. Control Builder :

It is the main development tool which is used for the implementation of controllers along with the development and loading of control strategies. It possesses an intuitive graphical user interface for building or programming control strategies into real or simulated controller.

2. HMIWeb Display Builder :

It is a specialized drawing application used by developers to create custom HTML displays for operator station. These custom displays are usually operator screens that displays information linked to a fully operational Experion system.

3. SIM-C200 :

The SIM-C200 offer a Control Execution Environment "CEE" for control builder functions use, it supports the full simulation of an actual Honeywell C200/C300 controller. Honeywell's Experion software suite does not differentiate between a real or simulated controller and will operate according to how it has been set up.

All control modules and logics programs for our boiler simulator were developed and loaded into this simulated CEE.

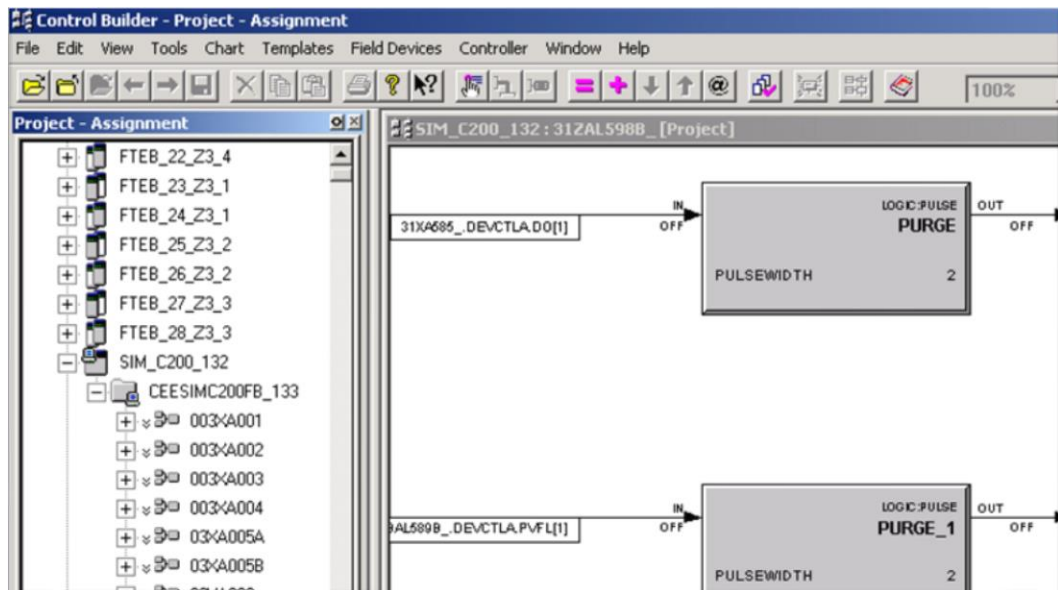


Fig 3

How this boiler simulator was build?

1. A two years data base was collected to build mathematical model for all process parameters:
 - Each loop was considered -and identified- separately (level , flow , pressure, temperature)
 - Each % valve opening correspond to real % value of process parameter
 - From real process data , a new simulate process function was find by numerical interpolation
 - New control modules with process simulated values (but the same control strategy from real project/process)
2. Identical graphics pages from the project with modification of static and dynamic shapes according to the simulation data progress
3. New control modules for the integration of BMS and ESD functions

Building mathematical model for all process parameters:

From the DCS data base history we collected all process values associated with different loops (% opening valves - measured parameters : flow / level / pressure / temperature), and to build a model of experimental simulation we chose a approach modeling by linear interpolation control loops (with consideration of each loop as a system to identify separately)

In the mathematical field of numerical analysis, interpolation is a method of constructing new data points within the range of a discrete set of known data points.

