# THE DEVELOPMENT AND ASSESSMENT OF THE THERMO-ENERGETIC BALANCE FOR SIGNIFICANT CONSUMERS AROUND A BURNING KILN

**DAN CODRUT PETRILEAN**[1]

**Abstract:** The paper deals with the development of a real hourly energetic balance for a lime burning kiln. The parameters the present assessment is interest in were obtained through direct measuring, reading as well as determined.

**Keywords:** real hourly energetic balance, lime kiln, specific heat consumption, thermodynamic efficiency

## 1. OPERATION. TECHNOLOGIC PROCESS

This type of furnace is widely spread within the industry of binding agents as well as in the food, chemical and iron and steel industry. **Figure 1 represents a gas heated lime kiln**.

The corresponding granulation limestone is lifted by the electric bucket car 1, powered by the electric trolley 2, to the inlet shaft *3 of the kiln.* From the inlet shaft, the limestone passes through the funnel 4 to the pre-heating area 5 of the kiln. The pre-heating area outlet burning gases are evacuated through the exhaust shaft 6. *Some of the burning gases* are sucked in by a ventilator 7 and blown in the aeration chamber of the oil injectors 8 placed on two levels of the burning area 9.

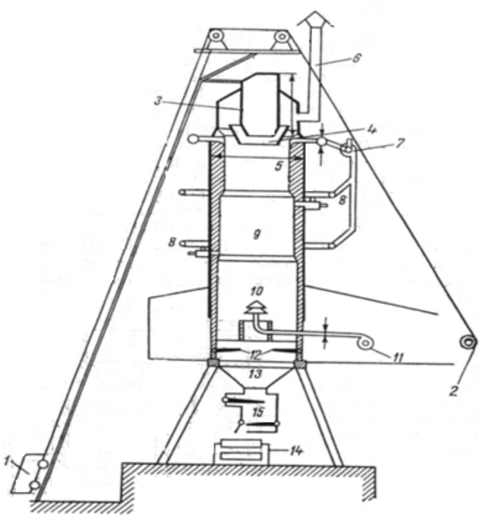


**Fig.1.** Vertical lime kiln

[1] *Lecturer Ph.D. Eng, at the University of Petroşani, dcpetrilean@yahoo.com*

*The lime resulted in the burning area, descends to the cooling are 10 where it is cooled down by an air flow blown by the ventilator 11.* The cooled down lime is taken by the vibrating extractor 12 to the bunker 13. Then, the kiln being under pressure, the lime is transported by the conveyor 14 through the outlet 15.

The specific heat consumption for such a furnace is 4400÷4600 kJ/kg lime, while the specific electric energy consumption is 14÷15 kWh/t lime. The specific productivity oscillates usually between 14 and 20 t/$m^2$ and 24 ore.

The hourly transport and supply capacity is 100 tons of limestone. The specific electric energy consumption is 0.8 - 1 kWh/ton. The fuel used for the calcination process is methane which is delivered considering the quality standard and the caloric efficiency: $H_i$ = 8343 kcal/$m^3_N$ for a temperature of t = 15°C and pressure p = 2.5÷4 bar; the operating pressure is 3.5 bar. Calcination is obtained by burning methane mixed with combustion air.

The limestone original from Suseni deposit belonging to SC Lafarge the determinations made by their own laboratory, has the following characteristics:

- the endothermic effect starts at 850$^0$C, carbon dioxide is eliminated by partially decomposing the calcium carbonate marked by the first step of losing weight on the gravimetric curve.

- the, pregnant, endothermic effect at 950$^0$C, continues the elimination of carbon dioxide by decomposing the calcium carbonate, marked therefore by a step of weight loss on the gravimetric curve. The total loss reached during the calcination process is 45.58%, and a calcination of 97.71%.

The calcination process through limestone burning described above contains two key principles which take place in two different areas of the kiln:

**a) The pre-heating area** is the area where the limestone enters the kiln and it acts as a regenerator where the heat accumulated by the gases is transferred to the limestone; the temperature reaches 800°C, resulting therefore in the chemical reaction called decarbonisation, actually taking place alternatively in two of the three shafts which are interconnected.

**b) The calcination area** is the area where the calcination phenomenon reaches approximately 1050°C. The Furnace operates with a high level of air excess, namely 30% in the furnace this assessment has considered. The combustion air quantity of the vertical kiln is approximately 17,575 $m^3_N$ air/hour. The combustion air is ensured by the combustion blowers. The proportion of cooling air in the combustion air is 65%. The required quantity for cooling air is 11,424 $m^3_N$ /hour.

## 2. THE ENERGETIC BALANCE AND THE SANKEY DIAGRAM

The values comprised in Table 1 are the values which have been taken into consideration in order to make the real hourly energetic balance. These values were obtained through direct measuring using the laboratory equipment of the beneficiary as well as through determinations (Table 1).

