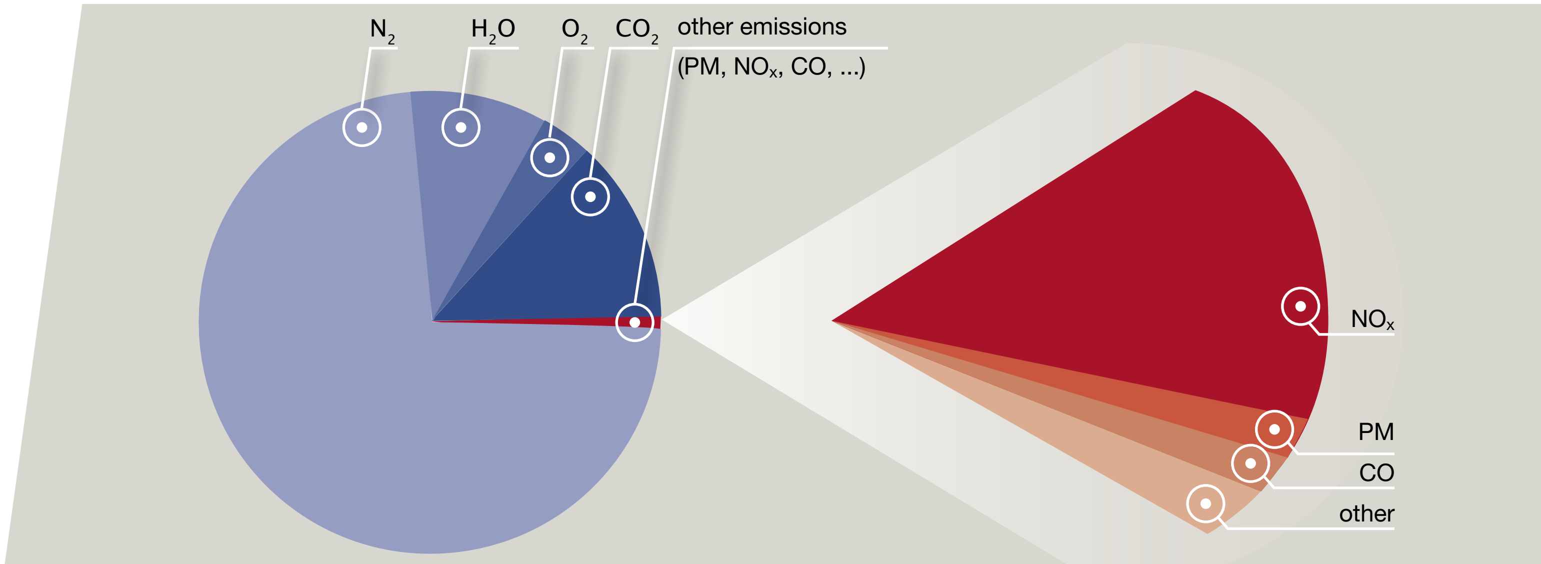
EMISSIONS

The subject of emissions is very wide and complex. The scientific literature in this field is under continuous update and there's no way to describe it briefly.
The boiler room is a source of pollution caused by the combustion of hydrocarbons. Combustion products consist mainly of nitrogen, carbon dioxide and steam delivered into the atmosphere through the chimney. The products of secondary combustion include a long list of chemicals, such as (CO), nitrogen oxides (NO_x), fine particulate matter (PM) and others. The normatives in force provide their max limits.
The level of emissions depends on many factors, including:
- fuel composition;
- shape of the combustion chamber and characteristics of the boiler;
- type of burner head.

For example, liquid fuels usually contain sulphur and other impurities.
These substances do not burn, therefore, if there is a need to reduce emissions, it is necessary to use a high-performance burner or to use complex systems for the treatment of fumes.
The emissions of nitrogen oxide also depend on the characteristics of the combustion chamber and the combustion head.
Due to the fact that the limit values required by the technical standards for the environmental protection are more and more restricted it is necessary to pay particular attention to propose a correct choice of burner and boiler.
CIB UNIGAS Technical Management keeps always an eye on new technologies to reduce emissions. For these reasons CIB UNIGAS has been investing in the development of low environmental impact burners.



Typical composition of fumes

Less polluting emissions

All CIB UNIGAS burners are certified for both gaseous and liquid fuels in accordance with European standards and meet the requirements for polluting emissions.
Measurements of CO and NO_x emissions are carried out on standard size boilers, on all test conditions.

TABLE: LIMIT VALUES FOR EMISSIONS OF NITROGEN OXIDES AND CARBON MONOXIDE ACCORDING TO THE EUROPEAN STANDARD

Type of fuel	Burner class	Unit of measurement	CO	NO_x	Standards
natural gas	Class 1	mg/kWh	100	170	UNI EN 676
natural gas	Class 2	mg/kWh	100	>80 <120	UNI EN 676
natural gas	Class 3	mg/kWh	100	>60 <80	UNI EN 676
natural gas	Class 4	mg/kWh	100	<60	UNI EN 676
LPG gas	Class 1	mg/kWh	100	230	UNI EN 676
LPG gas	Class 2	mg/kWh	100	180	UNI EN 676
LPG gas	Class 3	mg/kWh	100	140	UNI EN 676
LPG gas	Class 4	mg/kWh	100	110	UNI EN 676
light oil	Class 1	mg/kWh	110	250	UNI EN 267
light oil	Class 2	mg/kWh	110	185	UNI EN 267
light oil	Class 3	mg/kWh	60	120	UNI EN 267

CIB UNIGAS burners, NOx emissions:
- Low NO_x gas burners correspond to Class 2, Ultra Low NOx burners without FGR correspond to Class 3.
- LPG burners correspond to Class 1, Low NOx LPG burners correspond to Class 3;
- Oil burners have a maximum NOx emission of 250 mg/kWh (Class 1);
- Heavy fuel oil burners (non-standard fuel oil) can, in the worst case, reach a maximum NOx emission of 700 mg/kWh.

CIB Unigas also offers Low NO_x solutions for complex systems and revamping of existing plants.
As far as carbon monoxide (CO) is concerned, a properly set CIB UNIGAS burner delivers a very small CO level.

If necessary, CIB UNIGAS offers FGR (Flue Gas Recirculation) solutions – these are burners with flue gas recirculation system which deliver emissions of less than 50 or 30 mg/kWh. Burners with FGR are designed for installations with Low NO_x emissions requirements, such as greenhouses or boilers in large residential areas where low levels of contaminants are a priority. Our FGR solutions meet environmental impact requirements.

The burners belonging to the different classes of NO_x emissions are identified by the following logos:

Often non-EU countries follow different normatives and measurement conditions. To ensure that the levels of pollutant emissions are always correct, it is necessary to know exactly the conditions in which tests were carried out, i.e. measurement of the gas, the error, type of fuel, boiler size, atmospheric conditions, etc.
In addition, standards can use different units of measurement*, therefore for the comparison, it is necessary to translate the limit values expressed as follows in mg/kWh (milligrams per kilowatt hour), using the correct formula, depending on the selected fuel and residual oxygen in the exhaust gases.
* For example: ppm (parts per million), mg/Nm^3 (milligrams per normal cubic meter), etc.

