CONSIDERATIONS ON SIZING THE PREHEATERS OF THE FURNACES

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Abstract .*Recovering the exhaust heat from metal industry's furnaces is realized, in general, by preheating the combustion air. Thus, the exhaust gases are discharged through the chimney with lower temperatures and lower energy content. When in the gases exhausted from the furnaces, the sulphur oxides are found, at lower temperatures, the low temperature corrosion occurs affecting the air pre-heaters.*

It is therefore important to size the air pre-heaters so as to avoid the low temperature corrosion. For sizing the air pre-heaters, a computer program is used, by which the recovery solution to avoid the low temperature corrosion can be established. Such constructive solution, together with the experimental results obtained during the operation, is illustrated.

Key words: *pre-heaters, exhaust gases, furnaces, metal materials.*

1. INTRODUCTION.

Reducing the natural gas consumption is currently the major energy desire of integrated steel plants. Modern plants use natural gas (hydrocarbons) only at a rate of several percent (the coal consumption is approx. 85% and the power consumption of approx. 10-12%) while in the developing countries' plants, this consumption exceeds 10% [1,2,3].

Reducing the natural gas consumption is realized by recovering the exhaust heat from metal industry's furnaces. Recovering is realized, in general, by preheating the combustion air.

The fuels used in the furnaces from integrated steel plants are, in general, natural gas and residual fuel gases. The residual gases are produced in integrated steel plants in coke (coke oven gas), iron (furnace gas) and steel (converter gas) production processes, and also contain sulphur compounds. These gases are recovered and used mainly in technological processes, including in furnaces, particularly in the form of gas mixtures, composed of natural gas with residual gases [4,5].

The existence of sulphur compounds in the fuel gases used in furnaces leads to low temperature corrosion of the air pre-heaters.

It is therefore important to size the air pre-heaters so as to avoid the low temperature corrosion. For sizing the air pre-heaters, a computer program is used, by which the recovery solution to avoid the low temperature corrosion can be established [6,7]. Such constructive solution is illustrated, together with the experimental results obtained during the operation.

2. DESCRIPTION OF THE EXISTING SOLUTION.

The existing air pre-heating plant (Fig. 1, Fig. 2) consists in using an air pre-heater with two air passages through the combustion gas flow so that the exhaust gases are discharged through the pipes and the air washes their exterior. The air inlet and outlet pipes in the pre-heater are made "pipe in pipe" in order to increase the internal temperature of the pipes crossed by the combustion gases with the lowest temperature to avoid reaching the dew point temperature. Thus, the initial pre-heater is conducted by the two passages counter-current air flow and has the following features:

Quantity of recovered heat : 2,259,900 kJ/h;
Heat exchange surface : 254 m^2 ;
No. of pipes :658 ;
Pipe size: Φ38x2mm;
Pre-heater inlet flue gas temperature: 507ºC;
Pre-heater outlet flue gas temperature: 300ºC;
Pre-heater inlet air temperature: 50ºC;
Pre-heater outlet air temperature: 250ºC;
Air flow :7763 Nm^3/h;
Total mass : 6900 kg.

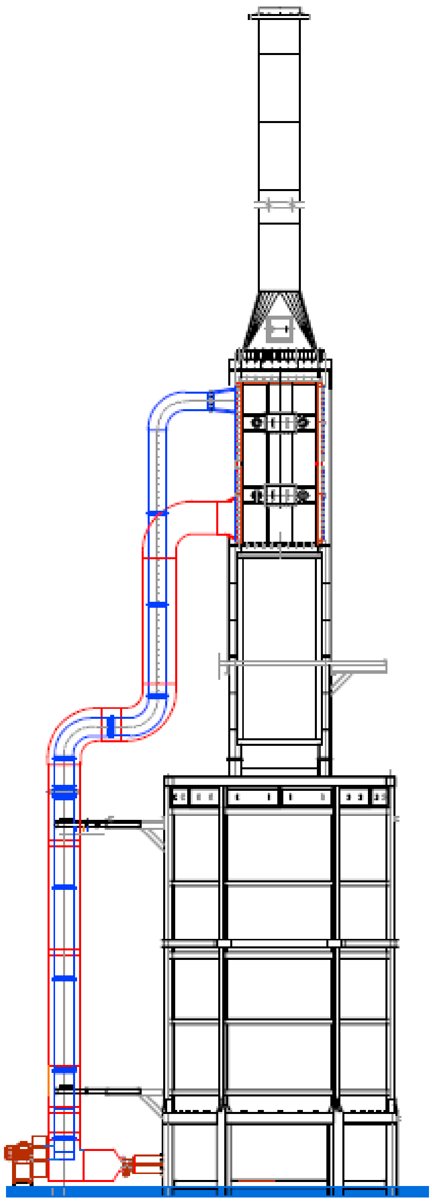

Fig.1. View of the pipe and of the air pre-heater (with two air passages) (initial general assembly):

