THE COGENERATION PLANT OF PAPETERIE ETIENNE (13) ARLES

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In 2001, TRACTEBEL Energy Engineering supplied to the “Papeterie Etienne” paper mill in Arles (France) a 45 MWe cogeneration plant, to be run by the ELYO Company.

The HRSG, of MACCHI (Italy) brand, is equipped with a TEG by-pass system (including vent + a diverter) and with a postcombustion burner supplied by PILLARD, REBURNFLAM® type, firing on natural gas either in TEG or fresh air mode.

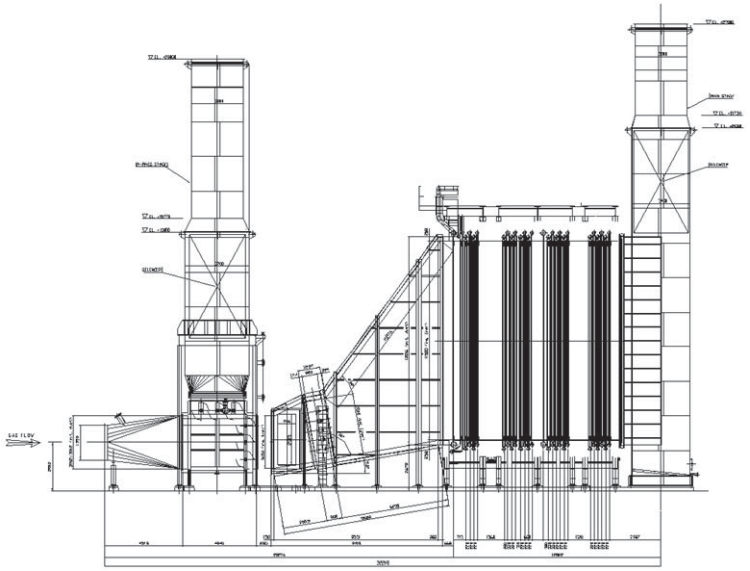


Fig.1 - Cogeneration plant, side view.

Main characteristics :

Gas turbine	:	General Electric LM 6000, 45 MWe		
HRSG	:	60.5 t/hr HP steam, 44 bar (max. 55 bar) + 7.0 t/hr LP steam, 5 bar (max. 9 bar)		
TEG	:	Max. flow	:	139.9 kg/s at 437°C
		O_2 content	:	14.3 % vol.
		Water content	:	6.1 % vol.
Burner	:	In TEG mode	:	Heat release = 2.1 to 26.5 MW (turndown ratio 1 to 12.6)
		Fresh air mode	:	Heat release = 2.1 to 66 MW (turndown ratio 1 to 31.4)
		Fuel	:	Natural gas
		Nombre de rampes	:	5

In fresh air mode, the combustion air is supplied by 2 fans which are each fitted symmetrically on each side of the upstream duct (see Fig. 2).

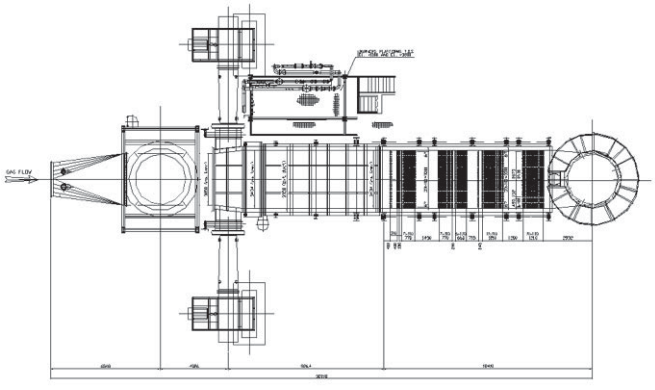


Fig.2 - Cogeneration plant, plan view.

EMISSION LIMITS

The first specific problem submitted to PILLARD was to obtain a uniform velocity distribution upstream to the burner, which was a difficult goal when taking into account the fact that the two combustion air inlets are perpendicular to the duct, just upstream to the burner.

The second goal was to meet the emission limits :

In TEG mode :
The NOx and CO emissions limits are the same as those at the turbine outlet. Therefore, combustion through the burner must not cause any increase in emissions.

