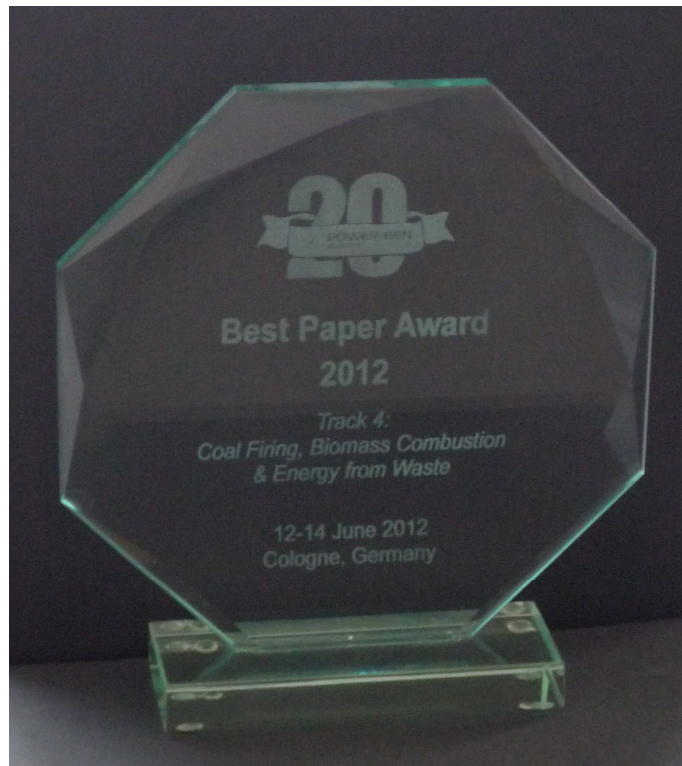


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Ansaldo Caldaie coal biomass co-firing testing experience

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Abstract

Ansaldo Caldaie, in the frame of its own product development activities, has carried out studies and full scale testing activities at its Combustion Centre for a primary Italian customer in order to verify the performance behaviour of Ansaldo Caldaie existing TEA-C coal burners (rated 34 MWth) in a 20 – 30% co-firing configuration of bituminous coal with biomass from wood pellets. Based on the experience gained, the paper gives an overview of the most significant combustion testing results with different types of biomasses and coal nozzle arrangements as well as air / pulverised biomass transport solutions to the burners. Finally, the paper reports the feasibility studies of the various biomass dosing and transport solutions in relation to the lay-out and performance optimizations.

Introduction

Ansaldo Caldaie is a global supplier of utility boilers and heat recovery steam generators, with headquarters in Gallarate, near Milan, Italy. The company origin dates back over 150 years and today operates as a privately owned boiler company with one of the largest fabrication facilities in Europe. Our mission is to supply high quality equipment and services to the power sector, and to support our clients throughout the operating life of the plant.

Ansaldo Caldaie today has a strong financial base and is owned by the Sofinter Group, which includes shareholding by the Gammon Group of India, and BT Global (Birla of India/Metro Eleven of USA), as well as retaining significant Italian private shareholding.

Tirreno Power is one of the primary Italian Power Generation companies. As a result of the liberalization of the Italian electricity market, on January 2003, Tirreno Power shareholders purchased from Enel SpA parts of his assets. The shareholders of Tirreno Power are primary companies operating in the energy, gas and utilities market: 50% GdF-SUEZ, 50% Energia Italiana (78% Sorigenia, 11% Hera, 11% Iren).

Tirreno Power is now the seventh operator of power generation in Italy, it is present throughout the country with the Power Plants of Torrevaldaliga South, Vado Ligure and Naples, and 17 hydroelectric power units located upon of the Liguria region and provides about 4% of the energy production in Italy. In 2010 the energy output to the grid has been of

10,229 GWh, (61% combined cycle, 36% coal, hydro 2%, 1% PV) and the turnover has been of 1,308 million of euro.

Ansaldo Caldaie has been active in the field of NO_x control technologies for coal fired utility boilers for more than 25 years. A specific burner design (TEA-C Low-NO_x burner) was developed and plant qualified in 1997. Several burners of this type have been installed, as original firing equipment or environmental retrofit, and are presently operating in many utility boilers in Italy and abroad.

In the past five years a special version of the burner, named TEA-C EFS (Enhanced Flame Stability), was developed, engineered and plant qualified for the efficient firing of low calorific value, high ash, high moisture coals like those typically fired in India and in other countries where the low cost of these fuels make their use particularly attractive. More than 50 burners of this version are at present supplied on 5 boilers in India, many of them already brought into successful commercial operation, others presently under erection / commissioning.

This “Low-NO_x burner family” is only one of the several NO_x control technologies in-house developed by Ansaldo Caldaie (AC) for the environmental benefit of modern utility boilers’ design. These technologies cover the use of different fuels (solid – coals, lignite -, liquid – light & heavy fuel oils, residual oils, crude oil, OrimulsionTM -, gaseous – Natural Gas, refinery gases with high hydrogen content, low CV gases from steel plants, etc.) and involve the use of specific components (like Low-NO_x burners, OFA & Reburn injectors) and/or in-furnace technologies (like air staging, fuel staging, flue gas recycling, liquid fuel atomisation, steam / water injection, etc.).

In recent years the drive for reduction of CO₂ emissions has been pushing the power generation sector and the boiler manufacturer towards the use of renewable energy sources.

Several European countries are encouraging this option through the implementation of economical benefits which reduce the “pay-back time” of the related investments.

Also in Italy a wide interest exists to assess the technical and economical feasibility of co-firing retrofits for existing utility boilers and/or for new built units incorporating since the beginning this co-firing capability.

AC has been active in this area for about 15 years and many full-scale firing tests have been performed at Ansaldo Caldaie Combustion Centre (CCA) located in southern Italy (Gioia del Colle, near Bari), where also the company’s pressure parts factory is located.

The combustion of pulverised coal and suitable biomass fuels was the subject of dedicated tests starting from 1998 and involved RDF (Refuse Derived Fuel), exhausted olive cake, MBM (Meat and bone meal), WP (Wood pellets), PKS (Palm kernel shells).

The last two renewable sources (WP and PKS) have been extensively tested, as pulverised fuel, for direct co-firing with pulverised coal in TEA-C / TEA-C EFS burners in the frame of an engineering study for the potential co-firing retrofit of 320 MWe class utility boilers in Italy.

This technical paper summarises the test results achieved through this experimental campaign and outlines the basic design of major biomass feeding components for the implementation of the co-firing technology in a large scale boiler.

The test facility

CCA - Centro Combustione Ambiente s.r.l. (Combustion & Environmental research Centre) is the Ansaldo Caldaie owned combustion research centre.

