ESTABLISHING THE ENERGY BALANCE FOR THE LOOS DAMPFIX 1250 STEAM GENERATOR

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Abstract: In the article, the real hourly thermal energy balance was conceived in order to establish the energy performance indicators for a steam generator. The diagrams showing the variation of the efficiency and the specific heat consumption depending on the thermal load, as well as the dependence of the heat consumption from the fuel depending on the steam flow rate, were drawn up.

Keywords: efficiency, balance heat, steam generator, specific fuel consumption

1. INTRODUCTIVE ASPECTS

The energy balance is a practical way of expressing the principle of energy conservation and highlights the equality between the energy input and output from the analyzed circuit for a certain period of time.

A steam generator is a form of low water-content boiler, similar to a flash steam boiler. The usual construction is as a spiral coil of water-tube, arranged as a single, or monotube, coil. Circulation is once-through and pumped under pressure, as a forced-circulation boiler. The real thermal balance of a steam generator is perform through direct method.

The purpose of the article is to verify the operation of the steam generator under energy efficiency conditions. In the specialized literature, there are concerns in this field, especially to be able to design and justify measures to reduce the consumption of electricity and thermal energy at the consumer [1], [2], [3].

2. CASE STUDY ON THE LOOS DAMPFFIX DF 1250 STEAM GENERATOR

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The usefulness of establishing the thermal energy balance resides in the fact that it allows the determination of energy performance indicators, identifying solutions to reduce energy consumption and energy costs.

The real balance of heat, for the steam generator, using as combustible the methane gas with an inferior specific heat capacity H_i = 31666 kJ/kg and the elementary analysis were draw up: CH_4 = 97.91; C_2H_4 = 0.26; O_2 = 0.21; N_2 = 1.17. There is no preheated air outside the steam boiler.

According to the manufacturer, the steam generator has the following nominal data: steam flow 1250 kg steam/hour and pressure 10 bar, power 834 kW, natural gas consumption 106.1 kg/h, temperature 184 ^{0}C.

The equation for the steam boiler's balance of heat is:

$$Q_{c,ch} + Q_{c,f} + Q_a + Q_L = Q_u + Q_{ga,f} + Q_{inc} + Q_p + Q_r \quad (1)$$

where:- Q_{chc} - combustible's chemical heat;

Q_{cf},- combustible's physical heat;

Q_a- physical heat of the input water ;

Q_L-Input air heat;

Q_u- useful heat, equal with the steam heat of eliminated from the boiler;

$Q_{ga\,f}$,- physical heat wastage of the burned gases;

Q_{inc}- wastage through incomplete chemical burning;

Q_p- wastage through the boiler purge;

Q_r- wastage caused by radiation and convection.

Figure 1 shows diagrams of the heat quantities entering and leaving the balance contour defined at the beginning of the analysis:

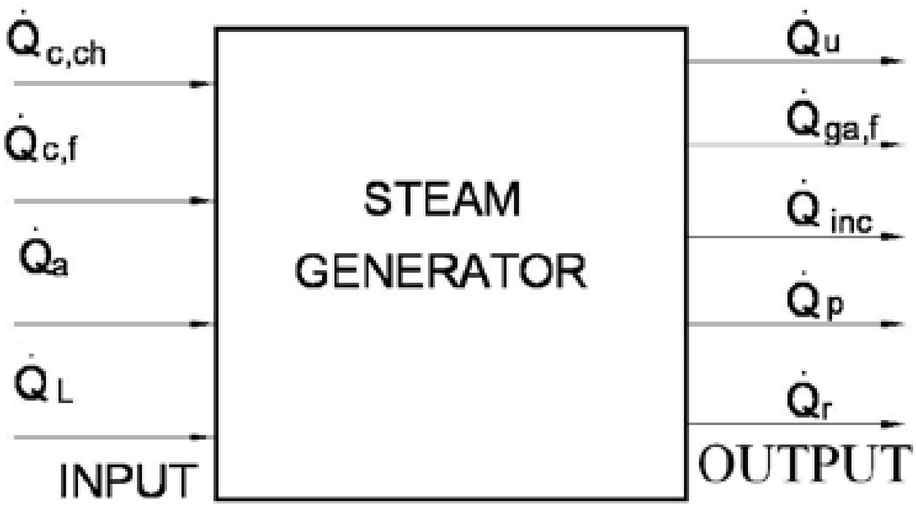

Figure 1. Heat that goes in and out of the balance outline [1]