SULFUR OXIDES EMISSIONS

The polluting emissions of sulfur oxides (SO_x) mainly include sulfur dioxide (SO_2) and trioxide (SO_3). These chemicals are particularly aggressive and dangerous, both for the environment and human health.
However, sulfur oxides represent a separate case from CO and NO_x since their production during hydrocarbons combustion does not depend on the burner, nor on the boiler, but only on the quantity of sulfur already present in the fuel upstream of the process.
On the one hand, higher quality, gaseous fuels (methane, LPG) include insignificant amounts of sulfur, and the use of these fuels minimizes hazardous emissions. On the other, the problem is evident in liquid fuels (especially crude oil and heavy fuel oil), whose composition always includes a certain amount of sulfur - it will inevitably be oxidized in the combustion chamber and emitted as SO_x pollutant.

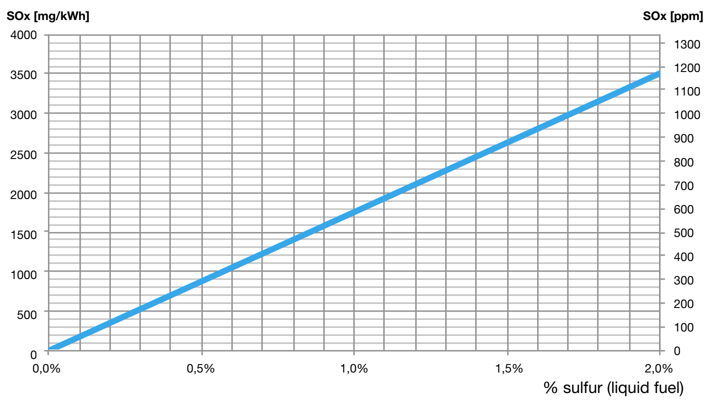
It is possible to estimate the quantity of SO_x produced with the diagram on this page, or with the following procedure.
Given the quantity of sulfur present in the fuel (expressed as a percentage by mass), just multiply this value by a numerical factor, 1.750.
The resulting number represents the emissions of SO_x at the chimney, expressed in mg/kWh.

Example
Given a fuel that contains 0,5 % sulfur, SO_x emissions will be equal to
0,5 x 1.750 = 875 mg/kWh

Conversely, once the SO_x emission limit is known for a given thermal plant, it is possible to calculate the maximum admissible sulfur concentration in the fuel, dividing by the same coefficient above.

Example
Let 300 mg/kWh be the SO_x emission limit required by project specifications.
The maximum percentage of sulfur in the fuel can be 300 : 1.750 = 0,17
The numerical result represents directly the percentage in mass: 0,17 %.

If the fuel oil contains a higher fraction of sulfur, the required limit will be exceeded, regardless of burner or boiler selection!



Reference conditions
Heavy fuel oil with net heating value Hi = 9.800 kcal/kg
Residual oxygen at the chimney O_2 = 3 % (λ = 1,15)

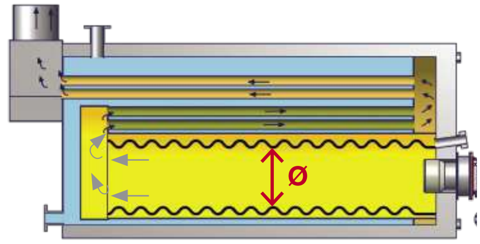
WHY DIFFERENT THERMAL GROUPS RELEASE DIFFERENT LEVELS OF NITROGEN OXIDES AT THE SAME OUTPUT?

The CO, NO_x and other pollutants are strongly influenced by a number of factors, not always burner related. There are factors independent from the thermal plant, such as environmental conditions (altitude, humidity, fuel composition, etc…) and factors related in particular to the design of the generator. The most important factors are summarized below.
It becomes evident that burner and boiler must be evaluated as a single thermal group, in order to comply to the rule on emission levels, or to the specific requirements of designers. The correct match between burner and boiler is discussed in greater detail on the following pages.

BOILER TYPE

↓

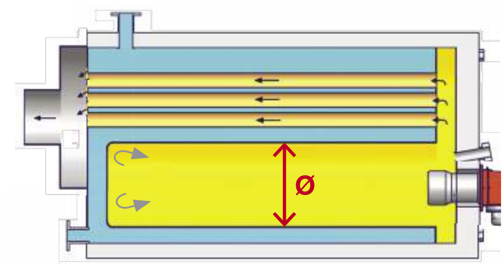
- type of generator (reverse flame, or 3 smoke-pass)
- dwell time of the flame within the combustion chamber
- heat exchange surface
- temperature and type of heat transfer fluid



DIMENSIONS OF THE COMBUSTION CHAMBER

↓

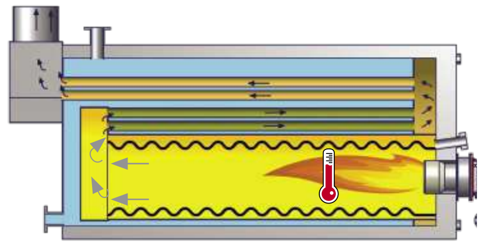
- combustion chamber internal gas circulation
- dwell time of the flame within the combustion chamber
- thermal load of the chamber



THERMAL LOAD OF THE COMBUSTION CHAMBER

↓

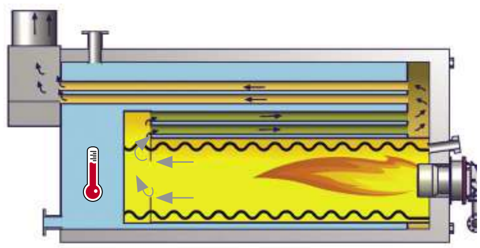
- flame temperature
- speed at which the NO_x is formed



BOILER TEMPERATURE

↓

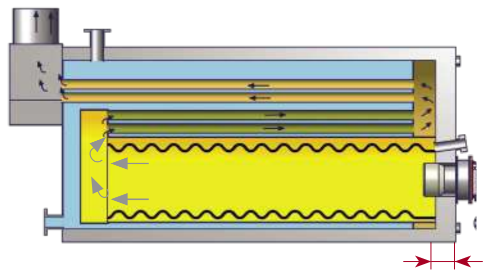
- flame temperature
- speed at which the NO_x is formed



