

PERFORMANT INSTALLATIONS FOR DRYING AND HEATING THE STEEL LADLES

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Abstract. *The installations for drying and heating the ladles are, mainly, installations with vertical setting of the ladle made up of a burner set on an arm for support and handling and of an installation for automatic operation of the process. Recently, a lid was added to this type of installations that is set on the ladle, the exhaust of the burnt gases being made through the room between the lid and the ladle or through holes in the lid. In order to recover the energy contained by the gases when exhausted from the ladle there have been produced recovery burners mounted on the lid of the ladle, set in vertical position, and installations with ladles set in horizontal position endowed with heat recovery devices. The installations for drying and heating the ladles set in horizontal position present the disadvantage of additional handling when setting the ladle and after preheating the takeover and the disadvantage of a not uniform heating. The paper presents an analysis of those performing solutions and installations for drying and heating the ladles together with the main technical characteristics. It also presents the results obtained on an installation for drying and heating the ladles vertically set at high temperatures, installation endowed with heat recovery device.*

Key words: *instillation, ladle, steel, experiments.*

1. INTRODUCTION.

The installations for drying and heating the ladle are, mainly, installations with the ladle set vertically, made up of a burner set on an arm for support and handling and of an installation for automatic operation of the process.

Recently, a lid was added to that type of installation, being set on the ladle, the exhaust gases being exhausted through the room between the lid and the ladle or through holes in the lid. As a result, the energy contained by the exhaust gases is lost and the efficiency of those installations is very low.

The modern processes for steel treatment in the ladle require preheating the ladles at minim 1200 °C temperatures. Thereby, the temperature of the exhaust gases through the ladle lid reaches 1250 – 1300 °C at the end of the preheating process, the energy contained by the exhaust gases being significant.

In the past years there were made installations for drying and preheating the ladles at approx. 1200 °C to recover the heat of the exhaust gases. The recovery of the heat of the exhaust gases can be done by using some pre-heating devices for the combustion air, that can be recovery devices (with heat exchange surface that separates the combustion air from the exhaust gases) or regenerative devices (made up of two regenerators filled with balls or cylinders of refractory ceramic

material) with high heat capacity, that absorb the heat from the exhaust gases and deliver it to the combustion air alternatively).

The installations for drying and heating the vertically set ladles may be equipped with recuperative preheaters only, while the installations with horizontally set ladles can be equipped with recuperative or regenerative preheaters. The installations for drying and heating the horizontally set ladles present the disadvantage of additional handling for setting the ladle after preheating the takeover too, and that is why they are usually used when they are equipped with regenerative preheaters that can preheat the air at temperatures higher than the recuperative preheaters. The installations are equipped with special burners called regenerative burners.

For drying and heating the high capacity ladles that are set vertically, are used installations with recuperative devices set on the ladle lid, while the low capacity ones are equipped with recuperative burners. Those burners contain a recuperative air preheater. For the medium capacity ladles it is used one of the above solutions or mixed solution with a recuperative burner and a heat exchange surface set in the ladle lid.

The new technological processes in the metallic materials industry require ladle drying and heating temperatures and speeds as high as

possible. They can be done by using the air enriched with Oxygen or combustion air preheated at temperatures as high as possible by recovering the heat of the exhaust gases.

2. PERFORMANT SOLUTIONS AND INSTALLATIONS FOR DRYING AND HEATING THE LADLES

The basic diagram of the installations for drying and heating the horizontally set ladle is presented in Fig. 1. The installation is set on a transfer car that can move on a railway and is made up of:

- burners, set in the shaft of the vertical lid that seals the ladle;
- exhaust gases pipe connected to the hole located at the bottom of the lid, through the exhaust gases go to a heat recuperative device;
- the heat recuperative device in which the combustion air supplied by a fan absorbs the heat from the exhaust gases;
- the exhaust gases exhauster that provides the depression required for absorbing the exhaust gases from inside the ladle and then after the recuperative device, their evacuation.

