ANALYSIS OF THE THERMO-ENERGY BALANCES OF C. E. T. PAROȘENI NETWORKS

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Abstract: *The paper aims at measuring the thermal energy delivered to the transmission / distribution thermal networks by the S.A. Paroșeni. The calculation methodology and appliances used are presented, while, finally, quantitative and percentage analytical calculations of the thermo energy components are performed. On the basis of the results obtained, measures are proposed for increasing the energy efficiency along the heat transfer and distribution network.*

Key words: *network, thermal energy, thermo energy balance*

1. Summary of technological process

The centralized heat system supplied by S.E. Paroșeni comprises two hot water transport systems, namely:

a. Paroșeni-Vulcan-Petroșani main pipe, which supplies urban and industrial consumers in Vulcan and Petroșani.

b. Paroșeni - Lupeni main pipe, which supplies Lupeni Mine with thermal energy.

The configuration of the hot water transport network is shown in figure 1

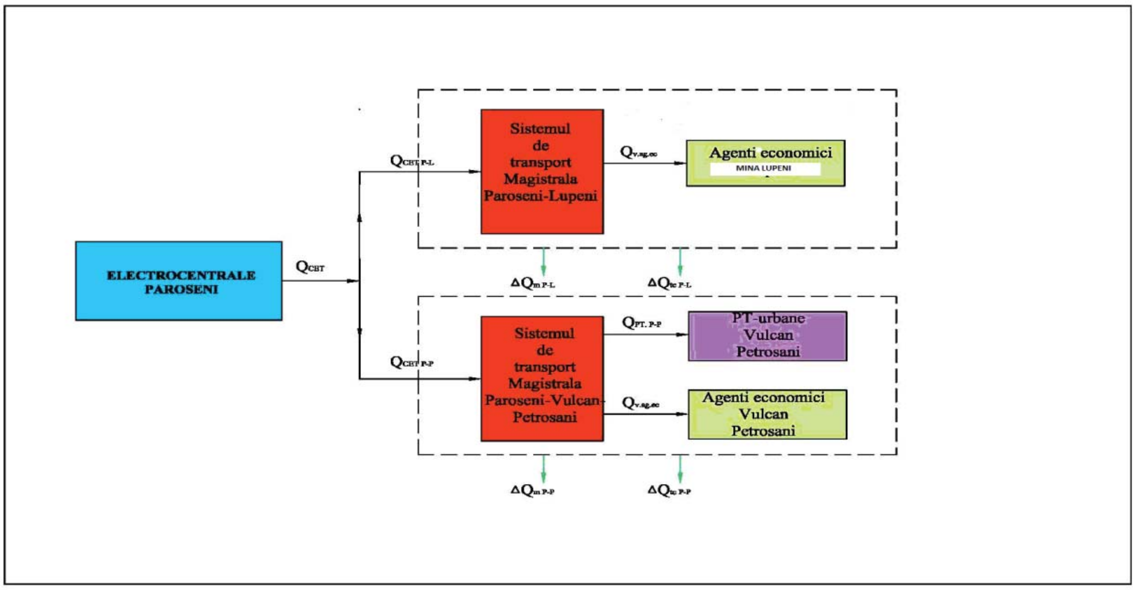

Fig. 1 *Simplified flow path*
Source: S.E. Paroșeni- Energy Management Office

The simplified scheme of thermal energy supply of Petroșani, Vulcan and Lupeni towns and the diagram showing the heat energy points and devices are presented in figure 2.

The symbols in figure 1 and 2 are explained below:

Q_{CET} – thermal energy delivered by CET Paroșeni during the balance sheet period

$Q_{CET\ P\text{-}L}$ – the thermal energy delivered in the Paroșeni-Lupeni network

$Q_{CET\ P\text{-}P}$ – the thermal energy delivered in the Paroșeni-Petroșani network

$Q_{PT\ P\text{-}L}$ – the thermal energy entering the thermal points on the Paroșeni-Lupeni network

$Q_{PT\ P\text{-}P}$ – the thermal energy entering the thermal points on the Paroșeni-Petroșani network