THICKNESS OF THE REFRACTORY OR BOILER DOOR

↓

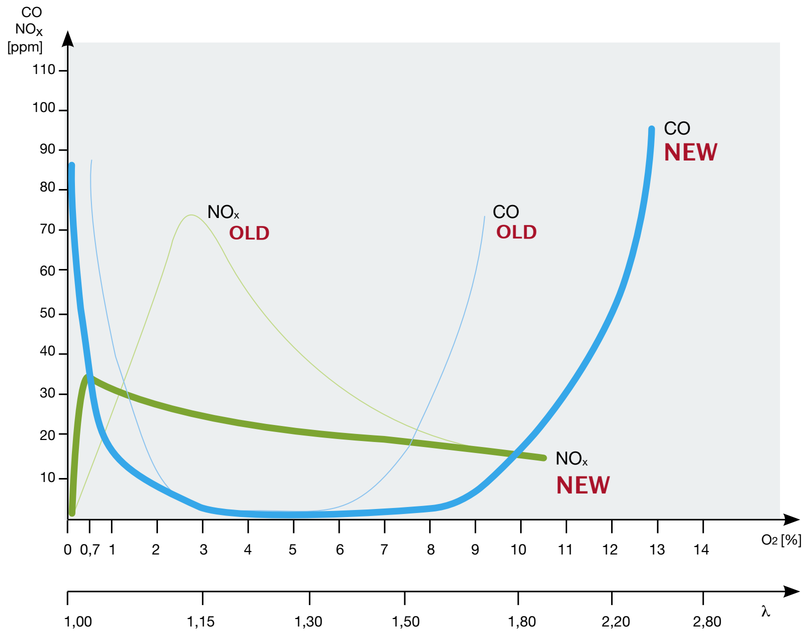
- length of the combustion head
- internal combustion gas circulation



Reverse flame boilers: contact our Technical Department.

Relation between NO_x emissions and CO

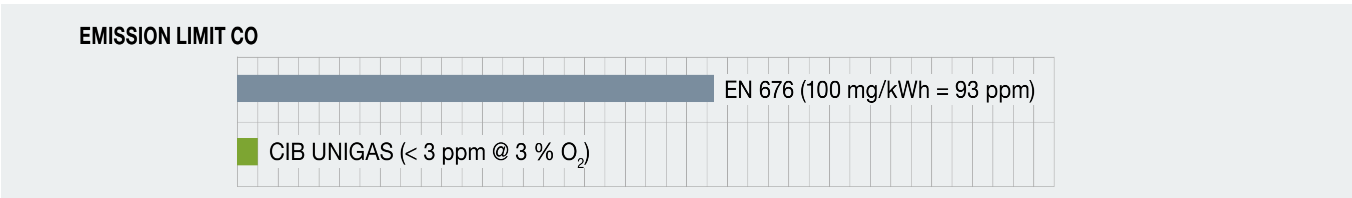
Emissions of nitrogen oxides and carbon monoxide are strongly correlated as both depend on the stoichiometry of the combustion. Excess of air affects both emissions and the efficiency of the generator. In a logic of compromise, reducing fuel consumption requires a reduction of excess air.
The limit is given by the emission of CO.
In the burners of the previous generation this choice had priority on NO_x emissions.

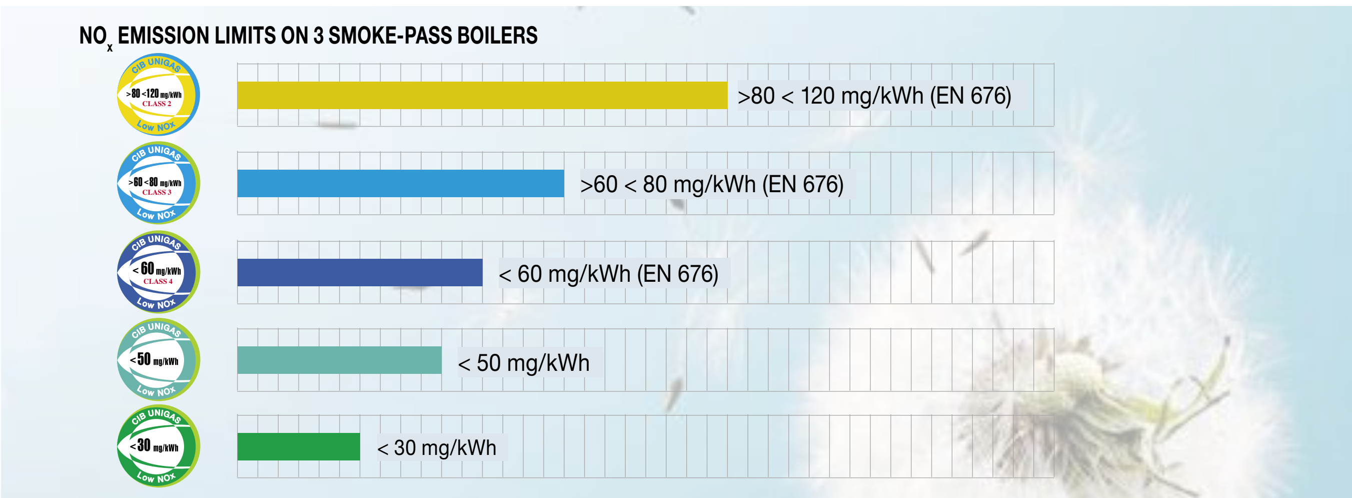


THE "ECOLOGIC" BURNER SERIES HAS REACHED A GREAT GOAL: WIDE RANGE OF COMBUSTION FLEXIBILITY

The development of low burners emissions represent a real revolution in the way NO_x and CO interact when changing the excess of air.
The new series of Low NO_x burners from the CIB UNIGAS ensures zero CO values in a very wide range of operation, with residual oxygen between 0,5 % and 8 %, while maintaining low NO_x emissions almost constant.
The advantage is obvious: the careful choice of the generator makes possible, for example, to set the oxygen at 1,5% without formation of CO; increasing the efficiency of the thermal group
without deteriorate the NO_x emissions.
It is economical and ecological.

ECOLOGIC





Reverse flame boilers: contact our Technical Department.

MATCHING LOW NO_x BURNER AND HEAT GENERATOR

The procedure to match a burner and evaluate the emissions attainable by a thermal unit can be divided in a few simple steps. The first one is to check the operating point of the generator and select a suitable burner size. The next step is to calculate the thermal load of the combustion chamber and use this data to estimate NO_x emissions.
In the case of standard boilers, proceed in the following way.

Introduction
To choose the proper burner, the following data are necessarily required:
- Boiler type
- Burner input
- Backpressure in the combustion chamber
- Dimensions of the combustion chamber included the reverse smoke chamber
- NO_x emissions requested, 80, 50, 30 mg/kWh.

The counting procedure is divided into three steps:
- choosing the burner;
- choosing the depowenty burner output to obtain the correct emissions;
- choosing the combustion head length.

CHOOSING THE BURNER

To clearly explain the procedure about choosing a suitable burner, please follow the example:

Boiler type	3 pass
Furnace input	950 kW
Backpressure in the combustion chamber	6 mbar
Dimensions of the combustion chamber	Length L = 1.750 mm (1,75 m)
Smoke reverse chamber	Length L = 250 mm (0,25 m)
Total length of the calculation	Length TL = 2.000 mm (2,0 m)
Diameter	Diameter D = 680 mm (0,68 m)
Calculation combustion chamber volume	D x D x 0,78 x TL 0,68 m x 0,68 m x 0,78 x 2,0m = 0,72 m^3
Calculation thermal load	950 kW /0,72 m^3 / 1.000 = 1,31 MW/m^3
Gas type	Natural gas

Procedure
First, identify the burners whose requested output is included within their performance curves.