The company has deep roots in AC know-how and is the result of a twenty years' experience gained by Ansaldo research department in the field of reduced environmental-impact combustion processes and product development.

Over the years extensive specialized experience has been acquired in combustion processes for both steam boilers and gas turbines.



The CCA main boiler facility is a very special test facility able to operate in full scale a boiler burner up to 40 MWth fuel heat input with different fuels; this facility was recently equipped with a new pulverised biomass feeding system that allows testing of burners with biomass fuel heat input up to 35 MWth . The facility is probably the only facility in Europe readily capable of managing these objectives.



The facility has a special design in order to comply with the main requirements of boiler combustion test. The combustion chamber is refractory lined in order to balance the heat extraction from the flame and to generate the flame thermal boundary condition and the proper flame temperature with the best achievable similarity with a real boiler burner flame.

The combustion chamber develops horizontally and is equipped with a hopper bottom with dry ash extraction system. The main furnace dimensions are:

- 12,0 m length
- 4,5 m wide
- 6,0 m height (excluding hopper, which is 2,5 m high).

The combustion chamber volume is represented in the following pictures (fig.1)



Fig. 1- 40 MWth Ansaldo Caldaie burner test rig - Internal view

Downstream of the combustion chamber, the flue gas passes through a convective pass located at the end of the right hand side of the boiler where part of the total steam produced is superheated.

The special design provided on the left side of the combustion chamber is a complete set of windows for the flame view and instrumental access.

The boiler is operated in a dedicated way for experimental activity and it is not connected with any industrial production. This guarantees a complete flexibility in running time and operation conditions.

The combustion chamber is pressure balanced by forced and induced fans; a tubular air heater can control air temperature up to 300 °C, a flue gas recirculation can be operated by an RG fan.

Combustion air can be supplied independently to the burner connection or along the combustion chamber as External Air Staging. The test rig is complete in auxiliaries and instrument for a very wide range of experimental applications. Any special process to be simulated and tested can be easily setup.

On the top and on the side of the burner CCTV system allows the complete view of the flame and video recording.

The boiler flue gas stream leaving the furnace can be treated with injection of additives; a bag filter is installed before the chimney.

For heavy ash the boiler hopper has a dry extraction system and for fly ash a complete pneumatic extraction system is provided.

The rig can be operated automatically; all the process and measurements data can be collected and processed in real time.

Flue gas can be analyzed in gas composition and in dust content.

The burner test rig can be fed with different fuels as:

- gaseous (natural gas and controlled addition of Hydrogen, Nitrogen and Carbon Dioxide in various proportions);
- liquids (LFO, HFO, Orimulsion™, etc.);
- solids (pulverized coal, Biomasses, etc.).

The rig can manage two pneumatic solid streams in parallel:

- A coal stream including coal silo, ball mill and dedicated fan for transport air controlled in temperature and flow rate. The coal fineness is controlled by a rotating classifier;
- A second stream consisting of pulverised biomasses ready to be transported by pneumatic conveying system.

This last system, recently implemented, can feed pulverised products in a dense phase with a product to air ratio from 5 to 10.

The core of the system is based on a biomass dosing and feeding equipment that is able to guarantee a complete and accurate control of the product flow rate to the burner. A scheme of the system is reported in Fig. 2.

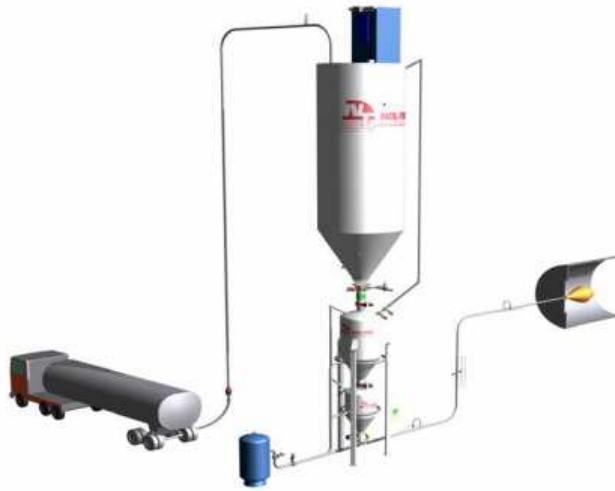


Fig. 2 – Pulverised biomass handling system (courtesy of Nol-Tec Europe)

The system has fully automated controls and includes safety procedures. The system is composed of the following main sections:

- Bunker silo; 70 m³ capacity equipped with:
 - Silo feeding line by pressurized truck or direct feeding by bags from the top;
 - explosion venting to prevent explosion overpressure;
 - filter with antistatic bags and extraction fan to blow out excess of air from the silo;
 - over/under pressure safety valve;
 - N₂ inertisation and CO₂ fire extinguisher systems completely automatic assisted by sensors;
 - two levels bulk loosening system assisted by compressed air.

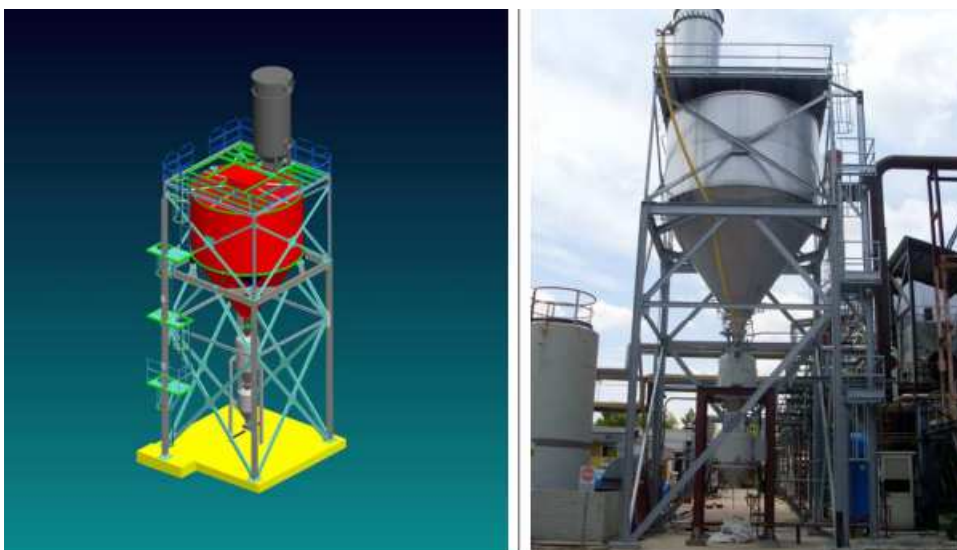


Fig. 3 - Bunker silo

- Pressurised dosing system and assisted conveying lines to the burner

All the system is designed and constructed to operate also with combustible and potentially explosive powders in fully safe condition.