$Q_{v.ag.ec}$– thermal energy sold to economic agents

$\Delta Q_{m\ P\text{-}L}$- losses of thermal energy through mass losses in the Paroșeni-Lupeni network

$\Delta Q_{m\ P\text{-}P}$- losses of thermal energy through mass losses in the Paroșeni- Petroșani network

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$\Delta Q_{tc\ P\text{-}L}$- thermal energy losses through heat transfer in the environment in the Paroșeni-Lupeni network
$\Delta Q_{tc\ P\text{-}P}$- thermal energy losses through heat transfer in the environment in the Paroșeni-Petroșani network
$t_{T/R}$ – the hot water temperature in the flow and return pipes
$t_{RP\text{-}L}$ – the temperature of the hot water in the return pipes on the Paroșeni-Lupeni network
$t_{RP\text{-}P}$– the temperature of the hot water in the return pipes on the Paroșeni-Petroșani network.

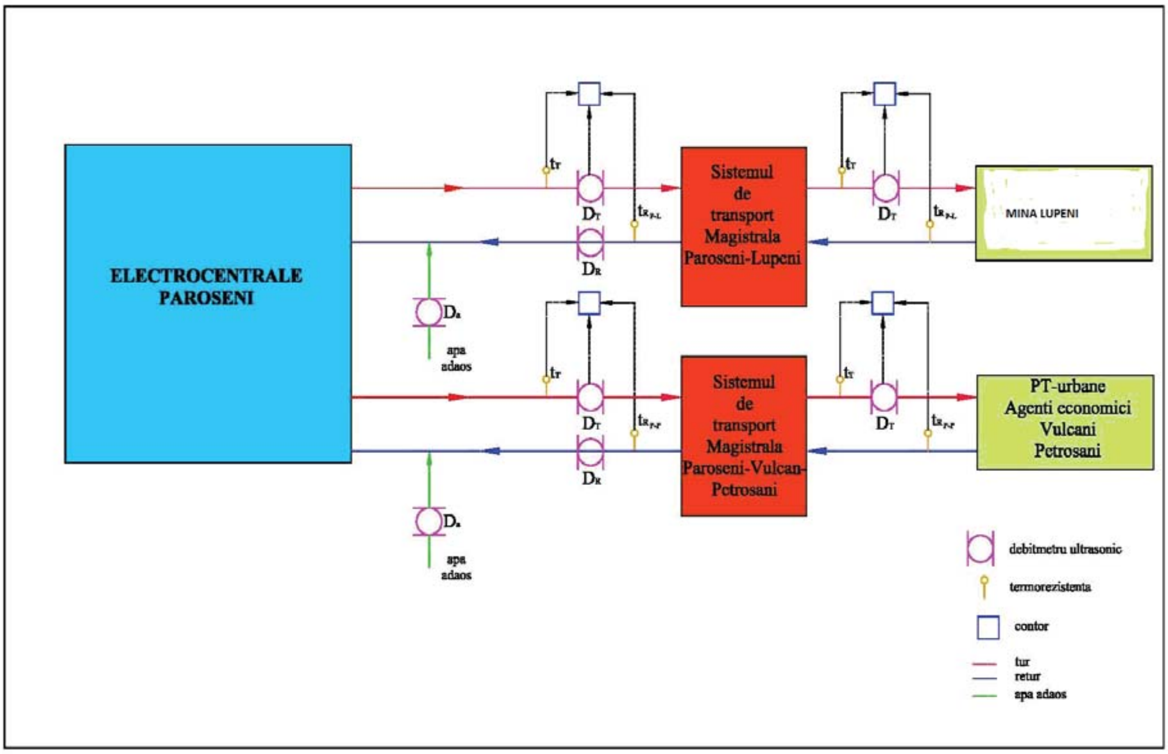

Fig. 2 *Diagram showing the thermal energy points and devices*
Source: S.E. Paroșeni- Energy Management Office

The transfer of hot water from the hot water production plants to the consumers in the Jiu Valley is done through the pumping station which is located in the boiler room and is designed in two stages of pumping, which send hot water through two transport networks:
- Paroșeni-Vulcan-Petroșani network (Dn-900 mm)
- Paroșeni-Lupeni network (Dn-500 mm).