*Table 1* **Thermo-energetic measures considered for the framework of the balance**

| No. | Measure | Value | Unit |
|---|---|---|---|
| 1 | Limestone mass flow | 9000 | kg/h |
| 2 | Mass of outlet lime | 4500 | kg/h |
| 3 | CaCo3 specific heat | 0.808 | kJ/kg·K |
| 4 | CaO (lime) specific heat | 0.77 | kJ/kg·K |
| 5 | Gas consumption | 575.2 | $m^3_N$/kg |
| 6 | Superior caloric power at $0^0$C | 40958.65 | kJ/$m^3$ |
| 7. | Superior caloric power at $15^0$C | 38748.59 | kJ/$m^3$ |
| 8. | Inferior caloric power at $0^0$C | 36871.4 | kJ/$m^3$ |
| 9 | Inferior caloric power at $15^0$C | 34930.82 | kJ/$m^3$ |
| 10 | Inferior caloric power used in determinations | 34930.82 | kJ/$m^3$ |
| 11 | Furnace air inlet flow (combustion + cool down) | 26986 | $m^3$/h |
| 13 | The surface of the walls on steps in total | 61.43+56.14 4+58.32+68. 904+69.984 | $m^2$ |
| 14 | Average temperature of the walls 2nd step | 66.84 | $^0$C |
| 15 | Average temperature of the walls 3rd step | 72.28 | $^0$C |
| 16 | Average temperature of the walls 4th step | 78.45 | $^0$C |
| 17 | Average temperature of the walls 5th step | 51 | $^0$C |
| 18 | Average temperature of the walls 6th step | 47 | $^0$C |
| 19 | Environmental temperature | 30.2 | $^0$C |
| 20 | Environmental pressure | 99880 | N/$m^2$ |
| 21 | Methane temperature entering the fireplace | 20 | $^0$C |
| 22 | Fuel enthalpy | 33.488 | kJ/$m^3_N$ |
| 23 | Burning gases enthalpy | 296.71 | kJ/$m^3_N$ |
| 24 | Air enthalpy | 162.8 | kJ/$m^3_N$ |
| 25 | Burning gases volume | 27586 | $m^3$/h |
| **No.** | **Measure** | **Value** | **Unit** |
| 26 | Limestone burning temperature | 900 | $^0$C |
| 27 | The surface of non-tightness | 21.7 | $m^2$ |
| 28. | Exhaust shaft gas volume | 53159 | $m^3$/h |
| 29 | Limestone pre-heating temperature | 598 | $^0$C |

Based on the values measured, read or determined, using the thermo-dynamic relations for an energetic balance of a kiln presented by the speciality literature, the energetic measures which are comprised by the framework of the balance have been determined. These values are presented in Table 2.

*Table 2* **Summary table for the lime kiln – real hourly balance**

| **Inlet heat** | **MJ/h** | **%** | **Outlet heat** | **MJ/h** | **%** |
|---|---|---|---|---|---|
| Chemical heat of the fuel | 20090 | 69.64 | Heat of the endothermic reactions | 7907 | 27.41 |
| | | | Sensitive heat of lime at the kiln outlet | 104.64 | 0.37 |
| | | | Sensitive heat of limestone at the burning temperature | 2196 | 7.61 |
| | | | Total useful heat | 10207.64 | 35.39 |
| Sensitive heat of the fuel | 19.262 | 0.07 | Losses through the heat of the exhaust gases | 15770 | 54.66 |
| Sensitive heat of the combustion and cool down air | 4393 | 15.23 | Losses due to incomplete chemical burning | 35.633 | 0.14 |
| Sensitive heat of the limestone | 4348 | 15.06 | Heat loss due to non-tightness and through open orifices | 2,337.0 | 8.1 |
| | | | Heat lost through the walls of the kiln | 492.986 | 1.71 |
| | | | Total heat loss | 18642.61 | 64.61 |
| Total inlet | 28850.26 | 100.0 | Total outlet | 28850.26 | 100.0 |

The following energetic efficiency parameters were obtained based on the above presented heat values:

1. Thermodynamic efficiency: $\eta_t = 35.39\,\%$

2. Raw thermal efficiency: $\eta_{tb} = 39.3\,\%$

3. Specific heat consumption: $C_s = 4469\,\frac{kJ}{kg\,var}$

For a more suggestive representation of the energetic values which compose the framework of the balance, the Sankey diagram of the real hourly energetic balance was therefore created and it is represented in Figure 2.

