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The Study of Recovery Possibilities of a Part of the Waste Pressure Let Down Energy by Means of Gas Lamination on Bilciuresti Structure in the Butimanu Measurement Point

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Abstract

This paper presents a study performed on the Bilciureşti structure regarding the possibility to partially recover natural gas energy let down in the lamination process at Butimanu measurement and regulation point. For the purpose of energy recovery we advise the use of turboexpanders placed inside the Butimanu measurement and regulation station.

Key words: *gas, flow, pressure*, *turboexpander*

Introduction

The diagram showing pressure variation during natural gas extraction at Bilciureşti storage facility reveals energy recovery is possible only until the 72nd day of the cycle when gas pressure hits the level of 53 bar.

For the variant set forth in this paper we set out with the premises that at all rigs lamination will be accomplished through the existing nozzles but only up to a pressure of 62 bar, the collectors will transport the gas extracted to the Butimanu compression station where a turboexpander station will be set up to recover the expansion energy from 60 to 30 bar, the value required for injection into the transport network. The turboexpanders will function throughout the first 72 days of the extraction cycle as gas pressure in the storage facility will then drop below 60 bar. Once expanded, the gas is measured and then injected into the National Transport Network.

Based on the premises presented above we developed a calculation software able to simulate the variations in the various thermodynamic parameters for suitable delivery into the transport network. For the calculation of the thermodynamic parameters we had as starting point the values measured on the structure as a result of the experimental research undertaken. The thermodynamic parameters were calculated starting from the figures measured on the structure as a result of the experimental research undertaken.

Presented below are the results of the method employed to recover the energy generated during gas expansion at the measurement point of the Butimanu compression station.

Energy Recovery at Butimanu Measurement Point

Energy is recovered via a group of turboexpanders set up inside the measurement point. The turboexpanders will be operational starting with day 1, when the overall flow rate from the storage facility amounts to 11.965.000 Nm^3/day (98,855 kg/s) and the gas reaching Butimanu has a pressure of 60 bar and a temperature of 14°C, until day 72 when the flow rate is 8.101.000 Nm^3/day, the gas pressure is 53 bar and its temperature 12°C. The gas is expanded in turboexpanders until it reaches a pressure level of 30 bar.

This paper studies two types of turboexpanders, in one step and in two steps, with and without pre-heating. For heating some of the gas processed in the turboexpander is used.
Fig. 1 features the calculation diagram of the thermodynamic parameters underlying the development of the calculation software.

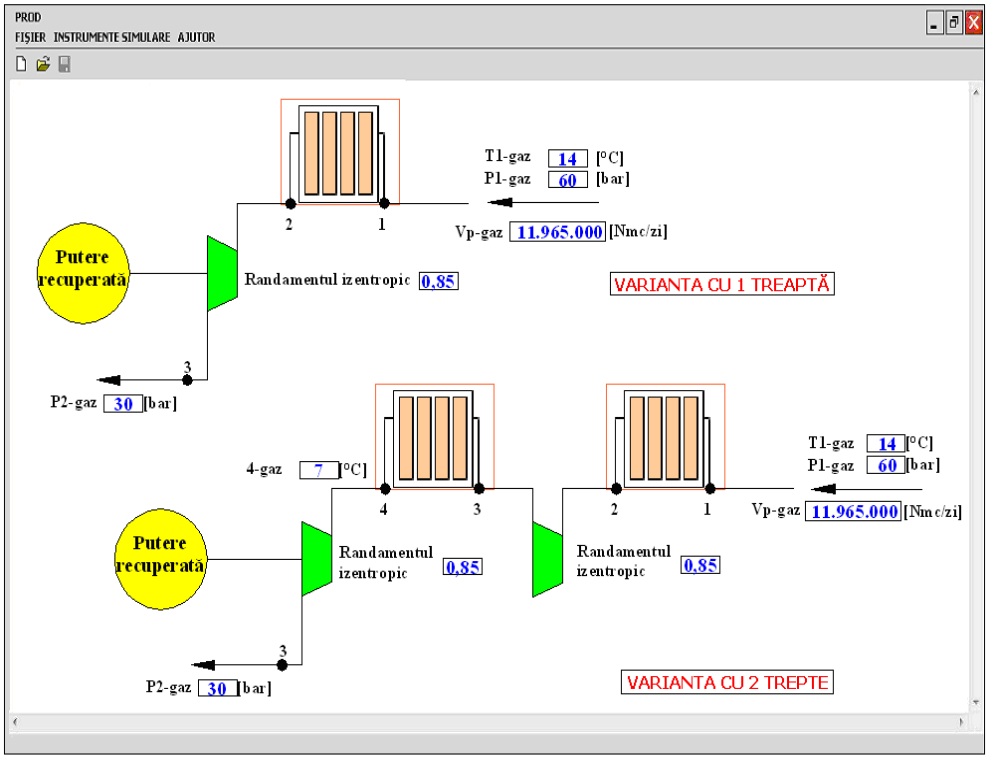

Fig. 1. Calculation diagram of the thermodynamic processes

The results of the recovery process simulation are presented below.