The pressurised system provides a complete and continuous control of the product flow.

It consists of five main items:

- A “Bin Bottom” device; it is a loosening system positioned at the connection with the silo bunker in order to facilitate the feeding of the system by gravity;
- A first barrel which pressurises the product operating in batch;
- A second pressurised barrel which feeds the feeder continuously;
- A rotary valve which calibrates the product flow rate to the feeding line
- The pneumatic transport system which carries the product along the 3” pipe line to the burner.

The whole system is controlled by a PLC, allowing change of the operative parameters in order to optimize the feeding process with different products.

The transport pipe is equipped with strategically placed Air Assists™ special devices, in order to decrease air pressure requirements and to improve material flow by injecting small amounts of compressed air into the convey line.

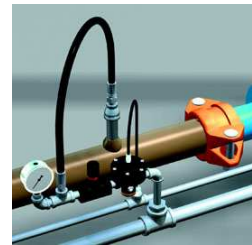


Fig. 4 – Pneumatic feeding components

The full understanding of the combustion performance and the complete characterization of the combustion system can derive benefits from special measurements. In flame temperature and gas analysis can be measured in an extensive pattern by water cooled probes. Velocity field in isothermal condition can be measured by both hot wire and LDA technique.

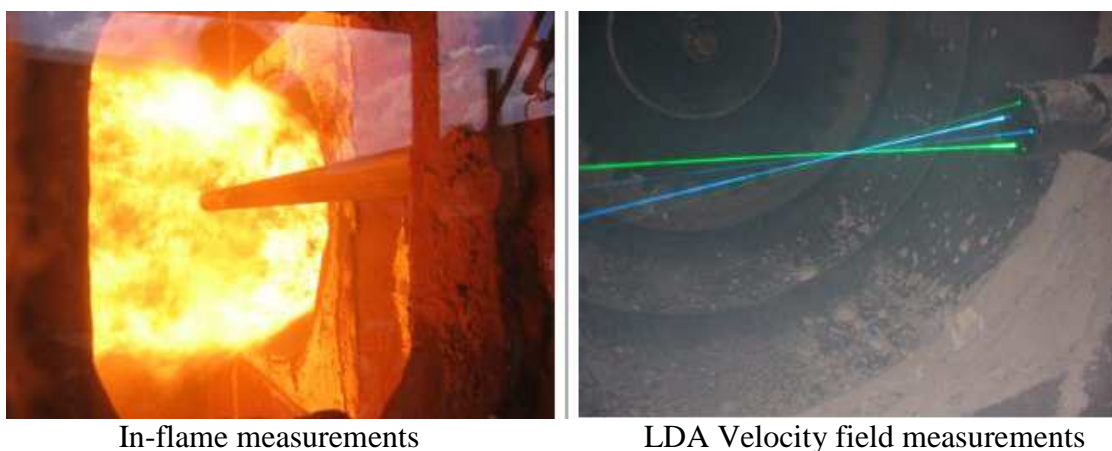


Fig. 5 – Special measurements

The properties of fuels fired

Physical properties

		Initial test period			Late test period		
Coal (Russian)		AR	DB	DAF	AR	DB	DAF
total moisture	% wt	19.94	-	-	13.83	-	-
Ash	% wt	5.94	7.42	-	6.73	7.81	-
Volatile matter	% wt	32.51	40.61	43.86	35.06	40.69	44.13
Fixed carbon	% wt	41.61	51.97	56.14	44.38	51.5	55.87
FC/VM		1.28			1.266		
Higher Heating Value	Kcal/Kg	5446	6803	-	5880	6824	-
Lower Heating Value	Kcal/Kg	5162	-	-	5588	-	-
Sulphur	% wt	0.48	0.6	0.8	0.66	0.77	0.83
Nitrogen	% wt	1.06	1.32	1.43	1.09	1.26	1.37
HGI		46					

		Initial test period			Late test period		
Pulverised wood pellets	(WP)	AR	DB	DAF	AR	DB	DAF
total moisture	% wt	11.99	-	-	11.99	-	-
Ash	% wt	0.98	1.11	-	1.09	1.24	-
Volatile matter	% wt	74.43	84.57	85.52	74.48	84.63	85.69
Fixed carbon	% wt	12.6	14.32	14.48	12.44	14.13	14.31
FC/VM		0.169			0.167		
Higher Heating Value	Kcal/Kg	4225	4801	-	4262	4843	-
Lower Heating Value	Kcal/Kg	3855	-	-	3891	-	-
Sulphur	% wt	< 0.1	-	-	< 0.1	-	-
Nitrogen	% wt	< 0.1	-	-	< 0.1	-	-

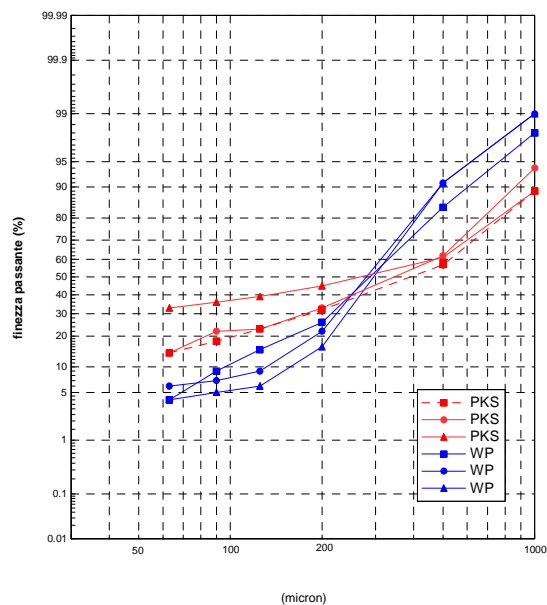
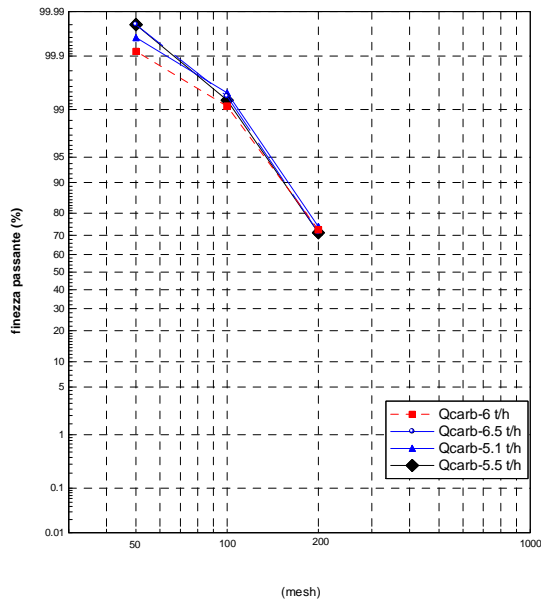
		Supplier data		
Palm kernel shells	(PKS)	AR	DB	DAF
total moisture	% wt	19.12	-	-
Ash	% wt	-	1.91	-
Volatile matter	% wt	-	-	-
Fixed carbon	% wt	-	-	-
FC/VM		-		
Higher Heating Value	Kcal/Kg	-	-	-
Lower Heating Value	Kcal/Kg	3988	-	-
Sulphur	% wt	-	0.1	-
Nitrogen	% wt	-	0.43	-
Chlorine	% wt	-	0.03	-
Alkali (K+Na)	% wt	-	0.2	-
Vegetable oil	% wt	-	0.82	-