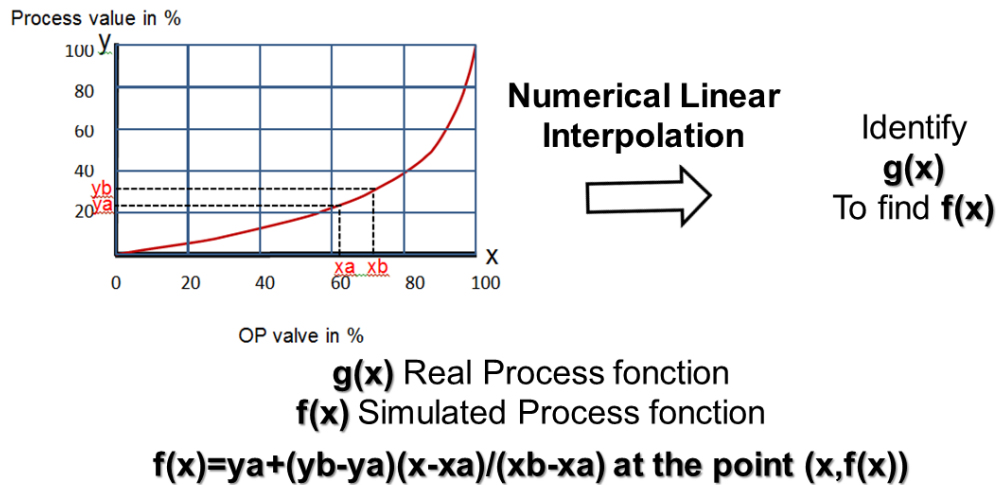


Fig 4

Building mathematical model for Oxygen measurement:

The optimization of gas consumption is based on oxygen theoretical curve from air /gas Ratio, the hard work was to identify this mathematical function from the chemical combustion theory and from the real gas analysis used on boiler combustion (table 1 : gas mixture from natural gas and refinery gas) , a calculated oxygen concentration is given for each ratio for air and gas (table 2)

| Table 1 : | |
|------------------|------------------|
| H2 | 33,79 % |
| CH4 | 55,43 % |
| C2H6 | 7,04 % |
| C3H8 | 3,03 % |
| iC4H10+nC4H10 | 0,56 % |
| iC5H12+nC5H12 | 0,15 % |
| H2 | 33,79 % |
| CH4 | 55,43 % |
| C2H6 | 7,04 % |
| C3H8 | 3,03 % |
| iC4H10+nC4H10 | 0,56 % |
| Table 2 : | |
| AIR / GAS Ratio | theoretical O2 % |
| 8.24 | 0 |
| 8.70 | 1 |
| 9.21 | 2 |
| 9.78 | 3 |
| 10.41 | 4 |
| 11.12 | 5 |
| 11.93 | 6 |
| 12.85 | 7 |
| 13.92 | 8 |

Different components of the simulator:

1. Control system for the main boiler including :
 - Combustion control
 - Water Drum level control
 - Steam temperature control
2. Integrated Burner Management System
3. Integrated Emergency Shutdown System

Simulator displays:

1. Burners display

It is the principal view for ignition of the boiler, it permits to execute the different stages of this operation :

- Boiler purge - The ignition of the first pilot - The ignition of the first burner - The ignition of the second pilot - The ignition of the second burner From this view we can also check all trip parameters and permissive to start