Initial data

Steam flow $D = 935\ kg/h$

Enthalpy of steam $iv = 2773\ kJ/kg$ (at T = 448 K and p = 8 bar)

Purge flow $D_p = 9.956\ kg/h$

Enthalpy of water $iA = 385.1\ kJ/kg$

Fuel enthalpy $ic = 38.09\ kJ/m_N^3$

Lower calorific power $Hi = 31666\ kJ/m_N^3$

Fuel flow $Cc = 82.76\ m_N^3/h$

Air flow $La = 9.8 \cdot Cc = 811.048\ m^3/h$

Air enthalpy $ia = 27.39\ kJ/m^3$

Flue gas flow $Vga = 1557\ m^3/h$

Empirical relationship Vga calculation

$Vgal = 1.5225 \cdot D \cdot \frac{iv}{3600}$ $Vgal = 1.097\ \cdot 10^3\ m^3/h$

Combustion gas enthalpy $iga = 215\ kJ/m^3$

Global heat exchange coefficient $\alpha = 70\ kJ/(m^2hgrd)$

Total heat transfer surface $St = 12\ m^2$

The average temperature of the wall $tp = 68\ °C$

Air temperature $ta = 18\ °C$

The input data for the steam generator are shown in table 1:

Table 1. **Input values for the analyzed steam generator**

No.	**Size measured**	**U.M.**	**The measured value**
1	Live steam	kg/h	935
2	Steam enthalpy	kJ/kg	2773

The most input values were obtained through ″situ″ measurements, and a small part was taken from specialized literature. Based on the specific relationships from the specialized literature, the real hourly heat balance for the steam generator was achieved by the direct method [4]. The obtained results are presented in value and percentage in summary table 2:

Table 2. **Synthesis of heat quantities obtained for the heat balance, real hourly steam generator: LOOS Dampffix DF 1250**

Input heat	MJ/h	%	Outgoing heat	MJ/h	%
Chemical heat of fuel	2621.56	87.20	The heat of the steam produced	2593.507	86.249
			Total useful heat	**2593.507**	**86.249**
Feed water sensible heat	360.07	11.97	Sensible heat losses of exhaust gases	334.345	11.118
The sensible heat of the fuel	3.15	0.10	Purge losses	28.567	0.951
The sensible heat of the air entering the generator	22.22	0.73	Losses in the environment	50.581	1.682
			Total heat lost	**413.493**	**13.751**
Total input	**3007**	**100**	**Total output**	**3007**	**100**

A more suggestive representation of these values was obtained by drawing up the Sankey diagram in figure 2.

Performance parameters have been calculated and are presented in table 3.

Table 3. **Performance parameters of the steam generator**

No.	Size calculated	U.M.	Value
1	Thermal efficiency	%	86.249
2	Thermal efficiency of operation	%	84.378
3	Fuel efficiency	%	85.195
4	Specific heat consumption	MJ/(kg steam)	3.215
5	The thermodynamic efficiency of combustion	%	87.226
6	Specific fuel consumption	m^3_N/MJ	0.037
7	Specific fuel consumption per Kg of steam	m^3_N/(kg steam)	0.089

The values of the performance parameters according to the prospectus provided by the manufacturer are presented in table 4.

Table 4. **Performance parameters provided by the manufacturer**

No.	Parameter	U.M.	Value
1	Thermal efficiency	%	88.72
2	Specific consumption of combustible	m^3_N/kg of steam	0.085