Fuel fineness (as fired)

		Typical		
Coal (Russian)		Sample 1	Sample 2	Sample 3
< 300 µm (passing 50 mesh)	% wt	99.92	99.96	99.98
< 150 µm (passing 100 mesh)	% wt	99.12	99.48	99.3
< 75 µm (passing 200 mesh)	% wt	72.86	74.34	71.42

Pulverised wood pellets	(WP)	Sample 1	Sample 2	Sample 3
< 1000 µm	% wt	99.23	99.12	99.2
< 500 µm	% wt	87.42	85.25	87.16
< 200 µm	% wt	15.05	9.17	11.36
< 125 µm	% wt	5.66	3.81	3.32
< 90 µm	% wt	3.38	3.12	2.42
< 63 µm	% wt	1.86	0.61	1.88

Palm kernel shells	(PKS)	Sample 1	Sample 2	Sample 3
< 1000 µm	% wt	89.44	93.69	88.62
< 500 µm	% wt	57.84	61.72	60.92
< 200 µm	% wt	31.76	32.93	44.97
< 125 µm	% wt	23.05	22.83	39.37
< 90 µm	% wt	18.43	18.08	36.37
< 63 µm	% wt	14.38	14.43	33.07



The full-scale test results

The testing activity was developed in the period February – October 2011 firing a Russian High Volatile Bituminous Coal alone and with different proportions of pulverised biomasses (Wood Pellets and Palm Kernel Shells); PKS biomass has been tested as representative of a biomass category with higher moisture and different granulometry.

The majority of tests was performed at burner MCR (approx 35 MWth fuel HHV basis), using the “standard” version of Ansaldo Caldaie TEA-C Low-NO_x Burner and the Enhanced Flame Stability (EFS) version of it, extensively used in coal fired boilers designed for firing Low HV, high ash coals where the improved aerodynamics for flame stabilisation proves to be a key issue for the efficient and environmentally friendly combustion. The burner size was readily suitable for the future application on full scale boilers because it is in the typical range of coal burners capacities installed on several old coal units suitable to future co-firing retrofits

The following figures 6 and 7 show some pictorial views and pictures of the two different versions of TEA-C burner.

The testing activity was aimed at the following main targets:

- Burner **firing performance** for nominal co-firing heat input of 20-30 % and for increased amounts of biomass heat input up to “full biomass firing”
- Investigation on the role played by **pulverised fuel fineness** (for both coal and biomass) and validation of “commercially achievable” p.f. fineness levels for the industrial utilisation of biomass co-firing approach for utility boilers
- Investigation and validation of **biomass dosing and transport technologies** within a wide range of air / biomass ratios (dense vs. semi dense phase solutions), as necessary to identify the optimised cost-benefit option for the engineering of a biomass co-firing fuel supply system

The basic design choices for setting-up the test campaign were based on the past experience for similar co-firing projects in Europe and on the specific feasibility requirements for retrofit projects on existing utility boilers in Italy as follows:

- **Direct injection of pulverised biomasses into the main pulverised coal piping upstream the coal burners**
benefit: no need for additional, dedicated burners, no grinding problems through the pulverisers
- **Separate biomass handling and pulverisation**
benefit: no interaction with coal pulverisers and related auxiliary equipment; no extra safety procedures related to coal grinding and pulverised coal transport
- **Pneumatic transport of pulverised biomasses**
benefit: relatively small pipes; segregated environment
- **Dense or semi-dense phase transport**
benefits: small pipes; no special safety requirements along the fuel distribution path; minimum impact on plant lay-out



Fig. 6 - Standard TEA-C Low-NOx Burner

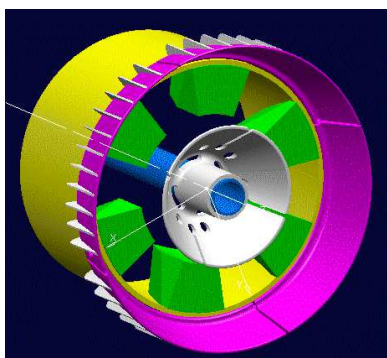
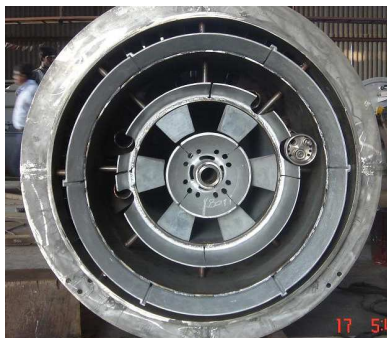


Fig. 7 - TEA-C EFS Low-NOx Burner

The pulverised biomass transport system was investigated in the following operating range:

- dense system: air-biomass ratio 1 : 4
- semi-dense system: air-biomass ratio: from 1 : 1 to 0.5 ÷ 1

The pulverised biomass was injected into the p.c. pipe upstream of the burner inlet.

Coal firing

This set of experimental data was collected mainly with the aim of identifying a kind of “baseline” assessment of the burner performance, in both versions, in order to allow an easy comparison with other burner operating conditions (co-firing of coal and biomass, full biomass firing).



As previously mentioned, the majority of tests were performed at burner design (MCR) load, with some investigations also at part-loads (between 70% and 100% MCR).

In the full load condition, the fuel/air mixture (primary air + pulverised fuel) was kept within air / fuel ratios of 1.85÷2.0; pulverised coal was constantly supplied by a direct feeding system based on a dedicated mill equipped with rotary classifier and a primary air fan equipped with primary air mixture temperature control at mill outlet. Test results are directly reported in the following paragraphs, for direct comparison with co-fired firing conditions.

Coal-biomass co-firing

The following graphs show a summary of test results in co-firing operating mode.