Day 1: Maximum volume flow rate of the gas 11,965,000 Nm^3/day (98.855 kg/s). The expansion takes place from 60 to 30 bar.

One-step expansion. It takes place from 60 to 30 bar according to the diagram in fig. 2. The parametric values defined during the expansion process taking place in the turboexpander, both without and with pre-heating, are shown in tables 1 and 2.

Table 1. Parametric values defined in the expansion process with no pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Density [kg/m³]
1*	60	287.0	820.534	4.309	45.520
3p*	30	239.4	737.081	4.309	27.282
3*	30	244.3	749.599	4.361	26.488
Recovered power 7012.354 kW					

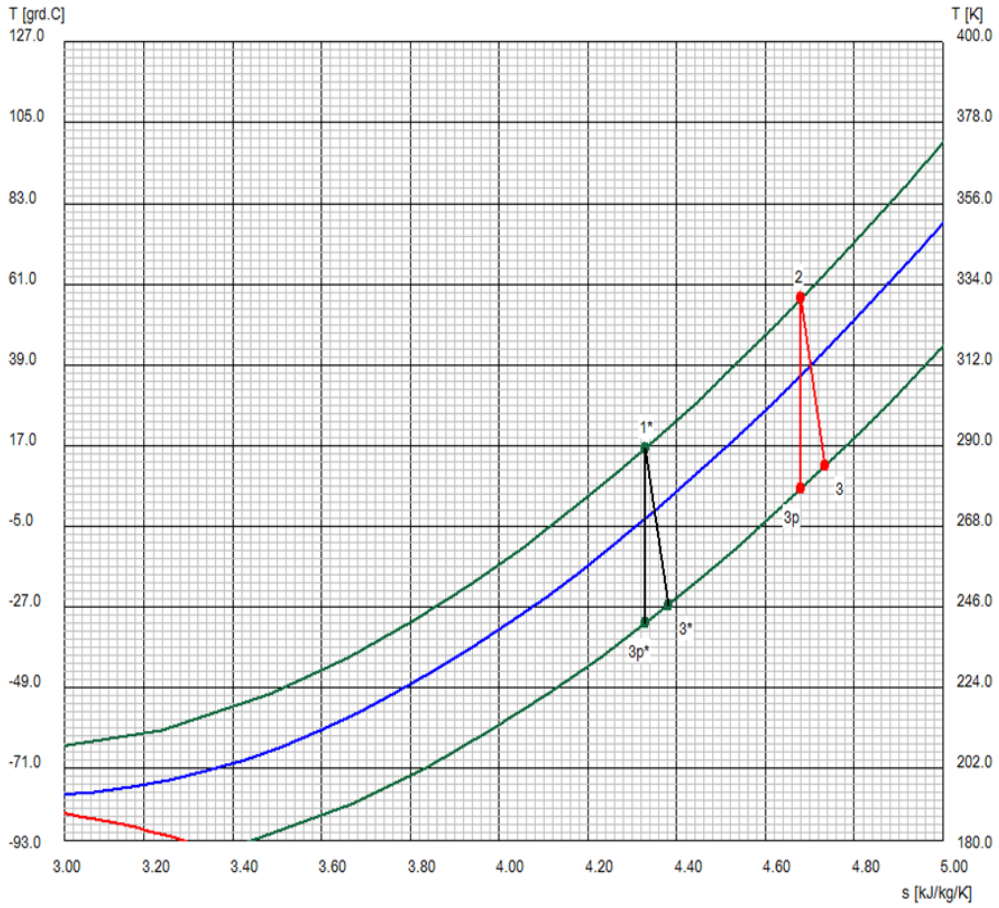

Fig. 2. Diagram of the thermodynamic processes in a one-step turboexpander

Table 2. Parametric values defined in the expansion process with pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Density [kg/m³]
1	60	327.8	928.439	4.661	37.767
3p	30	276.0	827.492	4.61	22.500
3	30	282.2	842.634	4.715	21.875
Recovered power 8482.247 kW					

Two-step expansion. It takes place from a pressure of 60 bar to 42.43 bar (step 1) and from 42.43 to 30 bar (step 2) according to the diagram in fig. 3. The parametric values defined in the expansion process taking place in the turboexpander, both with and without pre-heating, are given in tables 3 and 4.

