June 2015

THE SCIENCE OF A PURE ENVIRONMENT

Certified ISO9001

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Presentation of DeNox Technology

Denitrification Type S.C.R.
Selective Catalytic Reduction

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IDRECO DeNox - Denitrification Type S.C.R.

FIUME SANTO 3

P. STATION :	ENEL – PORTO TORRES ITALY
POWER:	1 x 320
FUEL :	COAL
CAPACITY :	940.000 Nm3/h

FIUME SANTO 4

P. STATION :	ENEL – PORTO TORRES ITALY
POWER:	1 x 320
FUEL :	COAL
CAPACITY :	940.000 Nm3/h

LA SPEZIA 3

P. STATION :	ENEL – LA SPEZIA ITALY
POWER:	1 x 600
FUEL :	COAL
CAPACITY :	1.800.000 Nm3/h

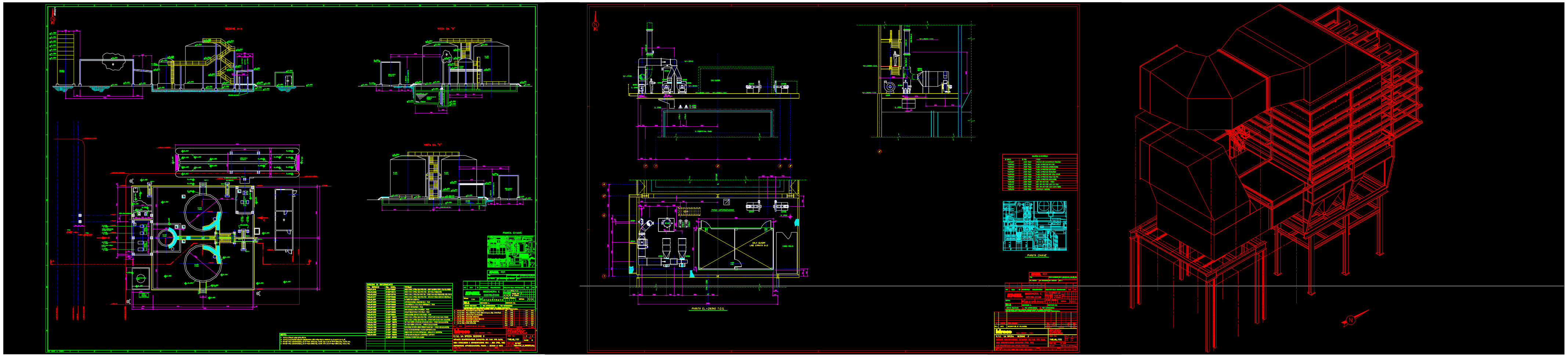
C.T.E. ENEL – FIUME SANTO - ITALY
REACTOR ASSEMBLY

MAIN PART OF S.C.R DENITRIFICATION

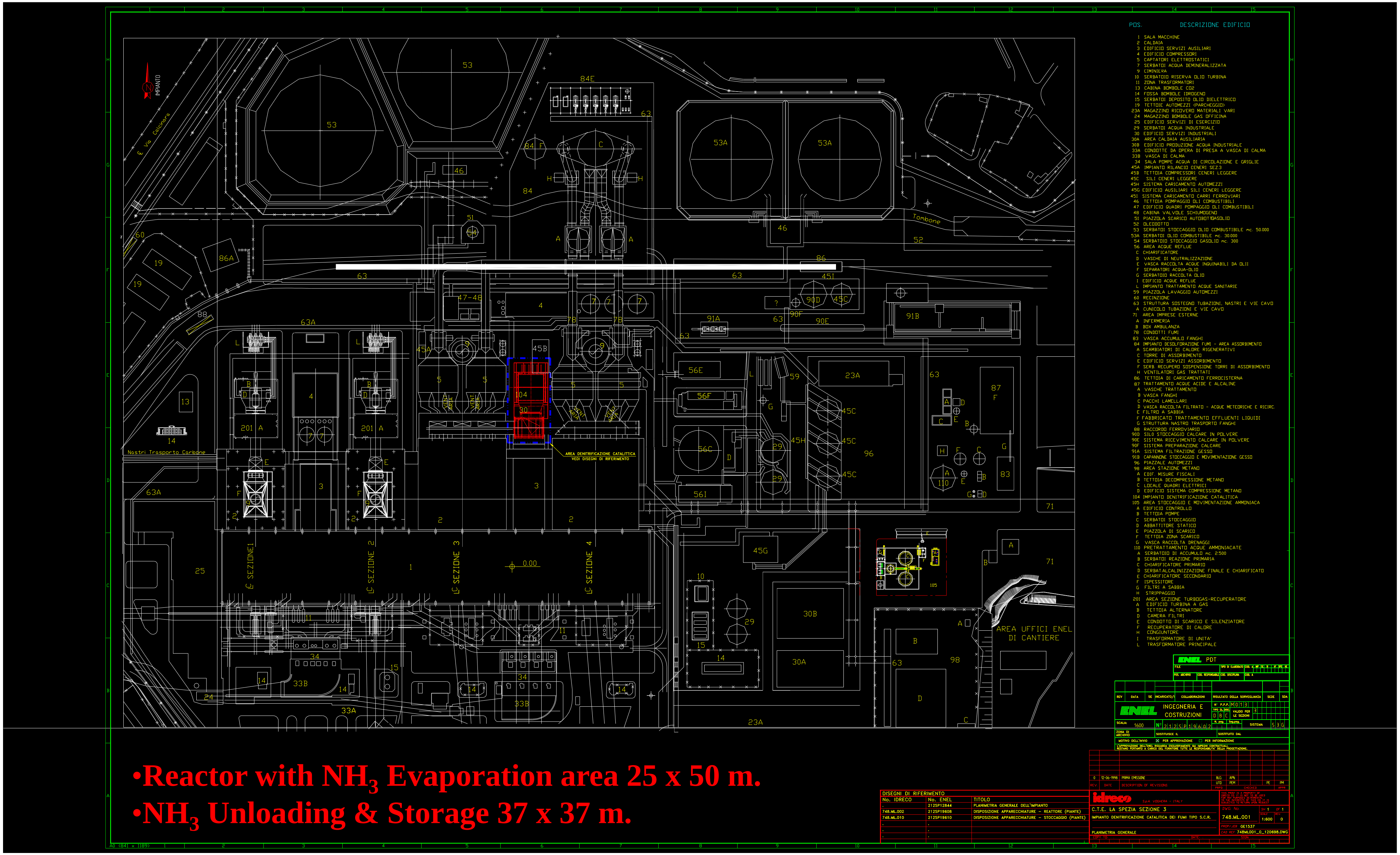
The DeNOx plant in composed by the following 3 main systems:

- **Unloading and Storage of Ammonia**
- **Ammonia Evaporation**
- **Reactor SCR**

Ammonia as Anhydrous, Aqueous or from Urea

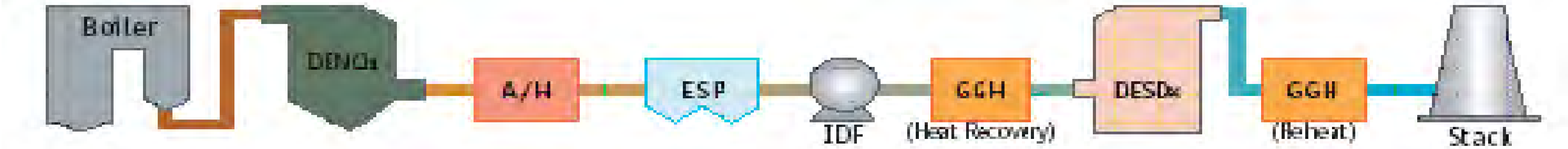


GENERAL LAYOUT OF S.C.R "HIGH DUST" DENITRIFICATION

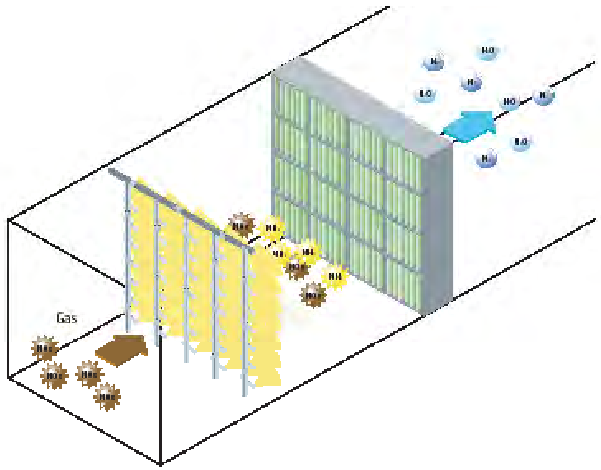


- Reactor with NH_3 Evaporation area 25 x 50 m.
- NH_3 Unloading & Storage 37 x 37 m.

PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION



The Selective Catalytic Redution of Nitrogen Oxides NOx \ (NO, NO_2) by means of ammonia injected on catalyst to obtain free N_2 Nitrogen, follows the below chemical reactions:



Chemistry of the SCR Process

$4NO + 4NH_3 + O_2 \longrightarrow 4N_2 + 6H_2O$

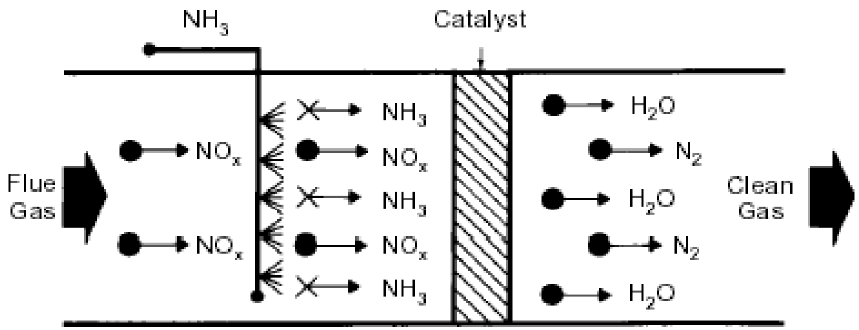
$2NO_2 + 4NH_3 + O_2 \longrightarrow 3N_2 + 6H_2O$

