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THERMAL ANALYSIS OF A UNIVERSITY CAMPUS HEATING PLANT

BY

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Abstract. University campus buildings are high energy consumers, despite the fact that they have low operating periods during the holidays that coincide with periods of maximum energy consumption. These buildings are used for diverse activities (research, classrooms, offices, dormitories, libraries) by a variable number of people for different time periods. This study describes the thermal analysis of the buildings and the district heating system with natural gas boilers performed in order to identify the components with higher inefficiency and then to determine strategies for energy saving. The study revealed an energy saving potential of about 7%. The main strategies for thermal energy saving on campus are: increasing the efficiency of heating boilers, controlling indoor temperature design, and improving the thermal performance of buildings envelope. A future research direction will be to analyse the possible energy, environmental and economic gains by recovery of waste heat contained in flue gas exhausted by heating boilers.

Key words: heating plant; thermal analysis; university campus.

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1. Introduction

Worldwide, new heating technologies are turning our attention to energy efficiency, reduced fuel consumption, reduced water consumption and exhaust emissions. The European Union (EU) set the ambitious objective to reduce the greenhouse gas emissions by 20% till 2020 (http://ec.europa.eu/). As the energy consumption in buildings at European level is 40% of total energy consumption, it results that the greatest potential for energy conservation is found in buildings. Buildings in universities campuses, as well as hospitals, hotels, schools, commercial buildings are considered as energy-guzzling buildings, equivalent to buildings with an annual consumption of more than 2000 tonne oil equivalent/year (Min Hee Chung and Eon Ku Rhee, 2014). The buildings in universities campus have high energy consumption because they are used for diverse activities (research, classrooms, offices, dormitories, libraries) and are also used by a variable number of people for different time periods. The energy consumption of these buildings should have lower energy consumption due to holidays overlap with periods in which heating or cooling demand is the highest. More studies have been conducted regarding energy conservation in universities campuses and various strategies have been proposed such as: improving administrative policies, using automatic metering systems, using of high efficient energy equipment, implementing energy conservation technologies and renewable energy systems (Min Hee Chung and Eon Ku Rhee, 2014; Nurdan Yildirim, 2006).

This study attempts to analyse the potential for energy conservation only in the heating system of "Dunărea de Jos" campus, excluding buildings, since most of them are old and have already been upgraded in recent years, new windows, doors and roofs being changed.

From this perspective, energy conservation strategies may include: increasing the efficiency of heating boilers, implementing a system for controlling indoor temperature and thermal insulation of buildings.

2. University Campus Presentation

The main campus of "Dunărea de Jos" University consists of 22 buildings with different characteristics and different utilization (Fig. 1). The total floor area is 17027 m^2 and the heat load (according to the natural gas bills) in the last heating season was 6165956.99 kW. The buildings are heated by a district heating system with 3 (similar) natural gas boilers. The buildings characteristics are given in Table 1 and the heating boilers characteristics are given in Table 2.

The main components of the heating system are distributed in (1) heating boilers building, (2) heat exchanger building, (3) pipe lines between

these two buildings, (4) pipe lines for hot water distribution to buildings (consumers) and (5) circulation pumps.

The hot water from boilers flows to the heat exchanger where transfers a part of its heat to the water for buildings heating (consumers).The water is redirected towards the consumers through 4 main pipes; each pipe having a number of buildings that need to be heated.