BURNER SELECTION FOR NO_x < 80 mg/kWh

Reference conditions
- Measurement tolerances according to EN 676 standard
- Temperature: 20 °C
- Dried flue gases
- Barometric pressure: 1013 millibars
- Relative humidity: 70 % (equivalent to 10 g H_2O/kg of air)
- Boiler temperature: 110 °C
- Fuel: G20 (natural gas, 100 % CH_4)
- Three-smoke pass boiler

PERFORMANCE CURVE OF THE BURNER

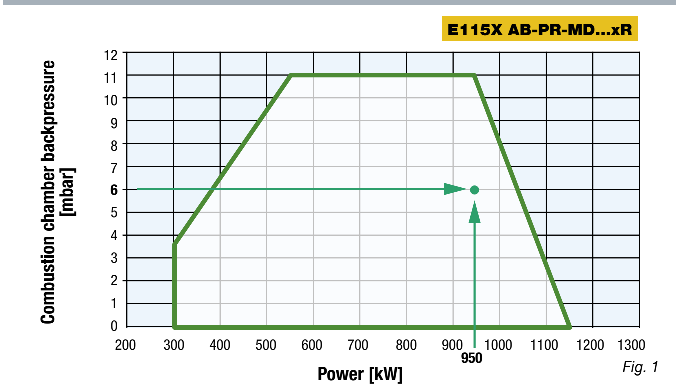


Fig. 1

NO_x DIAGRAM IN REFERENCE TO THE THERMAL LOAD

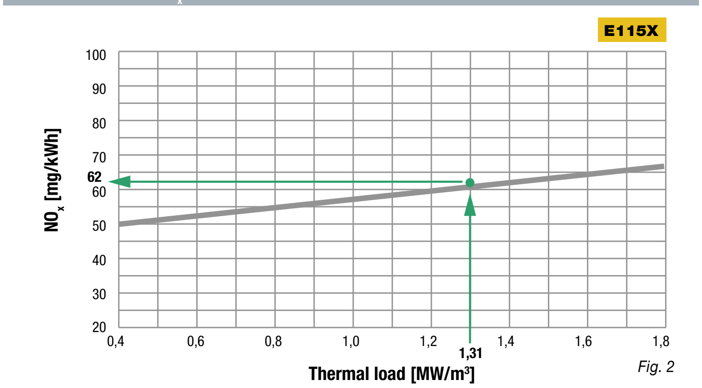


Fig. 2

The required operating point is inside of Low NO_x burner model E115X (Fig.1).

In the thermal load - NO_x diagram (Fig. 2) of the selected burner, find the calculated thermal load, draw a vertical line to meet the the NO_x curve and read the value on the ordinate.

In the example, it is possible to estimate an emission of approximately 62 mg/kWh at 3% O_2 of NO_x.
Diagrams of the various models are given on the following pages.

COMBUSTION HEAD LENGTH SELECTION

The final step is to check combustion head dimensions, in relation to combustion chamber, because they are a critical parameter to obtain the expected emissions.
Two conditions should be met:

1) It is recommended that the diameter of the chamber is 2,5 to 3 times larger than the diameter of the burner combustion head.
2) The low NO_x combustion head must penetrate 150÷200 mm into the combustion chamber.

In the cited example, the boiler chamber diameter was 680 mm, so the optimal combustion head diameter lies in the range between 215 mm and 270 mm.
The dimensional table on page 95 or 100 shows that E115X combustion head diameter is equal to 219 mm, thus the first condition is met.
Regarding the combustion head length, suppose the boiler door is 219 mm thick, refractory included. The combustion head must penetrate at least 150 mm as said above, thus the long combustion head variant is selected (390 mm). The short combustion head (305 mm) is insufficient as it only penetrates by 85 mm into the combustion chamber.
In this case we have 170 mm.
To properly install the burner, please refer to Fig. 3 to the side.
Of course, it is possible to carry out the reverse procedure as well: given an emission limit that cannot be exceeded by design, the NO_x diagram provides the admissible thermal load for a given heat generator. This way, designer can select a suitable boiler based on project specifications and required power. In any case, burner combustion head dimensions must be checked to complete the matching procedure.

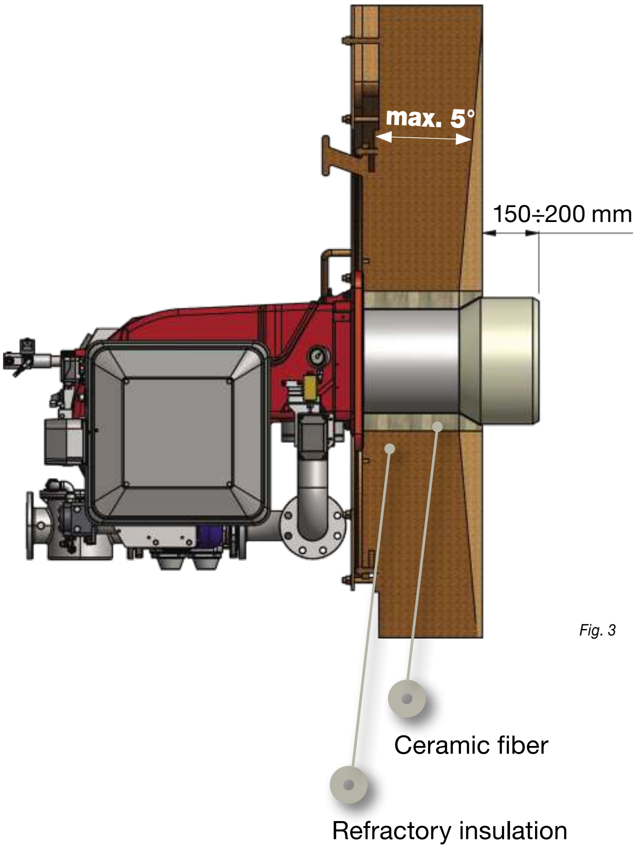


Fig. 3

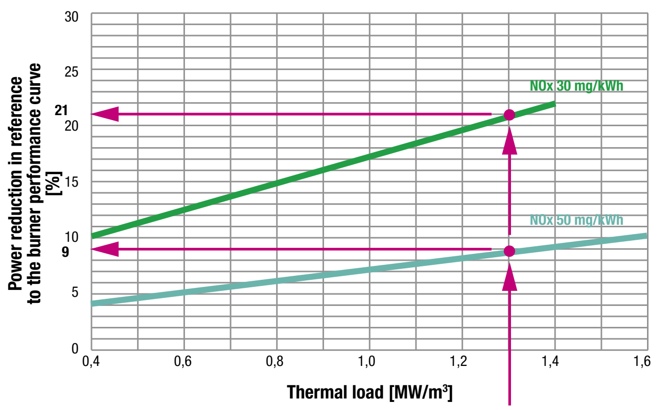
Reverse flame boilers: contact our Technical Department.

BURNER SELECTION FOR NO_x < 50 mg/kWh and < 30 mg/kWh

With NO_x < 50 mg/kWh and < 30 mg/kWh we need to have a smoke recirculation (FGR).
The smoke recirculation decreases a percentage of the performance curves and increases the backpressure in the combustion chamber. This percentage depend also of the thermal load of the combustion chamber.
In order to select the correct burner we can calculate the depowering percentage needed.