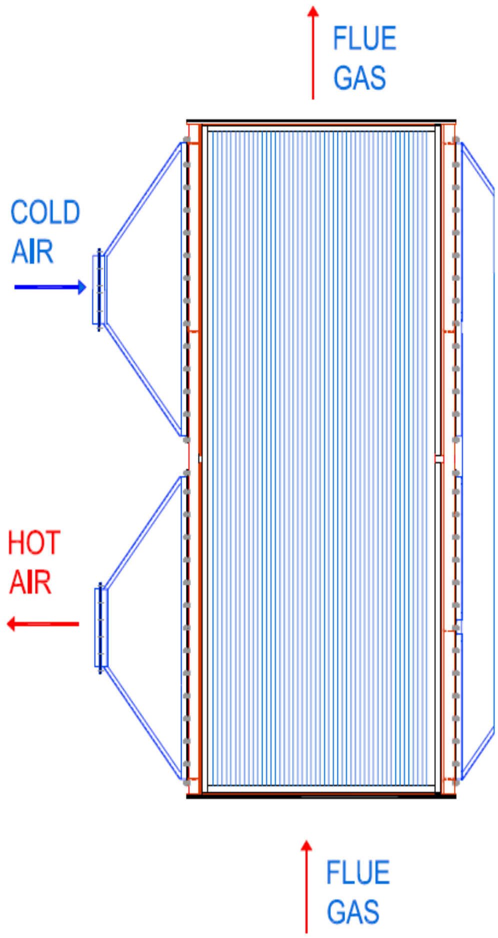

Fig.2. Section through the tubular air pre-heater with the steering current (combustion gases) through pipes (existent assembly).

3. DESCRIPTION OF THE PROPOSED SOLUTION FOR UPGRADING

The main constraints that had to be taken into account in order to replace the existing pre-heater to another one with higher efficiency have been:
-keeping within the limits of the old pre-heater the total mass of 6900 kg maximum, in order not to lead to additional costs in foundation - buildings
-arranging of air passages so as to avoid the pipe temperature to reach below the dew point temperature (to avoid the appearance of low temperature corrosion)
-providing a pressure drop in combustion gas flow that does not endanger the natural circulation of the furnace

Given these observations the configuration shown in Fig. 3 resulted

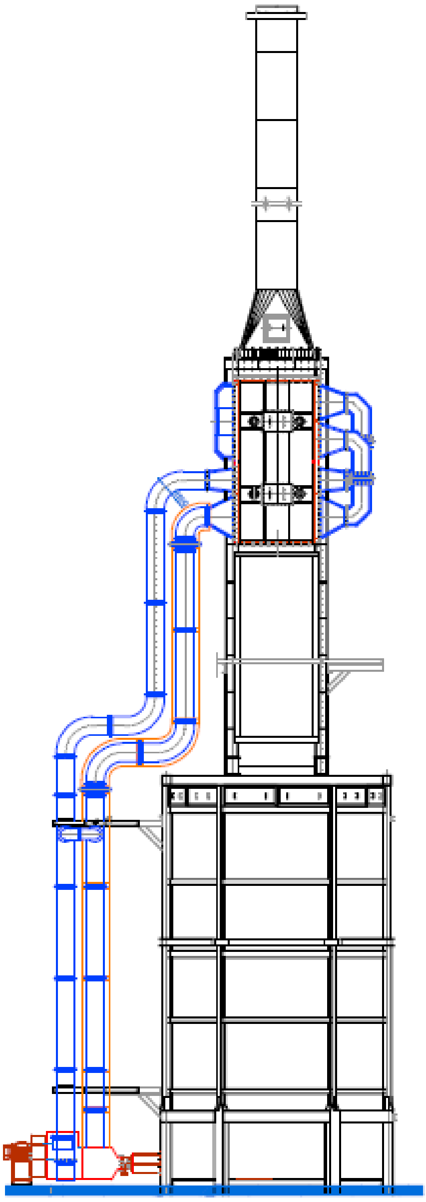

Fig. 3. Modernized air pre-heater location scheme.

To have pipes' walls temperature above the dew point, air flow was introduced in a section of the pre-heater with higher gas temperature, so as the resulting temperature in the pipe to be higher than 180 ºC.
The sizing of the heat exchanger was performed by a computer program and the results are presented in Table 1.The equipment's construction is convective type - "Pipes beam type air heater with gases passing through the pipes."
The constructive solution of the air pre-heater is shown in the diagram in Fig. 4.