Turbine emissions :
NOx < 52 mg/Nm^3 (at 15 % O_2)
CO < 80 mg/Nm^3 (at 15% O_2)

Emission limits downstream from the burner :
NOx < 52 mg/Nm^3 (at 15% O_2)
CO < 80 mg/Nm^3 (at 15% O_2)

In fresh air mode :
NOx < 200 mg/Nm^3 (at 3% O_2)
CO < 250 mg/Nm^3 (at 3% O_2)
in accordance with the regulations in force.

SELECTED COMBUSTION TECHNIQUE

Induct burner type : REBURNFLAM® LOW NOx, section 3430 x 3500 mm.

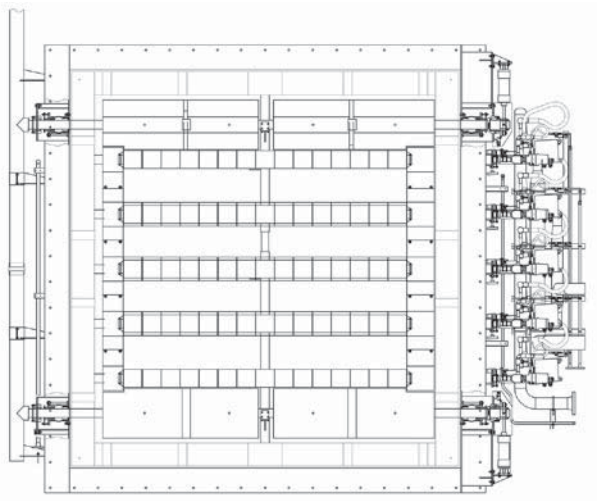


Fig.3 - Brûleur PILLARD type REBURNFLAM® LOW NOx

In order to reach a very high turndown ratio of more than 1 to 30, the burner has been fitted with :
- 2 duct dampers which are closed when the burner is operated at reduced load, in order to maintain a sufficient combustive velocity through the rows
- 2 separate gas supplies which allows 2 gas rows out of 5 to be used.

Operational range :

Fresh air mode	**2,1** to 20 MW	: 2 rows, dampers closed
	10 to **66 MW**	: 5 rows, dampers open
TEG mode	2,1 to 12 MW	: 2 rows, dampers open
	10 to 26,5 MW	: 5 rows, dampers open

In order to limit the NOx emission to less than 200 mg/Nm^3 at 3 % O_2 in fresh air mode without significant CO emission, 3 of the 5 rows have been equipped with “LOW NOx” elements (PILLARD patent n° 00/01455) allowing to operate :

With 2 rows	In such a case, 2 LOW NOx rows are used
With 5 rows	In such a case, with 3 LOW NOx rows and 2 standard rows.

Moreover, in order to switch automatically with a total reliability from TEG mode to fresh air mode (in the case of a turbine shut-down), each row has been fitted with :
- one permanent pilot ignitor of PILLARD brand
- two self-checking flame detectors, PILLARD RUBY type, connected in parallel.

STUDY OF THE COMBUSTIVE FLOWS

A modelisation by using FLUENT® software (property of FLUENT Inc.) has been used to optimize the flow for the two TEG and fresh air modes, in spite of the very low pressure drop (< 20 mmWG).
Such a study led PILLARD to add 2 perforated plates in the fan ducts + several deflectors and a perforated plate in the main TEG duct (see Fig.4).

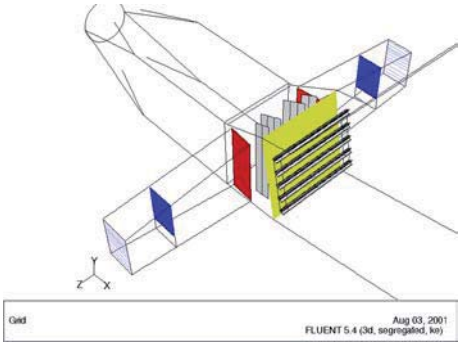
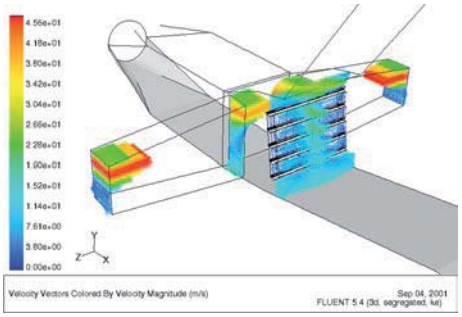
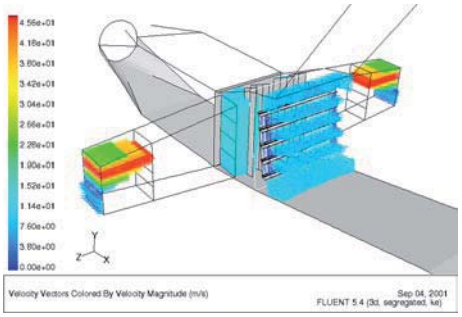