SELECTION 1: E115X

OUTPUT REDUCTION IN REFERENCE TO THE BURNER PERFORMANCE CURVE

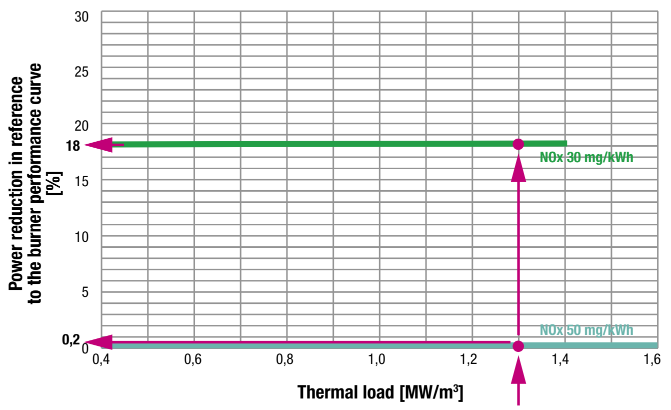


< 50 mg/kWh
In the selection 1 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 9 %.

< 30 mg/kWh
In the selection 1 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 21 %.

SELECTION 2: E150X

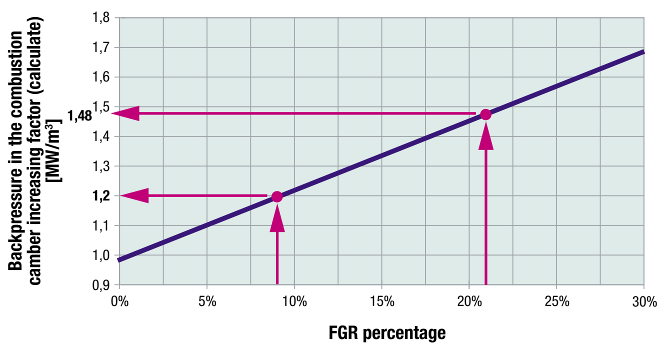
OUTPUT REDUCTION IN REFERENCE TO THE BURNER PERFORMANCE CURVE



< 50 mg/kWh
In the selection 2 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 0,2 %.

< 30 mg/kWh
In the selection 2 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 18 %.

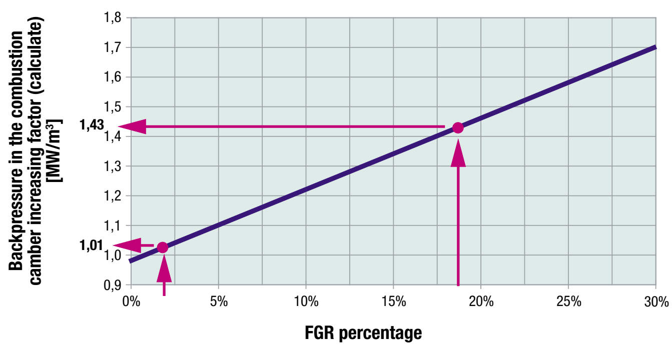
BACKPRESSURE IN THE COMBUSTION CHAMBER INCREASING FACTOR CHART (CALCULATE)



< 50 mg/kWh
In the selection 1 with the thermal load 1,31 MW/m³ the percentage of the depowering of the burner is 9 %, and the backpressure in the combustion chamber increases
6 mbar x 1,2 = 7,2 mbar.

< 30 mg/kWh
In the selection 1 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 21 %, and the backpressure in the combustion chamber increases
6 mbar x 1,48 = 8,9 mbar.

BACKPRESSURE IN THE COMBUSTION CHAMBER INCREASING FACTOR CHART (CALCULATE)



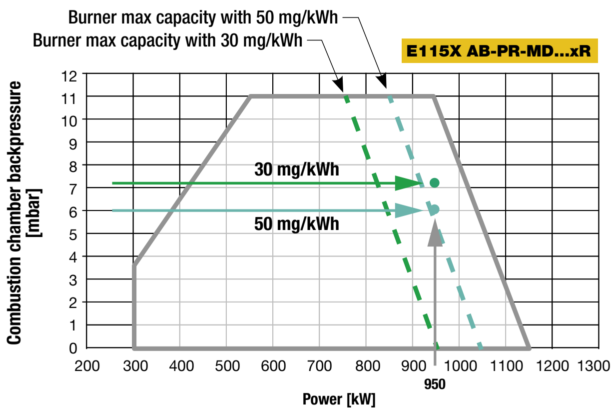
< 50 mg/kWh
In the selection 2 with the thermal load 1,31 MW/m³ the percentage of the depowering of the burner is 0,2 %, and the backpressure in the combustion chamber increases
6 mbar x 1,01 = 6,06 mbar.

< 30 mg/kWh
In the selection 2 with the thermal load 1,31 MW/m³, the percentage of the depowering of the burner is 18 %, and the backpressure in the combustion chamber increases
6 mbar x 1,43 = 8,58 mbar.

MATCHING LOW NO_x BURNER AND HEAT GENERATOR

SELECTION 1: E115X...FGR

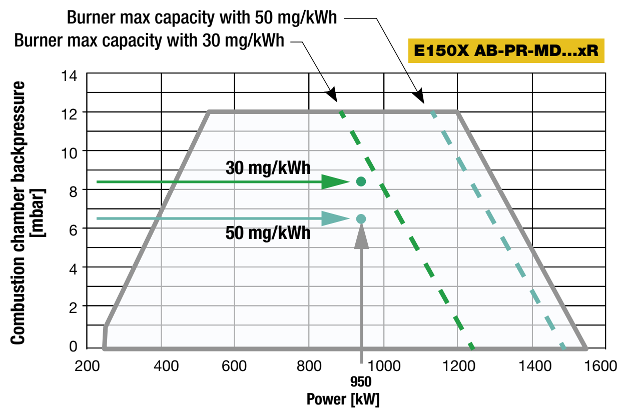
OUTPUT REDUCTION IN REFERENCE TO THE BURNER PERFORMANCE CURVE



The burner E115X in the selection 1 is outside of the performance curve, for this reason we can not choose this burner.

SELECTION 2: E150X...FGR

OUTPUT REDUCTION IN REFERENCE TO THE BURNER PERFORMANCE CURVE



The burner E150X in the selection 2 is correct because is inside of the performance curve with emissions 50 and 30 mg/kWh.

COMBUSTION HEAD LENGTH SELECTION

In the cited example, the boiler chamber diameter was 680 mm, so the optimal combustion head diameter lies in the range between 215 mm and 270 mm.
The dimensional table on page 95 or 100 shows that E150X combustion head diameter is equal to 259 mm, thus the first condition is met.
Regarding the combustion head length, suppose the boiler door is 220 mm thick, refractory included. The combustion head must penetrate at least 150 mm as said above, thus the short combustion head variant is selected (400 mm).
The long combustion head (500 mm) penetrate too much (280 mm) into in the combustion chamber.
In this case with short combustion head we have 180 mm.
To properly install the burner, please refer to Fig. 4 to the side.
Of course, it is possible to carry out the reverse procedure as well: given an emission limit that cannot be exceeded by design, the NO_x diagram provides the admissible thermal load for a given heat generator. This way, designer can select a suitable boiler based on project specifications and required power. In any case, burner combustion head dimensions must be checked to complete the matching procedure.

