APPENDICE E

Appendice E

Esempio di Flue Gas System per Impianti SCR

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RINA

STC POWER

EP PRODUZIONE
Trapani

Trapani Power Plant – New OCGT Units

FLUE GAS SYSTEM

2 FLUE GAS SYSTEM

2.1 General description

For this SCR project, ammonia solution @ 24,9% concentration is used as a reagent, it is important that staff involved understand the properties of ammonia and that they be thoroughly informed for its storage and handling.

The vaporization of ammonia (NH_3) in aqueous solution has the purpose to get the quantity of anhydrous NH_3 necessary for catalytic reactions of the NOx reduction. Aqueous ammonia is pumped from the storage tank to the AFCU module. It is first injected by spray nozzle(s) into an evaporator where a small portion of flue gas from the main duct casing with an average temperature of 530°C (in case of GT model Siemens SGT-800) or 450°C (in case of GT model GE LM6000PF+Sprint), is used to evaporate the aqueous ammonia droplets, with the result to have an ammonia gas stream. The mixture of ammonia and flue gas is then injected into the exhaust duct, upstream of the catalyst, through several nozzles, to spread the ammonia homogenously over the catalyst surface. A homogenous distribution of ammonia in the flue gas is important to achieving efficient NOx reduction and a low ammonia slip, and thus efficient utilization of the catalyst.

Dilution media is circulated by dedicated, special design, high temperature fan in configuration 2 x 100%. Vaporization vessel is sized for residence time suitable to assure complete evaporation of the droplets in anhydrous ammonia (NH_3) and water vapor. NH_3 produced in the vaporizer and diluted in the hot flue gas is injected in each section of the casing cross-section by AIG (Ammonia Injection Grid), located directly in front of the catalyst; the AIG is designed as a combination of nozzles and divided in control zones; each control zone can be adjusted by manual control valve. NH_3 flow rate is controlled by required reduction of NOx and load of the boiler; inside the SCR catalyst produced with a special formulation, containing elements at high activity converts NOx almost completely in N_2 and H_2O in presence of O_2 contained in the flue gas according to the following reactions:

$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$
$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$
$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

CFD modelling of complex systems is used for the effective optimization of the system with the aim to reduce pressure drops, maintenance and to improve the life and the performance of the equipment. The purpose of ductwork profile section modelling is to check and to optimize flue gas flow through the complete system that includes tempering air injection, SCR Catalyst, Ammonia Injection Grid (AIG) with connected ducts. CFD is used to develop the optimum configuration and to apply if necessary advanced flow correction and control devices to promote consistent flue gas velocities as well as good NH_3/NOx distribution across the face of the catalyst for efficient performances.

The proposed Flue Gas System is composed by these main components:

- Common Unloading Module
- Common Ammonia Storage System
- Common Ammonia Detection and Abatement System
- Common Ammonia Pumping and Circulation Module
- No. 4 Ammonia Flow Control Units (AFCU)
- No. 4 Tempering Air & Injection Modules
- No. 4 Exhaust Main Casings with Reactor, Silencer and Stack
- No. 4 Ammonia Injection Grids + Catalysts

2.2 Common Unloading Module

The unloading module performs the unloading of the ammonia water delivery tanker and return of vapors to the same tanker in an automated and reliable manner. The truck driver or, the operator connects the electrical ground to the truck and connects the hoses for the supply to the unloading centrifugal pump (configuration 2 x 100%), the vapor returns to the tanker and then with the manual valves open, presses the start button on the Unloading Panel. Automatic valves open and a high flow, low pressure pump is used to transfer the ammonia water from the tanker to the storage tank. Vapor laden air in the storage tank which is displaced by the incoming ammonia water, is returned to the tanker thus avoiding a discharge of gas to the atmosphere. The unloading module is fitted with a filter with its DPI upstream pumps in case of impurities in the delivered ammonia water and, ali necessary valves for draining the system for maintenance, for venting air or for isolating the system. All piping on the module is stainless steel welded or flanged where possible.

A GRP unloading panel will be installed near the unloading point in a safe area, this panel will allow the main unloading operation locally under the control of the operator. In addition, the panel will house the terminal board to be connected with the DCS for the connection of "permissive", the "emergency" and other interchanged signals defined during HAZOP.

The unloading module with its unloading panel is suitable to be installed in non-classified area (safe area).