Fig.4 - Final arrangement (plates/deflectors)

<u>Comparison of the velocity distribution before and after optimisation :</u>

Velocity vectors at several levels





Velocity profile at burner level

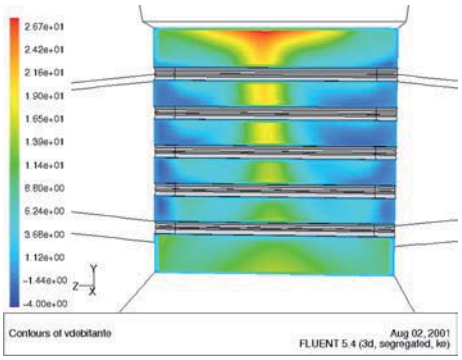


Fig.5 - Before correction

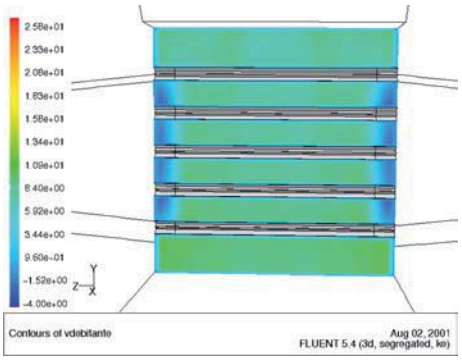
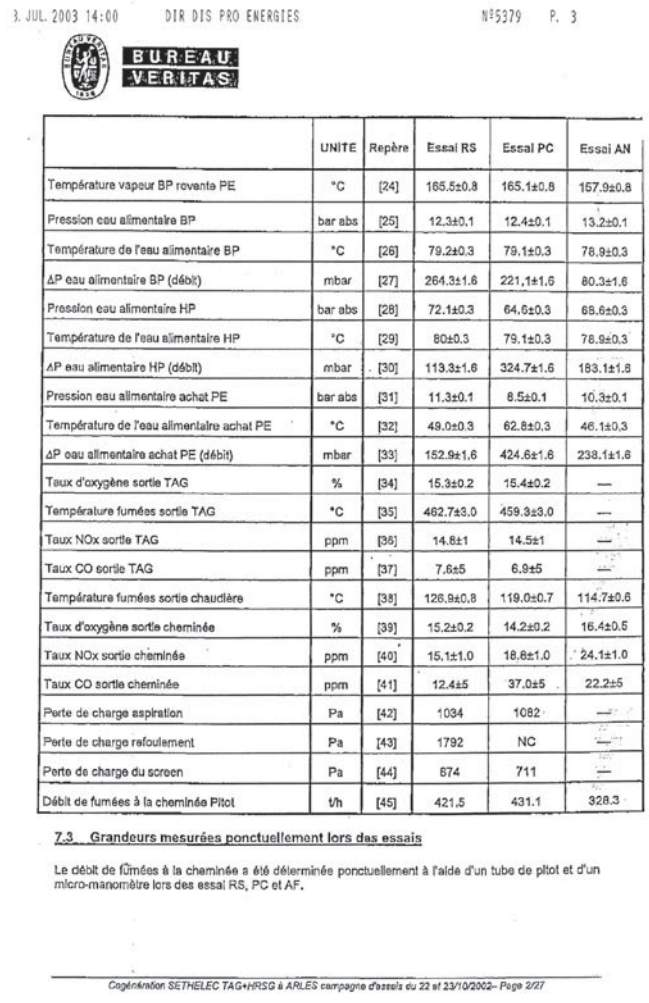


Fig.6 - After correction

Several velocity measurements were made between the burner rows during the commissioning period. They allowed PILLARD to verify the velocity distribution where the ± 10 % tolerance complies with the simulation's prediction.