Side Reactions

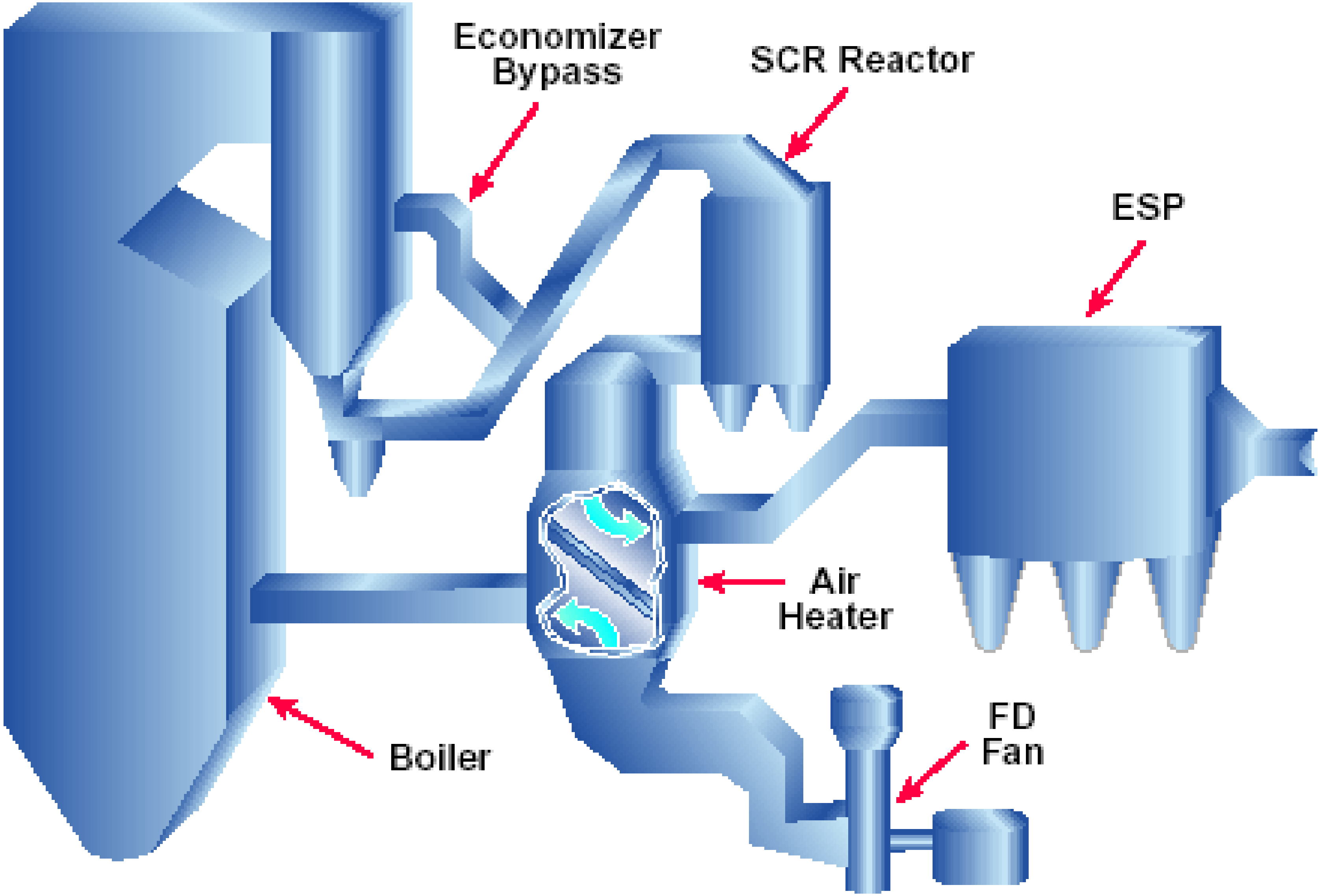
$SO_2 + 1/2\ O_2 \longrightarrow SO_3$

$2NH_3 + SO_3 + H_2O \longrightarrow (NH_4)_2SO_4$

$NH_3 + SO_3 + H_2O \longrightarrow NH_4HSO_4$

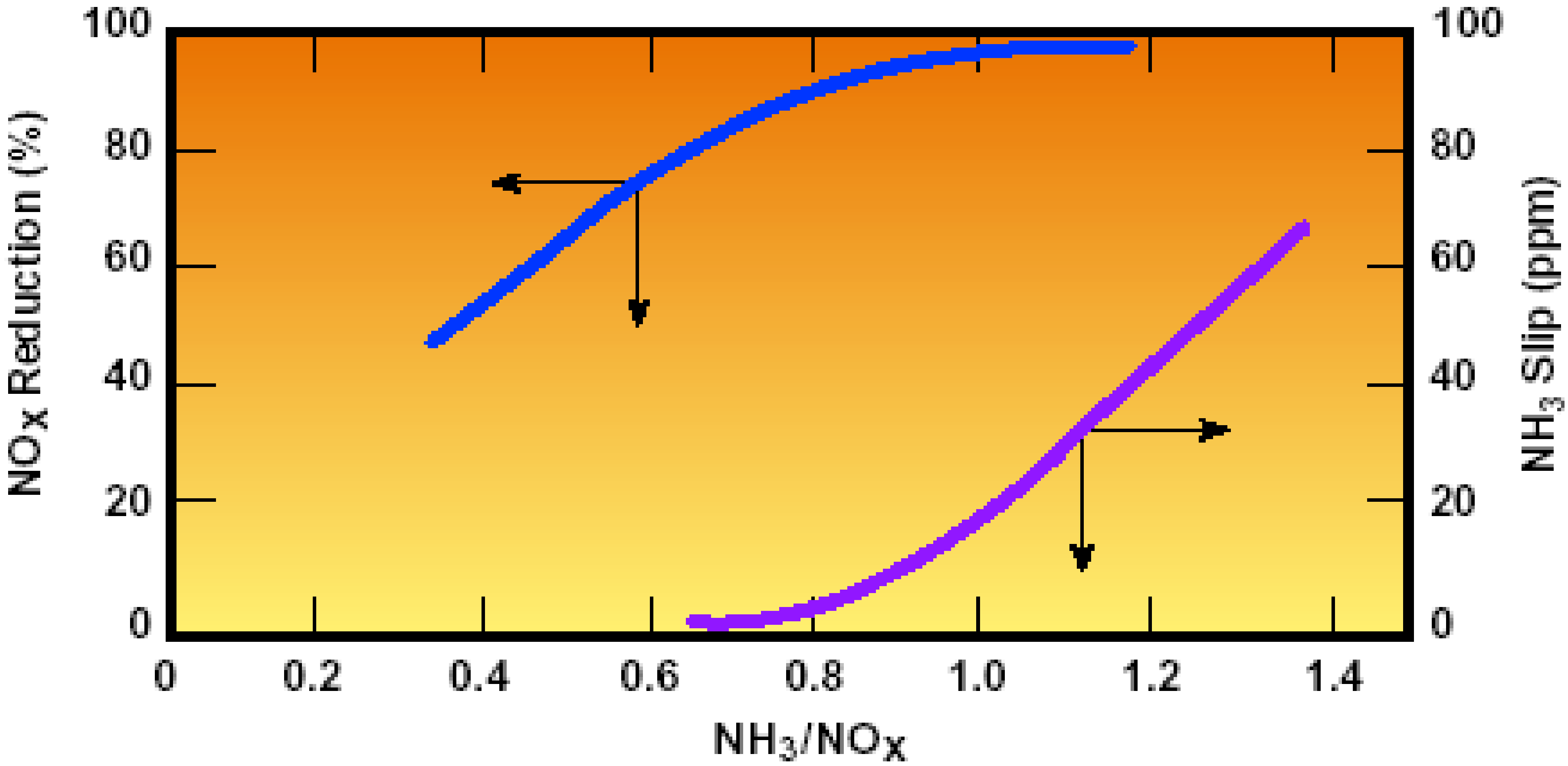


PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION



Schematic flow diagram of SCR process

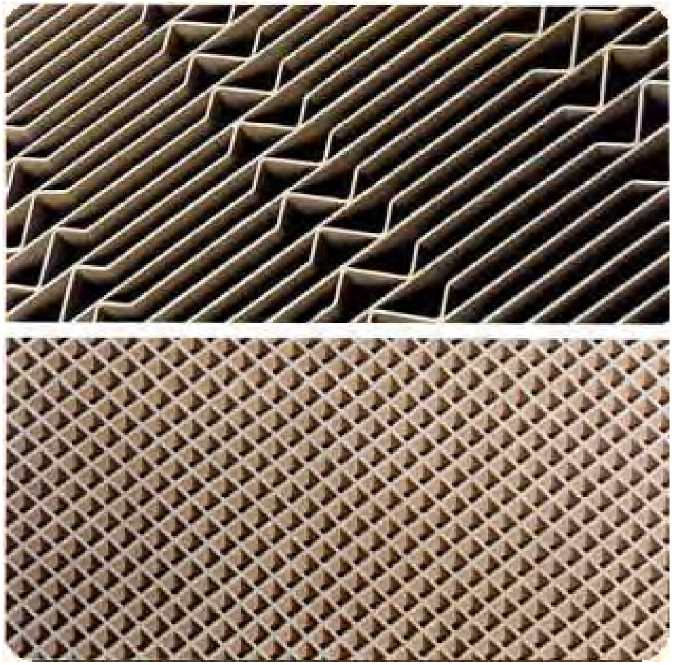
PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION



Typical SCR performance

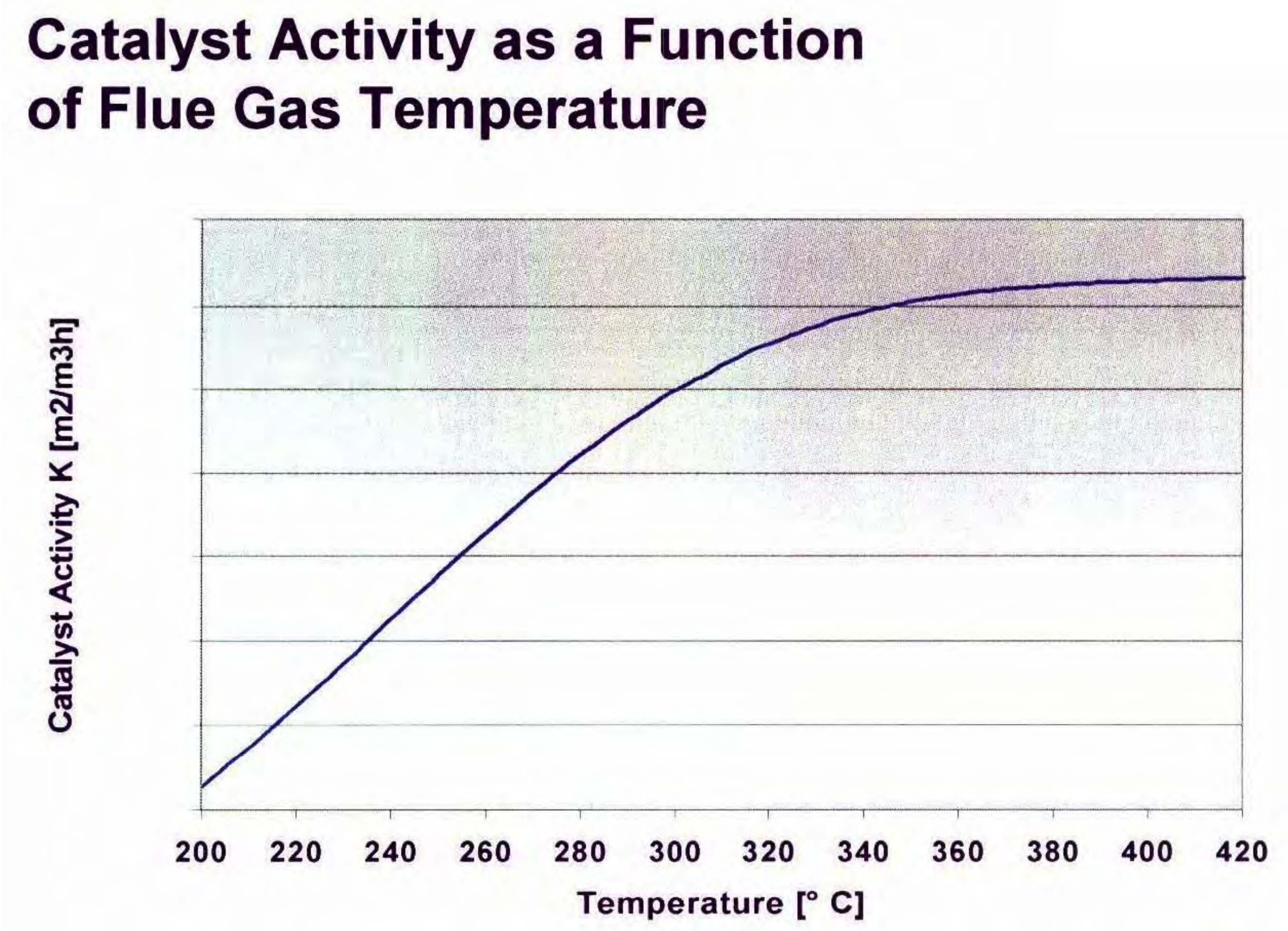
PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION

Plate



Honeycomb

PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION



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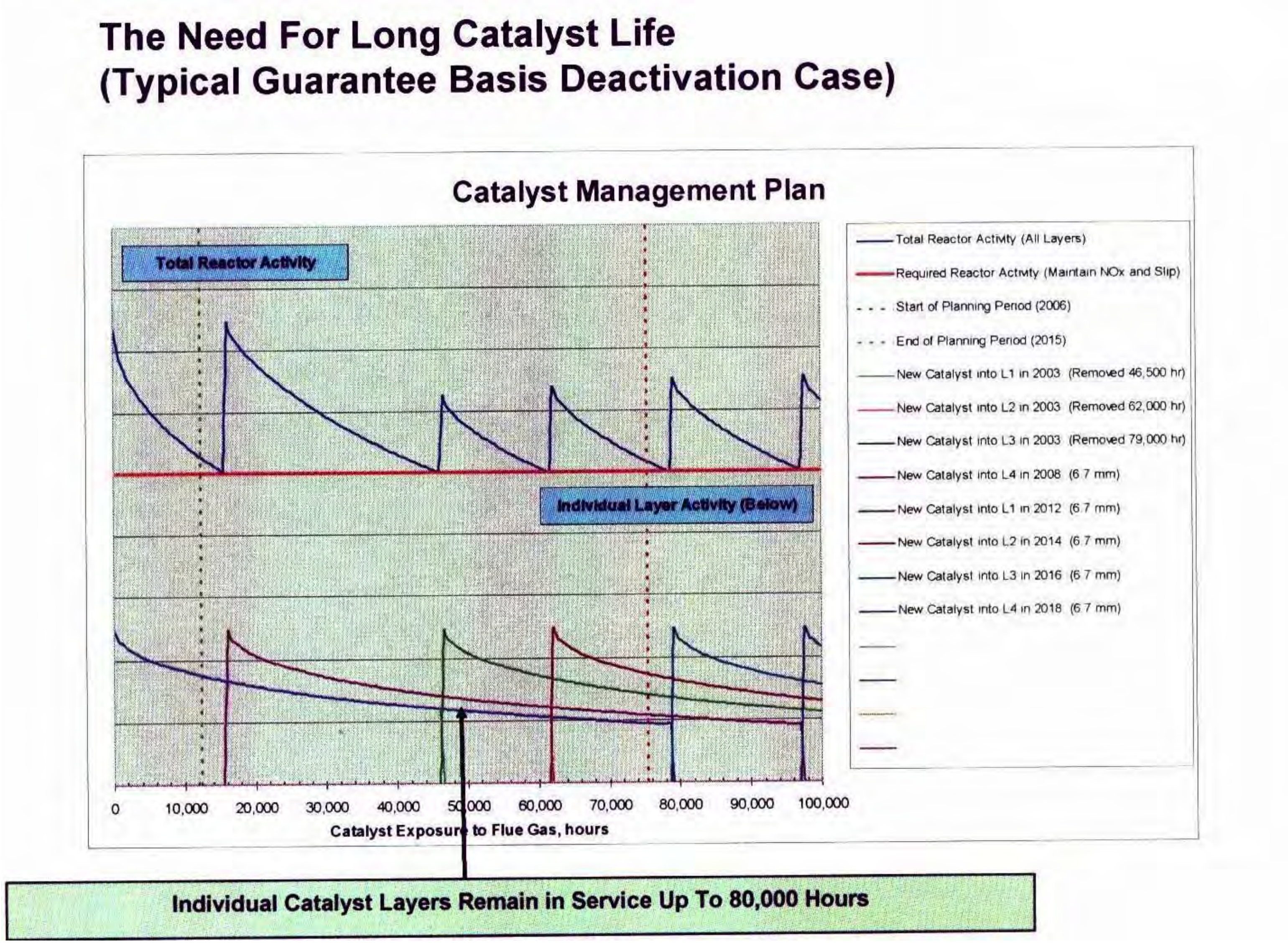

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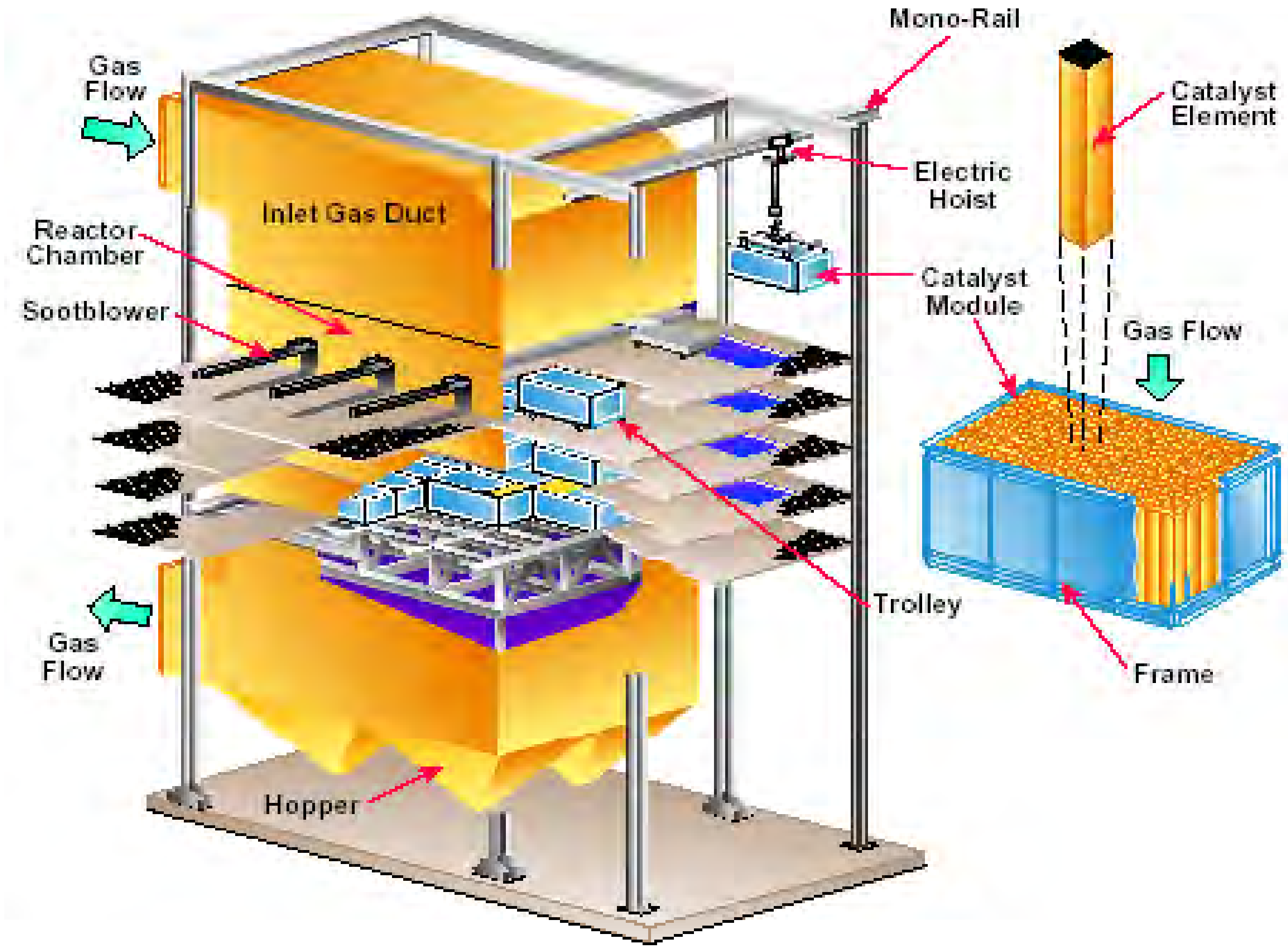
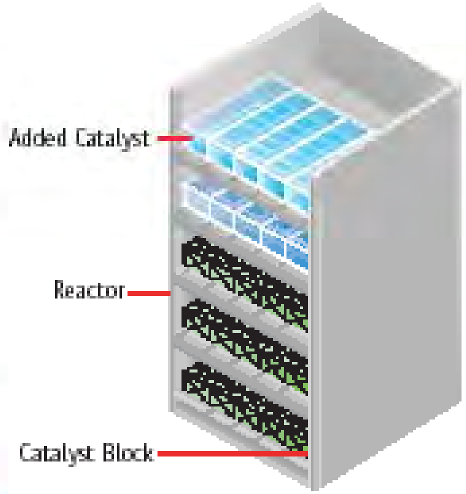


Vertical-flow fixed-bed type reactor chamber



(5-stage Model)
Multistage Reactor

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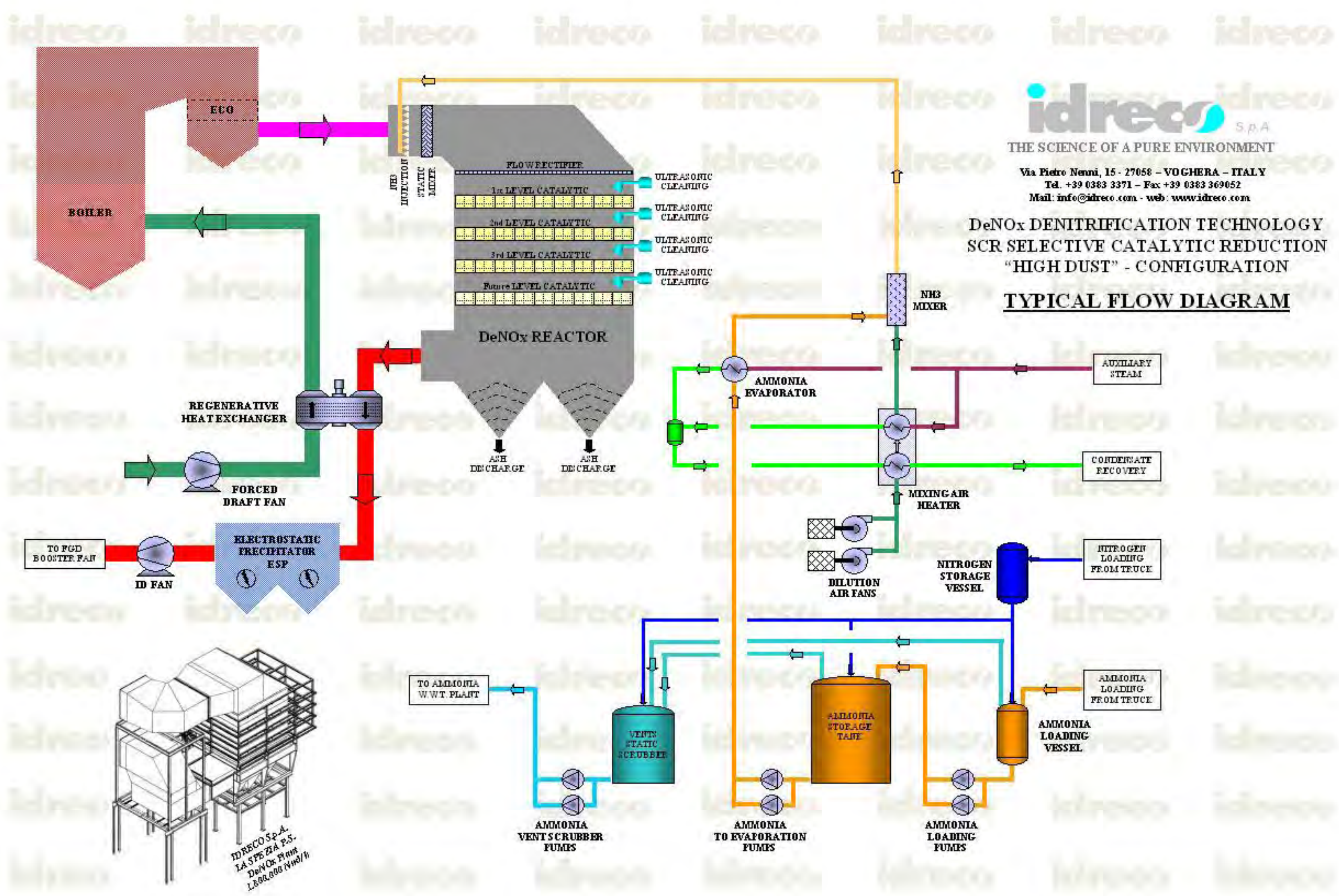

PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION

LA SPEZIA DESIGN DATA AND FUNCIONAL REQUIREMENTS

La Spezia power plant Section 3 is a multifuel unit operating in coal, oil and/or gas combustion.

