

# Cogen plant with FGR at SNC COGELYO in Saint-Denis (F)

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## 1 - PARTICULAR CASE OF THE SAINT-DENIS COGENERATION PLANT

It includes a gas turbine (GT) LM 6000 type (GE) and a HAMON HRSG producing superheated water at 180 °C (destined to the urban heating network of Saint-Denis), equipped with a PILLARD postcombustion burner REBURNFLAM® gas type designed to operate with FGR.

The particular property of such a plant is that it has been designed to operate for more than 500 hrs/year in ambient air mode (GT stopped), which -according to the new regulation dated August 11th, 1999-, imposes an NOx emission lower than 100 mg/Nm<sup>3</sup> @ 3% O<sub>2</sub>.

## 2 - OPERATION PRINCIPLE

The plant is run continuously all year. The HRSG is capable of a high turndown ratio thanks to the following provisions : the TEG (turbine exhaust gas) path is equipped with a progressive by-pass system thanks to a diverter and a vent which are both adjusted according to requirements :

- when operating in TEG mode without postcombustion, the load control acts on the diverter and the vent in order to adjust the TEG flow crossing the HRSG,
- if the heat demand still increases above that which would correspond to a full opening of the diverter, then the postcombustion burner is automatically started up and modulated.
- in the case of a turbine shutdown (or in the case of such an operator requirement) the HRSG automatically switches to ambient air mode : the diverter closes, the ambient air starts up, and its register opens.

### Characteristics :

- Gas turbine (GT) : LM 6 000, 47 MWe
- HRSG : HAMON producing superheated water at 180°C
- Availability : 8 600 hrs/year, 24 hrs/24, availability rate 98 %  
Self-checking operation according to NFE 32020 without human presence
- TEG (turbine exhaust gas) :
  - . max flow : 130 kg/sec at 450°C
  - . O<sub>2</sub> content : 14,3 % (vol, humid basis)
  - . H<sub>2</sub>O content : 6,3 %

### PILLARD burner REBURNFLAM® type :

- Fuel : natural gas, pressure available 4,7 bar
- Heat release :
  - . TEG mode : 1 875 to 15 000 kW (turndown ratio to 1 to 8)
  - . ambient air mode : 5 875 to 47 000 kW (turndown ratio to 1 to 8)
 } global turndown ratio 1 to 25
- Pressure drop : ≤ 25 daPa in TEG mode  
≤ 15 daPa in ambient air mode.

## GUARANTEED EMISSIONS

- In TEG mode : NOx < 40 mg/MJ  
CO < 70 mg/MJ
- In ambient air mode : NOx < 100 mg/Nm<sup>3</sup> at 3% O<sub>2</sub> (vol, dry basis)  
CO < 250 mg/Nm<sup>3</sup>

The target of NOx < 100 mg/Nm<sup>3</sup> has been set according to the new decree of August 11<sup>th</sup>, 1999 (operation in ambient air mode for over 500 hrs per year). Such a target is lower than the values which can be obtained when using "induct" gas burners with rows. This is why the specific arrangements described hereafter have been taken.

### 3 - SELECTED COMBUSTION TECHNIQUES

#### 3.1 Technical choices

The PILLARD "induct" burner used is the REBURNFLAM® LOW NO<sub>x</sub> type, its cross section is 3 000 x 3 500 mm, and it has the following specific devices :