VERIFIED PERFORMANCE

Such performance concerning the efficiency and the emissions have been verified by BUREAU VERITAS (22/23 October 2002). Measurements have been made at the nominal load in the three modes :
- Simple recovery (RS) (without postcombustion)
- TEG mode (PC)
- Fresh air mode (AN)



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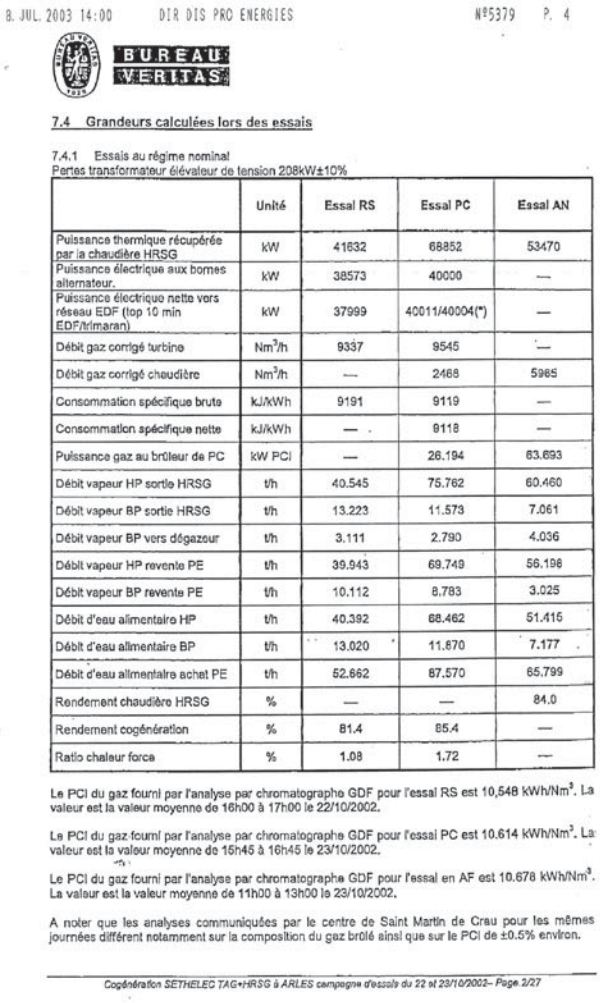
BUREAU VERITAS

	UNITE	Repère	Essai RS	Essai PC	Essai AN
Température vapeur BP revente PE	°C	[24]	165.5±0.8	165.1±0.8	157.9±0.8
Pression eau alimentaire BP	bar abs	[25]	12.3±0.1	12.4±0.1	13.2±0.1
Température de l'eau alimentaire BP	°C	[26]	79.2±0.3	79.1±0.3	78.9±0.3
ΔP eau alimentaire BP (débit)	mbar	[27]	264.3±1.6	221.1±1.6	80.3±1.6
Pression eau alimentaire HP	bar abs	[28]	72.1±0.3	64.6±0.3	65.6±0.3
Température de l'eau alimentaire HP	°C	[29]	80±0.3	79.1±0.3	78.9±0.3
ΔP eau alimentaire HP (débit)	mbar	[30]	113.3±1.6	324.7±1.6	183.1±1.6
Pression eau alimentaire achat PE	bar abs	[31]	11.3±0.1	8.5±0.1	10.3±0.1
Température de l'eau alimentaire achat PE	°C	[32]	49.0±0.3	62.8±0.3	46.1±0.3
ΔP eau alimentaire achat PE (débit)	mbar	[33]	152.9±1.6	424.6±1.6	238.1±1.6
Taux d'oxygène sortie TAG	%	[34]	15.3±0.2	15.4±0.2	—
Température fumées sortie TAG	°C	[35]	462.7±3.0	459.3±3.0	—
Taux NOx sortie TAG	ppm	[36]	14.8±1	14.5±1	—
Taux CO sortie TAG	ppm	[37]	7.6±5	6.9±5	—
Température fumées sortie chaudière	°C	[38]	126.9±0.8	119.0±0.7	114.7±0.6
Taux d'oxygène sortie cheminée	%	[39]	15.2±0.2	14.2±0.2	16.4±0.5
Taux NOx sortie cheminée	ppm	[40]	15.1±1.0	18.6±1.0	24.1±1.0
Taux CO sortie cheminée	ppm	[41]	12.4±5	37.0±5	22.2±5
Perte de charge aspiration	Pa	[42]	1034	1082	—
Perte de charge refoulement	Pa	[43]	1792	NC	—
Perte de charge du screen	Pa	[44]	674	711	—
Débit de fumées à la cheminée Pitot	t/h	[45]	421.5	431.1	328.3

7.3. Grandeurs mesurées ponctuellement lors des essais

Le débit de fûmées à la cheminée a été déterminée ponctuellement à l'aide d'un tube de pitot et d'un micro-manomètre lors des essai RS, PC et AF.

