FAQ – Efficient combustion in boilers – Which conditions must be provide for an efficient combustion in the boilers

This FAQ give a short explanation to the following questions:

1) Which conditions must be provide for an efficient combustion in the boilers?
2) What should be done to regulate the chimney gas temperature in the boilers?

What is combustion

I order to have a combustion, we need to have the following conditions:

Conditions for starting and spreading combustion

- ✓ Combustible and oxygen has to be mixed
- ✓ Combustible and oxygen has to be supplied in a determined proportion
- ✓ Combustion has to be carried on above the ignition temperature

Conditions to continue combustion

- ✓ Products has to be evacuated
- ✓ Combustible and oxygen has to be continually furnished

In order to measure the efficiency of a combustion, we can measure either the concentration of oxygen either the concentration of CO_2:

$$CH4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Combustion of methane

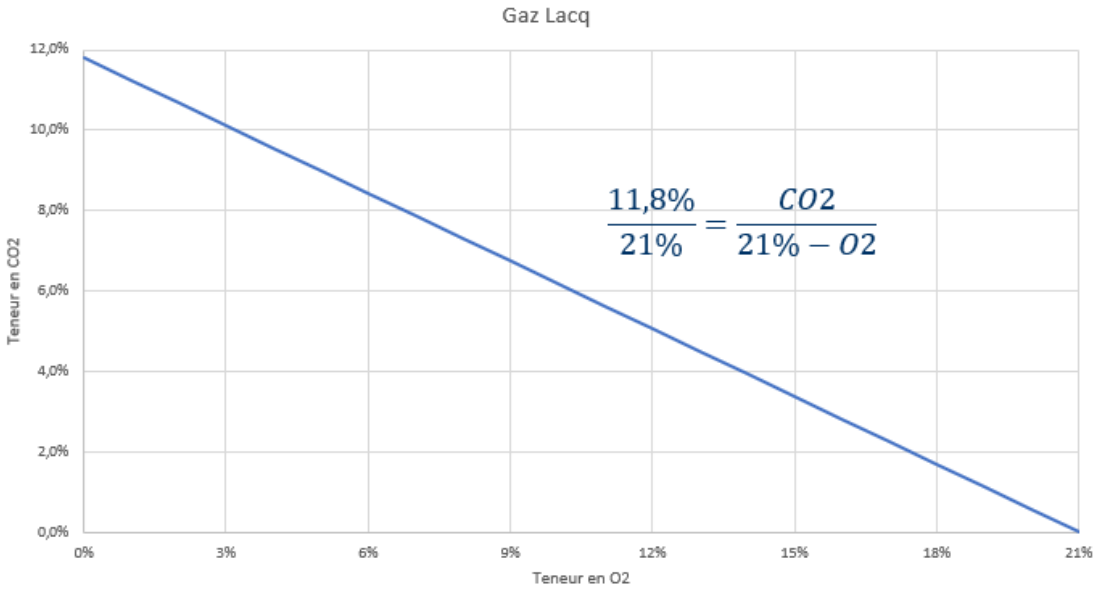
Combustion with excess air

A perfect combustion allows to burn all CH4 with exactly the good proportion of oxygen (2 O2 for 1 CH4 in the example above). This combustion is called “a stoichiometric combustion”. As the oxygen comes from the air and is free, most of the time we put more oxygen than it is necessary:

$$CH4 + Air \rightarrow CO_2 + O_2 + H_2O$$

Combustion of methane with excess air

The more efficiency combustion, the lower O2 in the fume. That means to, the higher CO2 concentration in fumes. This concentration depends on the type of fuel. For example for the natural gaz provided from Lacq (an old field in France):



Concentration of CO_2 depend from the the source of natural gas:

NATURE DU GAZ		Air théorique	POUVOIR FUMIGENE		CO_2 TOTAL	H_2O TOTAL		CO_2 max.
			HUMIDE	SEC				
		V_a	V'_{fo}	V_{fo}	V_{CO_2}	V_{H_2O}	V_{H_2O}	$(\tau CO_2)_o$
		$m^3(n)/m^3(n)gaz$	$m^3(n)/m^3(n)gaz$	$m^3(n)/m^3(n)gaz$	$m^3(n)/m^3(n)gaz$	$m^3(n)/m^3(n)gaz$	$kg/m^3(n)gaz$	% V_{fo}
GAZ NATURELS	Lacq	9,7	10,7	8,7	1,03	2,03	*1,63*	11,8
	Algérie (Le Havre)	10,7	11,8	9,6	1,16	2,16	*1,74*	12,1
	Algérie (Fos)	10,1	11,2	9,1	1,09	2,08	*1,67*	11,9
	Algérie (Montoir)	10,6	11,7	9,6	1,16	2,15	*1,73*	12,1
	Mer du Nord	9,6	10,6	8,7	1,05	1,98	*1,59*	12,0
	U.R.S.S.	9,6	10,7	8,7	1,03	2,00	*1,60*	11,9
	Groningue	8,7	9,7	7,9	0,94	1,80	*1,44*	11,8