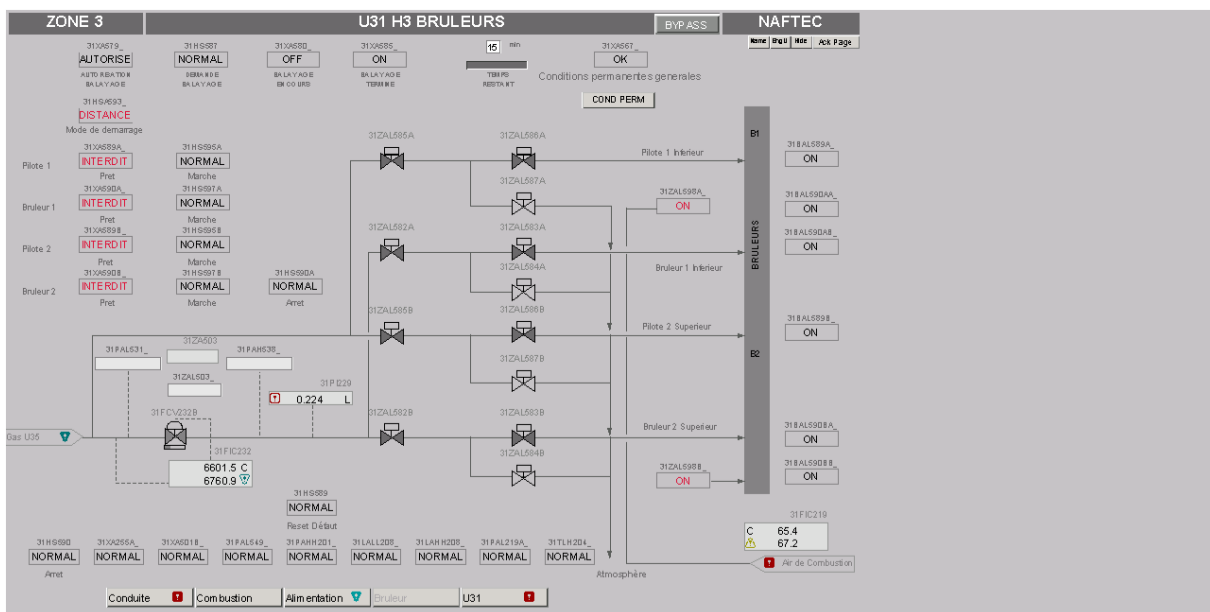


Fig 5

2. Combustion display

On this view the operator finds the access to the selector between regulation of HP pressure on pressure drum or common collector, he can also choose to put boiler on MAN load control, define a PCI and density values for combustion control

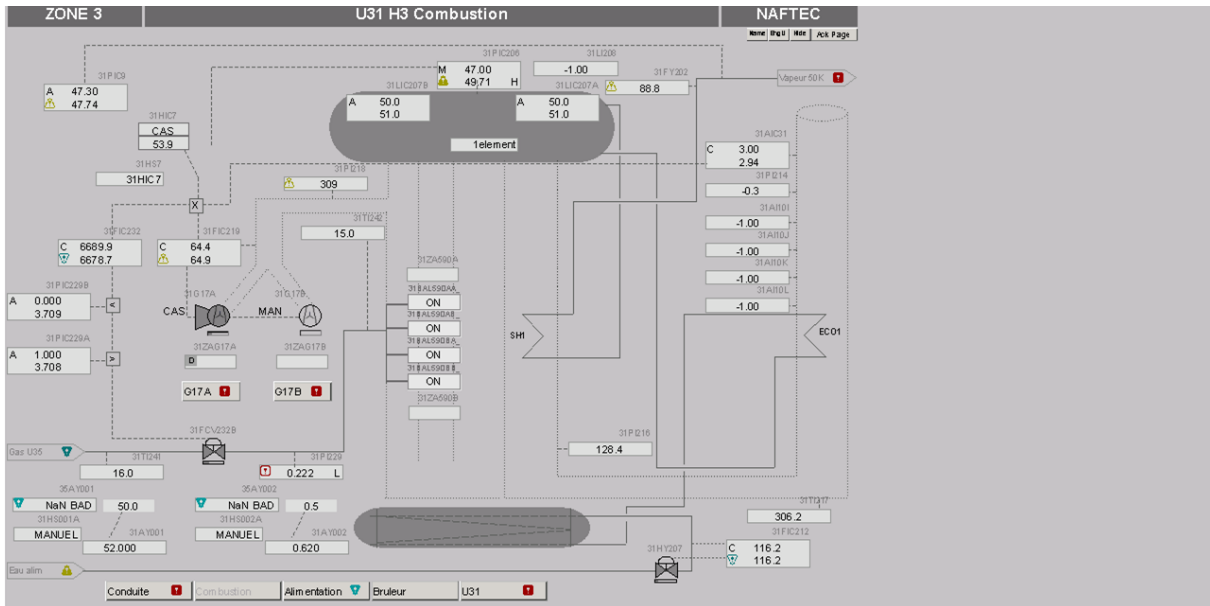


Fig 6

3. Boiler feed water display

From this view operator can select to pass on 3 element control of boiler drum level when conditions permits for a best control result.