The first network is supplying with thermal energy in the form of hot water the consumers in Vulcan and Petroșani. The length of the networks from Paroșeni Electrocentrale to the farthest consumer on the territory of Petroșani municipality is approx. 18 km (PT 28). The district heating networks have diameters ranging from Dn 900 to Dn 50.

The second network supplies only Lupeni mine during the analyzed period.

The length of the networks from Paroșeni Electrocentrale to Lupeni mine is 1.4 km. The hot water pumping station from the plant's hot water production plants to the consumers in the Jiu Valley consists of two pumping stages:
- Stage I contains four TD-300-60 heating pumps, pump flow rate 1700 m3 / h, one in operation and 3 reserve, in the operating mode, a pump in operation providing a flow rate of maximum 900 m3 / h, which send water to the Paroșeni -Vulcan-Petroșani main pipe;
- Stage II contains three heat pumps of the same type, pump flow rate 1700 m3 / h, due to the small flow required for Lupeni mine (max. 70 m3 / h) no need to start a pump in stage II.
- In the situation where the CAF works, the water circulation on the Paroșeni-Lupeni main pipe is made from the CAF circulation pump.

The main fuel used is the coal. Auxiliary fuel, used for starting and stabilizing flame, is natural gas.

2. Measuring devices

For the measurement of the thermal energy the measured data given by the measuring devices mounted along the hot water transport system and the distribution of the hot water for consumption and for heating were used.

The measuring devices used are: [6]

- Pressure gauges for measuring hot water pressure at the outlet and inlet of hot water in the boiler

- Heat-resistant temperature transducers mounted on hot water flow and return, precision class ± 0.2, Bailey type

- Heat meters with the following measuring functions:

- thermal energy
- thermal power
- hot water flow
- water flow pipe flow temperature
- water temperature in the return pipe..

3. Methodology for calculation

The period taken into account for the measurement of energy is: October 28th, 2016 - April 24th, 2017.

The equation for the thermal energy balance for the hot water transport and distribution system is the following:

$$Q_{CETParoseni} = Q_{Paroseni-Petrosani} + Q_{Paroseni-Lupeni} \quad [\text{Gcal}]$$

$$Q_{P-P} = Q_{Paroseni-Petrosani} = Q_{PT} + Q_{v.ag.ec} + \Delta Q_m + \Delta Q_{tc} \quad [\text{Gcal}]$$

$$Q_{P-L} = Q_{Paroseni-Lupeni} = Q_{PT} + Q_{v.ag.ec} + \Delta Q_m + \Delta Q_{tc} \quad [\text{Gcal}]$$

where:

$Q_{CETParoseni}$ - the thermal energy delivered by Paroșeni CET in the balance sheet period [Gcal]

Q_{P-P} - the thermal energy delivered to the Paroșeni- Petroșani network [Gcal]

Q_{P-L} - the thermal energy delivered to the Paroșeni-Lupeni network [Gcal]

Q_{PT} - the thermal energy entered to the thermal points [Gcal]

$Q_{v.ag.ec}$ - the thermal energy sold to economic agents [Gcal]

ΔQ_m - the thermal energy losses through mass losses [Gcal]

ΔQ_{tc} - the thermal energy losses through environmental heat transfer [Gcal]

The system percentage losses are determined with the relations: [5]

- the percentage of heat losses by mass losses (of heatened water)

$$q_m = \frac{\Delta Q_m}{Q_{CETParoseni}} * 100 \quad [\%]$$

- the percentage of thermal heat loss

$$q_{tc} = \frac{\Delta Q_{tc}}{Q_{CETParoseni}} * 100 \quad [\%]$$

- the percentage of annual losses in the transport system

$$q_{.sistem} = \frac{\Delta Q_m + \Delta Q_{tc}}{Q_{CETParoseni}} = q_m + q_{tc}$$

The heat supplied to consumers connected to the primary heating and hot water network was calculated on the basis of monthly consumption and other data provided by Paroșeni Electrocentrale.