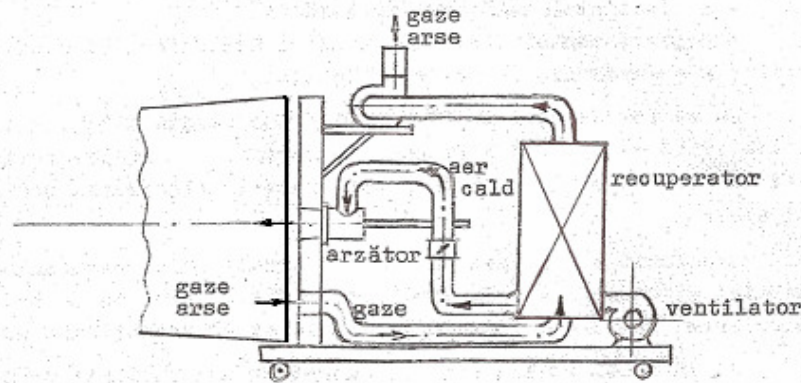


Fig. 1. The basic diagram of the installation for drying and heating the horizontally set ladles.

The heat recovery device can be a recuperative device in which the combustion air is preheated up to maximum 600 °C, or a regenerative one (made up of two parts equipped with two dumpers each, on the exhaust gases side and on the combustion air side, automatically operated to ensure the alternative transit through the two parts), in which the combustion air is preheated up to maximum 1000 °C [1,2].

The installations that use regenerative type recovery devices are called regenerative devices and are equipped with special burners named regenerative burners. The first regenerative installation for drying and heating the ladles set horizontally was made by Hotwork Development Ltd. [2,3].

After Hotwork licence, the French companies made regenerative installations for drying and heating the ladles set horizontally, with a thermal power between 600 – 4000 kW and which absorbed approx. 80% from the physical

heat of the exhaust gases [3]. Used in France for high capacity ladle heating the installations have the following functional parameters:

- ladle lining temperature: 1150 °C;
- preheated air temperature: 800 – 1000 °C;
- exhaust gases temperature when discharged: 80 – 200 °C;
- duration of the cycle: 12 ore;
- ladle capacity: 180 – 200 t;
- natural gas consumption:
 - average: 100 Nm³/h (6,3 Nm³/t liquid steel);
 - maximum: 230 Nm³/h (14,5 Nm³/t liquid steel).

The recuperative preheaters with which the installations for drying and heating the horizontally set ladles are equipped with, can be mounted in the ladle lid, on the ladle lid or in the body of the recuperative burners [1,2,3,4].

Installations with recovery devices set on the ladle lid are used in order to dry and heat the high capacity ladles set vertically.

This type of installation whose basic diagram is presented in Fig. 2, is used for heating the 225 t ladles the fuel used being natural gas with 39,4

MJ/Nm³ calorificity. The refractory lining of the ladles is heated up to 1220 °C. The metallic recovery device uses a part of the exhaust gases physical heat that leave the ladle enclosure, preheating the combustion air up to maximum 620 °C [1].

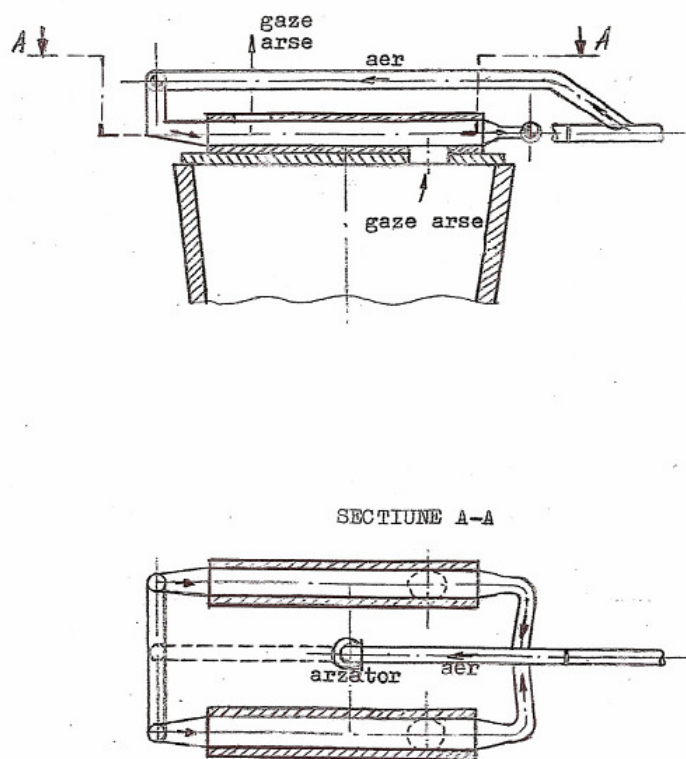


Fig. 2. Basic scheme of high capacity installations for drying and heating the vertically set ladles.