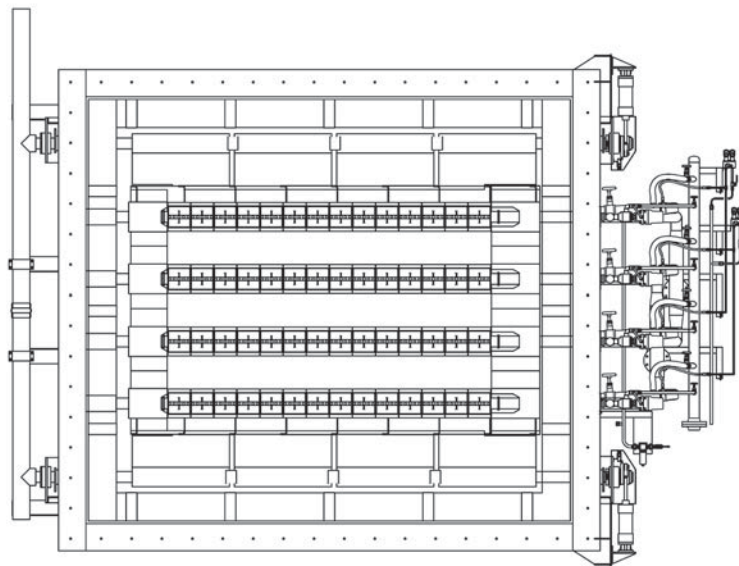


Fig.1 : PILLARD burner REBURNFLAM® LOW NO<sub>x</sub> type

a) In order to reach adequate combustive velocities both in TEG mode and ambient air mode, 2 mobile dampers have been positioned above and below the burner rows : open in TEG mode, they are closed in ambient air mode.

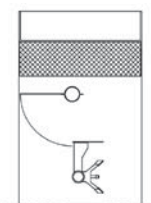


Fig.2 : Mobile dampers for TEG/ambient air modes

b) Burner rows made with LOW NO<sub>x</sub> elements having a staged gas injection according to the PILLARD patent n° 00/01455.



Fig.3 : LOW NO<sub>x</sub> elements

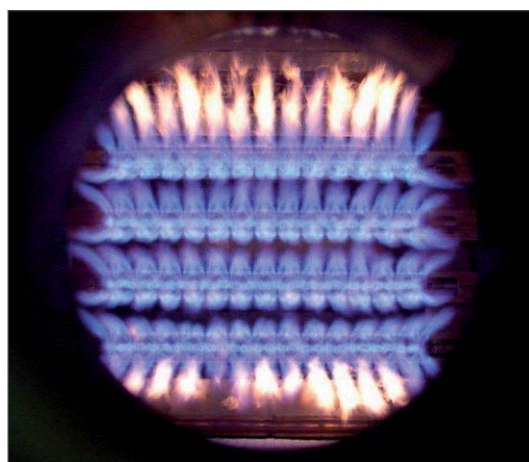


Fig.4 : Flame in ambient air mode

c) Flue gas recirculation (FGR) in the ambient air air aiming at reducing the combustive O<sub>2</sub> content from 21 to about 18 % (vol, dry basis)

### 3.2 Effect of FGR on the HRSG's thermal efficiency

The burner operates with a high excess air since the downstream flue gas temperature is about 900 °C. This is why a part of the air may be replaced by recirculated flue gases.

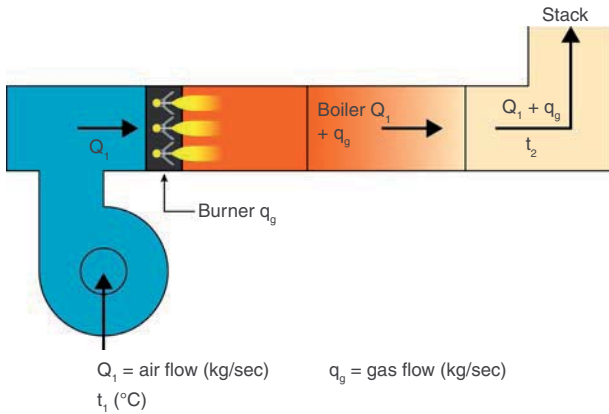


Fig.5 : Heat loss at stack (ambient air alone)  
 $P_1 = C_p \times (Q_1 + q_g) \times t_2$

