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COMBUSTION LOOP CONTROL FOR MULTIPLE FUEL BOILERS

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***Abstract**. The main function of boiler combustion control loop is to adjust suitably air flow and fuel flow to burners. Boilers with several burners have no individual burner control. In this case, it is supposed that fuel and air distribution between burners is equilibrated. But boilers with more then one fuel burning simultaneously in different burners need other control strategy This paper suggests the fuel pressure as the variable that could equalize burner load with different fuel. Air flow remains controlled by the sum of mass flow fuels.*

Keywords: Combustion, Boiler, Control.

1. INTRODUTION

Usually measurement and automatic control of combustion air flow in great capacity multiple burner boilers is not individualized by burner. Regardless boiler draft, if forced or in draft, it is used to control general air flow to this boiler in function of fuel flow. This represents a problem for boilers which can simultaneously consume different fuels in distinct burners, once the channels that drive air to burners are pre-adjusted to a equitable flow air distribution, while distribution of different fuels is a function of number of burners by fuel. This fact leads to a lack of air in some burners and excess in other ones, thus it is necessary to operate with excess of air in the boiler in order to supply more fuel in burners.

This paper shows a crossed limit combustion lattice, developed for a great capacity boiler (400 t/h vapor at 120 kgf/cm^2 and 538 ^{o}C) with nine frontal burners that can consume gas, oil or petrochemical fuel residues. This enables a suitable control of air/fuel mixture for each burner without individual measurement of air and fuel flows. The strategy of this control took as basis the fact that fuel pressure in a burner corresponds to its load percentage. So, by the equivalence of pressure measurement range between many fuels, it is possible to control burner thermal load through the same signal. Air flow to the boiler stayed controlled by weighed sum of each fuel flow, however burner thermal load stayed controlled by fuel pressure there.

2. COMBUSTION

Consumed fuels in boilers are formed by hydrocarbons $C_uH_vO_wN_xS_y$. Their burning corresponds to an exothermic oxidation reaction, where oxidizing agent, oxygen (O_2) stripped from atmospheric air, reacts with the hydrocarbon until it reaches its lowest energetic stage, CO_2 and H_2O.

Atmospheric air is basically formed by oxygen (21% O_2 in volume) and nitrogen (79% N_2 in volume). It is to be observed that this statement imply a little simplification, where nitrogen content includes gases like argon (0,093% Air in volume), carbon dioxide (0,003% CO_2 in volume), among other of less percentage (KOTAS, 1985).

Combustion reaction that takes place in boiler needs excess of air to process a complete fuel burning. This is described in Eq.(1), where “u, v, w, x, y ” values are defined by fuel composition and it was not considered formation of gases like NO_x. Showed indexes represent molar ratio (in volume) of each participant component per fuel mol.

General Fuel Combustion Equation

$$C_uH_vO_wN_xS_y + (u+v/4–w/2+y+e)(O_2+3,76N_2) \rightarrow u\ CO_2+ v/2\ H_2O + y\ SO_2 +[3,37(u+v/4–w/2+y+e)+x/2]\ N_2 + e\ O_2 \quad (1)$$

Considering that fuel composition (u,v,w,x,y) is known, it is necessary the combustion gas analyze to get the O_2 content in molar basis to solve the equation (1). These gases cool during sampling and contained water is condensed. For this reason, its analysis is determined in a dry basis, without considering contained water, Eq. (2).

O_2 content in dry combustion gases

$$\%\ O_2\ (dry\ basis) = [\ \mathbf{e}\ /\ \{\mathbf{u}\ + \mathbf{y} + [3,37(u+v/4–w/2+y+e)+x/2] +\ \mathbf{e})\ ]\ *\ 100 \quad (2)$$

The mass ratio air/fuel is given by the equation (3) :

Mass ratio air / fuel

$$Air / Fuel = (u + v/4 - w/2 + y + e)(2*16 + 3{,}76*2*14) \ / \ (12u + 1v + 16w + 14x + 32y) \quad (3)$$

Where each element molecular weight in fuel and air is carbon (C = 12), hydrogen (H = 1), oxygen (O=16), Nitrogen (N=14) and suffer (S=32).

Table below shows the mass ratio air / fuel for some fuels to 2% of O2 in dry combustion gases. In this cases, it is suppose that there are no S, N and O in fuel, or w, x and y equal zero.

Fuel			Mass flow ratio Air / Fuel
Methane gas (CH_4)	u = 1	; v = 4	17,9
Ethane gas (C_2H_6)	u = 2	; v = 6	16,8
Fuel oil OCA1 (C/H = 10)	u= 10 / 12	; v = 1 / 1	14,2

3. CROSSED LIMIT COMBUSTION LOOP CONTROL

The crossed limit combustion control loop, Fig.3.a, has as function to fulfill following requirements :

- Vary in a automatic way according to load increase or reduction in the boiler;
- In load increase, air flow increase precede fuel flow;
- In load reduction, fuel flow reduction precede air flow;
- Keep an adequate mass flow ratio for a good combustion.