Figs. 8 and 9 refer to the firing performance with “standard” TEA-C burner during operation with coal + pulverised wood pellets (WP) up to 20% heat input and dense phase transport of biomass.

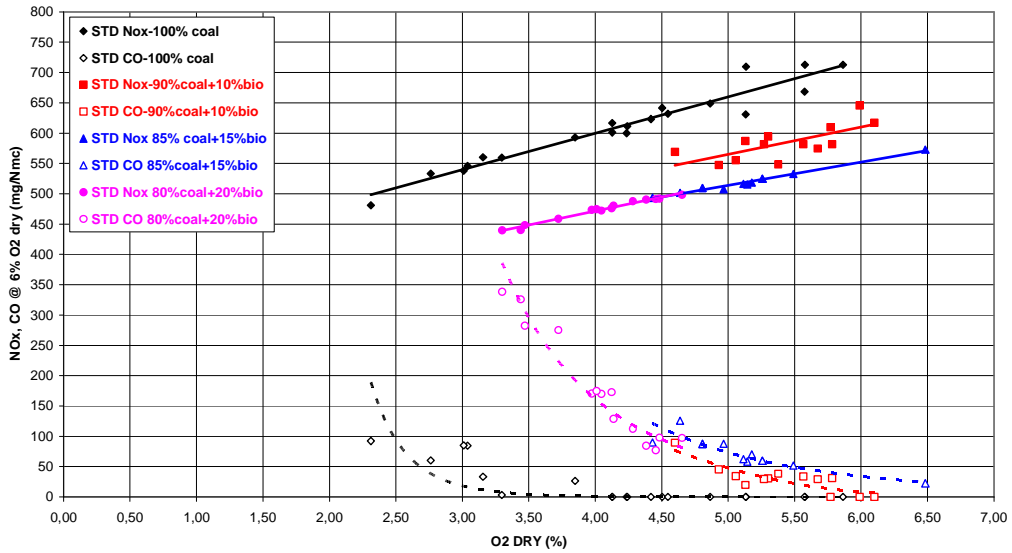


Fig. 8 – TEA-C burner – WP co-firing (dense phase)

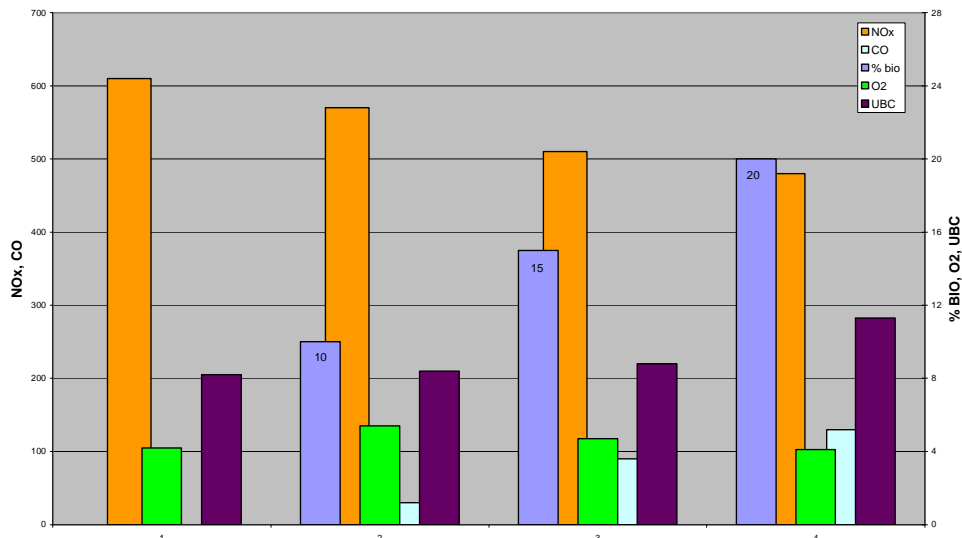


Fig. 9 – TEA-C burner – WP co-firing (summary of firing performances)

Fig. 10 shows the firing performance with TEA-C EFS burner during operation with coal + pulverised wood pellets (WP) up to 30% heat input and dense phase transport of biomass.

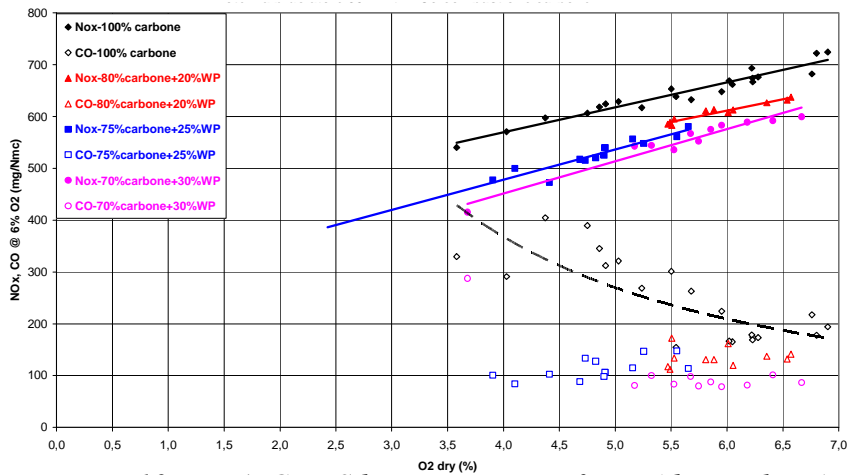


Fig. 10 – TEA-C EFS burner – WP co-firing (dense phase)

The following Fig. 11 summarises the firing performance of the same TEA-C EFS burner during operation with coal + pulverised palm kernel shells (PKS) up to 25% heat input and dense phase transport of biomass.

Fig. 12 shows the similar flame shapes achieved with TEA-C EFS burner during full load co-fired operation with pulverised WP and PKS and high heat input deriving from biomass.