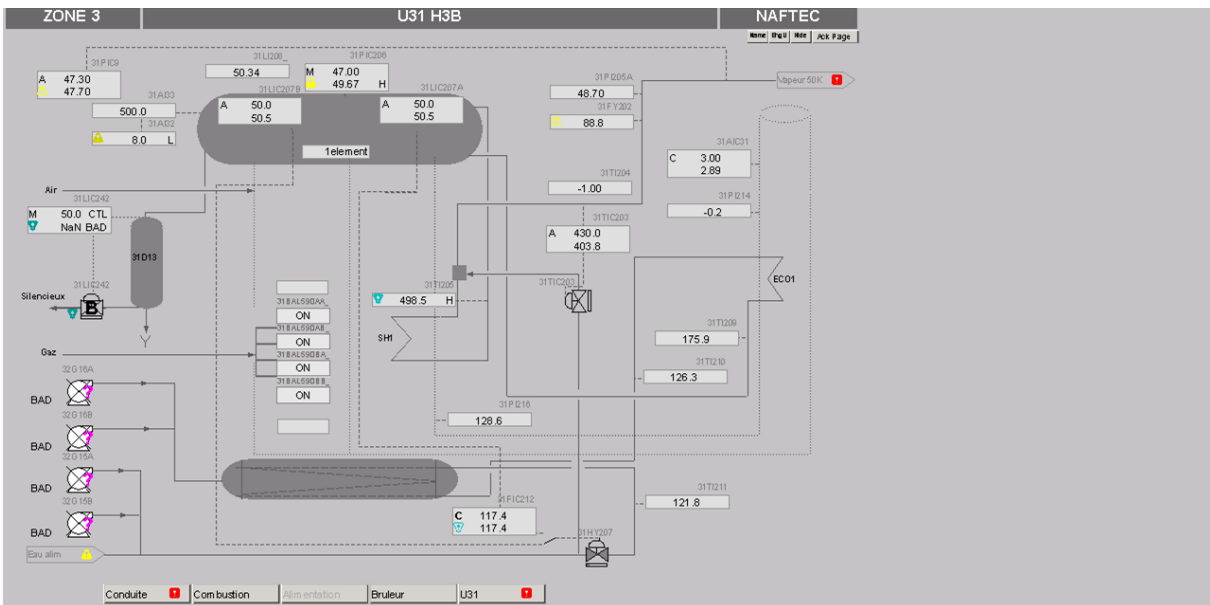
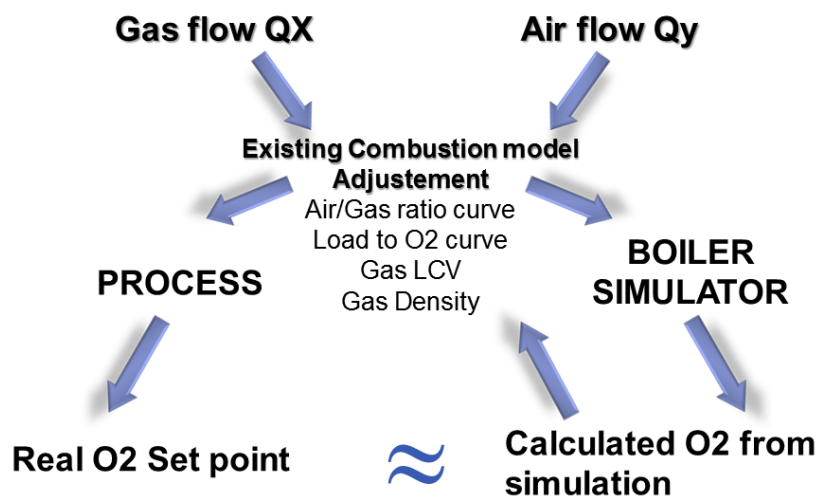