Natural gas is used only during start-up of the unit. Exceptionally the boiler may be fedded with fuel oil for the whole operating range.

The plant is provided with 1x100% SCR Reactor.

Mechanical design data for ducts and reactors are as follows:

TEMPERATURE:	**400 °C**
INTERNAL PRESSURE:	**+/- 650 mm/H_2O**
MAX. TRANSIENT PRESSURE:	**+/- 1100 mm/H_2O**

The plant normally operates with coal combustion in a range of 77% - 100%.
Minimum load is 30%.
Maximum Gas Flow shall be 110% of design load.

Ammonia will be provided in aqueous solution (25% - 30%) and completely vaporized in contact steam exchanger.

Evaporated water ammonia will be diluted with hot air (temperature after mixing >130 °C) before entering the ammonia injection system.

PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION

LA SPEZIA DESIGN DATA AND FUNCIONAL REQUIREMENTS (cont.)

30% of bolier load is 593.000 Nm3/h.

The flue gas flowrate crossing the ammonia injection system, comes partly from the economizer and partly from the the eco by-pass.

The ratio between the two streams varies depending on the load, in order to achieve the minimum required temperature at the catalyst.

At 100% boiler load and 350 °C temperature, the flue gas comes totally from the economizer and the eco by-pass is totally closed.

At 30% boiler load, the flowrate from eco by-pass is approximately 450.000 Nm3/h at 330 °C, while the flowrate from economizer is 143.000 Nm3/h at 280 °C.

Furthermore on the bottom of the main duct, upstream the ammonia inject system, the ducts for flue gas recycle are connected.

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PROCESS OF S.C.R "HIGH DUST" DENITRIFICATION

LA SPEZIA DESIGN DATA AND FUNCIONAL REQUIREMENTS (end)

The recycle flow rates, in Nm3/h, are as follows:

<u>100% MCR</u>

Recycled gas flow (10% to 15% of gas flow to DeNOx reactor)	**180.000 – 270.000**
Gas flow to DeNOx reactor	**1.800.000**

<u>50% MCR</u>

Recycled gas flow (20% to 25% of gas flow to DeNOx reactor)	**191.800 – 229.750**
Gas flow to DeNOx reactor	**959.000**

<u>30% MCR</u>

Recycled gas flow (28% to 32% of gas flow to DeNOx reactor)	**166.000 – 189.760**
Gas flow to DeNOx reactor	**593.000**

The system ammonia injection plus mixer is so efficient to reach the required velocity and mixing distribution values independently from the flow conditions upstream the ammonia injection system and particularly independently from the recycled flow rate and from the variation of the ratio between the flowrate from economizer and the flow rate from eco by-pass.

Buffles and guide vanes have been designed in order to prevent excessive deposit of dust.

The pressure drop for the NH3 injection plus mixer is less than 1.5 mbar.

AMMONIA

- **ANHYDROUS**
- **AQUEOUS**
- **AMMONIA FROM UREA**

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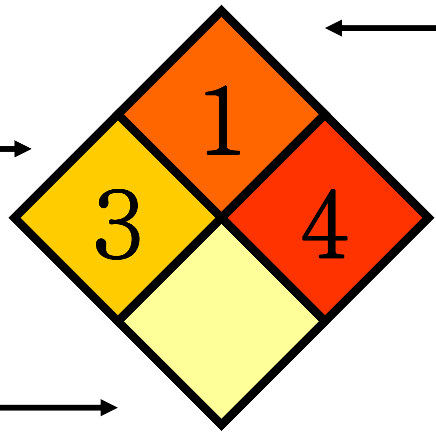
ANHYDROUS OR AQUEOUS AMMONIA HAZARD RATING

NFPA*standard rating system codes
NO_X reducing reagents
AMMONIA
Anhydrous or aqueous solution

HEALTH HAZARD
4 - Deadly
3 - Extreme Danger
2 - Hazardous
1 - Slightly hazardous
0 - Normal material

FIRE HAZARD
Flash Points °F / °C
4 - Below 73 / 23
3 - Below 100 / 38
2 - Below 200 / 93
1 - Above 200 / 93
0 - Will not burn



SPECIFIC HAZARD

Oxidizer	OXY
Acid	ACID
Alkali	ALK
Corrosive	COR
Use NO WATER	
Radiation Hazard	

REACTIVITY
4 - May detonate
3 - Shock/heat may detonate
2 - Violent chemical change
1 - Unstable if heated

U.S. EPA minimum reportable Spill Quantity:
Anhydrous = 45 Kg
Aqueous = 544 Kg

Classified by U.S. EPA as Regulated Toxic substance.
Mandatory risk management plan for storage above:
Anhydrous = 4.530 Kg
Aqueous = 9.060 Kg

* NATIONAL FIRE PROTECTION ASSOCIATION

The NFPA system is used to give response teams immediate information as to what dangers are present during an emergency

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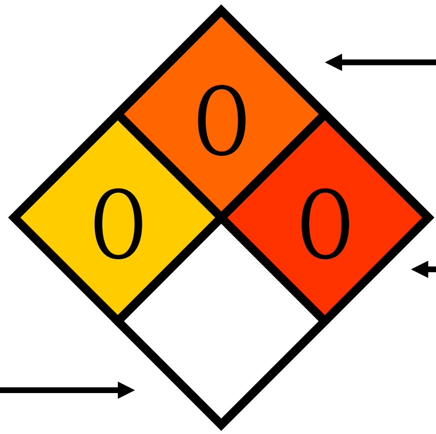
UREA HAZARD RATING

NFPA*standard rating system codes
NO_X reducing reagents
Stabilized 50 % urea-based reagent

HEALTH HAZARD
4 - Deadly
3 - Extreme Danger
2 - Hazardous
1 - Slightly hazardous
0 - Normal material

FIRE HAZARD
Flash Points °F / °C
4 - Below 73 / 23
3 - Below 100 / 38
2 - Below 200 / 93
1 - Above 200 / 93
0 - Will not burn



SPECIFIC HAZARD

Oxidizer	OXY
Acid	ACID
Alkali	ALK
Corrosive	COR
Use NO WATER	
Radiation Hazard	

U.S. EPA minimum reportable Spill Quantity: N / A

Non classified by U.S. EPA as Regulated Toxic substance.

* NATIONAL FIRE PROTECTION ASSOCIATION

The NFPA system is used to give response teams immediate information as to what dangers are present during an emergency

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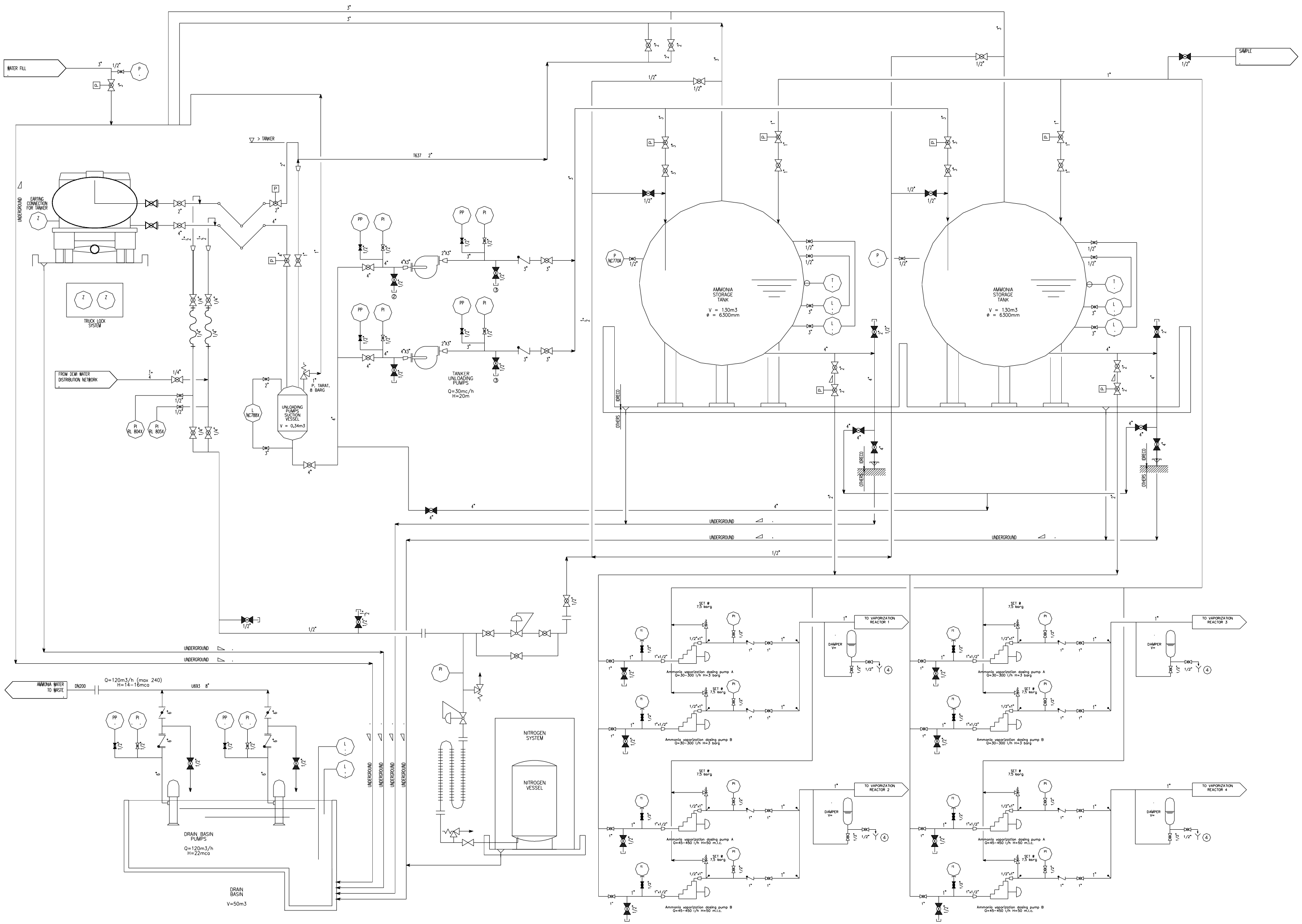
P&ID OF ANHYDROUS AMMONIA UNLOADING AND STORAGE



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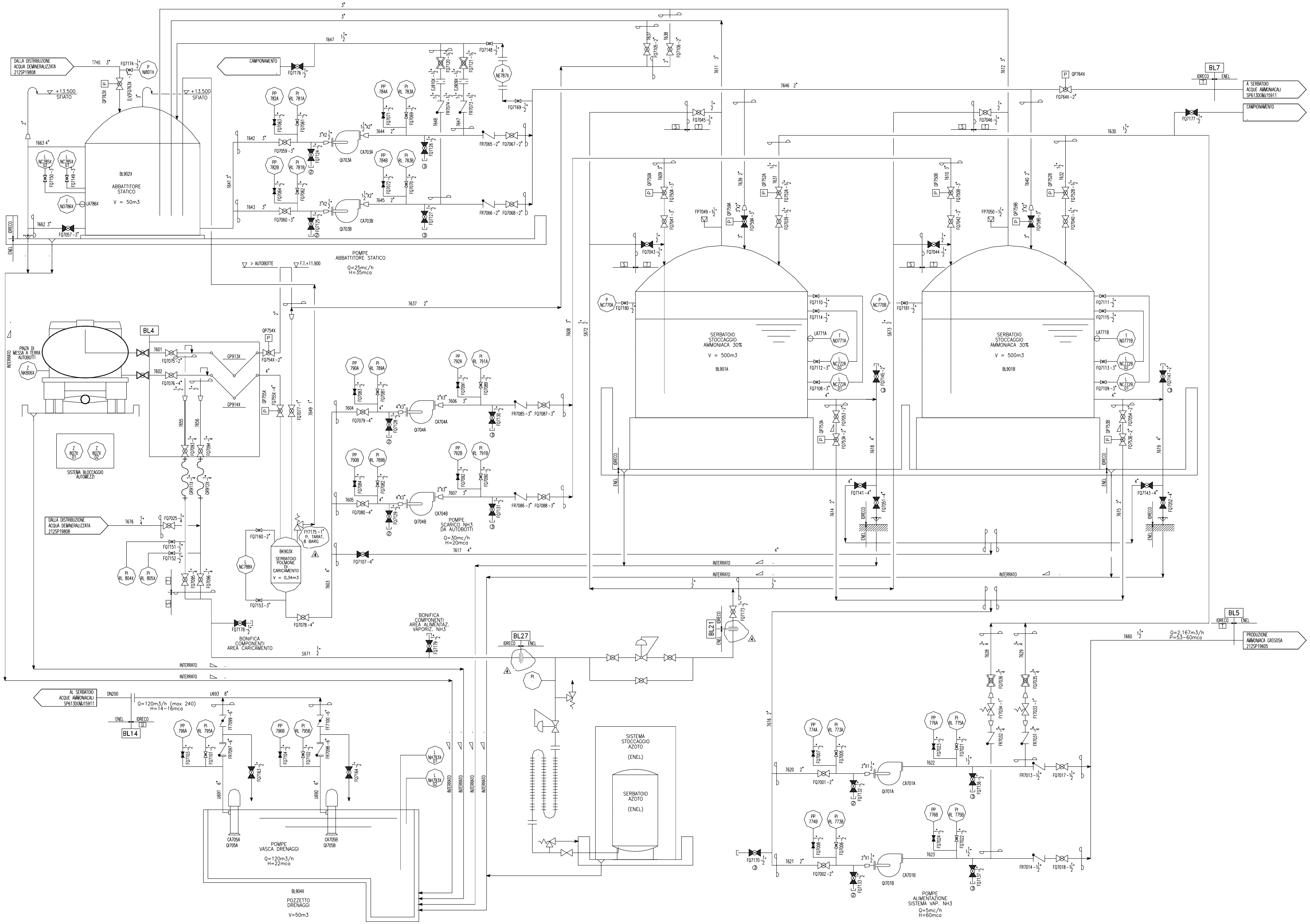
P&ID OF AQUEOUS AMMONIA UNLOADING AND STORAGE