Reverse flame boilers: contact our Technical Department.

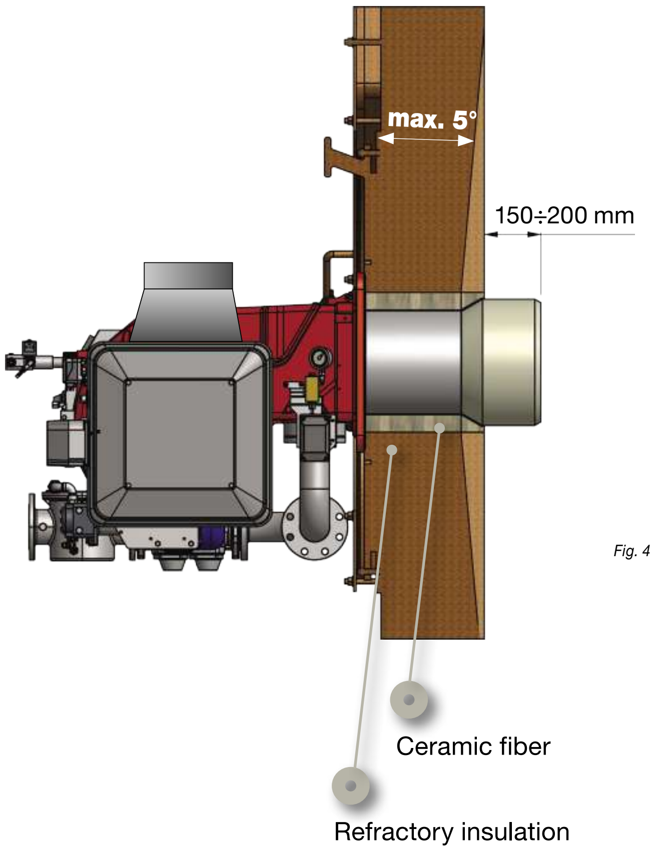
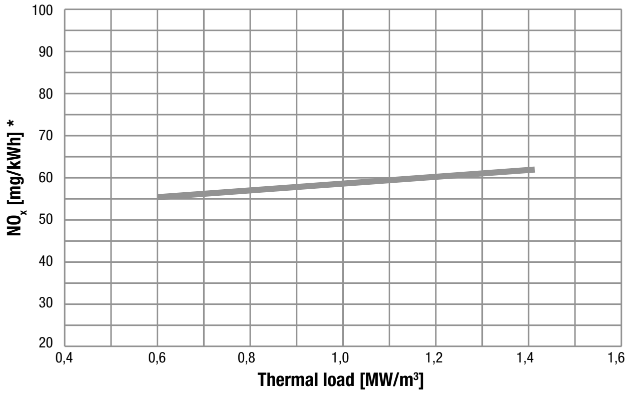