Source: APAVE 1997

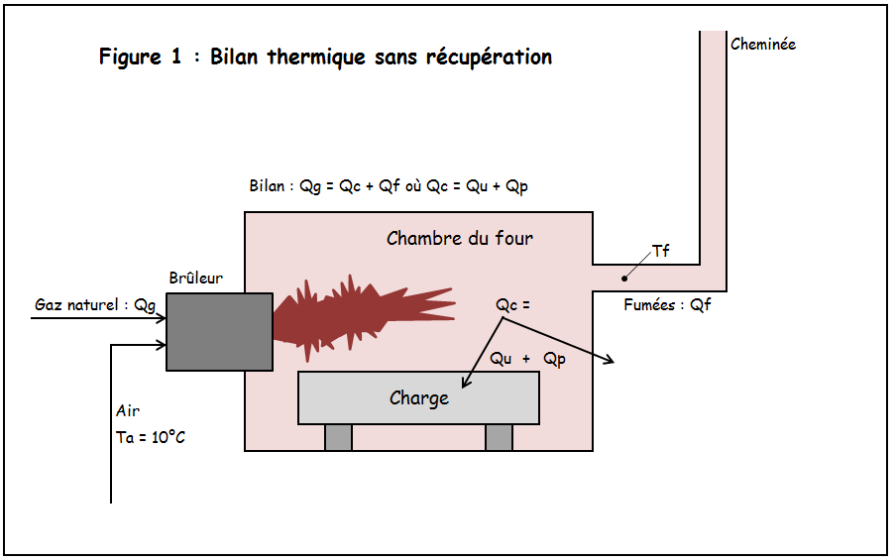
Max concentration of CO2 in gasoil fume is above 15.2%.

Characteristic of an efficient combustion

The combustion efficiency is defined as heat generated on fuel supplied.

$$\rho_c = \frac{Heat}{Fuel}$$

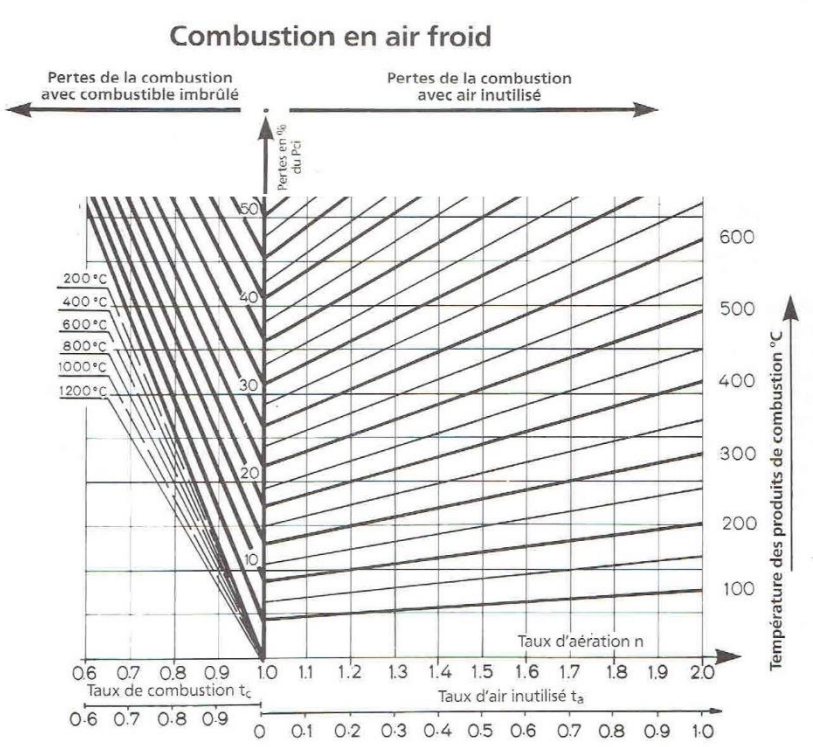
It is bellow 100% if the Energy contained in the fuel is calculated on lower heating value (The energy required to vaporize the water is not released as heat).



A higher ρ_c is obtained with:

- A higher air combustion (Te)
- A lower fume temperature (Tf)
- A lower O2 in fumes or a higher CO2 in fumes

The following diagram allows to calculate the loss of energy related to fume temperature and air excess:



For example a combustion with fume at 200°C and 20% excess air (l = 1.2) has 10% of heating loss (ρ_c =90%).

In Wallonia, the following data are given in order to have an efficient combustion a gas boilers:

Température d'eau (°C) [9] : 60	Indice de fumée MAXIMAL (Bacharach)	t° nette gaz combustion (t°gaz-t°air comb.) MAXIMAL (°C)	Teneur en CO_2 MINIMALE (%)	Teneur en O_2 MAXIMALE (%)	Teneur en CO MAXIMALE (mg/kWh)	Rendement combustion MINIMAL (%)	
Performances minimales [10]	1		12,0	4,4	155	90,0	
Valeurs mesurées							
Puissance maximale	0		12,30	4,0	118	90,8	
Allure 1 / Pmin							A remplir si brûleur à "plusieurs allures" (*) ou "modulant de P ? 1 MW" (*)
Allure 2 (25% si modulant)							
Allure 3 (50% si modulant)							
Allure 4 (75% si modulant)							
Comparaison	☒ OK ☐ non OK	☐ OK ☐ non OK	☒ OK ☐ non OK	☒ OK ☐ non OK	☒ OK ☐ non OK	☒ OK ☐ non OK	Résultat global ☒ OK ☐ non OK

That means that:

- ✓ O2 < 4.0 %
- ✓ CO2 > 12.3%
- ✓ CO < 118 ppm

With a burner full of charge, the combustion efficiency has to be higher than 90.8%

How to optimize the temperature?

In order to have an efficient combustion, we can act on air temperature in the burner (1) , fume temperature (2) or air quantity in the burner (3).

1) In order to increase the temperature of the air combustion, we can suppy the ventilator with air coming under the roof of the building (higher temperature). To do that, a pipe can be connected to the ventilator as shown on the picture bellow

2) On an existing boiler, the main way to reduce the temperature of fume is to limit oxygen input in the burner. On standard boilers, a manual screw controls the air/fuel input in the burner. It has to be calibrated during the maintenance.

3) A new “condensation boiler” allows to reduce the fume temperature with an heat exchanger between fume and water return heat pipe in order to condensate the water in the fume (higher heating value).

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