4. Measurement of the thermal energy delivered to the transmission / distribution networks by Electrocentrale Paroșeni

The real annual thermal energy balance realized for the hot water transport networks, S.E. Paroșeni to the urban consumers and the economic agents in Petroșani, Vulcan and Lupeni is presented in table 1. The values resulted from the balance performed on each network.

The annual real thermal energy balance realized for S. E Paroșeni is presented in table 2, and the Sankey diagram is shown in fig. 3.

Table 1. *Calculation of the real annual thermal energy balance components of S.E. Paroșeni*

No.	Name of the size	Symbol	U.M.	Method of determination	Value
1.	The thermal energy produced by S.E. Paroșeni	$Q_{CETParoseni}$	Gcal	metered	124959
2.	Thermal energy entering thermal points (PT)	Q_{PT}	Gcal	metered	26432.88
3.	Thermal energy sold to economic agents	$Q_{v.ag.ec.ST}$	Gcal	metered	2066.73
4.	Thermal energy entering thermal points and sold to economic agents	$Q_{t.ST}$	Gcal	calculated	28499.6
5.	Thermal energy losses through mass losses in the transport network	ΔQ_{mST}	Gcal	calculated	10360
6.	Total losses of thermal energy in the transport network	ΔQ_{ST}	Gcal	calculated	96459.4
7.	Heat losses through heat transfer in the transport network	ΔQ_{tcST}	Gcal	calculated	86099.4
8.	Percentage losses of heat through mass losses	q_{mST}	%	$q_{mST} = \frac{\Delta Q_{mST}}{Q_{CETParoseni}}$	8.29
9.	Percentage losses of heat by heat transfer	q_{tcST}	%	$q_{tcST} = \frac{\Delta Q_{tcST}}{Q_{CETParoseni}}$	68.90
10.	Total percentage losses in the transport system	q_{sistem}	%	$q_{sistem} = q_{mST} + q_{tcST}$	77.19

Source: Processing performed by the author who participated in the measurements, the analytical calculation and the drawing up of the Energy balance sheet for the thermal energy transmission networks produced by S.E Paroșeni in 2017

Table 2. *Table of annual real thermal balance of Electrocentrale Paroșeni transport system*

No.	Name of the balance sheet item	Symbol	Value	
			Gcal	%
A.	Heat input into the transport system			
1.	Thermal energy produced by S.E.Paroșeni	$Q_{CETParoseni}$	124959	100
B.	Output thermal energy in the form of useful energy			
2.	The thermal energy entering the thermal points and sold to the economic agents, out of which:	$Q_{t.ST}$	28499.6	22.81
3.	The thermal energy entering the urban thermal points	Q_{PT}	26432.88	21.15
4.	Thermal energy sold to economic agents	$Q_{v.ag.ec.ST}$	2066.73	1.66
C.	Thermal energy out of contour in the form of losses			
5.	The thermal energy lost in the transport system of which:	ΔQ_{ST}	96459.4	77.19
6.	- by mass losses	ΔQ_{mST}	10360	8.29
7.	- by transferring heat to the outside	ΔQ_{tcST}	86099.4	68.90

Source: Processing performed by the author who participated to the measurements, the analytical calculation and the drawing up of the Energy balance sheet for the thermal energy transmission networks produced by S.E Paroșeni in 2017