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LAYOUT OF AQUEOUS AMMONIA UNLOADING AND STORAGE AREA

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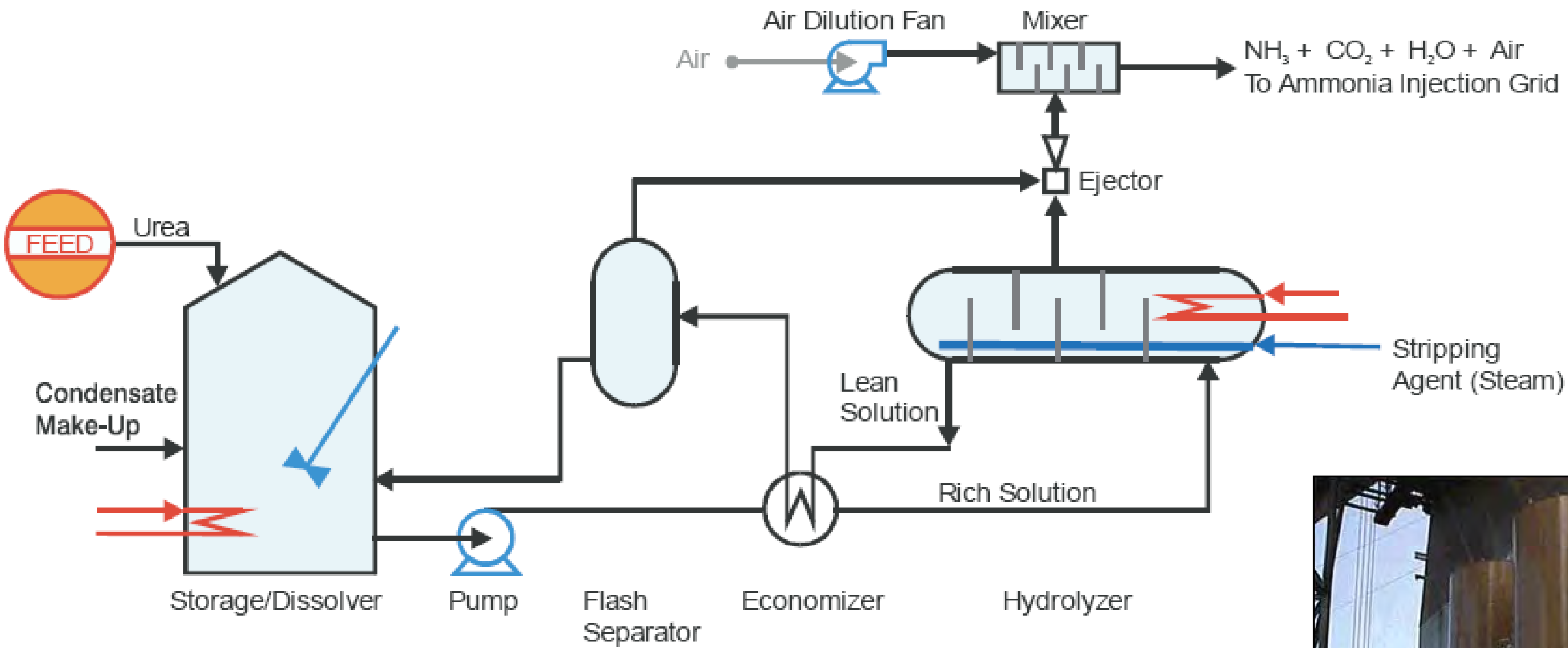
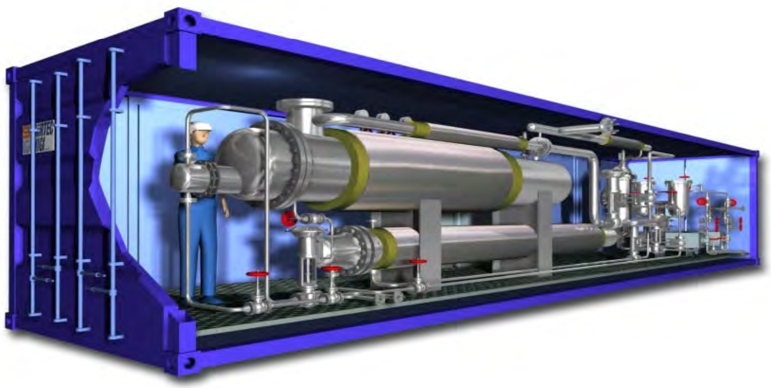
AMMONIA FROM UREA





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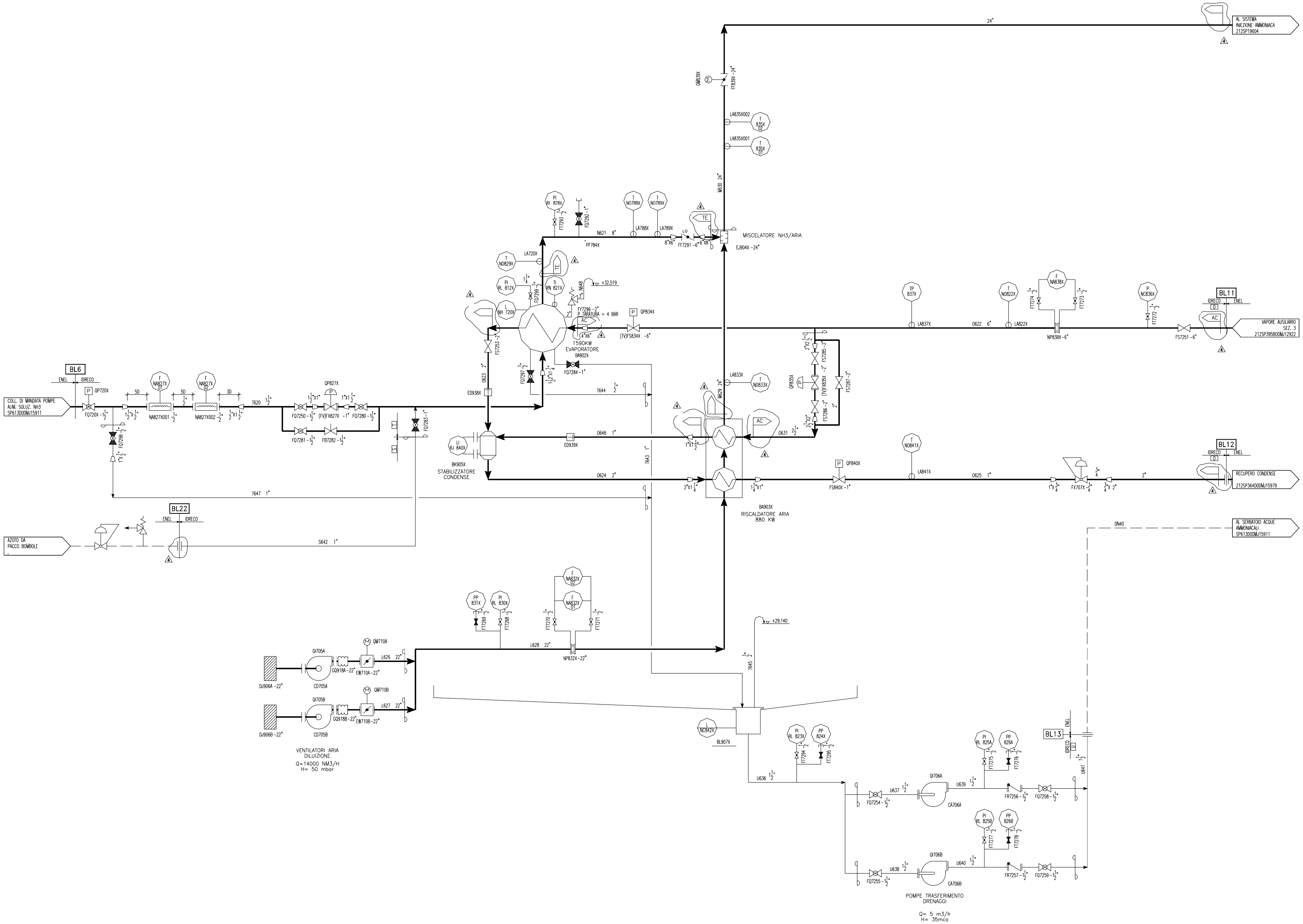
P&ID OF AMMONIA EVAPORATION



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LA SPEZIA DeNOx
DATA OF AMMONIA EVAPORATION SYSTEM

Evaporator	no.	1
Type	-	Steam Exchanger
Max. Flow rate of NH3 solution to be evaporated	Kg / m^3	1.972
Steam consumption @ 4 bar 180 °C	Kg / h	2.283
Mixing Air Heater	no.	1 with two stages
Steam consumption @ 4 bar 180 °C	Kg / h	669
Condensate Max. Temp.	°C	80
Air mixing fans	no.	1 + 1 stand-by
Flow rate mixing air	Nm^3 / h	14.000
Mixed air Temp.	°C	>130
Total Steam consumption	Kg / h	2.855

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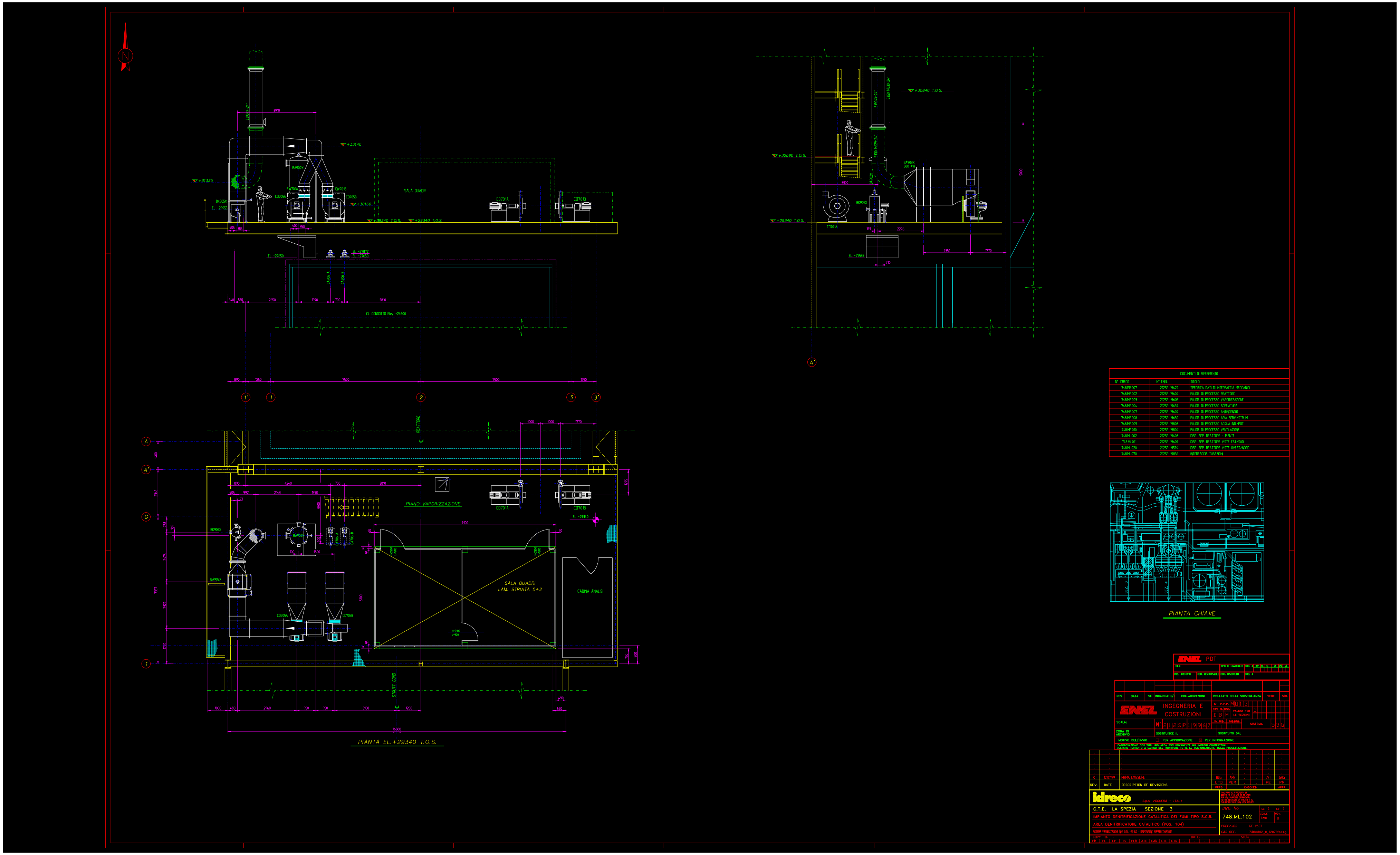
LAYOUT OF AMMONIA EVAPORATION SYSTEM



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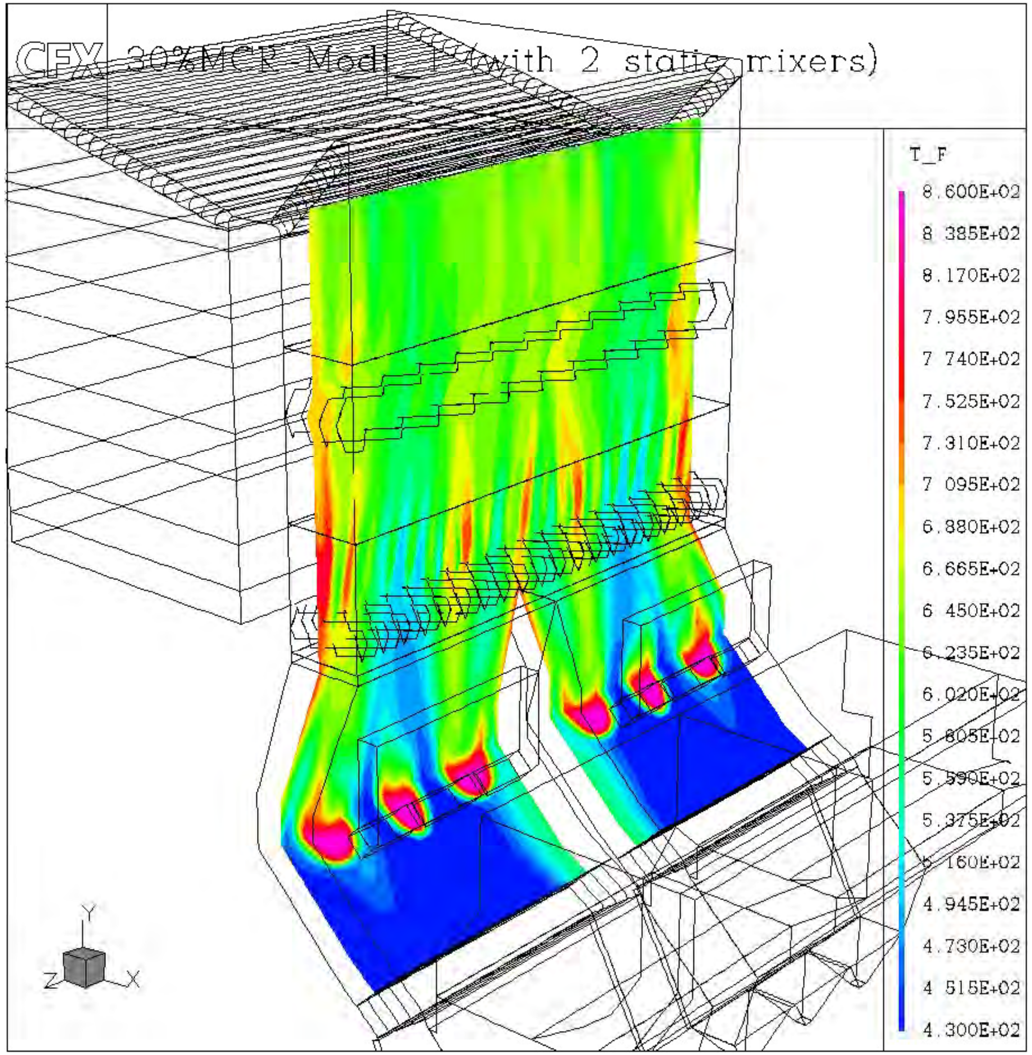
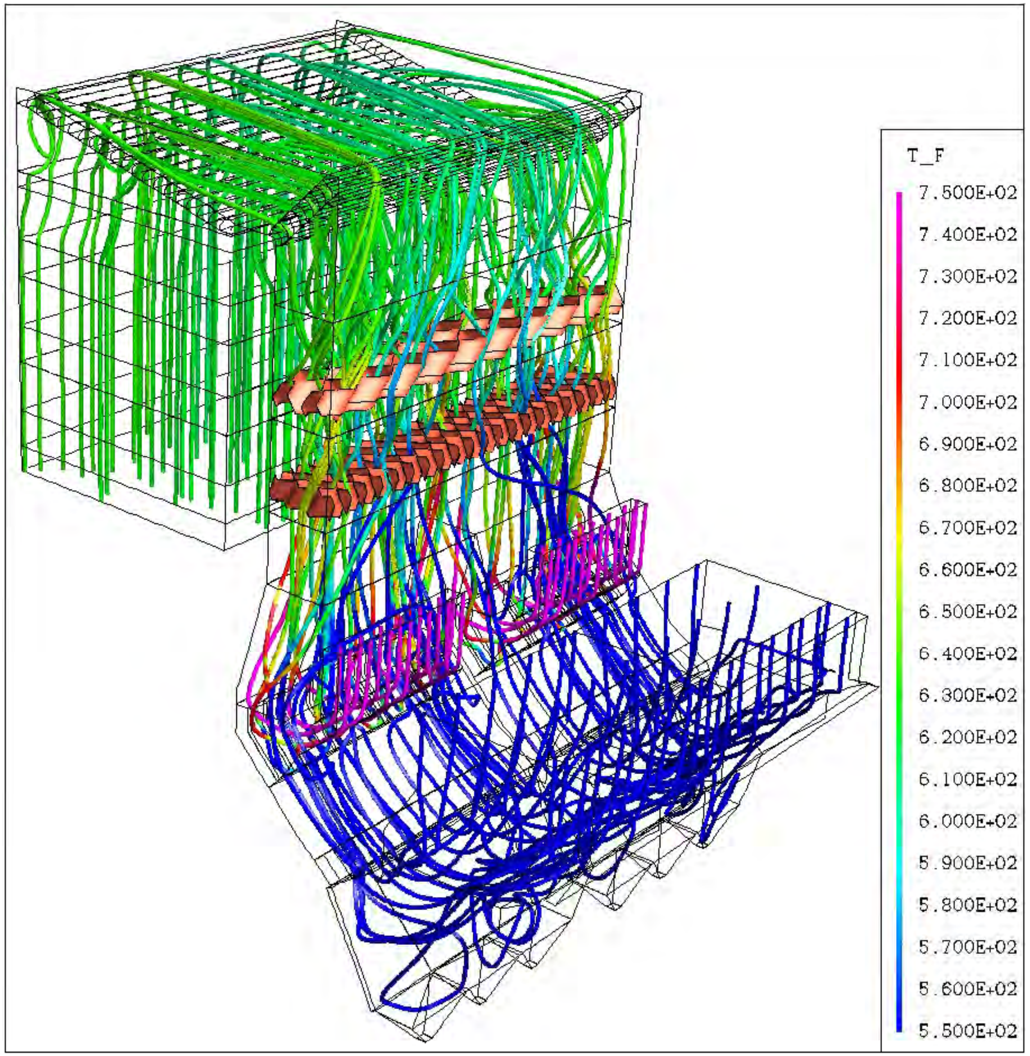
IDRECO DeNox – CFD Calculation