Fig 7

Gas consumption reducing:

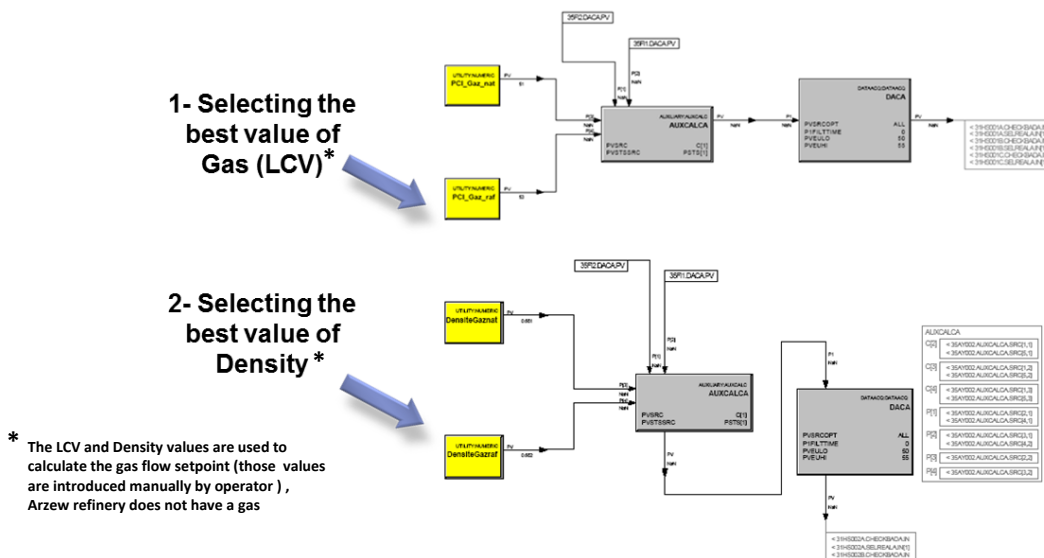
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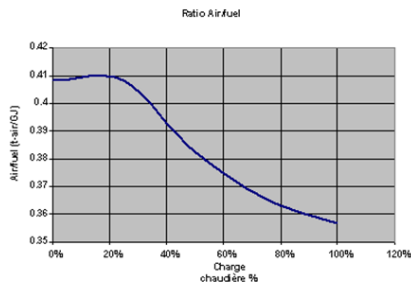
The goal is to have (with a good adjusted gas and air set points) a real measured O₂ on the flue gas equal to a calculate value from the boiler simulator, in order to optimize the combustion



How the simulator results can optimize combustion?

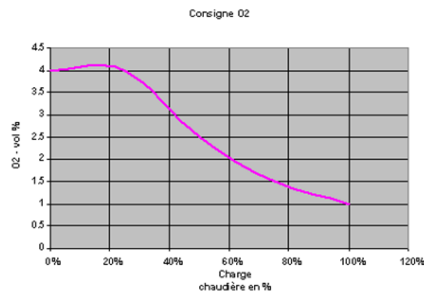
From our simulator results we have adjusted four main curves in PUCOFT combustion control, to finally adjust set points for Air and gas flow:





| Charge % | Air/gas t-air/GJ |
|----------|------------------|
| 0% | 0.408 |
| 25% | 0.408 |
| 50% | 0.3825 |
| 75% | 0.3655 |
| 100% | 0.357 |

3- Adjustment of Load to Air equal to Gj Gas curve



| Charge % | O2 vol % |
|----------|----------|
| 0% | 4 |
| 25% | 4 |
| 50% | 2.5 |
| 75% | 1.5 |
| 100% | 1 |

4- Adjustment of Load to O2 setpoint

Conclusion:

- Optimized O2 = decreased CO₂, CO
- Optimized O2 = good combustion = good boiler efficiency
- Good boiler efficiency = Reduced gas consumption
- Reduced gas consumption = Reduced refining cost
- Reduced gas consumption = Environmental Preservation