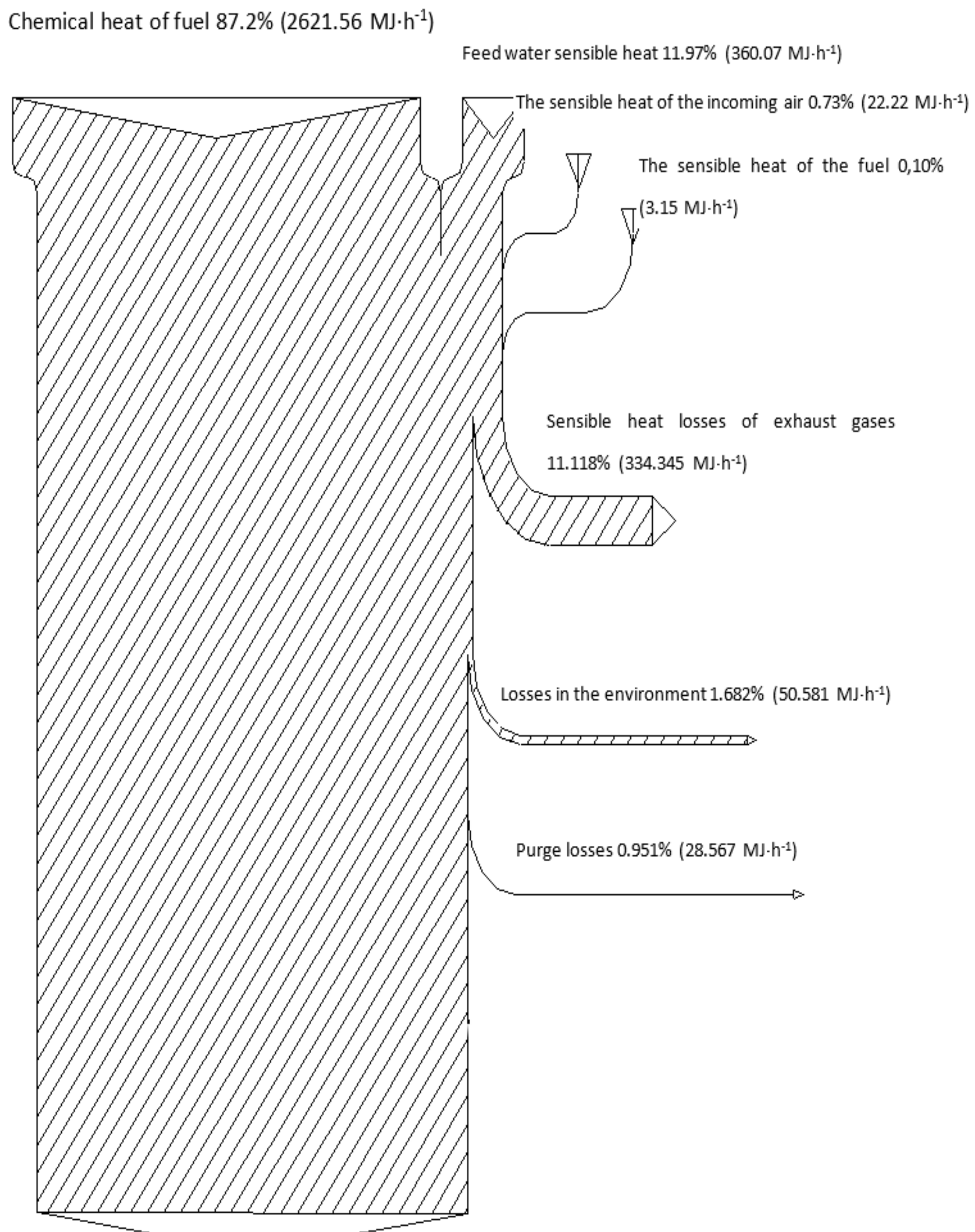

Figure 2. SANKEY diagram for the LOOS Dampffix DF 1250 steam generator

PERFORMANCE PARAMETERS

Thermal efficiency $\eta T = \frac{QD}{QT} \cdot 100$ $\eta T = 86.249$ %

Thermal efficiency of operation

$$\eta te = \frac{QD - QA}{QT - QA} \cdot 100$$ $\eta te = 84.378$ %

Fuel efficiency $\eta C = \frac{QD - QA}{Q_{cl}} \cdot 100$ $\eta C = 85.195$ %

Specific heat consumption $q = \frac{QT}{D}$ $q = 3.215$ MJ/(kg steam)

The thermodynamic efficiency of combustion

$$\eta A = \frac{Q_{cl} - Q_{ga}}{Q_{cl}} \cdot 100$$ $\eta a = 87.226$ %

Specific consumption of combustible

$$C_{sc} = \frac{C_c}{QD - QA - QL}$$ $C_{sc} = 0.037$ m^3_N/MJ

Specific fuel consumption per Kg of steam

$$C_{sca} = \frac{C_c}{D}$$ $C_{sca} = 0.089\ m_N^3$/(kg steam)

PERFORMANCE PARAMETERS AS PER PROSPECTUS

Thermal efficiency $\eta Tp = 88.72$ %

Specific consumption of combustible $Cscap = 0.085\ m_N^3/(kg\ steam)$

After that, the variations of energy performances at different loads of the steam generator are presented.