IDRECO DeNox – PHYSICAL MODEL STUDY

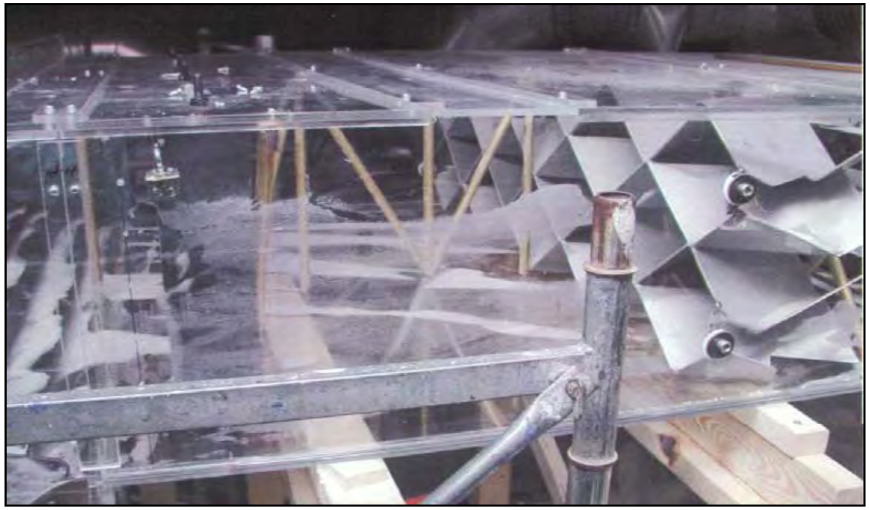
Model test for flue gas

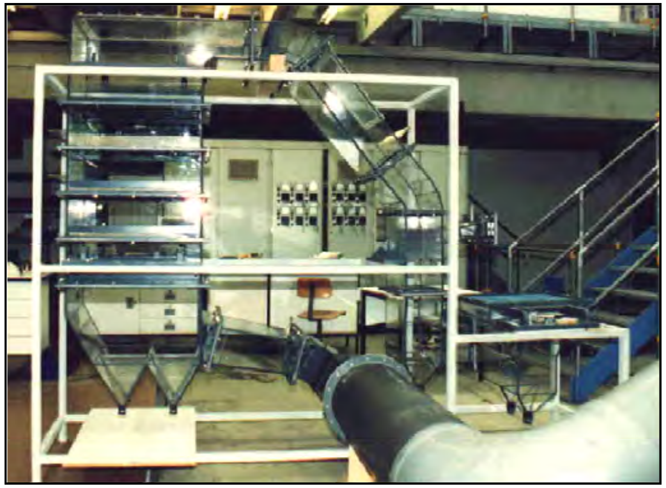
- Save design and scale up even at demanding process conditions

- Performance values for complex duct geometry

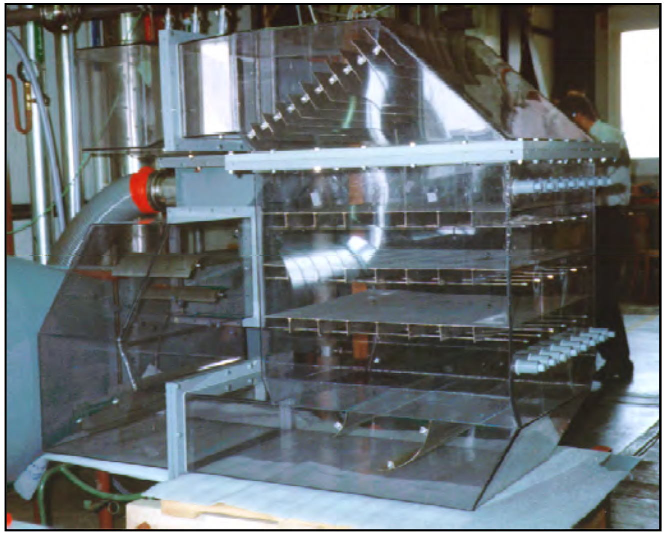
    - Homogeneity
    - Temperature deviation
    - Velocity distribution
    - pressure drop

- Elimination of dust deposits





C.T.E. ENEL – FIUME SANTO - ITALY



C.T.E. ENEL – LA SPEZIA - ITALY

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AIG AMMONIA INJECTION GRID WITH STATIC MIXER

AIG dosing system installed in a duct

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AIG AMMONIA INJECTION GRID WITH STATIC MIXER

STATIC MIXER installed in a duct

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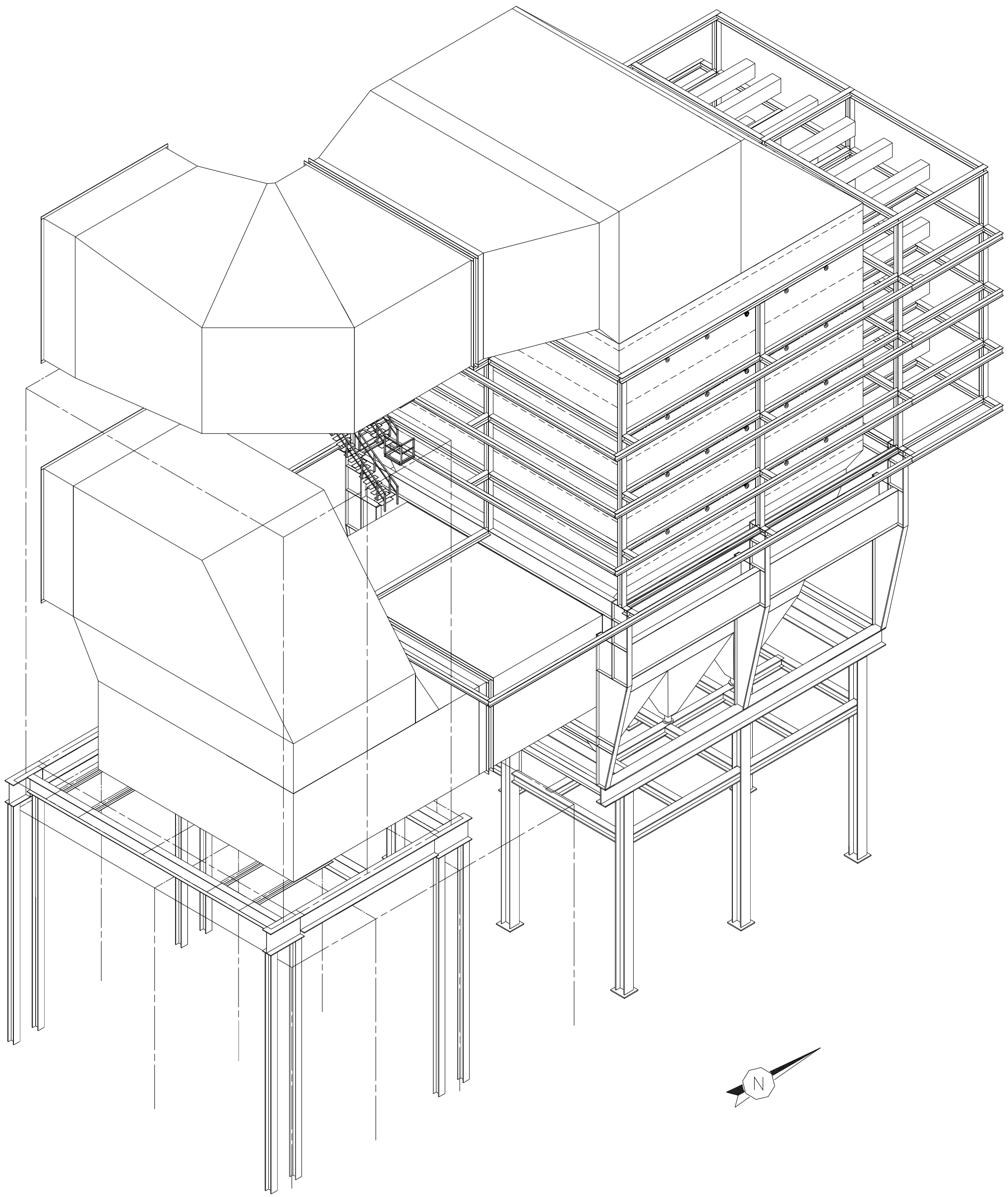
LA SPEZIA DeNOx REACTOR AREA BIRD VIEW



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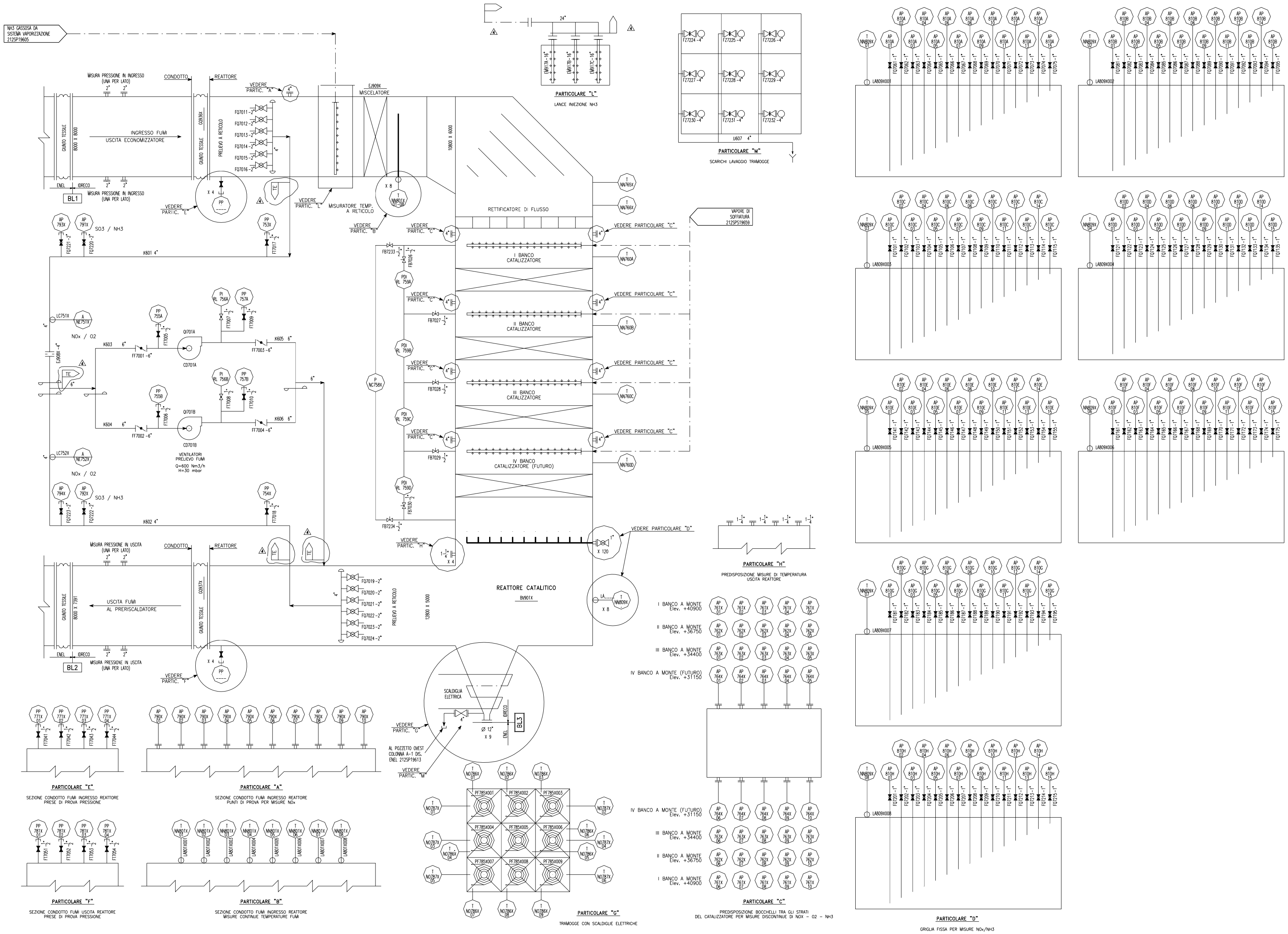
P&ID OF REACTOR SYSTEM



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LA SPEZIA DeNOx - REACTOR DESIGN DATA

	Unit	*Value*
GAS FLOW RATE	**Nm_3/h**	**1.800.000**
NOx INLET	**mg/Nm_3**	**900**
NOx OUTLET	**mg/Nm_3**	**< 190**
LEVELS OF CATALYST	**no.**	**3 + 1 future**
Consumption of NH_3 solution at 25%	**Kg/h**	**1.972**