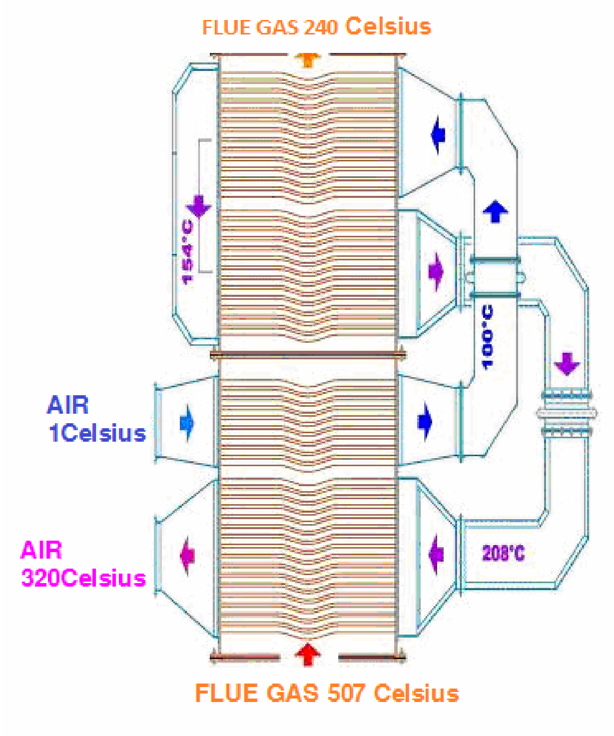

Fig.4. The constructive solution of the new air pre-heater.

Table 2 shows the technical features of the air pre-heater.

TECHNICAL FEATURES			
NAME	**U.M.**	**PIPES**	**BETWEEN PIPES**
FLUID	-	**Combustion air**	**Flue gases**
FLOW	**m^3N/h**	7763	8437
INLET TEMPERATURE	**ºC**	+1	+507
OUTLET TEMPERATURE	**ºC**	+320	+240
PRESSION DROP	**mmCA**	33.25	9.60
HEAT EXCHANGE SURFACE	**m^2**	218	
NO. OF PASSAGES	-	4	1
NO. OF PIPES	-	1173	-
PIPE SIZE	**mm**	**Φ38 x 2**	
PIPES' PITCH ON HORIZONTAL	**mm**	66	
PIPES' PITCH ON VERTICAL	**mm**	58	
YIELD	%	98	
INSULATION	**Type / thickness**	**Mineral wool / 120 mm**	
INSULATION PROTECTION	**Type / thickness**	**Galvanized sheet / 0.7 mm**	
NET MASS	**kg**	6690	

The manufacturing in "S" of the pipes was chosen [3] to allow axial deformation due to prevented dilatations. Views of the pipes beam and of the mounted pre-heater are shown in Fig. 5.

Fig.5. View of the air pre-heater's pipes beam.

Preheater calculation in Table 1:

Crt. no.	PARAM.	UNIT	SECT I	SECT II	SECT III.	SECT IV
1	Fuel flow	Nm^3/h	580.0	580.0	580.0	580.0
2	Fluid flow	Nm^3/h	7763	7763	7763	7763
3	Inlet fluid temperature	ºC	203	10	145	85
4	Outlet fluid temperature	ºC	320	85	203	145
5	Exchanger yield		0.99	0.99	0.98	0.99
6	Air excess coeff.	-	1.15	1.15	1.15	1.15
7	Ambient temperature	ºC	10	10	10	10
8	Inlet combustion gases temperature	ºC	507	409	348	298
9	Pipes inner diameter	m	0.034	0.034	0.034	0.034
10	Pipes outer diameter	m	0.038	0.038	0.038	0.038
11	Pipe length in one passage	m	1.8	1.8	1.8	1.8
12	Pipe plate length on vertical	m	1.38	0.5	0.94	0.94
13	Pipe plate length on horizontal	m	1.4	1.4	1.4	1.4
14	Pipes' pitch on vertical	m	0.07	0.07	0.07	0.07
15	Pipes' pitch on horizontal	m	0.063	0.063	0.063	0.063
16	Distance from the wall on vertical	m	0.05	0.05	0.05	0.05
17	Distance on horizontal	m	0.05	0.05	0.05	0.05
18	Number of passages	No.	1	1	1	1