Unloading Reagent Module is designed according to following basis:

– Reagent Solution pumps	AISI 316
– Reagent Solution pumps installed power	2 x 3 kW
– Piping Material	AISI 304 (not painted)

– Area Classification safe area

Main installed components:

– N°2 ammonia solution unloading pumps
– N°1 Set of pressure gauges and delta P across the filter
– N°1 "Y" filter
– N°1 flow switch
– N°1 pressure transmitter
– N°2 ON-OFF pneumatic valves.
– N°1 set of piping, manual valves and check valves
– N°1 Skid frame and supports
– N°1 Unloading panel
– N°1 Safety shower with eye/face wash

2.3 Common Ammonia Storage System

The 24,9% ammonia storage area is located outdoor. Storage tank area provides about 1 meter of clearance on all 4 sides of the tank for maintenance purposes, and that the tank be placed in an area that will not be exposed to damage by vehicular traffic. Access to the vessel for filling purposes shall be within 20 meters and located within line of site for tank truck delivery. The area must remain clear of debris or any combustible materials. If being placed inside of a fenced-in area, ingress/egress must be incorporated in the fence design to allow for escape in the event of an emergency. An ammonia solution storage tank is usually considered to have a maximum capacity of 85% (a 15% vapor space must always be maintained when filling, to allow for expansion). For this specific project, the storage area consists of one 50 m^3 (geometrical) horizontal configuration, single wall tank type, fabricated from stainless steel grade, suitable to store 42,5 m^3 ammonia solution.

The filling level of the storage tank is monitored by a remote level indicator with additional limit switch. The limit switch closes the pneumatically operated valve in the filling line and switches off the unloading pump, when high level is reached. Storage tank is equipped with a pressure relief valve and blow off valve, a vacuum breaker with flame arrestor is also installed to equilibrate the internal pressure throughout ammonia consumption.

The storage tank module is shaded from located in a retention basin (part of civil works). The retention basin shall be equipped with a suitable sump.

Ammonia storage area is designed according to following basis:

– Ammonia storage tank material pumps AISI 304L (not painted)

–	Ammonia storage tank mech. design	vacuum up to 3 barg
–	Piping material	AISI 304L (not painted)
–	Area Classification	safe area

Main installed components on storage tank:

- N°1 50 m^3 storage tank in horizontal configuration
- N°1 manhole, flanged
- N°1 standard ladder and platform to access the top served area of the tank
- N°1 guided radar level measuring unit with local LCD display
- N°1 level switch for overfill protection
- N°1 level switch for emptying protection
- N°1 pressure transmitter with gauge valve and with local LCD display
- N°1 pressure gauge with gauge valve
- N°1 temperature transmitter and with local LCD display
- N°1 thermometer
- N°1 pressure relief valves
- N°1 safety relief valves
- N°1 vacuum breaker with its flame arrestor
- N°1 pneumatic shut off valve in extraction line
- N°1 Safety shower with eye/face wash

2.4 Common Ammonia Detection and Abatement System

In order to protect the storage area from ammonia spills and to guarantee the safety of the operators during operations and inspections the following detection and abatement system is foreseen:

- Set of water spraying system above the storage tank
- N°2 Ammonia gas sensor above the storage tank
- N°1 Acoustic alarm
- N°1 Emergency push button
- N°1 Ammonia gas sensor above the unloading module
- N°1 Ammonia gas sensor above the pumping & circulation skid

As per same philosophy, above each AFCU is foreseen:

- N°1 Ammonia gas sensor
- N°1 Acoustic alarms

2.5 Common Ammonia Pumping & Circulation Module

The module ensures the pumping and the circulation of the reagent into a ring piping loop onto which all users are connected, this is necessary in order to have the reagent at the proper design pressure to downstream equipment. The module is presented under the form of a painted carbon steel skid with drip pan onto which all components are piped.

The module is composed by:

N°2 AISI 316 positive displacement pumps, (one in service and one in stand-by, (arrangement 2 x 100%) one pump serves all AFCU modules, this configuration ensures constant reagent supply with the other pump considered as a spare; upstream the pump's arrangement, two strainers (arrangement 2 x 100%) are foreseen, the module also includes all isolating valves for the pumps. The module's instrumentation consists of; differential pressure gauge between the inlet and outlet of the strainers to indicate if the strainer has to be cleaned-up; pressure gauges to indicate that the pressure is normal and constant; pressure transmitters with alarm to monitor the pressure on the supply line and inform the operator to start the standby pump in case of failure or low-pressure alarm.