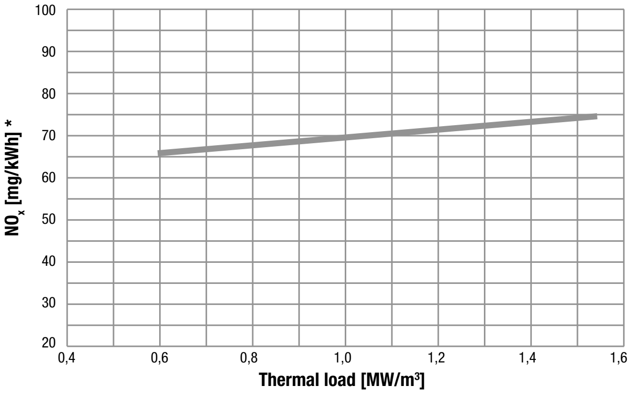
Fig. 4

NO_x DIAGRAM IN REFERENCE TO THE THERMAL LOAD

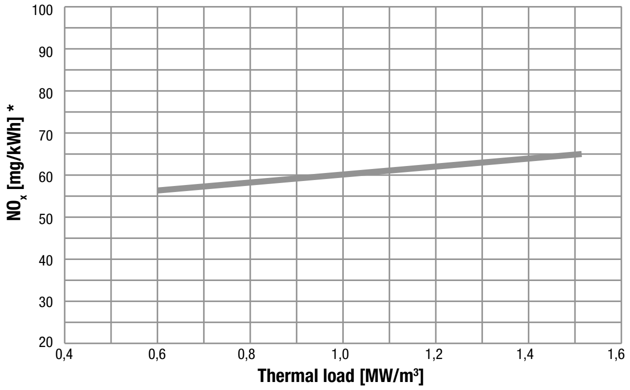
NGX70



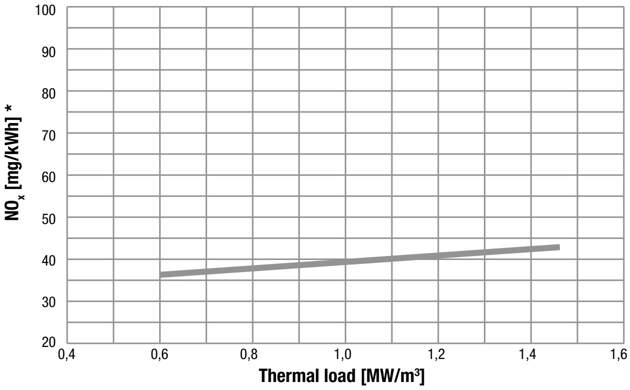
NGX120



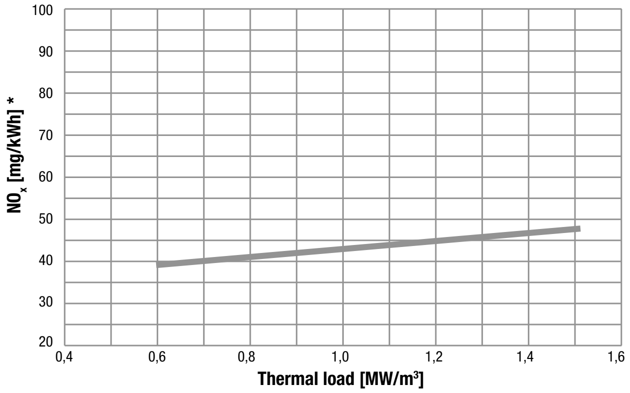
NGX200



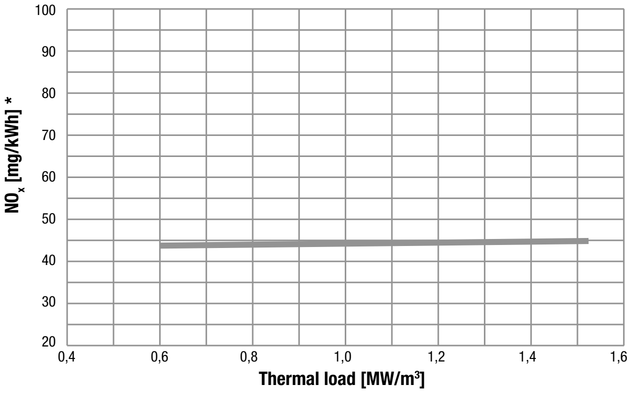
NGX280



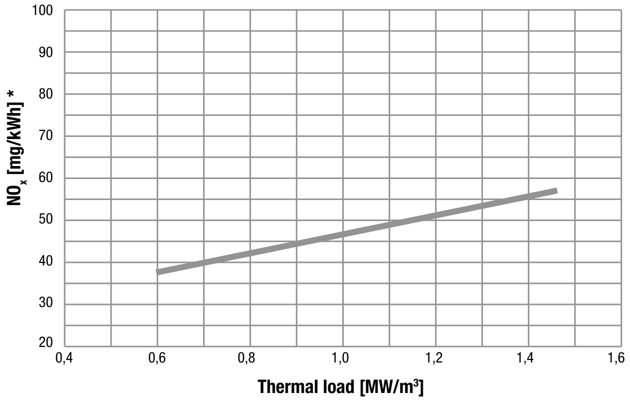
NGX350



NGX400



NGX550

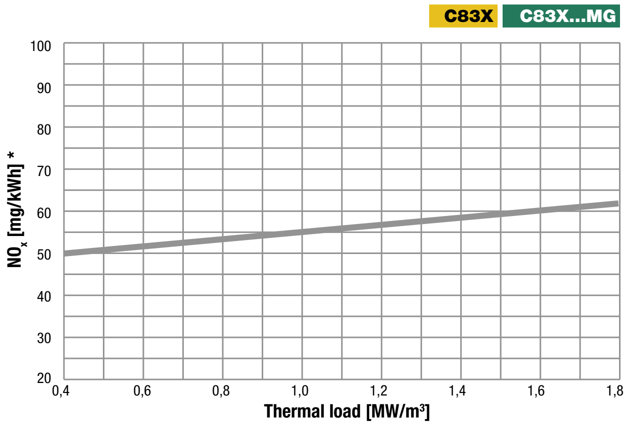


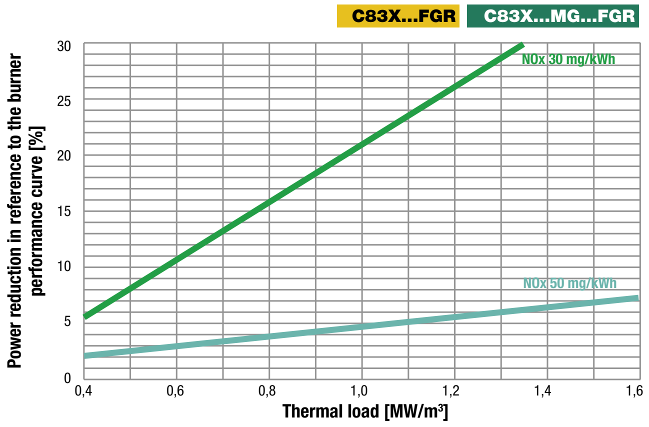
* According to UNI EN 676 correction method; p amb 1013 mbar; t amb 20°C; h 10 g/kg.

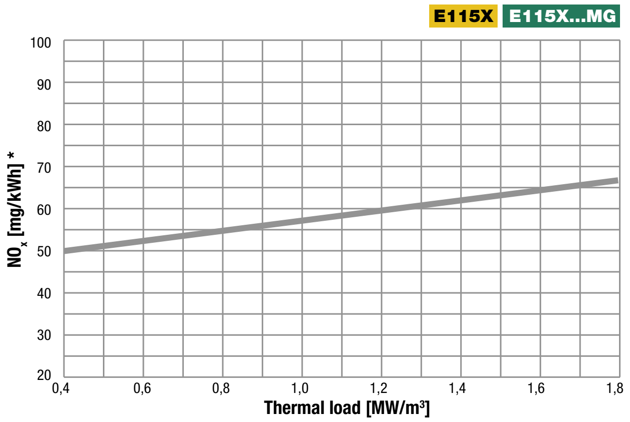
MATCHING LOW NO_x BURNER AND HEAT GENERATOR

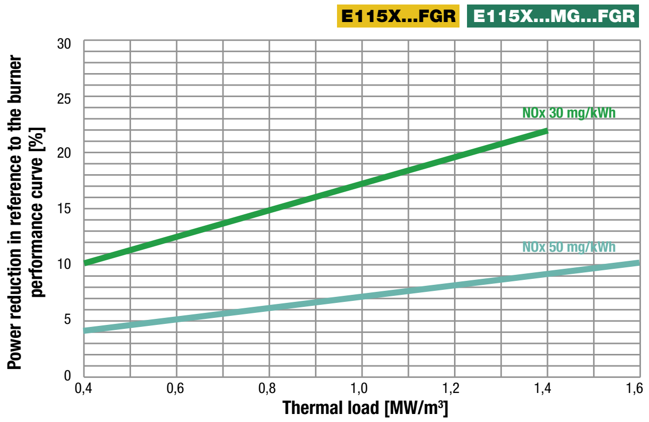
NO_x DIAGRAM IN REFERENCE TO THE THERMAL LOAD