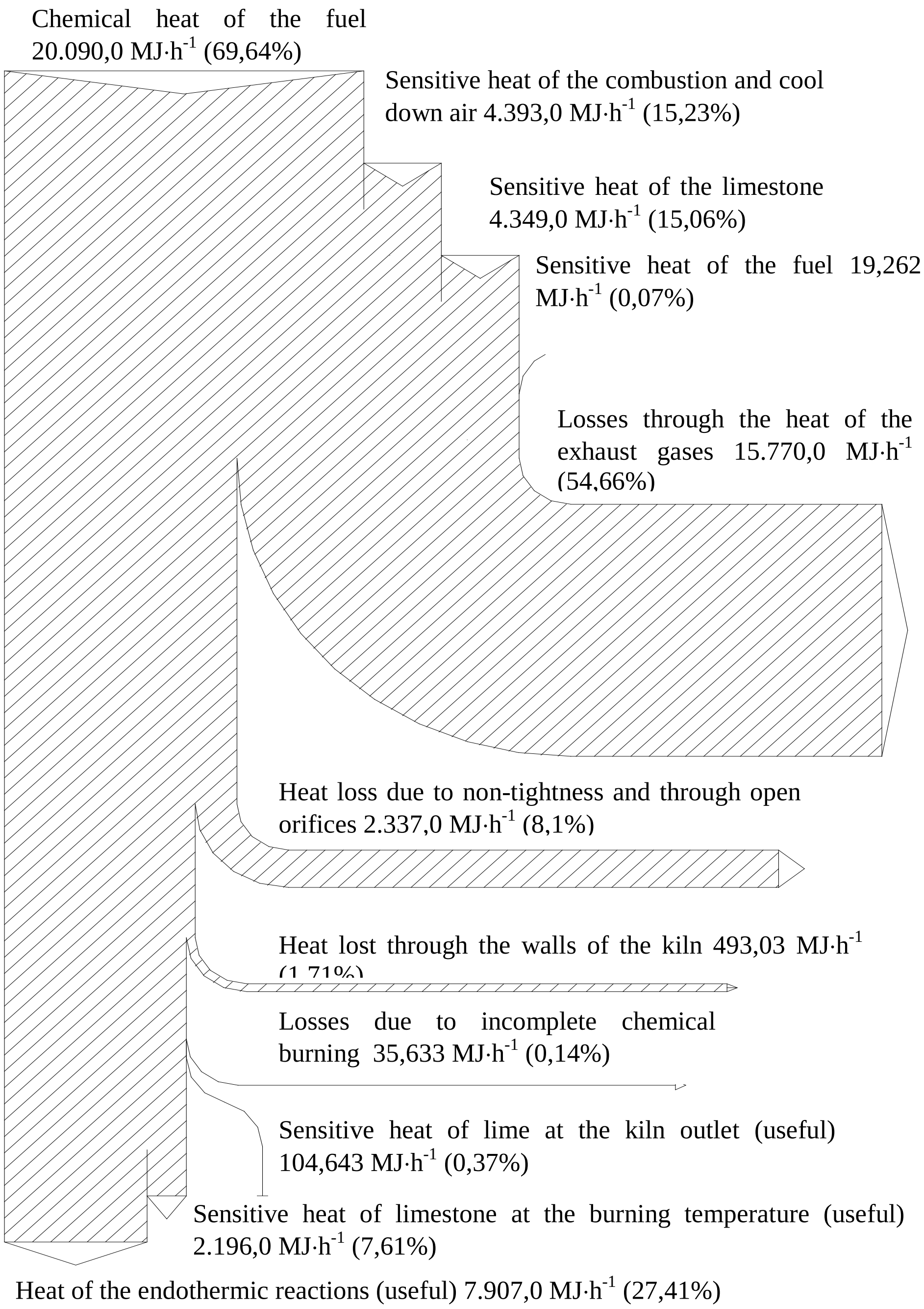


**Fig. 2.** Sankey Diagram of the real hourly energetic balance

## 3. CONCLUSIONS AND PROPOSITIONS

Having analysed the lime kiln, the following conclusions may be drawn:

1. The analysed kiln meets the functional parameters corresponding to this constructive type and age, the operational and technical staff ensuring a reasonable energetic efficiency. As 2 modernised MAERZ kilns are planned to be installed, there is no need to invest major material resources in modernising the old kilns;

2. The most significant loss of heat is through the heat of exhaust gases;

3. The measures destined for the increase of energetic performance relate to:

- The thermo-gaso-dynamic improvement of the gas circuit in the pre-heating – recovery area, in order to reduce the amount of gas evacuated to the exhaust shaft having a temperature of $178^0$C; this measure leads to a decrease of heat loss through the exhaust gas of 0.83 %.

- Reducing the losses through non-tightness and openings, the pressure loss inside the kiln leading to major losses; losses may reduced with 0.54% by tightening the external orifices and attentively manipulating the portholes.

## REFERENCES

**[1]** "*Elaborarea si analiza auditului energetic complex pentru consumatorii semnificativi de gaz metan şi energie electrică pentru cuptorul de producere var, tip Maerz*", Scientific Research Contract, no. 10/15.07. 2011. Contracting Parties: S.C. Macon SRL Deva – beneficiary, University of Petroşani, contractor.

**[2] Teoreanu I.,** and others *Instalatii termotehnologice*, Technical Publishing House Bucharest, 1979.

**[3] Brunklaus J.H.,** *Cuptoare industriale*, Technical Publishing House Bucharest, 1977.

**[4] Popa B. and others,** *Termotehnica , agregate si instalatii termice*, Technical Publishing House Bucharest, 1979.

**[5]** ***, *Prospecte ale firmelor constructoare de cuptoare pentru industria materialelor de constructie.*

**[6] Berinde, T**., - Întocmirea şi analiza bilanţurilor energetice în industrie, vol. I, vol. II, Technical Publishing House Bucharest, 1976.