In order to recover the energy contained by the exhaust gases when being exhausted from the low capacity vertically set ladle were made recuperative burners set in the ladle lid.

The first recuperative burner used for drying and heating the low capacity vertically set ladles was made by Hotwork Development Ltd. [2,3].

The basic diagram of the Hotwork recuperative burner is presented in Fig.3.

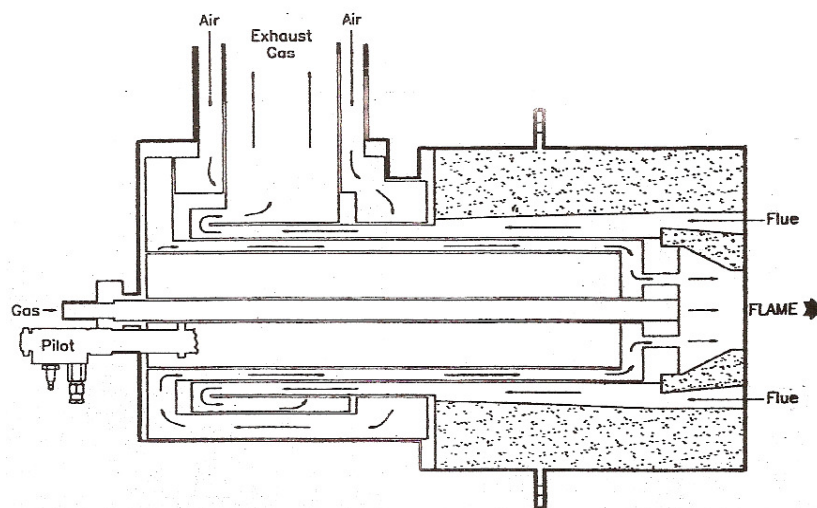


Fig. 3. The basic diagram of the Hotwork recuperative burner.

The recuperative burners can be used for the installations for drying and heating the medium capacity vertically set ladles too when they are combined with recuperative devices set in the ladle lid.

Fig. 4 presents a view of the mixed recuperative installation (recuperative burner with recovery device set in the ladle lid) [5]. The technical characteristics of the mixed recuperative burning installation is presented in the table 1 [5].



Fig. 4. View of the mixed recuperative installation (recuperative burner with recovery device mounted in the ladle lid)

Table 1. Technical characteristics of the mixed recuperative burning installation

Crt. No.	Name	U.M.	Value
1	Rated thermal capacity	kW	2000
2	Maximum thermal capacity	kW	2300
3	Minimum thermal capacity	kW	600
4	Type of fuel	-	Natural gas
5	Fuel nominal output	Nm ³ /h	200
6	Fuel maximum output	Nm ³ /h	230
7	Fuel minimum output	Nm ³ /h	60
8	Combustion air nominal output	Nm ³ /h	2000
9	Combustion air maximum output	Nm ³ /h	2300
10	Combustion air minimum output	Nm ³ /h	600
11	Adjustment ration (minimum/maximum output)	-	1/3,8
12	Fuel rated pressure	mmCA	200
13	Combustion air rated pressure	mmCA	600
14	Combustion air preheating maximum temperature	°C	400
15	Ladle preheating maximum temperature	°C	1200
16	Air excess minimum factor, α_{min} , at nominal power minimum power	-	1,05 1,10
17	Maximum CO content at α_{min} , at nominal power minimum power	mg/ Nm ³	70 90
18	Maximum NOx content at α_{min} , at nominal power minimum power	mg/ Nm ³	200 250
19	Maximum temperature deviation from the set diagram	°C	±10
20	Pre-ventilation time	sec	40
21	Ignition time	sec	10
22	Safety time when heating up	sec	1
23	Safety time when blowing out	sec	1

The dimensions of the recuperative burners are:
 - length: 1400 mm;
 - diameter: 500 mm;
 - net weight: 150 kg.