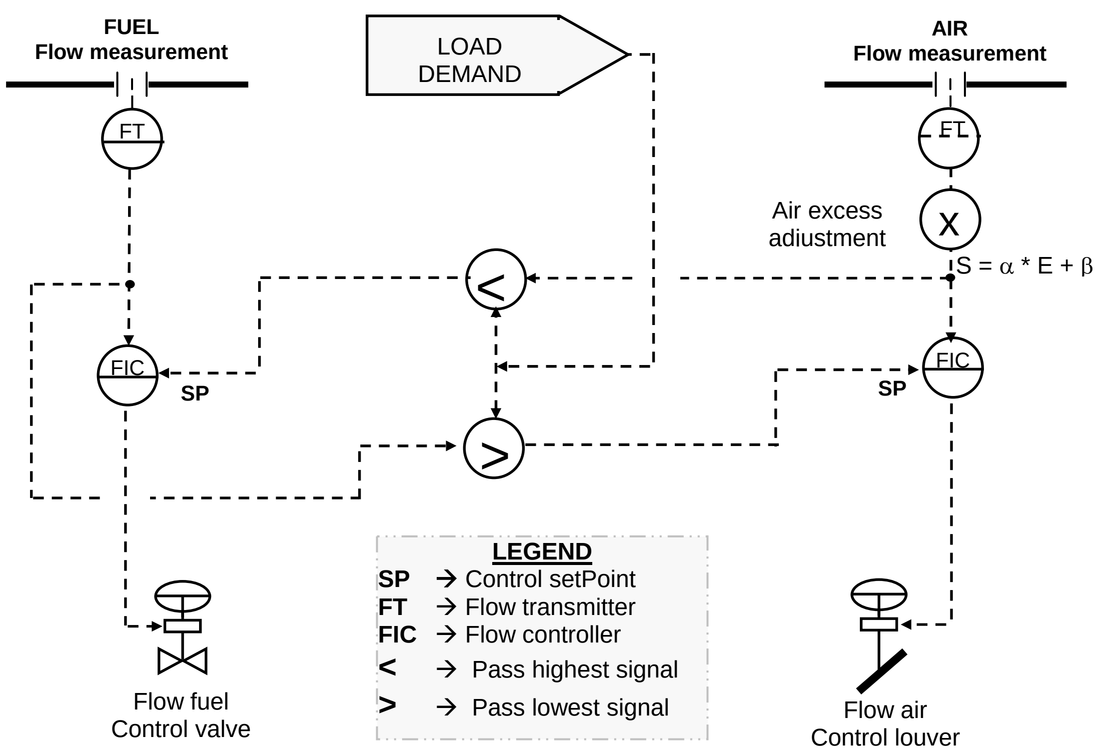

Figure 3.a - Crossed limit combustion control lattice

Loop showed in Fig.3.a fulfill specified requirements for a crossed limit combustion control loop, even with a multiple burners boiler. Once fuel flow control is single, it is supposed that its distribution is almost equal between the burners. The required condition is fuel flow measurement range be compatible with combustion air flow measurement range. For example, an increase of 10% in boiler load. It would correspond to an increase in air flow about 10% its measurement range and so such an increase in fuel flow about 10% its measurement range. These 10% air and fuel will be equally distributed between burners, keeping a good air/ fuel mass flow ratio.

Let see a boiler case with many burners having same capacity and more than one fuel burning simultaneously in distinct burners. How to behave in a load boiler increase or reduction, if burner number between fuels is different? Flow air variation will be similar for all burners in operation. However, fuel flow variation will have two problems. Firstly, more than one fuel will be answering to demand of load boiler change, causing unbalance between highest and lowest signal selectors of crossed limit, arising operational ranges without the requirement of crossed limit. The second problem corresponds to different fuel flow variations between burners of different fuels, causing a unbalance in air / fuel ratio.

A Fig.3.b shows a combustion control loop, that attempted to solve these problems. Essentially, this loop considers that each load burner is intrinsically related to its pressure. Burners with same fuel shall receive same flow if they have same pressure. If they have different fuels, there will be a fuel pressure range between them that put burners in similar loads. Let suppose that a set of burners that can consume fuel gas or fuel oil. If fuel gas burners reach its maximum load when fuel gas pressure reaches 150 kPa and the fuel oil burners reach their maximum load when fuel oil pressure reaches 1500 kPa. Under maximum condition, these burners with different fuels consume same air flow. Therefore, if automatic fuel flow control is exchanged for fuel pressure control, there will be a load control between burners with different fuels, provided that pressure measurement range are compatible each other. In case above, if fuel gas pressure transmitter is calibrated to 200 kPa, the oil pressure transmitter must be calibrated for 2000 kPa. In this case,, 50% of these measurement ranges will correspond to similar fuel amounts between burners. Weighed sum of flow measurements of each fuel must be used to define combustion air flow to boiler.