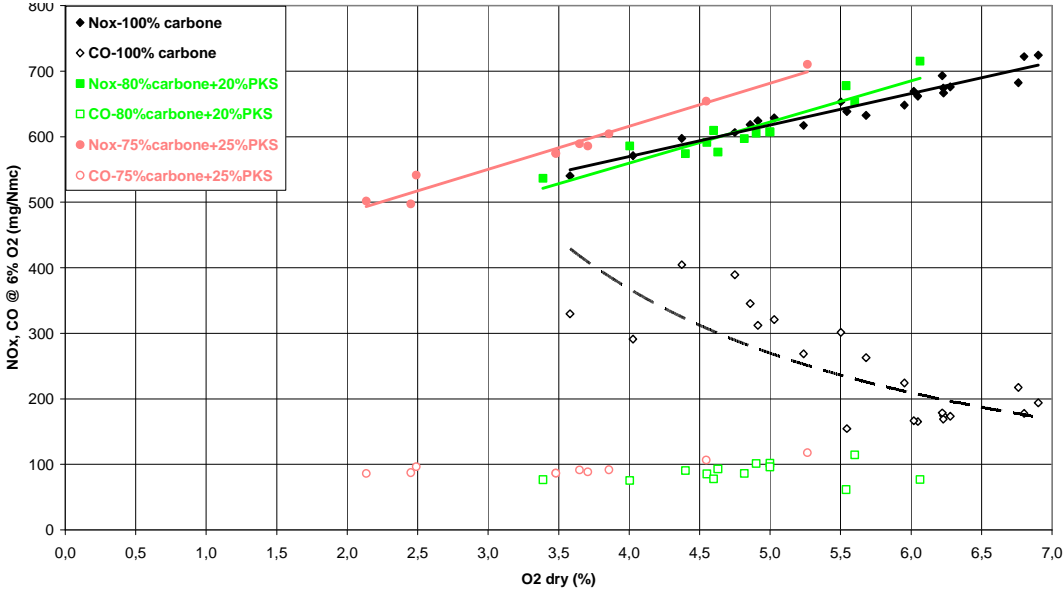


Fig. 11 – TEA-C EFS burner – PKS co-firing (dense phase)



Coal - WP flame



Coal – PKS flame

Fig. 12 – TEA-C EFS burner – different co-fired flames

The effect on combustion performance determined by a different amount of air transport medium for biomass powder was also investigated, and the results are shown in the following Fig. 13; this investigation was performed by simulating this extra air flow through the additional injection of a controlled amount of air into the coal pipe.

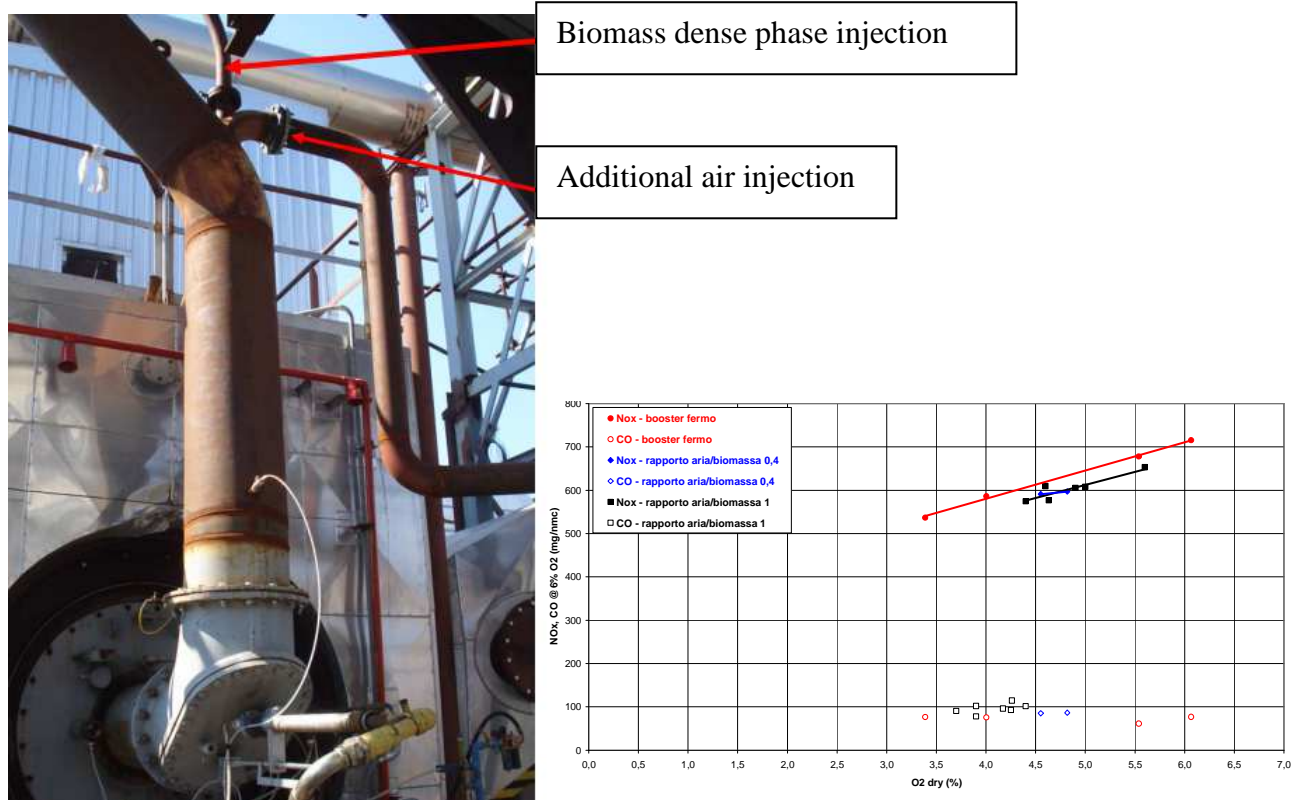


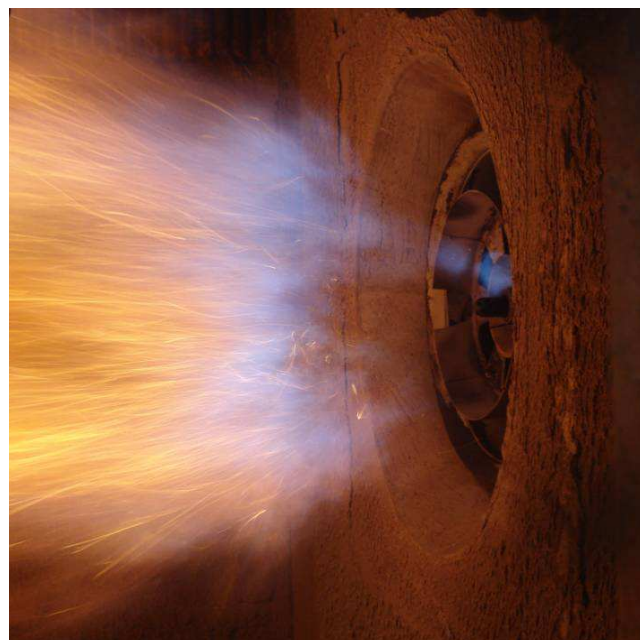
Fig. 13 - Effect of biomass air transport variation

As shown in Fig. 13 graph, the “semi-dense” phase transport approach did not produce any negative effect on combustion performance (no effect on CO emission, slight benefit on NOx control); such a result was taken in due account for engineering purposes.