The results obtained when operating the mixed recuperative burning installation for 100ton vertically set ladle are:
 - maximum natural gas flow: 238 Nm³/h;
 - maximum temperature for preheating the air in the lid and in the recovery device set in the body

of the burner, at 1210 °C as the maximum heating temperature of the ladle lining: 410 °C;
 - the maximum heating temperature of the ladle lining, for ladles used in continuous flow, with initial average temperature on the ladle inner surface of 570 °C and a 215 min heating process time: 1210 °C;
 - maximum temperature deviation versus the set diagram: ± 10 °C;
 - average specific consumption of natural gas, for ladles used in continuous flow: 7 Nm³/t liquid steel.

New technological processes in the metallic material industry require drying and heating temperatures and speeds as high as possible for the ladles. They can be accomplished by using air enriched in Oxygen or of combustion air preheated at a temperature as high as possible by recovering the heat of the exhaust gases. Fig. 5 presents the basic diagram of the recuperative burner mounted on the lid of the vertically set ladle that uses air enriched in Oxygen [6].

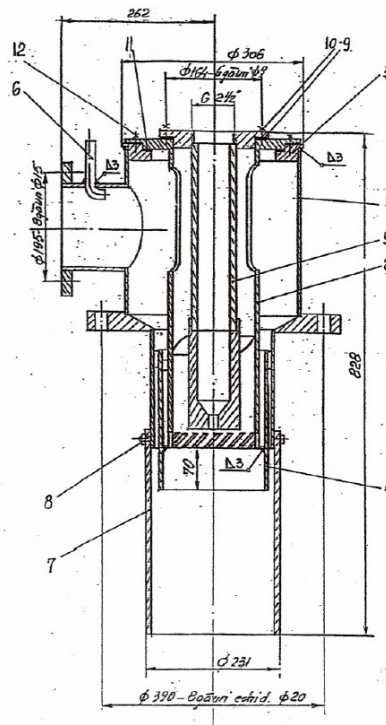


Fig. 5. The basic diagram of the recuperative burner set in the lid of the vertically set ladle that uses air enriched in Oxygen

The recuperative burner, mounted in the lid of the vertically set ladle that uses air enriched in Oxygen, was designed with the following technical characteristics:

- natural gas nominal flow: 250 Nm³/h;
- natural gas nominal pressure: 75 mbar;
- maximum oxygen flow: 150 Nm³/h;
- maximum oxygen pressure: 1,5 bar;
- excess air minimum factor: 1,02;
- combustion air nominal flow: 761 Nm³/h.

The dimensions of the recuperative burner that uses air enriched with oxygen are:

- length: 828 mm;
- diameter: 300 mm;
- net weight: 85,56 kg.

The parameters of the drying – annealing processes, as well as of the durability of the ladle refractory lining obtained in the industrial testing of the recuperative burning installation that uses air enriched in Oxygen are presented in work [7] and they showed the following performance: reaching the 1200 °C temperature at the end of the drying-annealing process both in the magnesium bricks lining, and

in the lining made of the dolomitic blocks; ensuring the technical conditions for observing the drying diagrams leading to an increase of the durability of the ladle refractory lining.

3. EXPERIMENTAL RESULTS OBTAINED ON A LADLE DRYING AND HEATING INSTALLATION.

The solution in which the energy contained by the exhaust gases is recovered at a higher degree is more economical than the one that uses the air enriched in oxygen. This solution consists in a new type of automatic installation for drying and heating the ladles that uses a recovery device and two impulse burners.

Fig. 6 presents a view of the installation for drying and heating the ladles at high temperatures and the table 2 its main technical characteristics.