Ammonia Pumping & Circulation Module is designed according to following basis:

- Reagent Solution pumps — AISI 316
- Reagent Solution pumps installed power — 2 x 0.37 kW
- Piping Material — AISI 304 (not painted)
- Area Classification — safe area

Main installed components:

- N°2 ammonia solution pumps (sliding vane type)
- N°1 Set of pressure gages and delta P across the filter
- N°2 Pressure Control Valve with its by-pass system
- N°2 cartridge filter quipped with differential pressure gauge
- N°2 pressure transmitters
- N°1 set of piping, manual valves and check valves
- N°1 Skid frame and supports
- N°1 Junction box with full instrument wiring

2.6 No. 4 Ammonia Flow Control Units (AFCU)

Each line is designed on the following basis:

- NH_3 solution pressure @ battery limit — 2,5 barg ± 4%, at 15 °C
- Ammonia dilution fluid — Hot flue gas
- Catalysts data according to data given at par. 2.9.2

The dilution of Ammonia in the hot flue gas is guaranteed by high temperature fan (2x100% configuration) and all the necessary interconnection piping, joints and valves that sucks flue gas from the main duct casing to vaporize Ammonia solution and to have a certain flow rate at AIG in order to produce a uniform distribution of Ammonia opposite to the catalyst. The evaporation of Ammonia shall be carried out in an Evaporator in which ammonia in solution will be spread by a special injection system with bi-phasic lance.

The required Ammonia flow rate will be dosed and controlled by the ammonia control valve in function of NOx to be reduced and load of the boiler. All components are skid mounted and full tested before delivery. All piping will be in stainless steel and will include all necessary valves and instruments, AFCU is provided with drip pan below the ammonia pipeline with an isolating valve for drain (one point). Skid equipped with lifting lug ad trunnions demountable type. Evaporator will be manufactured in stainless steel as well as the injector. The evaporator shall be complete with static mixer for even Ammonia distribution in the hot air and also for possible droplets removal.

AFCU is designed according to following main basis:

- Piping Material — AISI 304 (not painted)
- Ammonia solution vaporizer — AISI 304 (not painted)
- Fan casing material — Stainless steel
- Fan impeller material — Alloy 625
- Fan installed power per line — 2 x 18,5 kW
- Fan absorbed power — 10 kW
- Area Classification — safe area

Main installed components:

- N°1 pneumatic block ON-OFF valve on ammonia line
- N°1 pneumatic block ON-OFF valve on atomizing air
- N°1 pneumatic block ON-OFF valve to isolate the AFCU (loose supply)

- N°1 pressure transmitter, a magnetic flow meter and a pneumatic control valve on ammonia line
- N°1 PCV for compressed atomizing air
- N°1 Pressure transmitter on compressed atomizing air
- N°1 ammonia evaporator with IN-OUT temperature transmitters
- N°1 pressure transmitter on dilution flue gas
- N°1 ammonia injector
- N°2 complete high temperature centrifugal blowers
- N°2 pneumatic actuated flaps
- N°4 Manual isolating valves
- N°1 flow transmitter on dilution flue gas
- N°1 set of pressure gauges
- N°1 Skid frames with full wiring, JB and supports

2.7 No. 4 Tempering Air & Injection Modules

The operating temperature of the reduction catalyst has a critical effect on the NOx conversion efficiency. Depending on the catalyst active component chemical formulation and its substrate, the reduction catalyst is typically utilized at about 455°C, and the operating temperature cannot exceed in our case 545°C (for Alternative A) or 450°C (for Alternative B) for prolonged periods of time. Operating the reduction catalyst at lower temperatures allows for adding more of the active component (typically vanadium oxide) to the catalyst. As a result, the catalyst volume can be reduced and the catalyst life span increased.

In our specific case with both gas turbine models (Alternatives A and B) in open (simple) cycle configuration, the exhaust gas temperature exceeds the temperature range required by the reduction catalyst, and the exhaust gas must be cooled down. Consequently, the application requires air blower for injecting ambient air (so-called tempering air) into the exhaust system to bring the exhaust temperature within the operating range of the reduction catalyst.

An improved injection of tempering air is proposed, and standard temperature measurement techniques are employed, such as thermocouples with temperature transmitters. To obtain a representative sample, the exhaust temperature is measured at multiple locations. The average value of the operating temperature is calculated and the signal is sent to the DCS as a process value.