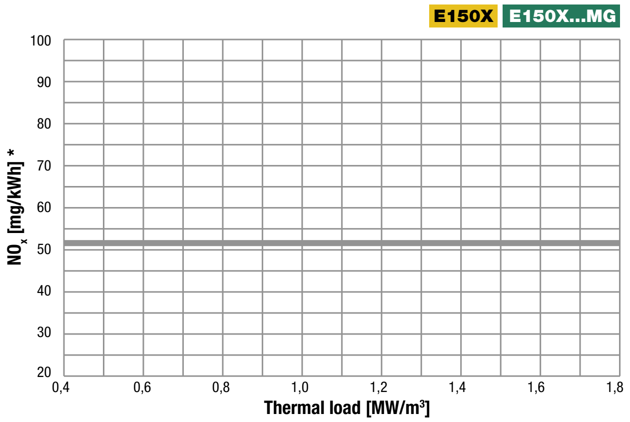
OUTPUT REDUCTION IN REFERENCE TO THE BURNER PERFORMANCE CURVE

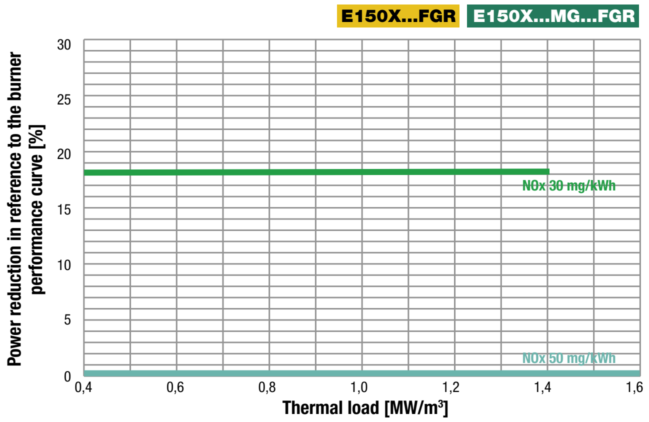


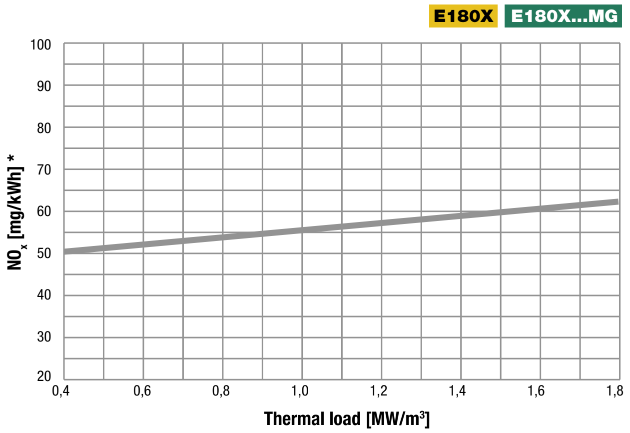


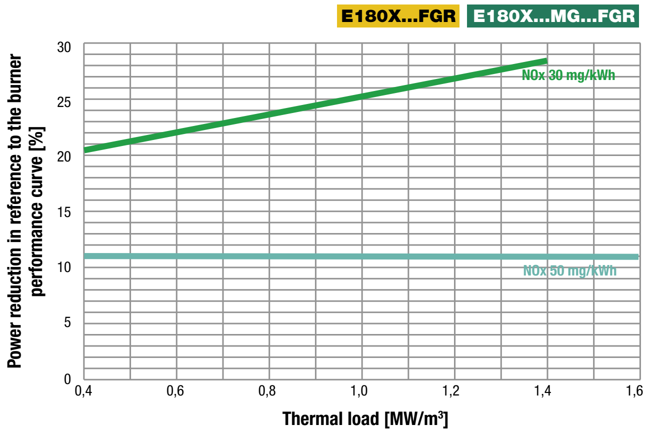






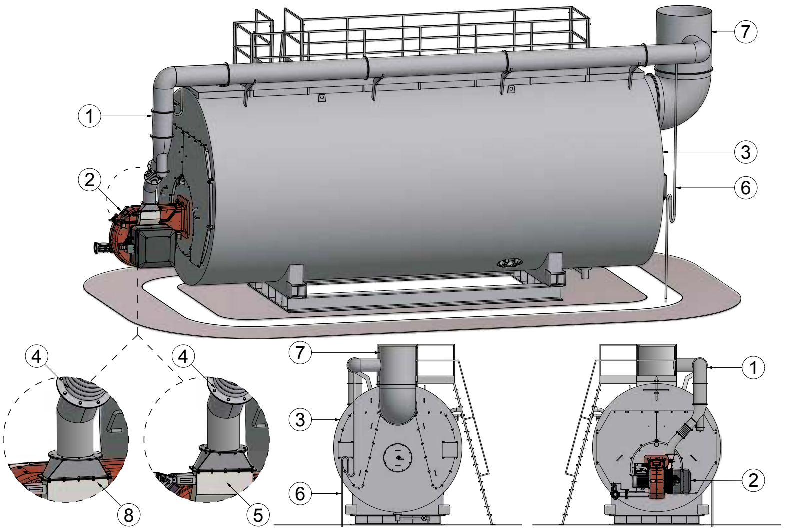






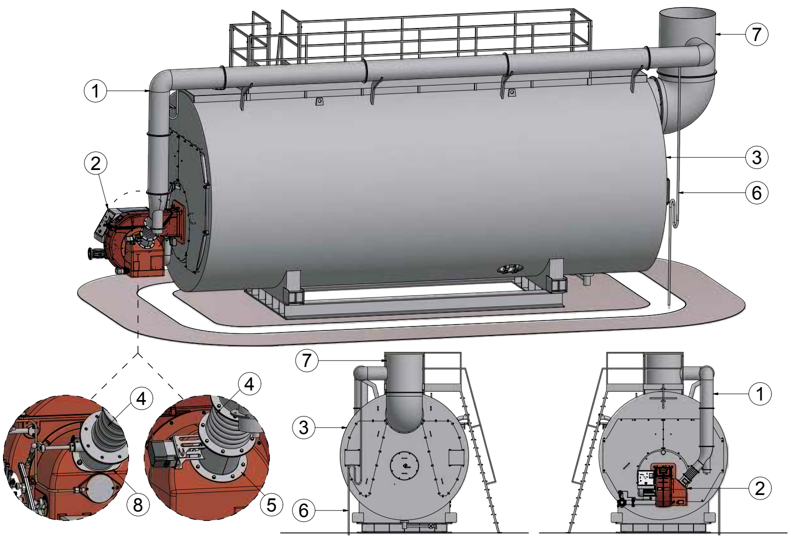
* According to UNI EN 676 correction method; p amb 1013 mbar; t amb 20°C; h 10 g/kg.

BURNER WITH AIR INLET SILENCER



Legend
1 - FGR pipe
2 - Burner with air inlet silencer
3 - Boiler
4 - Antivibrating joint
5 - FGR system 30 mg/kWh
6 - Condensate drain
7 - Chimney
8 - FGR system 50 mg/kWh

BURNER WITHOUT AIR INLET SILENCER

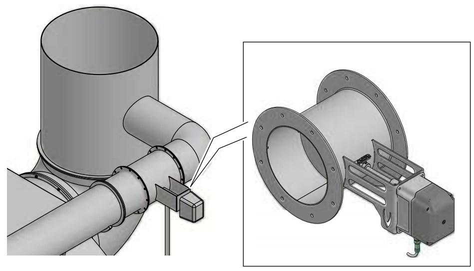


Legend
1 - FGR pipe
2 - Burner without air inlet silencer
3 - Boiler
4 - Antivibrating joint
5 - FGR system 30 mg/kWh
6 - Condensate drain
7 - Chimney
8 - FGR system 50 mg/kWh

BURNER LIGHT-OIL: ADDITIONAL DAMPER FOR EXCLUSION FGR

For burner Natural gas / light oil operation it is recommended to use an additional damper to close the flow of recirculation gas FGR.

Option 1: Damper with actuator
Connect the actuator to the electrical predisposition inside the electrical panel
Option 2: Damper manual
Damper manual with Opening / Closing signaling microswitches to be connected to the electrical predisposition inside the burner electrical panel.



Additional damper with actuator on chimney
(option 1)

For the use of the FGR during light oil operation, please consult our sales offices.

ACOUSTIC HOODS BOX ASSEMBLED ON WHEELED FRAME

All burners in this catalogue have lower noise levels than the standard values.
If a further reduction of the burner noise is required, the customer has at disposal a series of acoustic hoods box that can be integrated in the system.
The noise reduction range varies from 5 to 15 dB(A), depending on the design specification. For more important reductions, please consult our technical department.