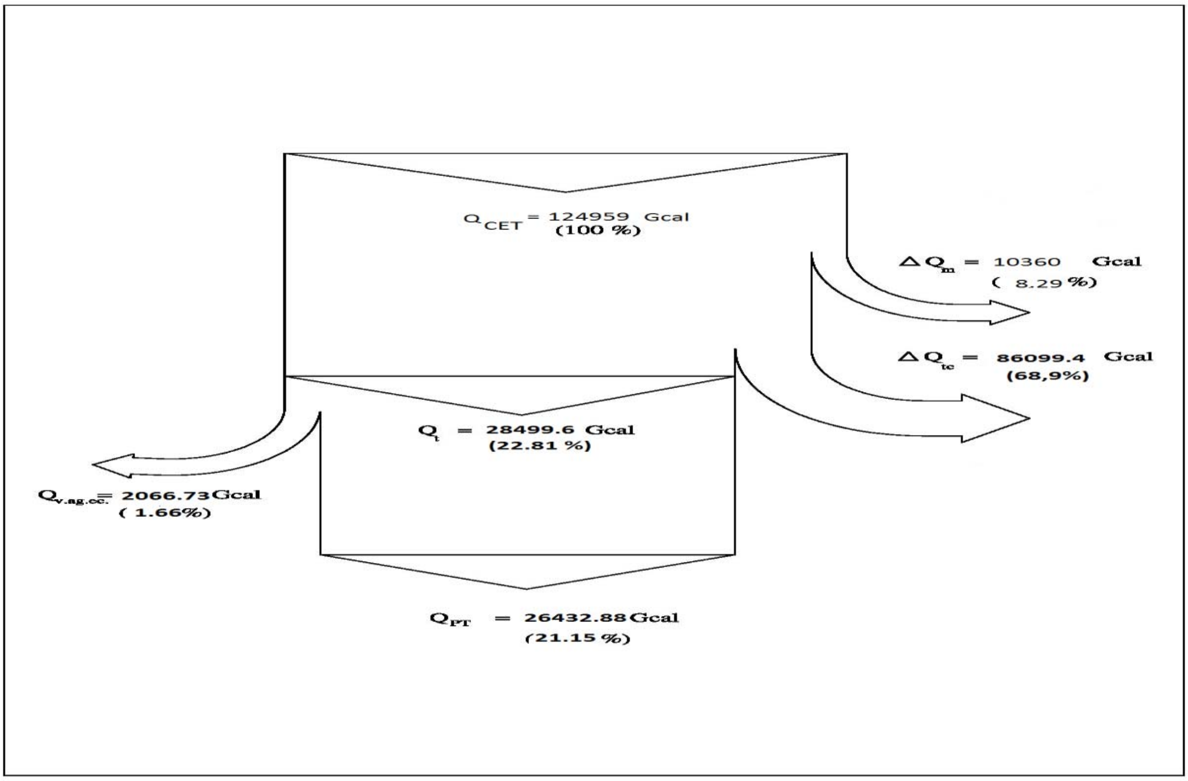

Fig. 3. *Sankey Diagram*

CET Paroșeni could provide the heat for 35268 apartments and 20 economic agents. The economic transformations have made the district heating network serve a small number of apartments, namely 2372 apartments and 12 economic agents.

From the analysis carried out on the entire transport system resulted that S.Electrocentrale Paroșeni delivered to the plant's limit, during the analyzed period, a quantity of thermal energy of 124959 Gcal distributed on the two heating networks it owns as follows:

a. Paroșeni - Vulcan – Petroșani network - 113325 Gcal

b. Paroșeni - Lupeni network - 11634 Gcal.

Total heat consumption of the Jiu Valley is 28,499.6 Gcal, of which 26432.88 Gcal enters the thermal points and 2066.73 Gcal is consumed by economic agents.

Total losses of thermal energy on the transport system totaled 96459.4 Gcal and represent 77.19% of the energy delivered by S.E.Paroșeni. Out of this amount, the thermal losses through mass losses amount to 10360 Gcal and represent 8.29% of the delivered energy, and the heat transfer losses are 86099.4 Gcal and represent 68.90% of the delivered energy.

5. Conclusions

To increase energy efficiency on the Paroșeni - Vulcan-Petroșani network we propose the following measures:

- Periodic control of heat losses and rapid intervention to reduce them
- Replacing some network sections during the scheduled shutdown
- Replacement and relocation of some connections from the district heating network to a new location, so as to avoid interference with the connections that currently cross the private property, as follows:
- Resizing and relocation of the network connection in the Petroșani Emergency Hospital area
- Rebuild damaged thermal insulation
- For the replacement and relocation of pipelines, execution projects regarding the pipe types, length and diameter of the pipes and the types of insulation used should be developed.

To increase energy efficiency on the Paroșeni-Lupeni network we propose the following measures:

- Replacement of some sections of the network, which display an advanced degradation state and even their relocation to a new location, as the pipelines now cross private property or social utility locations, such as:
- Replacing some sections from the district heating network to thermal point no. 8, in Lupeni Municipality
- Thermal insulation restoration

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