The average temperature of the operating exhaust temperature is fed to a controller and compared with the setpoint. The control system governs the amount of tempering air injected into the exhaust system. Tempering airflow is controlled utilizing a blower with variable speed control. With this control both the flow and the head are reduced. This method is more efficient than mechanical capacity control.

Tempering Air Module & Injection is designed according to following main basis:

– Fan, casing material	carbon steel
– Fan, impeller material	corten
– Fan installed power	160 kW
– Fan absorbed power (worst case)	150 kW
– Duct Material for Air	carbon steel
– Piping material	AISI 304L (not painted)
– Area Classification	safe area

Main installed components:

- N°1 pneumatic block ON-OFF flap to isolate the air injection
- N°1 complete standard centrifugal blower
- N°1 manual isolating valve
- N°1 set of local instrumentation with a pressure transmitter
- N°1 intake duct with bird screen
- N°1 skid frames and supports

Fresh air is pumped to the injection system thorough an external manifold and placed in the upper and lower side of the transition duct.

2.8 No. 4 Exhaust Main Casings with Reactor, Silencer and Stack

The exhaust flow leaving a gas turbine engine is a violently turbulent, swirling flow with average velocities in the range 40-50 m/s and temperatures as high as 500°-600°C. In addition, a gas turbine engine starts quickly so these conditions are established in a matter of minutes. Isolation of the casing and structure from these extreme conditions is thus preferred to eliminate excessive growth of these components, minimize differential growth between the structure and casing, and prevent cracking of the casing. This is achieved by utilizing a cold, gas-tight casing insulated on the inside with at least two layers of blanket insulation as shown in the following conceptual figure. The insulation is covered with a liner to prevent erosion from the hot gas stream. The liner material is selected to withstand the temperatures encountered and is designed to expand and contract freely in all directions. The inner liner is constructed from a series of independent panels that are covered with floating lap joints at the seams.

Cold casing construction with internal insulation and floating inner liners as described above permit rapid start-ups and are not damaged by transient gas conditions. It can be designed for gas with high temperatures as long as the insulation and liner materials are selected to withstand a very critical environment. The exhaust casing with its inlet and outlet junction ducts is made in carbon steel with internal insulation and containment sheet in stainless steel in contact with the exhaust flue gas.

A 25 m high with 3,81 m inner diameter, carbon steel, self-supporting exhaust stack is provided, heat protection according to what described above. The supply includes painted supporting structure, ladders and platforms, inspection door, warning red lights and provisions for CEMS connection, optimized position of the silencer inside the stack.

Exhaust casing and Stack are designed according to following basis:

–	Standard applied for stack design	EN-13084
–	Transition duct, Casing material, Stack material	S275 JR
–	Reinforcement & structures material	S275 JR
–	Corrosion allowance (included)	3 mm
–	Catalyst supporting structure	10CrMo910
–	Insulation thickness	250 mm
–	Insulation type	bio-soluble fibers (*)
–	Inner liner's panels	AISI 304 sp.>1,5 mm

(*) = thermal insulation according to ER par. 1.3.4

Main installed components:

- N°1 Perforated plate
- N°1 DPI across the catalyst layer, primary tubing and manifold
- N°4 TE+TT to optimize tempering air injection

2.8.1 No.4 Silencers

Our preliminary study involves the introduction inside the stack of a series of sound-absorbing partitions on horizontal planes. Soundproof exhaust flue gas transition will be maintained between the partitions with an overall section sized for both acoustic and fluid dynamic purposes. The baffles will be complete at the round tip inlet to limit pressure drops and optimize the outflow of exhaust flue gas between the panels themselves. Every single panel will be equipped with eyebolts for lifting means. The panels (with the exception of the two shorter panels) will be divided into 2 parts along the length. The fixing of the panels inside the duct is provided by means of a system of supports, guides and a central profile to be welded inside the stack.

Silencers are designed according to following basis:

– Panel's frame and profiles	AISI 304
– Soundproof material	Rockwool 100 kg/m^3
– Perforated plate	AISI 304

2.8.2 Exhaust Expansion Joints

Expansion Joint are required to isolate the system from the stresses induced by thermal movements and vibration within the duct system. This application requires an increasing demand on the expansion joints to accommodate greater movements and higher temperatures.