Full biomass firing

In this “limit” operating condition, the initial boiler warm-up was performed in a natural gas fired operation (but any reasonable start-up / warm-up fuel can be acceptable, see picture on the right side), with progressive load ramp with increased amounts of biomass fuel.

The flame support was totally removed from 70÷80% MCR, but only because the investigation of the lower operating load of the burner was not part of the test planning.



The following Fig. 14 shows the WP fired flame with 6.5 and 7 tons/hour biomass feeding rate without gas support.



Fig. 14 – TEA-C EFS burner in full WP firing at 6.5 and 7 t/h biomass feeding rate

For WP firing, stable operation was proven, with NO_x emissions of approx 150 mg/Nm³ @ 6% O₂ dry, normalised CO emissions in the range of 100÷150 mg/Nm³ and excess Oxygen of approx 4% vol.

UBC was recorded in the order of 12% (fly ash) and approx 24% (bottom ash).

Considering the low ash content in fuel, this corresponds approximately to an unburnt efficiency loss of 0.3%.

For PKS firing, a similar stable operation without flame support has not been achieved: a minimum amount of flame support, in the order of 500 Nm³/h of natural gas flow (approx 12÷15% of total fuel heat input), has proven to be necessary in order to avoid flame blow-out. This was considered to be mainly due to the higher moisture content in fuel, not allowing a sufficiently fast heat-up of fuel particles for sufficient volatile release in the flame stabilisation region.

The following Fig. 15 provides a picture of the flame behaviour, taken at about 8 m from the burner; it comes to evidence that a huge quantity of PKS fuel particles are still burning in solid phase (some of them were also observed falling into the boiler hopper and keeping on firing there).

It is straightforward to consider that the moisture and fineness level of this biomass fuel utilised during the testing activity is not sufficient to provide a self-sustaining flame without the support of a fossil fuel.

For the above mentioned operating condition in “almost full” PKS firing, stable operation was proven, with NO_x emissions of approx 220 mg/Nm³ @ 6% O₂ dry, normalised CO emissions in the range of 50÷100 mg/Nm³ and excess Oxygen of approx 4% vol.

UBC was recorded in the order of 11% (fly ash) and approx 70% (bottom ash) corresponding approximately to an unburnt efficiency loss of 1% taking into account the low ash content in fuel; however this detailed investigation on efficiency loss by further tuning of the burner was not included in the planned test activity.



Fig. 15 – TEA-C EFS burner in PKS firing at 6 t/h biomass feeding rate

To be noted that the test facility results represent, especially when analysing UBC, a conservative “picture” of what normally happens inside a multi-burner furnace, where co-fired burners can be only a portion of the whole firing system; the presence of fossil fuel fired burners at the lower elevation of the firing system provides an intense heat source and a fire barrier against big biomass particles “fall-down”.

In case of a fully biomass fired system, the presence of a powerful flame support system (i.e. Class 1+ igniters) and a dry bottom post-combustion system for bottom ashes might be advisable.

Tests conclusions

Tests demonstrated, for both the dense or semi-dense transport configurations, the following achievements:

- Burner co-firing capacities up to 20 – 30% heat input according to the initial requirements
- Flame stability with proper shape at various operating conditions
- Combustion parameters (excess air, NO_x, CO) achieved within an acceptable variation range
- Good part load performance
- Significant benefits of the EFS coal nozzle developed for low calorific value coals
- Capability of the TEA-C EFS burner design to accept full biomass firing on individual burner in a coal –biomass co-firing on different burner rows or in a pulverised wood pellets dedicated firing arrangement

The options for the pulverised biomass handling

The design of a biomass co-firing or full firing system for a coal fired (or coal designed) utility boiler has been carefully evaluated by Ansaldo Caldaie, taking into account the available experience and developing “in-house” a solid database for similar future applications both in terms of retrofitting of existing boilers and design of new units.

The various options among direct / indirect systems and possible arrangements for biomass fuel preparation (direct grinding in existing mills, separate pulverisation with different transport option to the furnace or to the existing burners) have been analysed in detail, considering also safety issues and capital costs of the installation; here below a comparison table is reported

TRANSPORT SYSTEM	DENSE PHASE	SEMI-DENSE PHASE	
		CASE A	CASE B
- Air-biomass ratio	~ 1 : 4	~ 1 : 1	~ 0.5 : 1
- Type of pulverised biomass	Wood pellets (design) PKS (verification)	Wood pellets (Design) PKS (verification)	
- Transport “flexibility” with different type of biomass	High	Medium (moderate density variations)	
- Dedicated line for each burner	Yes	Yes!	
- Transport air supply	Compressors (4, stazione in comune ai 2 gruppi)	One blower for line to individual burners	
Flowrate	4 x 3000 Nm ³ /h	24 x 2000 Nm ³ /h	24 x 900 Nm ³ /h
Pressure	3.5÷4.5 bar	0.6 max 1 bar	0.6 max 1 bar
- Livello operativo pressione	approx. 2.5 bar	approx. 0.4÷0.45 bar	approx. 0.5 bar
- Power consumption	High	High	Medium-low
- Transport system components (per boiler)	2 Silos 30 m ³ ⁽¹⁾ Loading valves (4 cycles/hour) 12+12 Barrels(sealing) With load cells 12 Rotary valves	2 Silos 30 m ³ ⁽¹⁾ 12 screw feeders Continuous feed	12 Loading valves (2 cycles/hour) Hopper 15 m ³ With load cells 12 Rotary valves (sealing)
- Transport lines diameter	3÷4"	5÷6"	4"
- Maximum lines length	300 m.	300 m.	
- Dosing system	Gravimetric for each line (2% accuracy)	Volumetric (~ 5% accur.)	Gravimetric for each group of 6 lines (~ 5% accur.)

(1) Or less, minimum required for correct operation of screw feeders

Based on a preliminary selection of biomass fuels readily available on the market and meeting some basic requirements like calorific value, moisture level and grinding power requirements, AC has selected the suitable handling option and full scale tested the whole system for the process validation.

The guidelines of AC reference design for coal-biomass co-firing include :

- Direct injection of pulverised biomass into the PC piping directly upstream the burners
- direct feeding system, with pneumatic transport
- semi-dense phase with air blowers, small dosing bin with screw feeders and carefully selected rotary valves (as a function of the density range of biomass to be handled)
- use of Class A biomass according to CEN/TS 14961 and EU Bionorm, with the following characteristics : LHV > 3400 Kcal/Kg , moisture upper limit at 20% wt. as received and fineness 100 % less than 1.5 mm.