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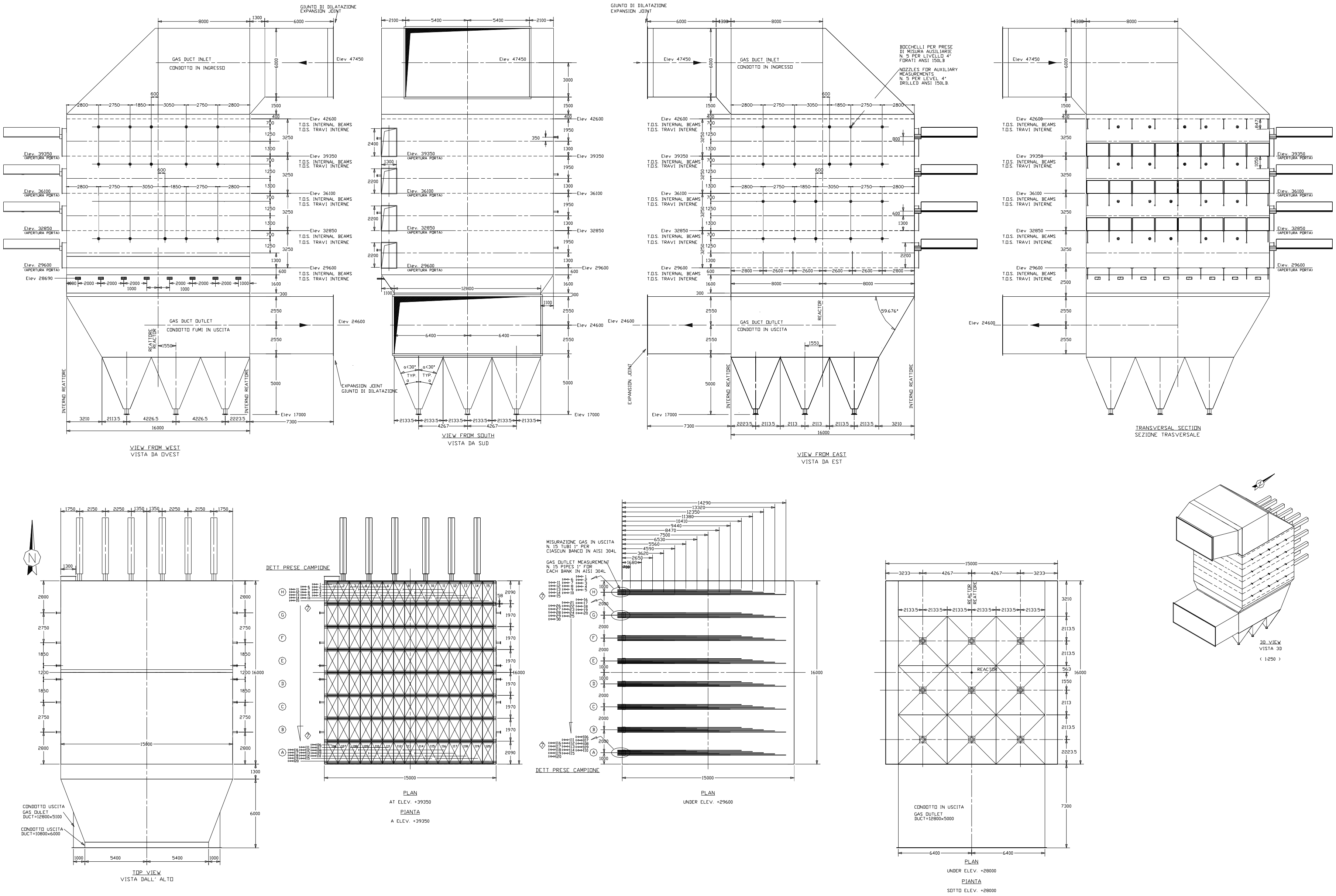
REACTOR OUTLINE



MATERIALS S.C.R “HIGH DUST” DENITRIFICATION

THE MAIN MATERIALS ARE AS FOLLOWS:

<u>REACTOR AND GAS DUCTS</u>

Steel Plates, Dust chutes, Flow rectifier and baffles/flow deflectors	**EN 10155 S355 JOWP**
Min Thickness of plates: 5 mm. for reactor and chutes and 6 mm. for the ducts	
External reinforcements, Beam for catalyst support (structural support parts)	**EU 28-85 16Mo3**
Outlet gas measurement fixed grid	**ASTM TP304L**
Connection of instruments	**ASTM TP316L**

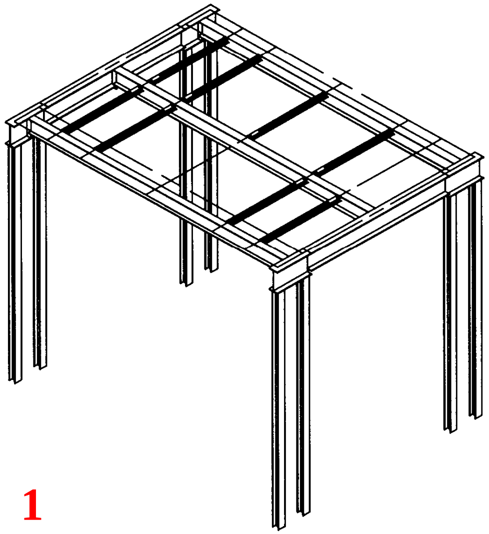
<u>REACTOR AND GAS DUCTS SUPPORTING STEELWORK</u>

Main supporting steel structures	**SO275 JO EN10025/95 (Fe 430 C)** **SO355 JO EN10025/95 (Fe 510 C)**

<u>PUMPS</u>

Casing and Impeller	**AISI 304L**

ERECTION SEQUENCE OF REACTOR & GAS DUCTS



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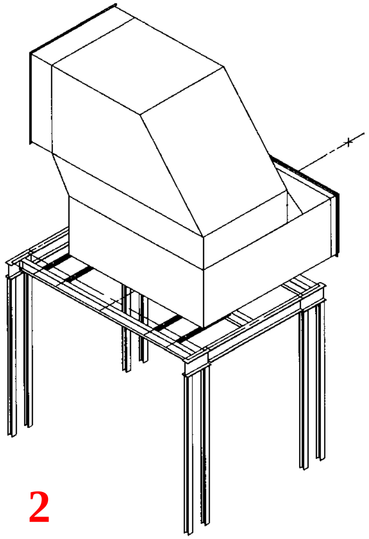

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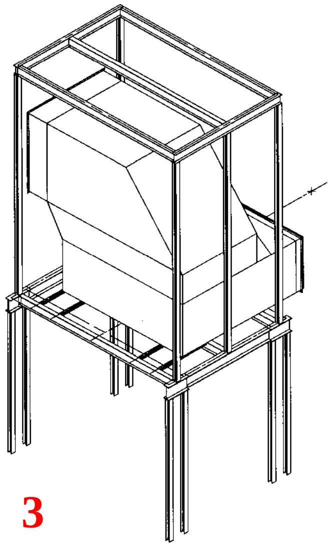

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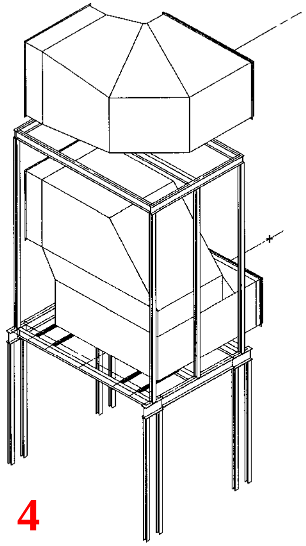

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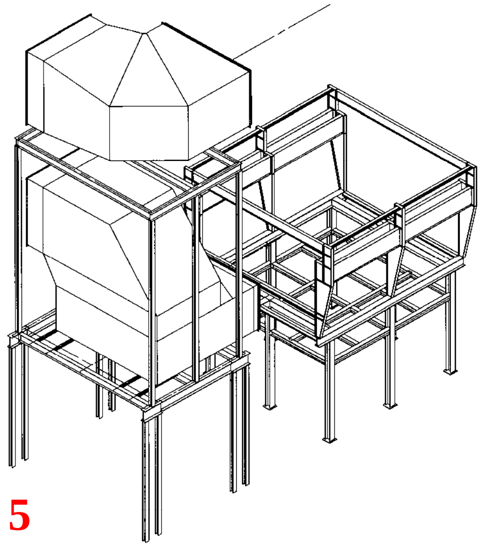

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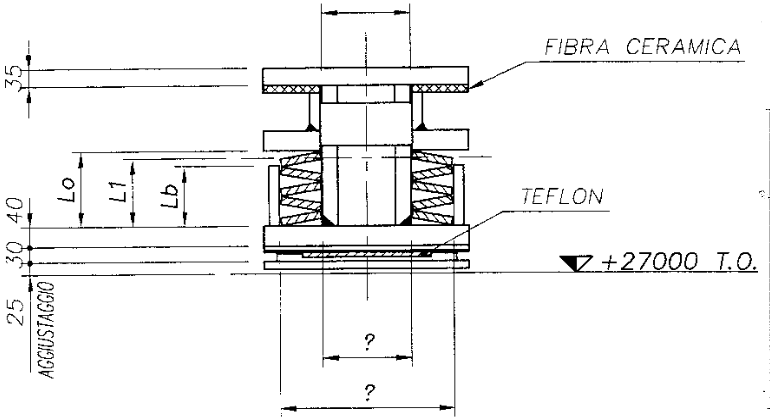
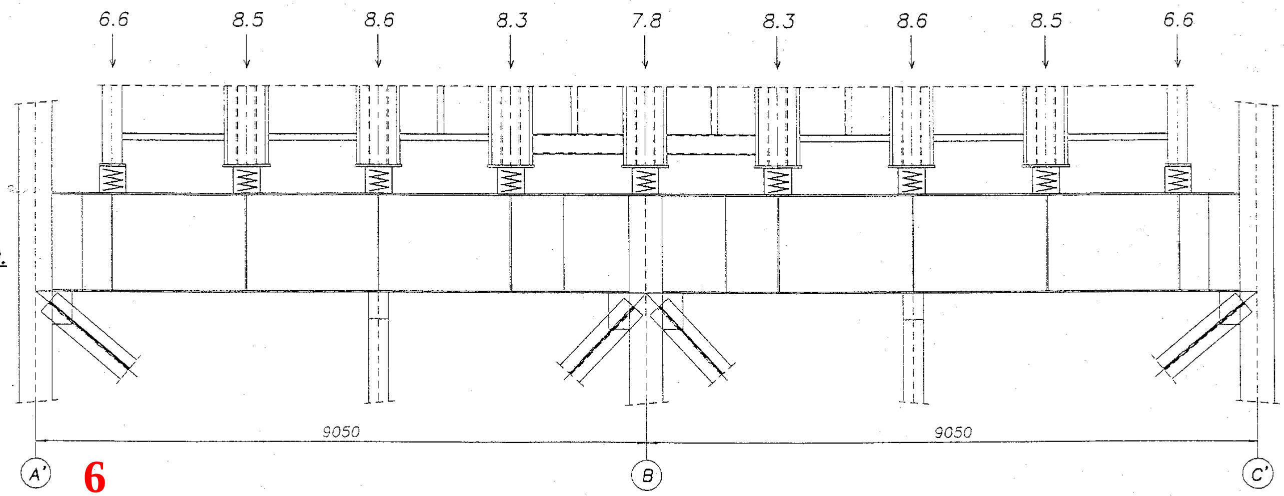


DETTAGLIO MOLLA



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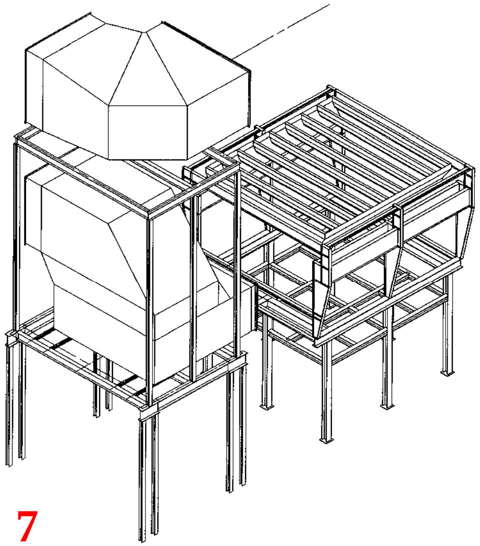
ERECTION SEQUENCE OF REACTOR & GAS DUCTS



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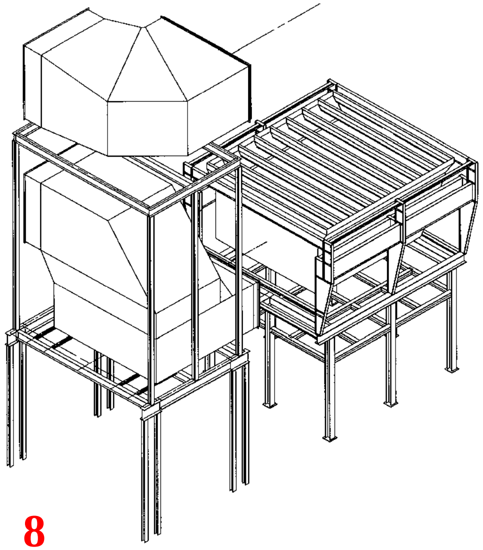

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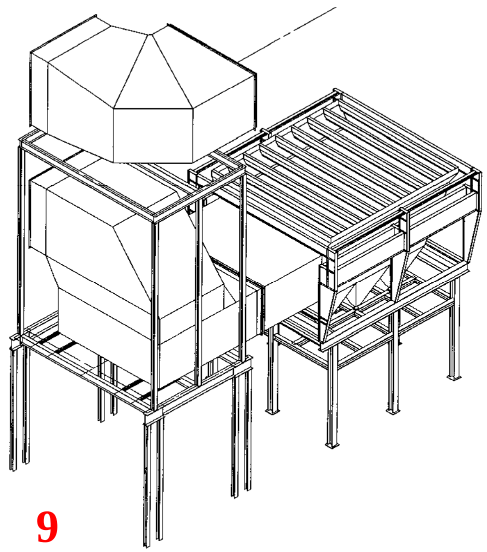

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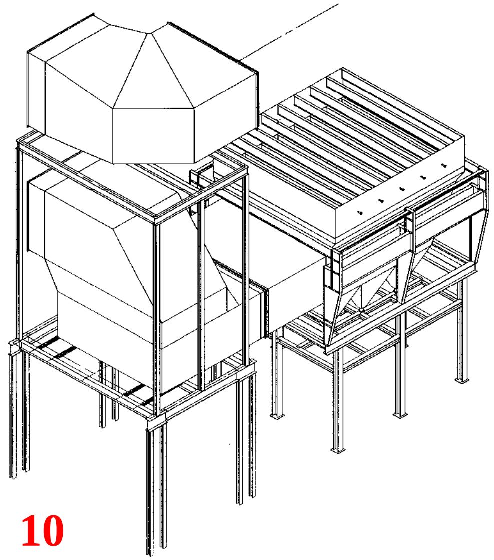

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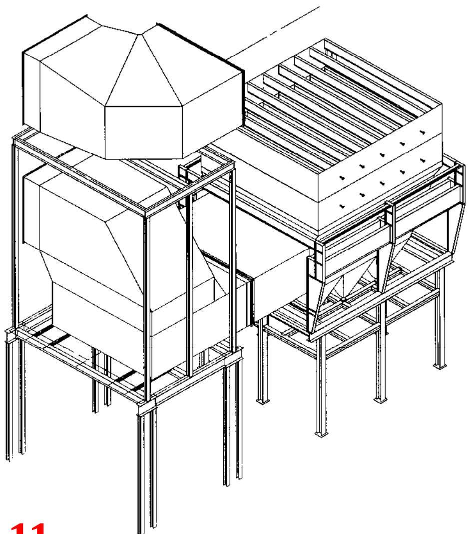

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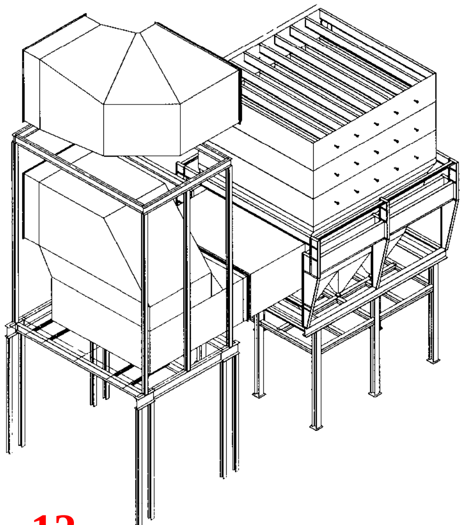

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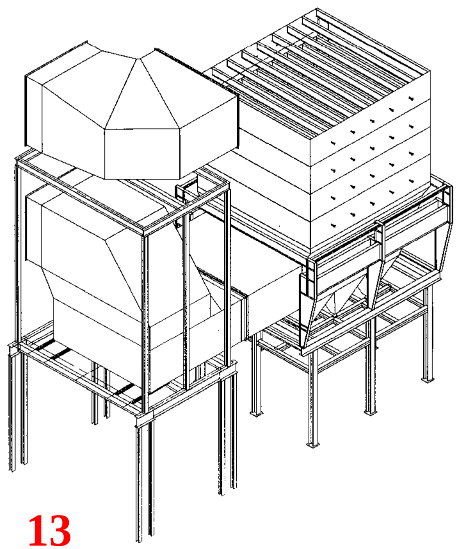

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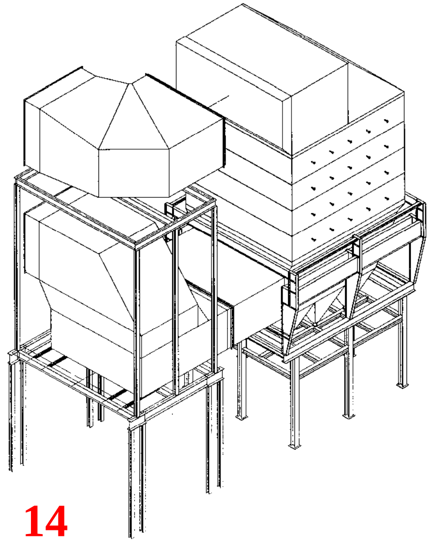