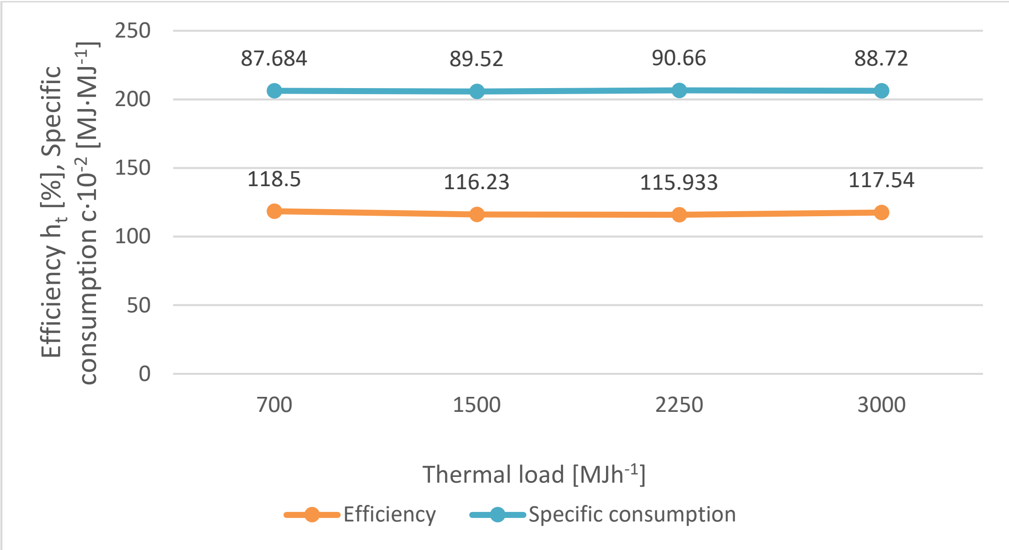

Figure 3. The variation of efficiency and specific heat consumption depending on the thermal load of the LOOS Dampffix DF 1250 steam generator

In order to verify the inclusion in the data from the specialized literature in the field, the variation of the specific fuel consumption according to the load of the steam generator was highlighted (fig. 4):

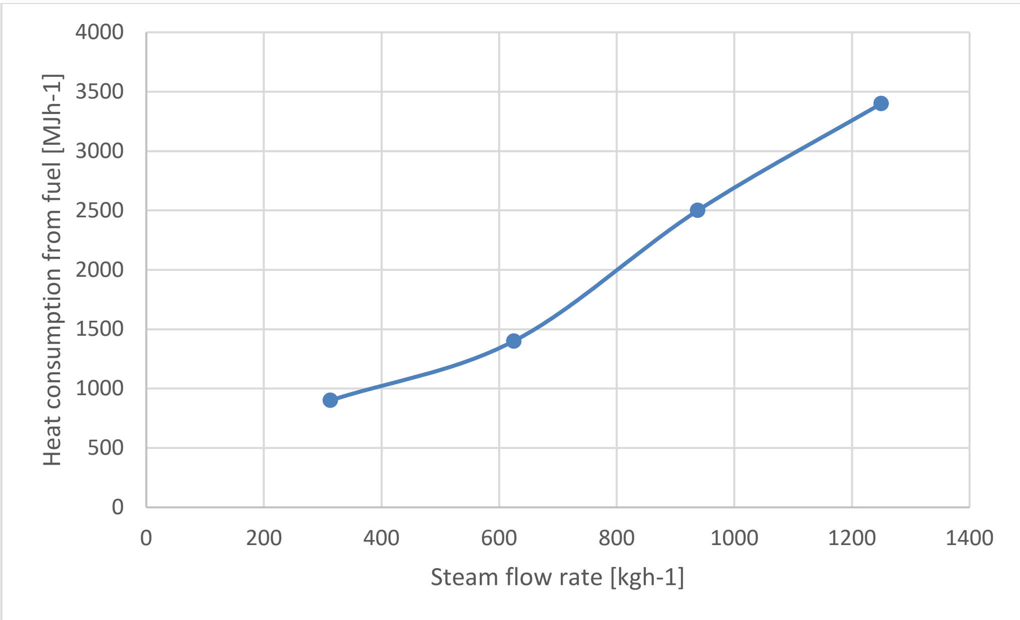

Figure 4. The variation of heat consumption from the fuel depending on the steam flow at the LOOS Dampffix DF 1250 steam generator

3. CONCLUSION

Comparing the performance parameters related to the real situation from the moment of experimental determinations with the nominal parameters from the prospectus of the LOOS Dampffix DF 1250 steam generator, insignificant differences are observed in terms of energy, from which it follows that no measures are required to increase energy efficiency.

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