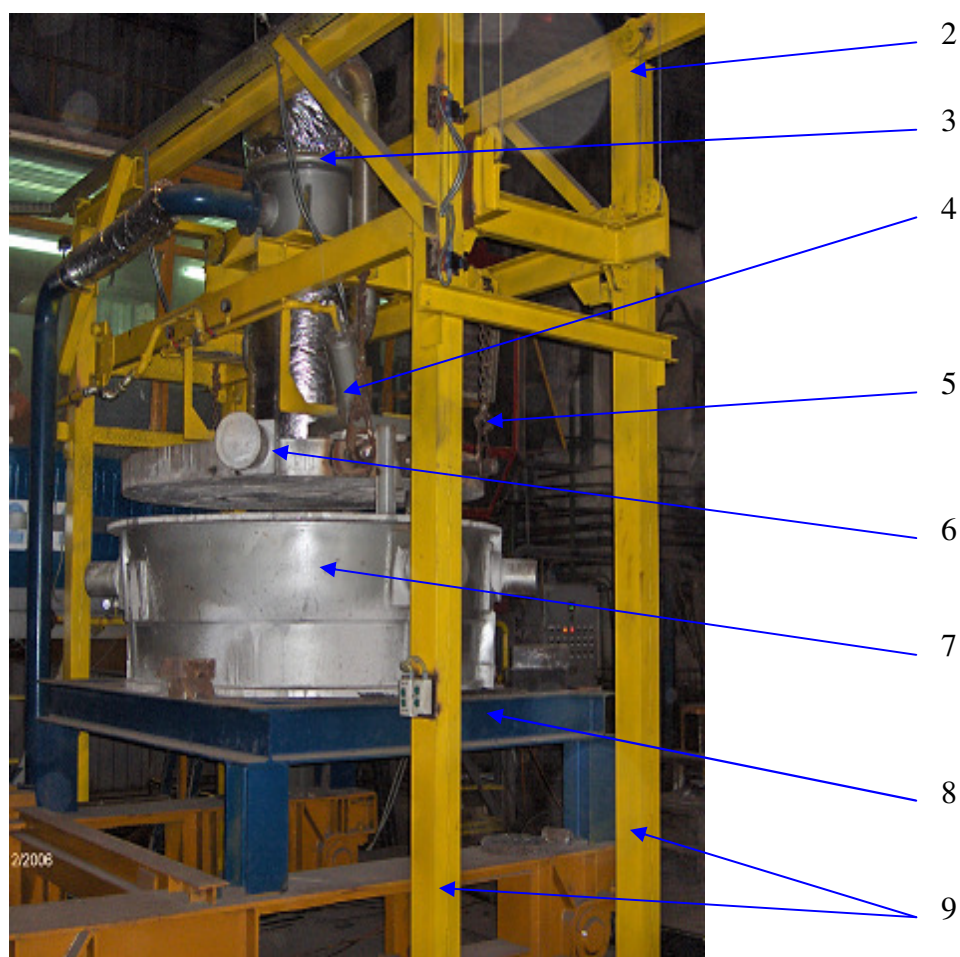


Fig. 6. View of the installation for drying and heating the ladles at high temperatures.

Legend:

1-electro-block; 2- heat recovery device; 3- lifting beam system; 4-burners; 5- lid clamping system; 6- lid; 7-ladle; 8-transfercar; 9- support structure for the lifting system.

Table 2. Technical characteristics of the installation for drying and heating the ladles at high temperatures.

Crt. No.	Name	U.M.	Value
1	Nominal thermal capacity	kW	700
2	Maximum thermal capacity	kW	700
3	Minimum thermal capacity	kW	140
4	Type of fuel	-	Natural gas
5	Fuel nominal output	m ³ N /h	70
6	Fuel maximum output	m ³ N /h	70
7	Fuel minimum output	m ³ N /h	14
8	Combustion air nominal output	m ³ N /h	700
9	Combustion air maximum output	m ³ N /h	700
10	Combustion air minimum output	m ³ N /h	140
11	Adjustment ration (minimum/maximum output)	-	1/5
12	Fuel rated pressure	mbar	120
13	Combustion air rated pressure	mbar	70
14	Combustion air preheating maximum temperature	°C	600
15	Ladle preheating maximum temperature	°C	1500
16	Air excess minimum factor, α_{min} , at nominal power minimum power	-	1,05 1,10
17	Maximum CO content at α_{min} , at nominal power minimum power	mg/ m ³ N	70 90
18	Maximum NOx content at α_{min} , at nominal power minimum power	mg/ m ³ N	200 250
19	Maximum temperature deviation	°C	±10
20	Pre-ventilation time	sec	40
21	Ignition time	sec	5
22	Safety time when heating up	sec	1
23	Safety time when blowing out	sec	1

Prior commissioning the installation for drying and heating at a high temperature the ladles vertically set the burners with impulse were tested on the stand. Apart from the

characteristic yield curve depending on the pressures, that matched the ones in the design, the emissions of pollutants were set, based on the air excess factor and on the temperature in the

stand. Fig. 7 presents the influence of the excess air factor and of the temperature in the stand on the CO emission and on the concentration of Nitrogen Oxides in the exhaust gases.