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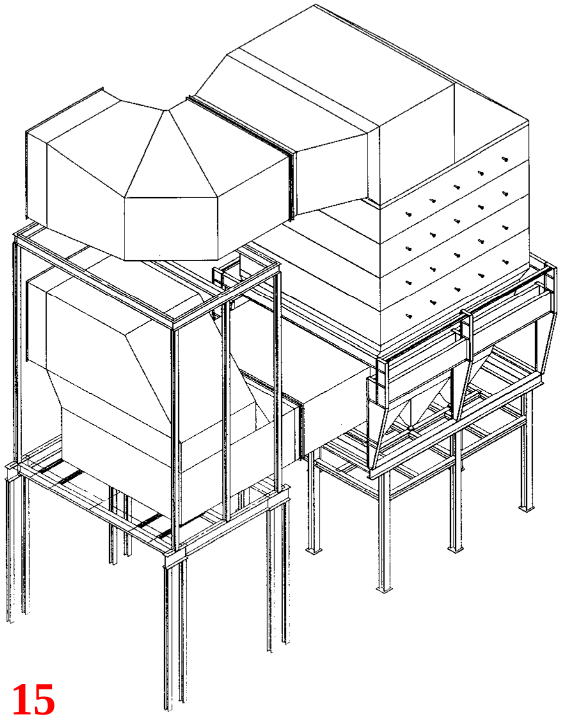
ERECTION SEQUENCE OF REACTOR & GAS DUCTS



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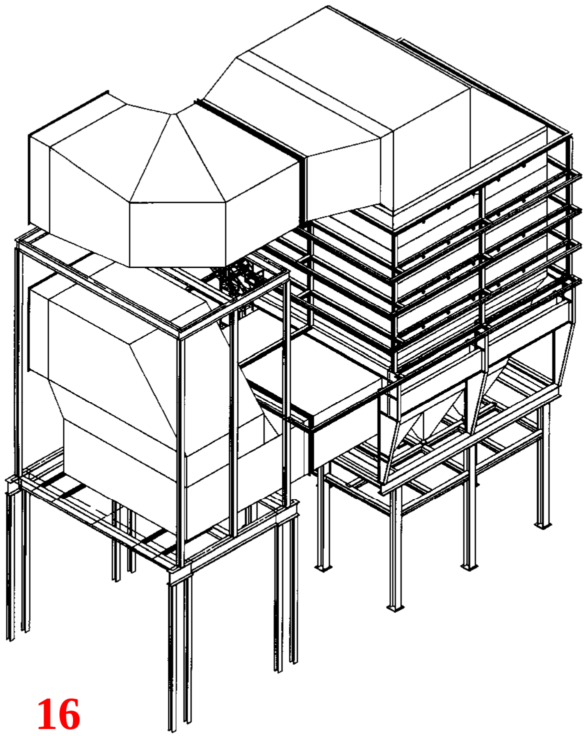

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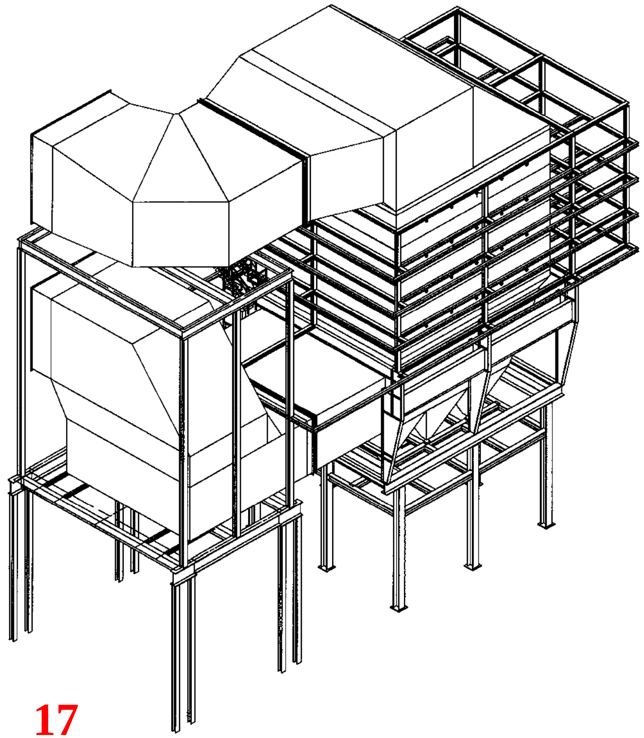

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LA SPEZIA DeNOx – DATA OF CATALYST

CATALYST	Type	HONEYCOMB
Main composition		
V_2O_5 Vanadium Pentoxide	% W	< 0,5
WO_3 Tungsten Trioxide	% W	< 9
T_iO_2 Titanium Dioxide	% W	80
Specific surface	m^2 / m^3	480 ± 15
Element dimensions	mm x mm	154 x 154 ± 3
Element height	mm	870 ± 8
Cells per elements (pitch)	no.	21 x 21
Module dimensions	mm x mm	1912 x 969
Module height	mm	1165 ± 3
Elements per module	no.	6 x 12
Modules per level	no.	120
Levels	no.	3
Total volume catalyst (levels/module)	m^3	178,3 / 535
Module weight	Kg	832
Module weight including packing	Kg	1168
Test elements per levels	no.	30

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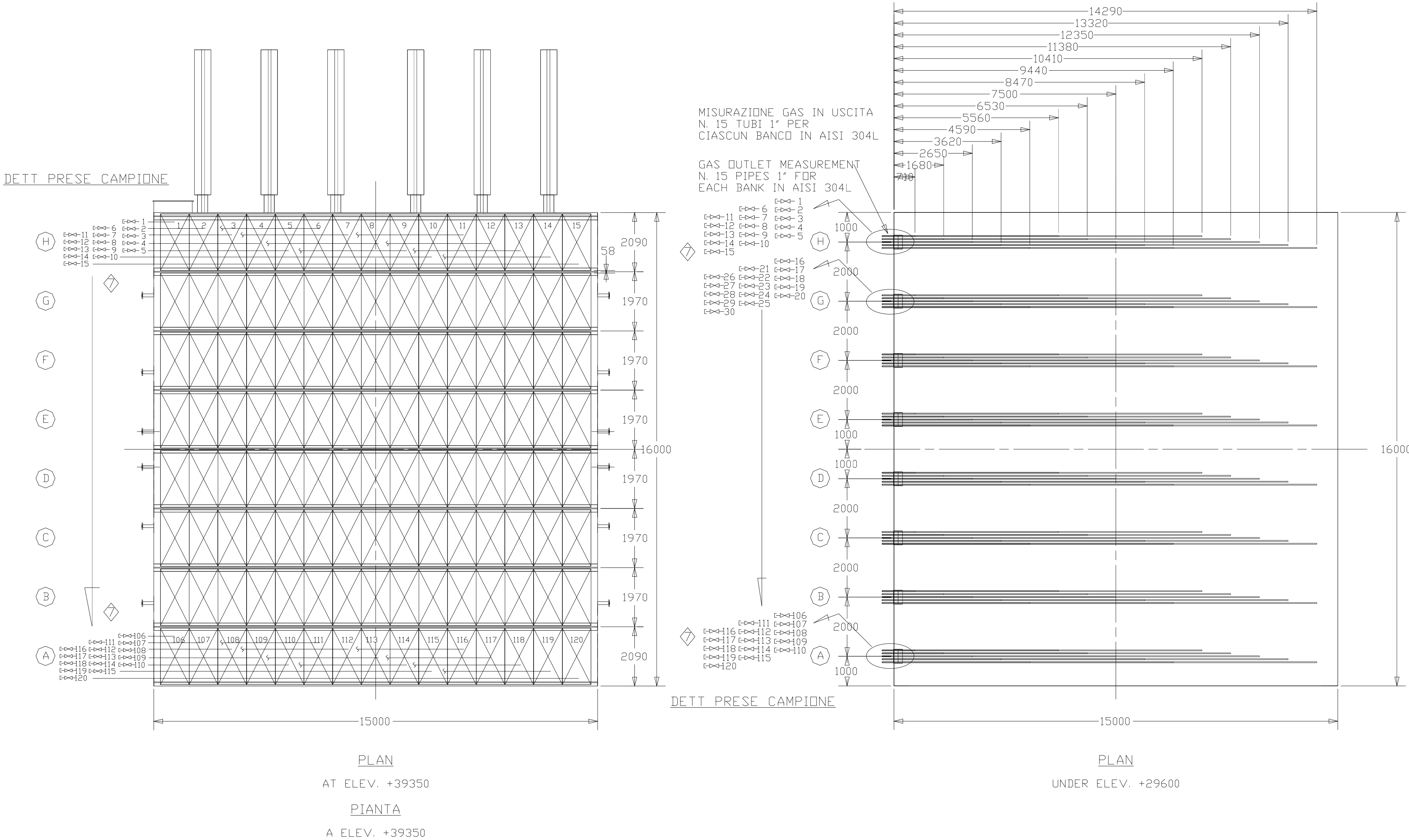
LAYOUT OF CATALYST WITH NOx MEASUREMENT POINTS



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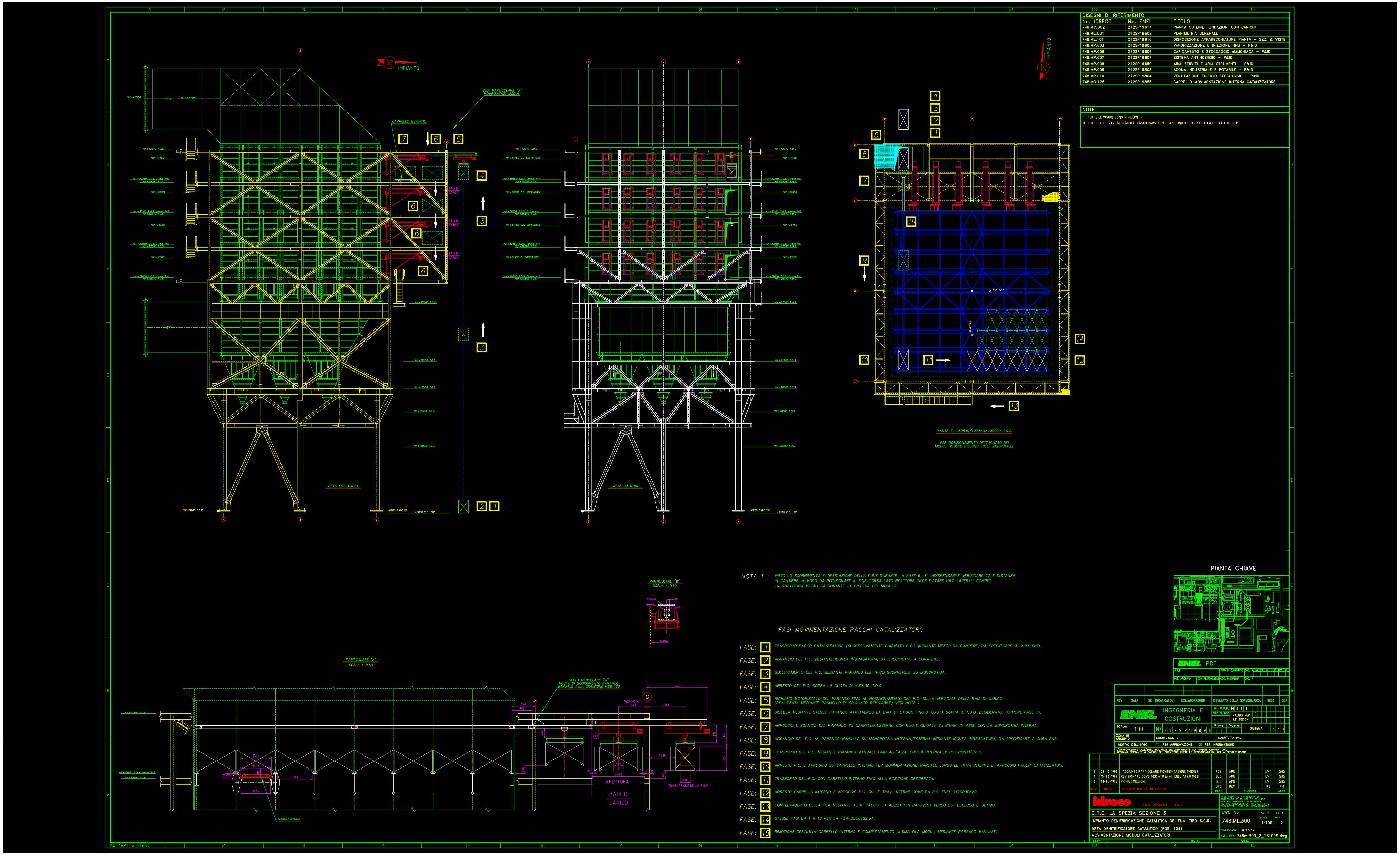
INSTALLATION OF CATALYST INTO THE REACTOR



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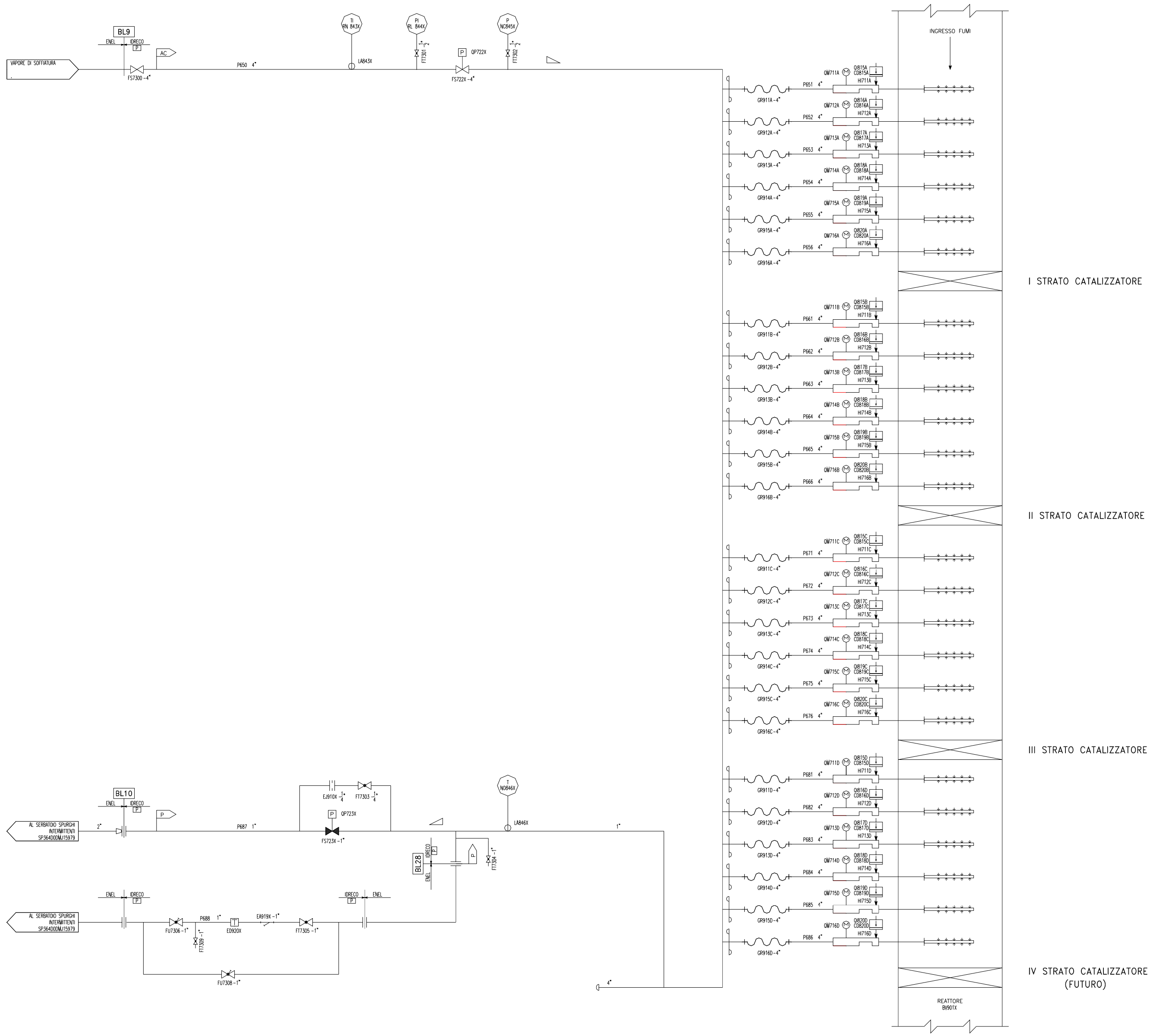
P&ID OF STEAM BLOWING FOR ASH CATALYST CLEANING