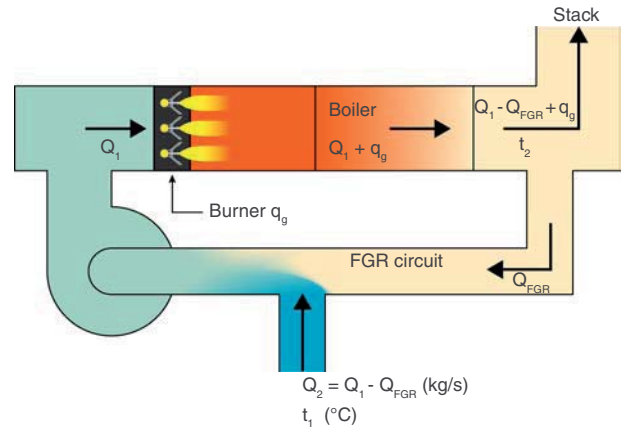


Fig.6 : Heat loss at stack (ambient air + FGR)  
 $P_2 = C_p \times (Q_1 - Q_{FGR} + q_g) \times t_2$

$$\frac{P_2}{P_1} = \frac{Q_1 + q_g - Q_{FGR}}{Q_1 + q_g} = 1 - \frac{Q_{FGR}}{Q_1 + q_g}$$

The heat loss at stack decreases when  $Q_{FGR}$  increases.  
 For our specific case, we obtain :

- without FGR : burner heat release = 40 MW,  $Q_1 = 155\,000$  kg/hr → HRSG efficiency 90,5 %
  - with FGR : burner heat release = 40 MW,  $Q_1 - Q_{FGR} = 110\,000$  kg/hr
  - $Q_{FGR}$  content of combustive = 47 000 kg/hr } → HRSG efficiency 92,6 %
  - 18 %
- theoretical efficiency increase = 2,6 %

The FGR circuit is made with an insulated duct, connected between the stack and the combustion air fan inlet. A valve closes the circuit when operating in TEG mode.



Fig.7 : FGR circuit connected to the stack



Fig.8 : FGR circuit connected to the combustion air fan inlet

The FGR's flow ( $Q_{FGR}$ ) is adjusted by measuring the  $O_2$  % upstream to the burner and acting on an adjustable damper located at the inlet of the combustion air fan.

#### 4 - MEASURED PERFORMANCES

In pure ambient air / ambient air + FGR mode : (Measurements made in Sept. 2001) :

		Pure ambient air	Ambient air (+) FGR Flue gas recirculation					
		Combustive	O <sub>2</sub> % (vol, dry basis)	21	18,8	19,1	19,9	18,5
NO (ppm)	0			5	4	5	6	
CO (ppm)	0		4	5,6	0,9	2,3	0	
FGR rate $\left(\frac{Q_{FGR}}{Q_{air} + Q_{FGR}}\right)$ (%)	0		55	41	24	30	26	
Fuel	Qgas (Nm <sup>3</sup> /h)	4000	1022	1455	1845	3268	4414	
	Pgas (bar)	1,4	0,15	0,28	0,45	1,0	1,45	
Flue gases	Average T° at boiler inlet	800	400	460	460	800	940	
	O <sub>2</sub> % flue gases (vol, dry basis)	15,7	17,0	16,4	16,5	12,6	10,5	
	NO (ppm) (O <sub>2</sub> real)	25,0	9,0	9,0	10,0	17,0	22,0	
	CO (ppm) (O <sub>2</sub> real)	5,9	10,7	17,6	14,7	16,3	7,3	
	NOx (eq NO <sub>2</sub> ) (mg/Nm <sup>3</sup> @3%O <sub>2</sub> )	174	83	72	82	75	77	Guaranteed emissions 100
	CO (eq NO <sub>2</sub> ) (mg/Nm <sup>3</sup> @3%O <sub>2</sub> )	25	60	86	74	44	20	250

#### 5 - CONCLUSION

Using FGR with the PILLARD burner REBURNFLAM® LOW NOx allowed to reach NOx emissions notably lower than the limit of 100 mg/Nm<sup>3</sup>, on a wide operational range, with a very low CO emission.

In addition, the use of FGR allowed to increase the HRSG's efficiency by more than 2 % in ambient air mode.