Table 1
Building Characteristics

Building code	Building type	Volume [m^3]	Total floor area, [m^2]	Number of floors	Orientation	Wall	
						Materials	Thickness [cm]
Y	Educational	48240	1.206	7	V	Concrete	30
G	Educational	11907	756	4	S	Concrete	30
I	Workshop	1874	310.8	0	E	Sandwich panels	10
E	Educational	10706	874	3	E	Concrete	30
L	Educational	6344	83807	1	E	Concrete	30
CN	Laboratories	3520	465	1	V	Brick	30
K	Laboratories	5388	857	2	S	Concrete	30
F	Educational	8949	885	2	E	Concrete	30
D	Educational	11340	1073	1	E	Concrete	30
B	Educational	8470	711	2	V	Concrete	30
H	Workshop	7614	1015	0	V	Concrete	30
P	Thermal point	2523	650	1	S	Concrete	30
SA	Educational	3006	288	1	E	Concrete	30
SB	Educational	8118	447	4	E	Concrete	30
SC	Educational	3194	398	0	E	Concrete	30
SD	Educational	11177	507	5	E	Concrete	30
SE	Educational	3279	292	1	N	Concrete	30
AN	Educational	16788	1492	2	V	Brick	30
AE	Educational	9926	88235	2	E	Brick	30
AS	Educational	12233	1087	2	S	Brick	30
AR	Educational	1477	19514	1	V	Brick	30
J	Workshop	6952	1137	0	N	Concrete	30

Table 1
Continuation

Building code	Roof type	Insulation	
		Materials	Thickness [cm]
Y	Mansard	Default	
G	Hipped	Default	
I	Flat	Mineral wool	10
E	Flat	Default	
L	Hipped	Default	
CN	Flat	Default	
K	Hipped	Default	
F	Flat	Default	
D	Flat	Default	
B	Flat	Default	
H	Flat	Default	
P	Flat	Default	
SA	Flat	Default	
SB	Flat	Default	
SC	Flat	Default	
SD	Flat	Default	
SE	Flat	Default	
AN	Hipped	Default	
AE	Hipped	Default	
AS	Hipped	Default	
AR	Hipped	Default	
J	Flat	Default	

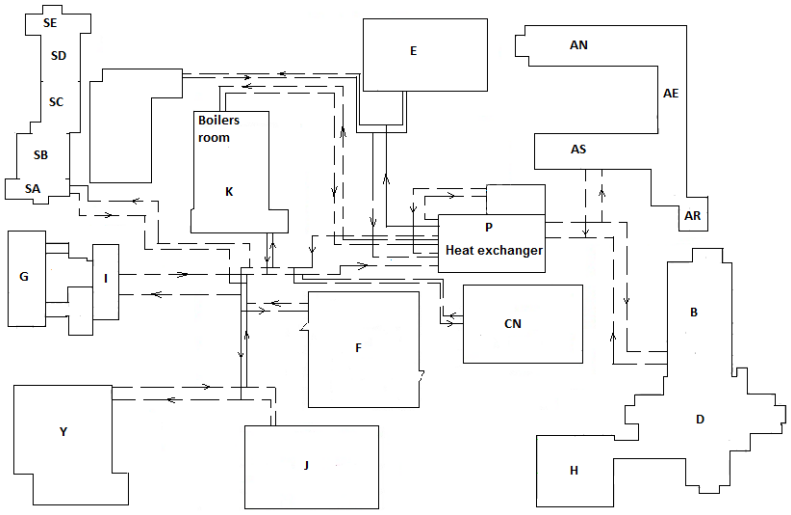

Fig. 1 − "Dunărea de Jos" University campus.

Table 2
Heating Boilers Characteristics

Net power / boiler	kW	2000
Efficiency at 100%	%	95.51
Efficiency at 30%	%	95.80
Maximum flue gas flow rate	m^3/h	3301.69
Flue gas temperature	°C	184
Pressure drop water circuit	mbar	25
Normal pressure	bar	5
Total capacity	l	2000
Electric power	W	20
Fuel type	–	natural gas

The pressure in the installation is set to 2.33 bars. The heating boilers are similar and have three levels of combustion control. The temperature of hot water is set at 70°C and the temperature of return water is set at 55°C. The heating system should provide a constant temperature of 21°C in buildings.

The heating boilers are fully automatized. They stop when the outside temperature reaches 20°C.

3. Thermal Analysis of Heating System

The heating system analysis started with calculation of energy consumption for heating according to the Methodology for calculation of buildings energy performance – Mc001-2006 (http://www.mdrl.ro/), developed based on European standards.