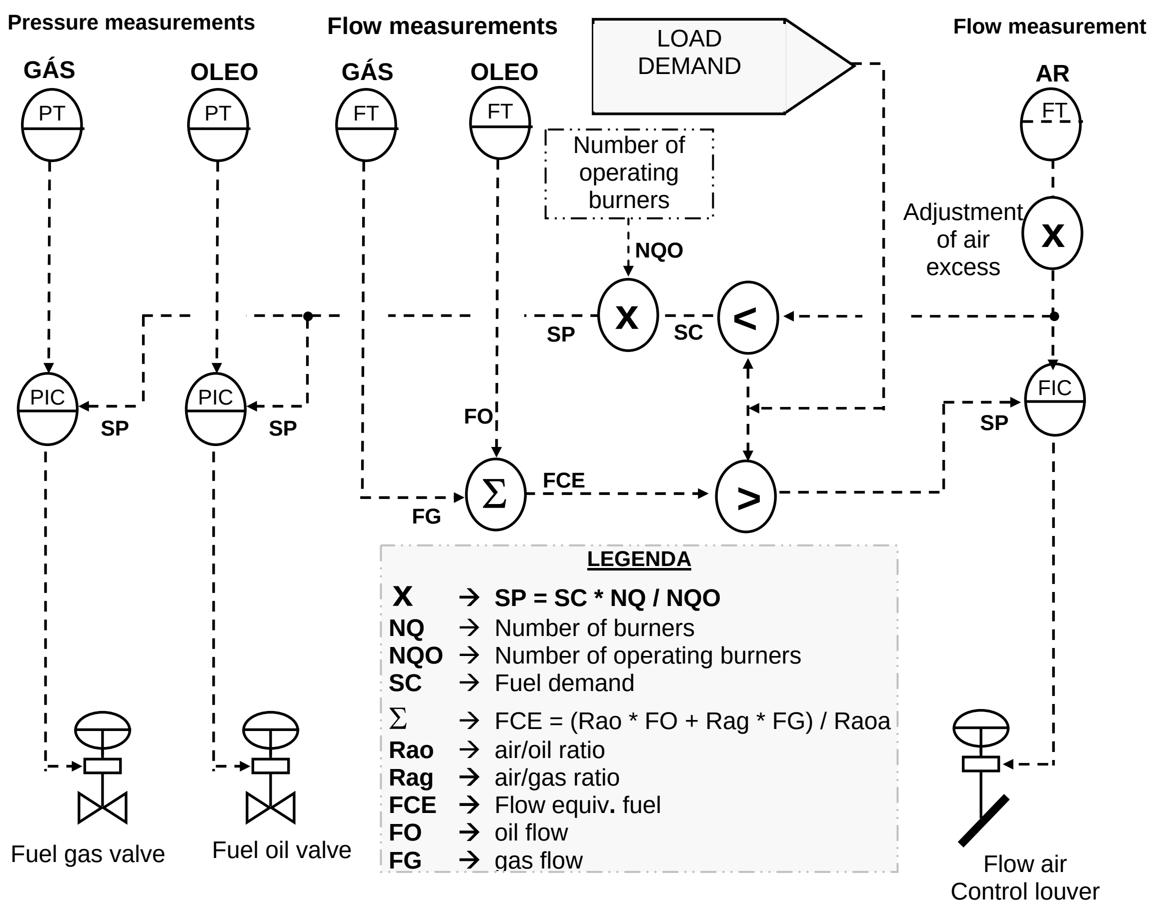

Figure 3.b - Crossed limit combustion control loop for multiple fuels

This combustion control loop, Fig.3.b, arise the need to adjust flow air measurement range with fuel pressure measurement range that determine operating burners capacity. This problem arises from the fact that flow air measurement is related to maximum boiler capacity, while fuel pressure measurement is related to only one burner capacity. This problem is solved when output signal lowest signal selector in crossed limit is multiplied by ratio “number of boiler burners and number of operating burners”.

4. OBTAINED RESULTS

The combustion control loop shown in Fig.3.b has been applied in a boiler (400 t/h vapor at 120 kgf/cm^2 and 538 ^{o}C) in the Power Plant in Camaçari Petrochemical Complex in Camaçari city. This boiler has nine 120 GJ/h burners, originally specified for an individual capacity of de 3 t/h fuel oil or 2,5 t/h natural gas. These burners are limited by air flow that restricts burning of only one fuel in each burner. But it is just possible burning simultaneously more than one fuel in distinct burners in the boiler. A third petrochemical liquid residues stream was available as fuel for this boiler which passed to operating condition with up to three fuels simultaneously.

Before this change, this boiler operated with a crossed limit combustion loop for one fuel, and the two other fuels were manual, without interfering in air flow, that were completed manually through excess boiler air adjustment station. It required a higher attention and skill from the operator. Oxygen monitoring in combustion gases in this boiler usually operated above 2% to keep these gases opacity within an acceptable operational limit, lower than 40%, corresponding to a good combustion. It is worth to emphasize that combustion gases opacity in this boiler has been the first parameter to indicate start of bad combustion, even before carbon monoxide increase, which is also monitored.

With the new loop, the boiler operates totally automatically, providing a better generated steam pressure control, a lower operational adjustment demand and an air excess corresponding to 1% of oxygen in combustion gases, providing an average increase in boiler efficiency about 0,5%.

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