Cogénération SETHELEC TAG+HRSG à ARLES campagne d'essais du 22 et 23/10/2002– Page 2/27



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BUREAU VERITAS

7.4 Grandeurs calculées lors des essais

7.4.1 Essais au régime nominal
Pertes transformateur élévateur de tension 208kW±10%

	Unité	Essai RS	Essai PC	Essai AN
Puissance thermique récupérée par la chaudière HRSG	kW	41632	68852	53470
Puissance électrique aux bornes alternateur.	kW	38573	40000	—
Puissance électrique nette vers réseau EDF (top 10 min EDF/trimaran)	kW	37999	40011/40004(*)	—
Débit gaz corrigé turbine	Nm³/h	9337	9545	—
Débit gaz corrigé chaudière	Nm³/h	—	2468	5985
Consommation spécifique brute	kJ/kWh	9191	9119	—
Consommation spécifique nette	kJ/kWh	—	9118	—
Puissance gaz au brûleur de PC	kW PCI	—	26.194	63.693
Débit vapeur HP sortie HRSG	t/h	40.545	75.762	60.460
Débit vapeur BP sortie HRSG	t/h	13.223	11.573	7.061
Débit vapeur BP vers dégazeur	t/h	3.111	2.790	4.036
Débit vapeur HP revente PE	t/h	39.943	69.749	56.198
Débit vapeur BP revente PE	t/h	10.112	8.783	3.025
Débit d'eau alimentaire HP	t/h	40.392	68.462	51.415
Débit d'eau alimentaire BP	t/h	13.020	11.670	7.177
Débit d'eau alimentaire achat PE	t/h	52.662	87.570	65.799
Rendement chaudière HRSG	%	—	—	84.0
Rendement cogénération	%	81.4	85.4	—
Ratio chaleur force	%	1.08	1.72	—

Le PCI du gaz fourni par l'analyse par chromatographe GDF pour l'essai RS est 10,548 kWh/Nm³. La valeur est la valeur moyenne de 16h00 à 17h00 le 22/10/2002.

Le PCI du gaz fourni par l'analyse par chromatographe GDF pour l'essai PC est 10.614 kWh/Nm³. La valeur est la valeur moyenne de 15h45 à 16h45 le 23/10/2002.

Le PCI du gaz fourni par l'analyse par chromatographe GDF pour l'essai en AF est 10.678 kWh/Nm³. La valeur est la valeur moyenne de 11h00 à 13h00 le 23/10/2002.

A noter que les analyses communiquées par le centre de Saint Martin de Crau pour les mêmes journées diffèrent notamment sur la composition du gaz brûlé ainsi que sur le PCI de ±0.5% environ.

Cogénération SETHELEC TAG+HRSG à ARLES campagne d'essais du 22 et 23/10/2002– Page 2/27

Les mesures d'émission de NOx et CO exprimées ci-dessus en ppm à l'O_2 réel doivent être converties en mg/Nm³ et ramenées à l'O_2 de référence pour comparaison aux valeurs garanties :

TEG mode (PC) :
In mg/Nm³ at 15 % O_2

	Measurements	Guarantees
NOx	34	52
CO	41	80

Fresh air mode (AN) :
In mg/Nm³ at 3 % O_2

	Measurements	Guarantees
NOx	193	200
CO	108	250

All the emissions comply with the guarantees.

CONCLUSION

This plant proves the efficiency of :
- optimising the combustive flows by simulation using FLUENT® software
- the use of the new PILLARD REBURNFLAM® LOW NOx burners to reduce the pollutant emissions.

Such a plant also proves the high turndown ratio of the burner (> 30) and the reliability of the automatic switch-over from TEG mode to fresh air mode.