The seasonal energy consumption for heating is given by the following general equation:

$$Q_{f,h} = \left(Q_h - Q_{rhh} - Q_{rwh}\right) + Q_{th}, \text{ [kWh]} \quad (1)$$

where: Q_h – energy demand for building heating, [kWh]; Q_{rhh} – heat recovered from the heating plant, [kWh]; Q_{rhw} – heat recovered from the preparing of domestic hot water and used for building heating, [kWh]; Q_{th} – total heat loss of the heating plant, [kWh].

The seasonal energy consumption for heating was also calculated by using the software given in (http://vl.academicdirect.ro/), which calculates in simplified way the heating demand considering several parameters such as: characteristics of walls, windows, roof, floor and environmental temperatures. The results of calculations are given in Table 3.

Table3
Heat Demand Calculation Results

Heat demand, [kWh]	First method	Second method
	5812239.59	5922118.98

It can be seen that there is a difference of about 1.5% between the results obtained using the calculation methodologies.

The real energy consumption for buildings heating was calculated by summing the monthly natural gas consumption during the period of 1st of October 2014 and 31st of March 2015 (Table 4).

Comparing the data given in Table 3 and Table 4 it can be noted that the real energy consumption for heating is higher with 7.24% than the calculated energy demand. The difference represents the heat losses associated to heating boilers, heat exchanger and hot water pipe lines.

Table 4

Registered Consumption of Natural Gas

Consumption period	Natural gas consumption [kWh]
1st of October 2014 – 31st of March 2015	6265958.99

4. Conclusions

The study results show an energy saving potential in the heating system, without energy modernisation of buildings, of about 7%. The main strategies for thermal energy saving on campus include increasing the efficiency of heating boilers, controlling indoor temperature design, and improving the thermal performance of buildings envelope. A future research direction will be to analyse the possible energy, environmental and economic gains by recovery of waste heat contained in flue gas exhausted by heating boilers. The average measured exhaust temperature of flue gas is about 170°C. An especial attention will be paid to application of water preheating in a condensing economizer as an alternative for the consumption of natural gas in boilers for university buildings heating. This is a solution that has been demonstrated successfully for many boiler applications (Gas Technology Institute, 2013).

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ANALIZA TERMICĂ A CENTRALEI TERMICE DINTR-UN CAMPUS UNIVERSITAR

(Rezumat)

Tehnologiile din sectorul energetic evoluează în permanenţă, iar atenţia se îndreaptă spre eficientizarea şi optimizarea sistemelor de încălzire pentru reducerea consumului de combustibil, a pierderilor de căldură şi creşterea randamentului centralelor termice. Uniunea Europeană şi-a propus un obiectiv ambiţios de reducerea emisiilor de gaze cu efect de seră cu 20% până în 2020, iar un pas important în această direcţie este reducerea consumului de combustibili fosili necesar încălzirii clădirilor. În categoria clădirilor mari consumatoare de energie se regăsesc şcolile, spitalele, hotelurile, clădirile cu destinaţie comercială şi clădirile din campusurile universitare.

În alte studii de specialitate s-au atins subiecte precum îmbunătăţirea politicilor administrative, utilizarea de echipamente de încălzire cu eficienţă energetică ridicată sau utilizarea sistemelor energetice regenerabile.

Acest studiu descrie analiza termică a clădirilor şi a sistemului de încălzire cu gaze naturale dintr-un campus universitar pentru a determina strategiile de utilizare mai eficientă a sistemului. Pe baza rezultatelor s-a stabilit că există un potenţial de economisire a energiei de aproximativ 7%, dacă se iau o serie de măsuri precum creşterea eficienţei cazanelor, automatizarea sistemului de control a temperaturii interioare fără a considera îmbunătăţirea performanţelor energetice ale clădirilor.

În cercetările viitoare se vor analiza posibilităţile de îmbunătăţire a sistemului de încălzire prin preîncălzirea apei într-un economizor cu condensare.