The exhaust stack is connected to the outlet of the exhaust duct with insulated ducting and an expansion joint suitable for the high temperatures expected. Despite the insulation and minimal movements, the expansion joint installed at the stack requires careful material selection, design construction, and installation to ensure reliable operation. The installation of insulated non-metallic (fabric) expansion joint absorbs movements caused by thermal changes. It is capable of multi-plane movements in small breach openings and produce very low spring rates.

2.9 No. 4 Ammonia Injection Grids + Catalysts

According to project documentation and nominal data from GT OEM(s), a dedicated process study for the EPP Trapani project has been carried out. The type of catalyst here proposed was evaluated and compared with what is required for the specific high temperature operating conditions with particular attention to minimise the pressure drop. The identified "Honeycomb" type catalyst is the most appropriate solution.

The output of this preliminary study is an Ammonia Injection Grid (AIG) specific to the requirements of the unit duct geometry and flow demands of the SCR system. In order to achieve uniform ammonia reagent distribution, the AIG will utilize multiple control zones, at present foreseen to be 10 zones, each supplying multiple injection lances permanently installed in the duct. Each control zones will be fed through an adjustable valve. The system includes ammonia flow control valve trains, injection lance assemblies, and header pipe assemblies. The injection grid shall be properly supported inside the ductwork to prevent thermal distortion and damage due to vibration induced by the flue gas flow.

AIG + Catalysts are designed according to following main basis:

– A suitably designed AIG composed of distribution pipes joined with manifolds spaced out in order to ensure an even distribution of the reagent in the flue gas.

– Fabrication and supply of Ammonia Injection Grid, the part located inside the exhaust casing will be in stainless steel as well as the external part. The distribution's pipes will be fixed to supports and connected to the control zone headers possibly in workshop. Project will be carried out in order to maximize the pre-fabrication degree and minimize field welds.

– Fabrication and supply of the distribution headers each with its orifice, tuning valves and DPI indicators.

– Design and supply of Catalyst supporting structure made in carbon steel installed directly in the main exhaust casing on a transversal section.

– Supply of SCR Catalyst modules with sealing systems and lifting yoke for modules.

2.9.1 Catalyst Guarantee Period

Due to different operating temperature for Alternative A and B, the catalyst guarantee period is:

– For Alternative A (Siemens SGT-800, SCR Catalyst): 4.000 operation hours or 40 calendar months from the delivery at site of the catalyst.

– For Alternative B (GE LM6000PF+Sprint, SCR+CO Catalyst): 15.000 operation hours or 60 calendar months from the delivery at site of the catalyst.

2.9.2 Design data

Assumed design data are provided in the following tables.

Main Design Parameters			
GT Model		**Alternative A Siemens SGT-800**	**Alternative B GE LM6000PF+Sprint**
GT Operative design condition		Full load, t amb. -5°C, power augm. ON	Full load, t amb. -5°C, power augm. ON
N° of Vaporizers	N°	1x100%	
Flue Gas particulate (wet)	mg/Nm^3	negligible	negligible
NH_3 @ 24,9% Concentration	kg/h	31	50
Estimated catalyst volume	m^3	16,5	7,9
Exhaust flow for dilution	Nm^3/h	900	900
Tempering air	Nm^3/h	45.000	50.000
Exhaust dilution blowers	N°	2x100%	2x100%
Tempering air blowers	N°	1x100%	1x100%
Injection system	N°	1	1
NH_3 Concentration @ AIG	% Vol.	≤ 0,5	≤ 1,3
AIG Contr. Zones	N°	10	10
Ext. Blowers electrical cons.	kW	10	10
Temp. Blower electrical cons.	kW	150	155
Exhaust Flow towards catalyst		Horizontal	

Catalyst Design		
GT Model	**Alternative A Siemens SGT-800**	**Alternative B GE LM6000PF+Sprint**
Reactor		
Reactor Layer Module Arrangement	2 x 7	2 x 7
Estimated Reactor Cross-Section (W x L)	5.49 x 9.68 m	5.49 x 9.68 m
Modules		
Module style	ELITE™	
Module steel	Chr.-Moly Steel	Chr.-Moly Steel
Number of modules provided per unit	14	14
Number of layers	1	1
Module width	2.673 m	2.673 m
Module length	1.382 m	1.382 m
Module depth (depth is flow direction)	1.030 m	0.670 m
Module weight	1600 kg	900 kg
Catalyst		
Catalyst Type	Honeycomb	Honeycomb
Active Materials	Ti-V-W	Ti-V-W
Catalyst Pitch	≤ 1.4 mm	≤ 1.4 mm