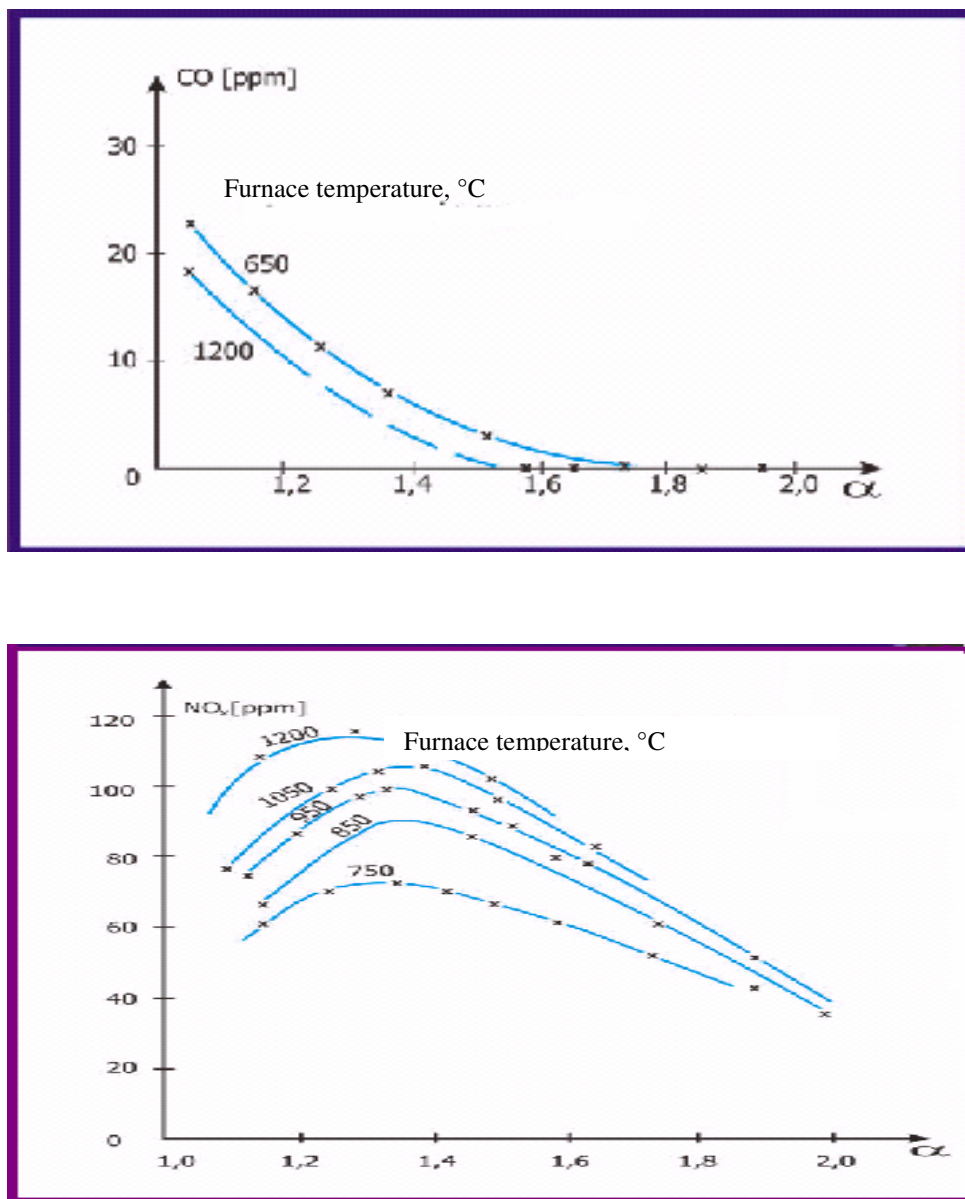


Fig. 7 Pollutant emission at the impulse burner

The installation for drying and heating the vertically set ladles at high temperatures was industrially tested and the temperatures diagrams in Fig. 8 were reached for exhaust gases and ladle lining.