Based on above and in cooperation with Tirreno Power, AC has developed a basic engineering study for the potential retrofit of 320 MWe class coal fired units applicable to the Tirreno Power Vado Ligure Power Plant. The study represents the reference design to implement the detailed engineering and supply phases for the project execution.

In the following figures 16 and 17 a pictorial view of the lay-out study and a preliminary process diagram are shown.

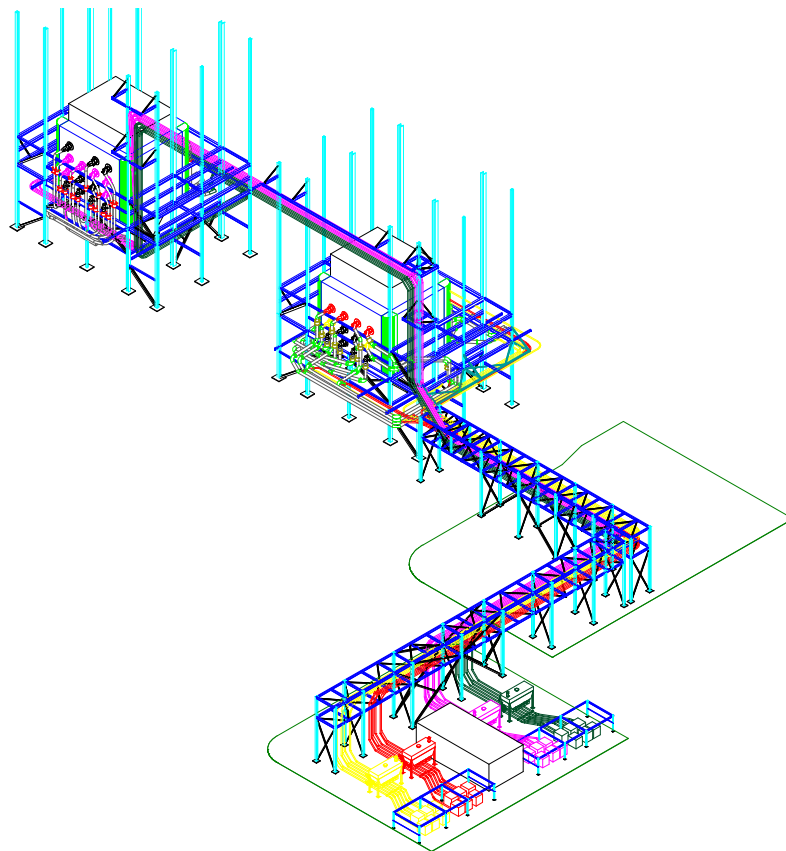


Fig. 17 – Lay-out study for a biomass co-firing fuel supply system

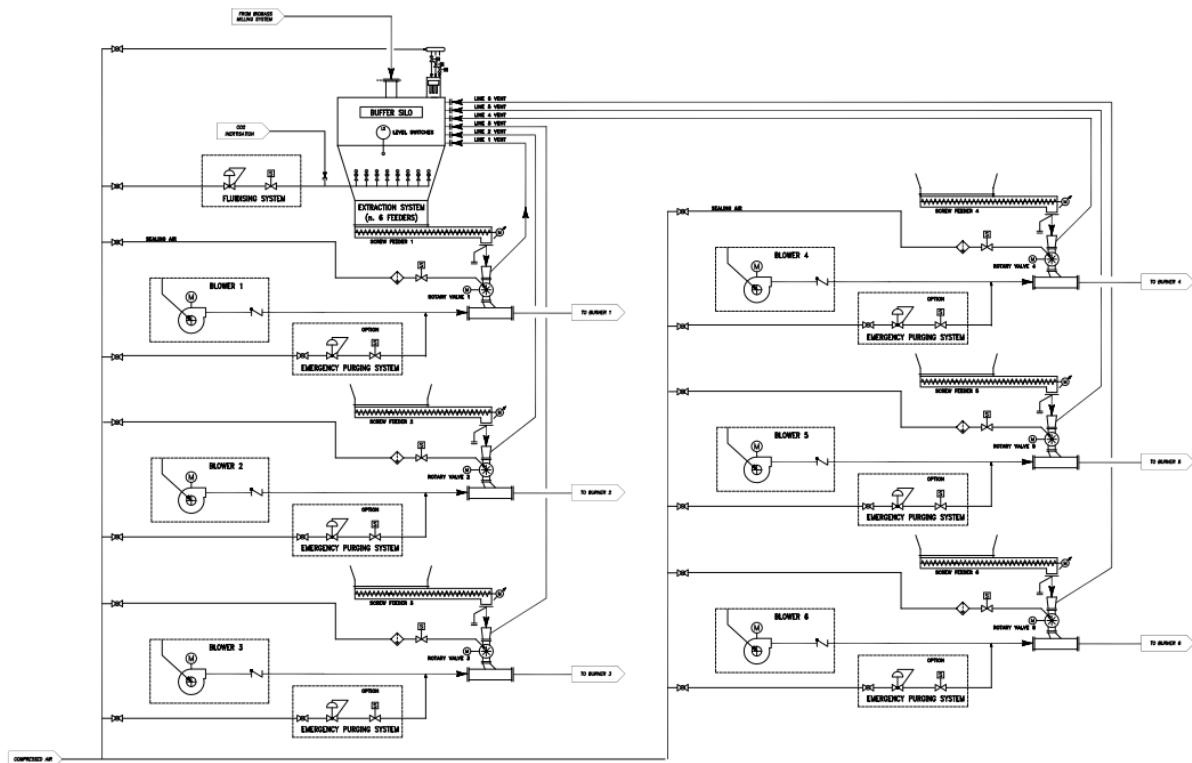


Fig. 18 – Process diagram for a biomass co-firing fuel supply system

Conclusions

Ansaldo Caldaie product development for coal biomass co-firing has achieved significant results in recent years.

Full scale testing activities at its own Combustion Centre demonstrated the excellent performance behaviour of Ansaldo Caldaie TEA-C burners, equipped with enhanced coal nozzles (EFS) in a 20 – 30% co-firing configuration of bituminous coal with biomass.

Good and stable combustion parameters, proper emission levels, wide operating load range and performance flexibility for various biomass types and for different kinds of biomass transport configurations (dense or semi-dense solutions) have been confirmed.

In addition, the capability of the TEA-C EFS burner design to accept full biomass firing on individual burner has been verified positively.

A pre-engineered reference design suitable to the retrofit of large utility boilers has been developed selecting the various biomass dosing and transport solutions in relation to the layout and performance optimization, and is ready for the construction phase of the project.

From the experience, Ansaldo Caldaie is ready for the development of a wide range of co-firing projects, to satisfy state of the art industry needs.