Crt. no.	PARAM.	UNIT	SECT I	SECT II	SECT III.	SECT IV
19	Pressure	bar	1	1	1	1
20	Salt layer thickness	m	0	0	0	0
21	Salt layer conductivity	W/m/°C	1	1	1	1
22	Soot layer thickness	m	0.0006	0.0006	0.0006	0.0006
23	Soot layer conductivity	W/m/°C	0.1	0.1	0.1	0.1
24	Steel conductivity	W/m/°C	50	50	50	50

RESULTS

Crt. no.	PARAM.	UNIT	SECT I	SECT II	SECT III.	SECT IV
1	Combustion gases flow	Nm^3/h	8436	8436	8436	8436
2	Outlet combustion gases flow	Nm^3/h	8436	8436	8436	8436
3	Inlet combustion gases average heat	kJ/ Nm^3/°C	1.4645	1.4476	1.436	1.426
4	Outlet combustion gases average heat	kJ/ Nm^3/°C	1.4476	1.4363	1.426	1.415
5	Inlet combustion gases heat	W	1740145	1387535	1171507	996456
6	Outlet combustion gases heat	W	1389749	1173024	998888	815993
7	Outlet combustion gases temperature	ºC	409	348	298	245
8	Temperature average difference	ºC	190	321	143	151
9	Gases average temperature	ºC	458	378	323	271
10	Fluid average temperature	ºC	267	57	180	120
11	Absorbed heat by the air	W	346891	212365	169167	178658
12	No. of pipes in a row in a vertical passage	No.	18	6	12	12
13	No. of pipes in a row in an horizontal passage	No.	21	21	21	21
14	Gas flow section	m^2	1.0836	1.0836	1.0836	1.0836
15	Fluid flow section	m^2	0.3431	0.114	0.228	0.228
16	Gas speed	m/s	5.79	5.16	4.72	4.31
17	Fluid speed	m/s	12.44	22.8	15.64	13.59
18	Gas convection coeff.	W/ m^2/°C	53.55	50.46	48.73	46.85
19	Fluid convection coeff.	W/ m^2/°C	54.75	85.78	64.67	57.2
20	Gas layer thickness	m	0.098	0.098	0.098	0.098
21	Radiation coefficient	W/ m^2/°C	5.322	3.531	3.28	2.57
22	Gas transfer coefficient	W/ m^2/°C	58.87	53.99	52.01	49.42
23	Global transfer coefficient	W/ m/°C	2.66	2.98	2.67	2.49
24	Global transfer coefficient	W/ m^2/°C	23.55	26.4	23.66	22.09
25	Machine length	m	1.8	1.75	1.74	1.87
26	Heat exchange surface	m^2	76.9	25.65	51.3	53.3
27	Necessary heat exchange surface	m^2	77.1	25.03	49.8	53.46
28	Pressure drop at air	N/ m^2	72.8	242.9	114.6	86.64
29	Pressure drop at gases	N/ m^2	77.17	37.32	47.5	43

4. EXPERIMENTAL RESULTS

The commissioning of the air pre-heater has demonstrated the correctness of the chosen solution.
Some experimental results are shown in Table 3.

Table 3 Experimental results obtained in the operation of the modernized air pre-heater.

Crt. No. /Param	*DC*	*DA*	*TAE*	*TGE*	*O2*	*CO*
U.M.	[mcN /h]	[mcN /h]	[°. C]	[°. C]	[%]	[ppm]
1	343	3300	326	246	2.5	130
2	345	3600	326	247	3.2	150
3	460	4500	348	264	0.8	65

The abbreviations are:
DC- fuel flow;
DA- combustion air flow;
TAE-pre-heater outlet combustion air temperature;
TGE – Flue gas temperature at stack;
O2 – Flue gas oxygen content;
CO – Flue gas carbon monoxide content.
In addition to tracking these parameters, also the pipe surface temperature from the beam where the cold air is entering is occasionally determined. It was found that this temperature does not drop below 180°C so the risk of low temperature corrosion is eliminated. Also found that the preheated air temperature increased from the initial pre-heater, with an average of approx. 100 °C, which means an economy of fuel of approx. 3.5%.

5. CONCLUSIONS

When sizing pre-heaters, in which the furnaces' combustion air is preheated, it is necessary to be done so to avoid the low temperature corrosion. This goal is achieved by using a computer program applicable on different alternatives.
An application is presented for a constructive alternative, in which the cold combustion air is introduced into the second stage of preheating.
Experimental results have validated the accuracy of calculations and also the avoidance of the low temperature corrosion. Also it was found that the preheated air temperature increased from the initial pre-heater, whit an average of approx. 100 °C, which means an economy of fuel of approx. 3.5%, from the use of the old pre-heater.

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