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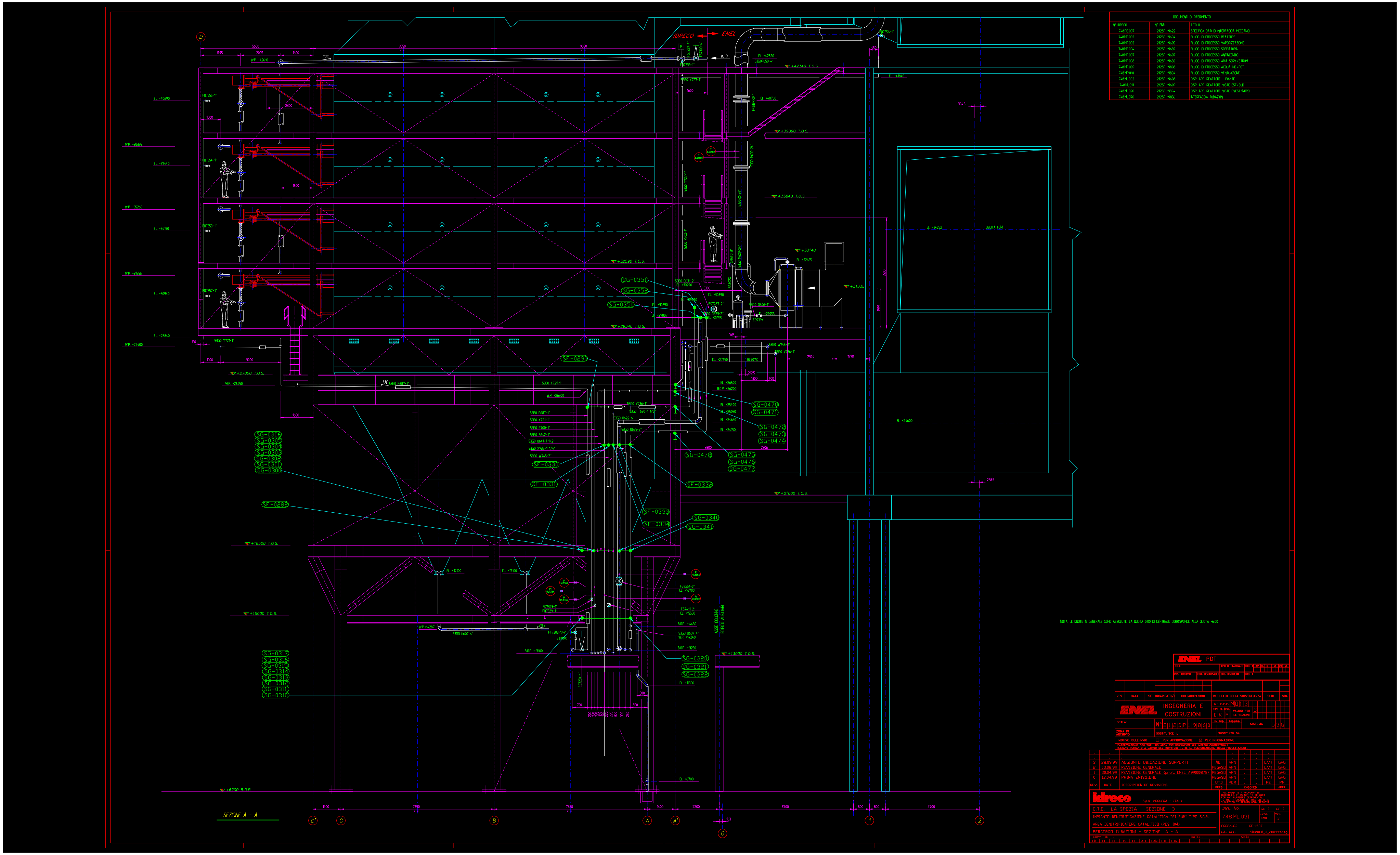
LAYOUT OF STEAM BLOWING



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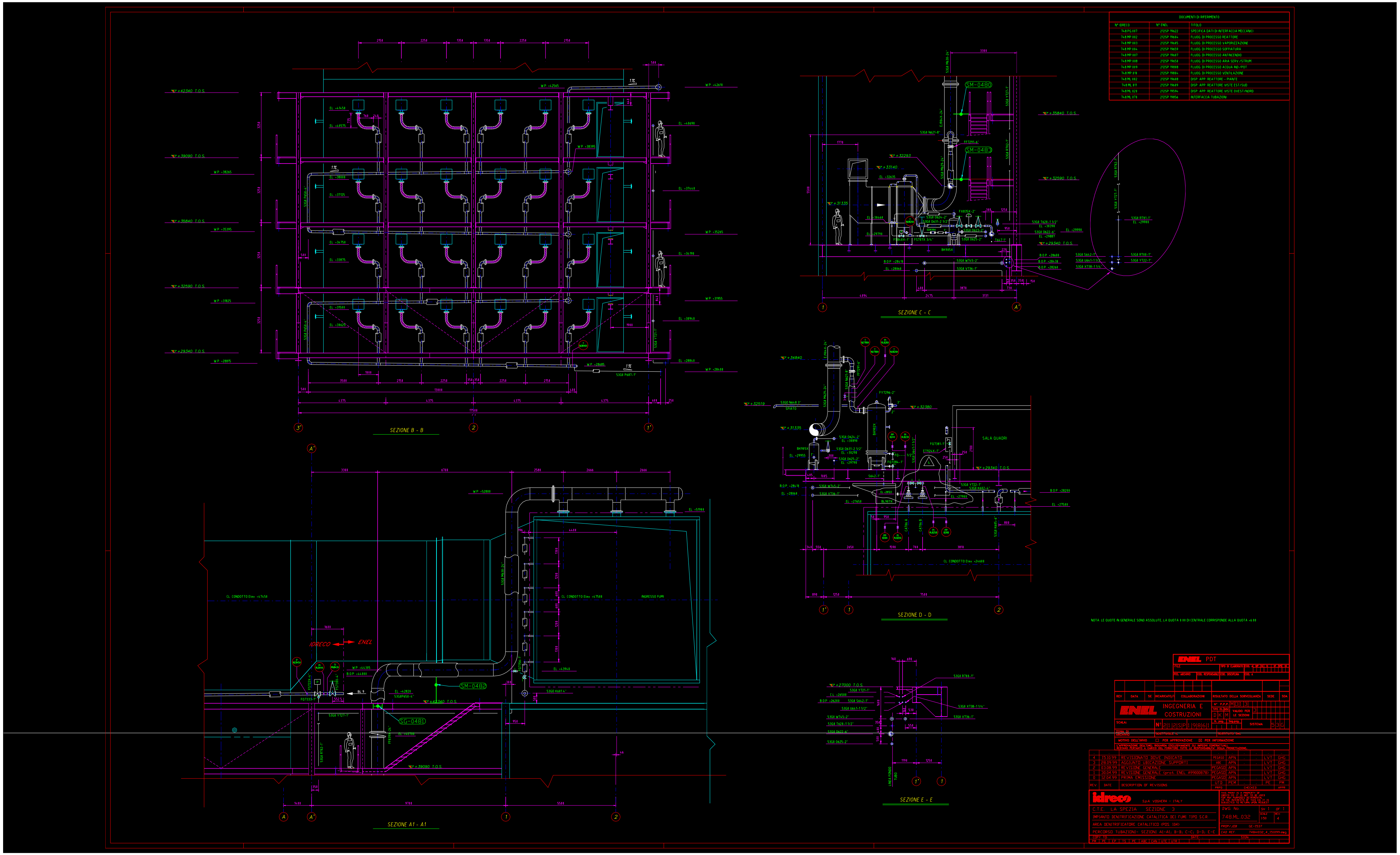
LAYOUT OF STEAM BLOWING AND NH_3 INJECTION



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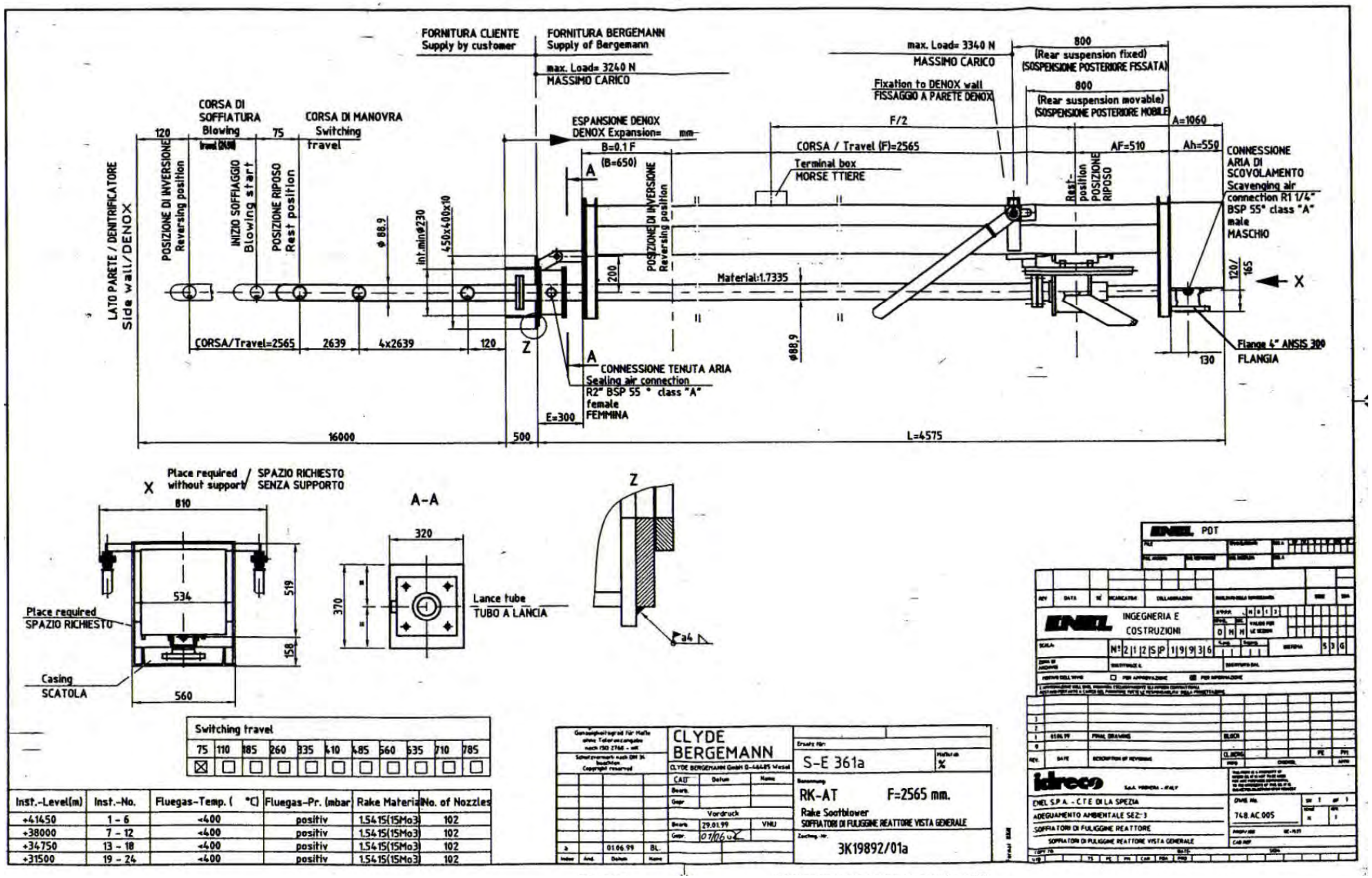
CATALYST CLEANING - RETRACTIBLE STEAM BLOWERS



Inst.-Level(m)	Inst.-No.	Fluegas-Temp. (°C)	Fluegas-Pr. (mbar)	Rake Material	No. of Nozzles
+41450	1 - 6	<400	positiv	1.5415(15Mo3)	102
+38000	7 - 12	<400	positiv	1.5415(15Mo3)	102
+34750	13 - 18	<400	positiv	1.5415(15Mo3)	102
+31500	19 - 24	<400	positiv	1.5415(15Mo3)	102

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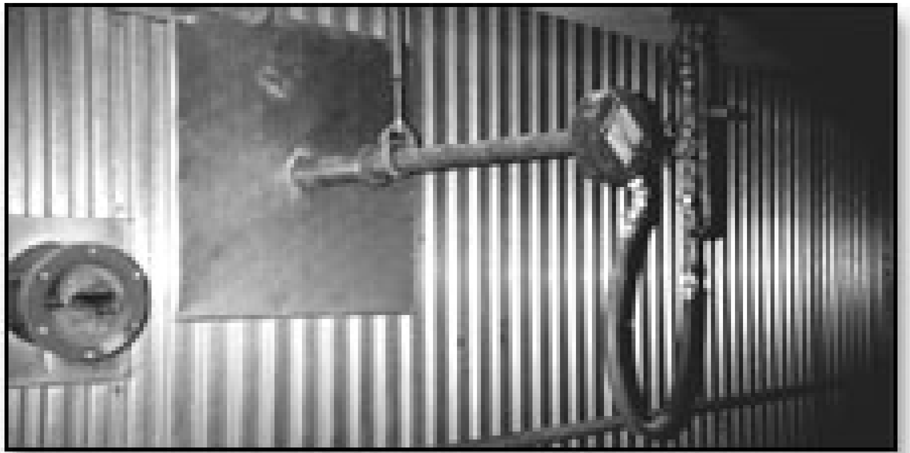
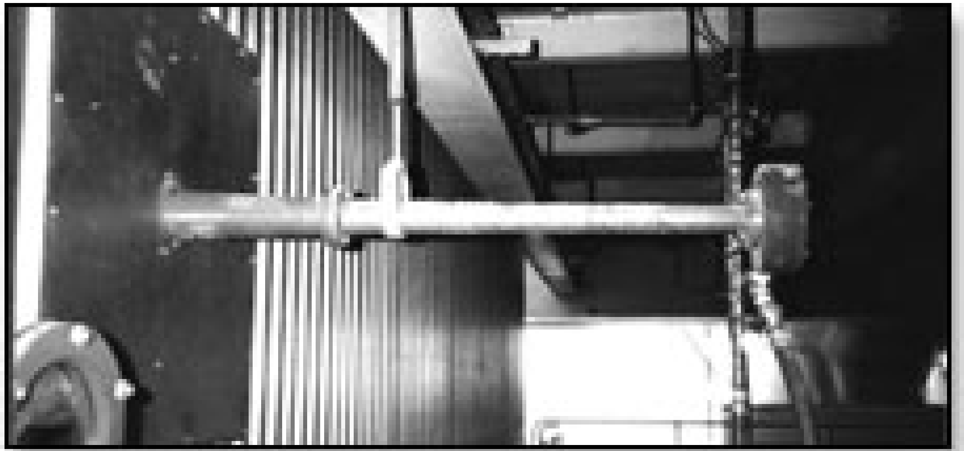
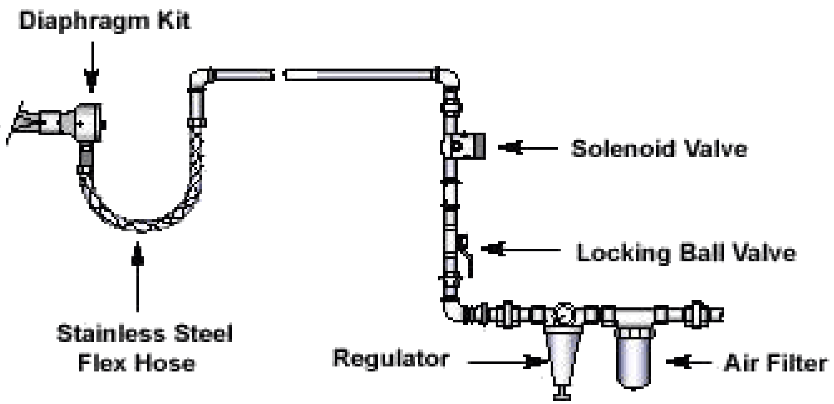
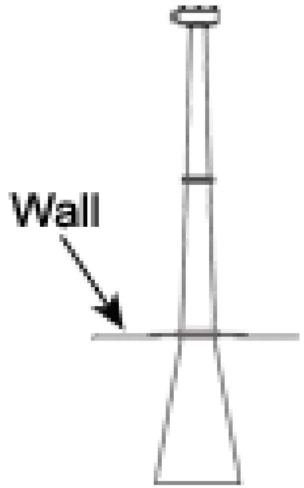
CATALYST CLEANING - ACOUSTIC ENERGY









Air supply requirements are simple, and are customized for each installation.

Acoustic energy is a viable, effective, and comparatively not expensive method for cleaning SCR catalyst. Acoustic cleaning has become the primary choice of OEMs on all SCR systems.

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Thank you !

STATE OF THE ART TECHNOLOGIES FOR AIR POLLUTION CONTROL