As compared to the classic ones, this installation provides: a natural gas specific consumption lower with abt. 30%, heating uniformity up to temperatures of 1500 °C,

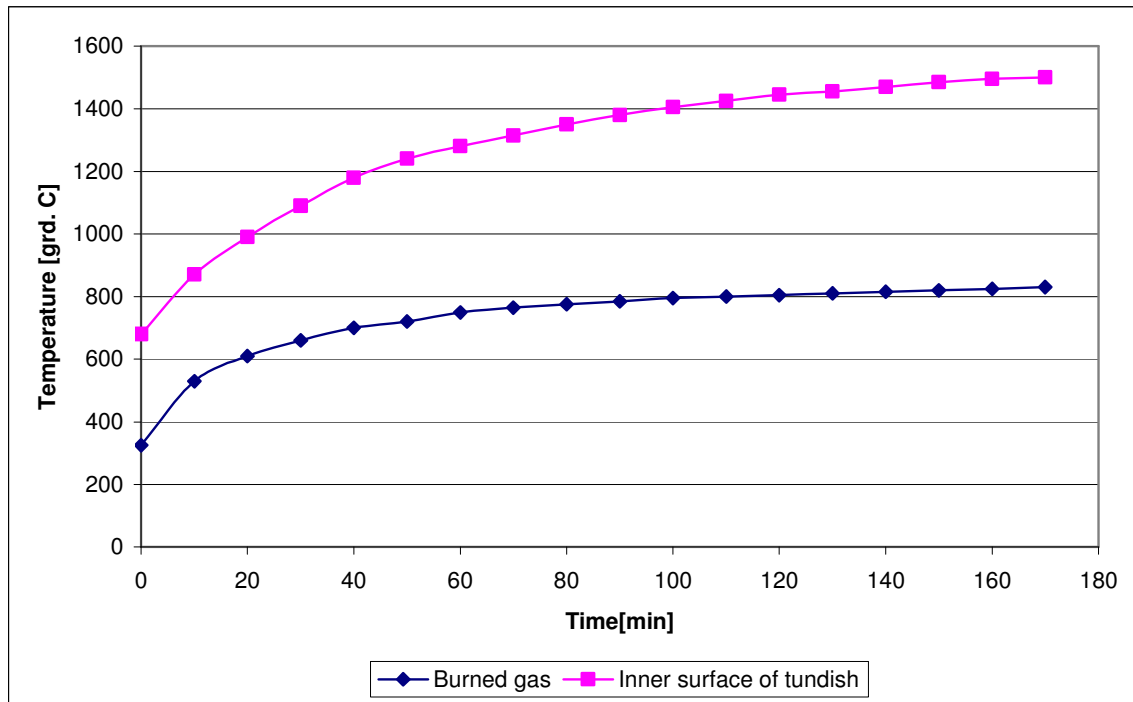


Fig.8. Temperature diagrams of the installation for drying and heating the ladles at high temperatures

4. CONCLUSIONS

The installations for drying and heating the vertically set ladles can be equipped with recuperative preheaters only, while the installations for horizontal set ladles can be equipped with recuperative or regenerative preheaters. The installations for drying and heating the horizontally set ladles present the disadvantage of additional handling required for setting the ladle after preheating the takeover, and that makes them to be used mainly when they are equipped with regenerative preheaters, that can preheat the air at higher temperatures than the recuperative ones.

For drying and heating the high capacity ladles set vertically, are used installations with recovery devices set on the ladle lid while the smaller capacity ladle are equipped with recuperative burners. Those burners contain a recuperative air preheater. For the medium capacity ladles it is used one of those solutions or a mixed one with a recuperative burner and a heat exchange surface set in the ladle lid.

The new technological processes in the metallic material industry require temperatures and speeds for drying and heating the ladles as high as possible. They can be done by using the air enriched with Oxygen or of the combustion air preheated at temperatures as high as possible by recovering the exhaust gases heat.

The solution for recovering the energy contained by the exhaust gases in a high extent is more economical than the one using the air enriched with oxygen. This solution consists of a new type of automatic installation for drying and heating the ladles, characterized by the usage of a recovery device and of two burners with impulse that provides as compared to the classical installations: a 30% lower natural gas specific consumption, a uniform heating up to temperatures of 1500 °C, reduced pollutants emissions, in advantageous operating conditions.

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