Table 3. Parametric values defined in the expansion process without pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Density [kg/m³]
1*	60	287.0	820.534	4.309	45.520
3p*	42.43	262.2	776.907	4.309	35.308
3*	42.43	264.7	783.451	4.334	34.811
5p*	30	241.7	743.052	4.334	26.897
5*	30	244.1	749.112	4.359	26.518
Recovered power 3666.899 kW (step I) + 3394.541 kW (step II)=7060.44 kW					

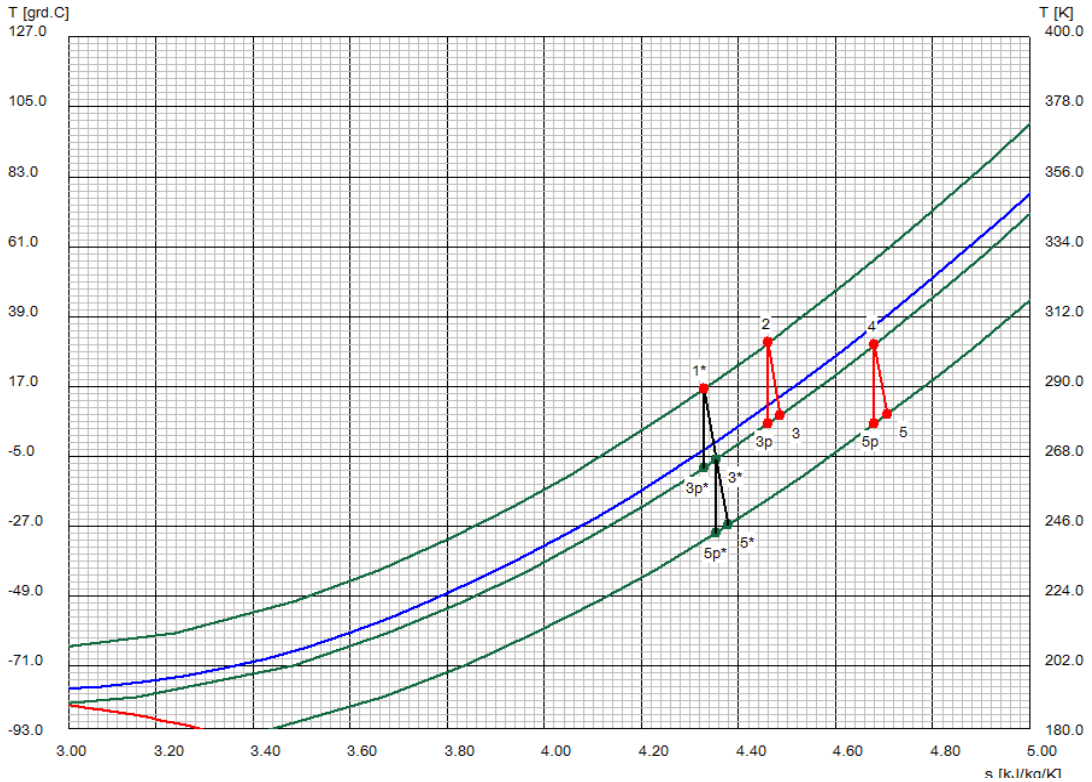

Fig. 3. Diagram of the thermodynamic processes in a 2-step turboexpander

Table 4. Parametric values defined in the expansion process with pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Density [kg/m³]
1	60	287.0	820.534	4.309	45.520
2	60	301.5	859.375	4.441	42.330
3p	42.43	276.0	812.421	4.441	32.789
3	42.43	278.8	819.464	4.466	32.337
4	42.43	301.1	875.740	4.661	29.177
5p	30	276.0	827.492	4.661	22.500
5	30	279.0	834.729	4.687	22.196
Recovered power 3945.372 kW (step I) +3945.372 kW (step II) =7999.503kW					

Day 72: Minimum volume flow rate of the gas 618,000 Nm^3/day (5.106 kg/s). The expansion occurs from a pressure level of 53 to 30 bar.

One-step expansion. It takes place between the pressure levels of 78 and 32 bar according to the diagram in fig. 4. The parametric values defined during the expansion process taking place with or without pre-heating in the turboexpander, are shown in Tab. 5 and 6.

Table 5. Parametric values defined in the expansion process without pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Densitate [kg/m³]
1*	60	287.0	820.534	4.309	45.520
3p*	30	239.4	737.081	4.309	27.282
3*	30	244.3	749.599	4.361	26.488
Recovered power 7012.354 kW					

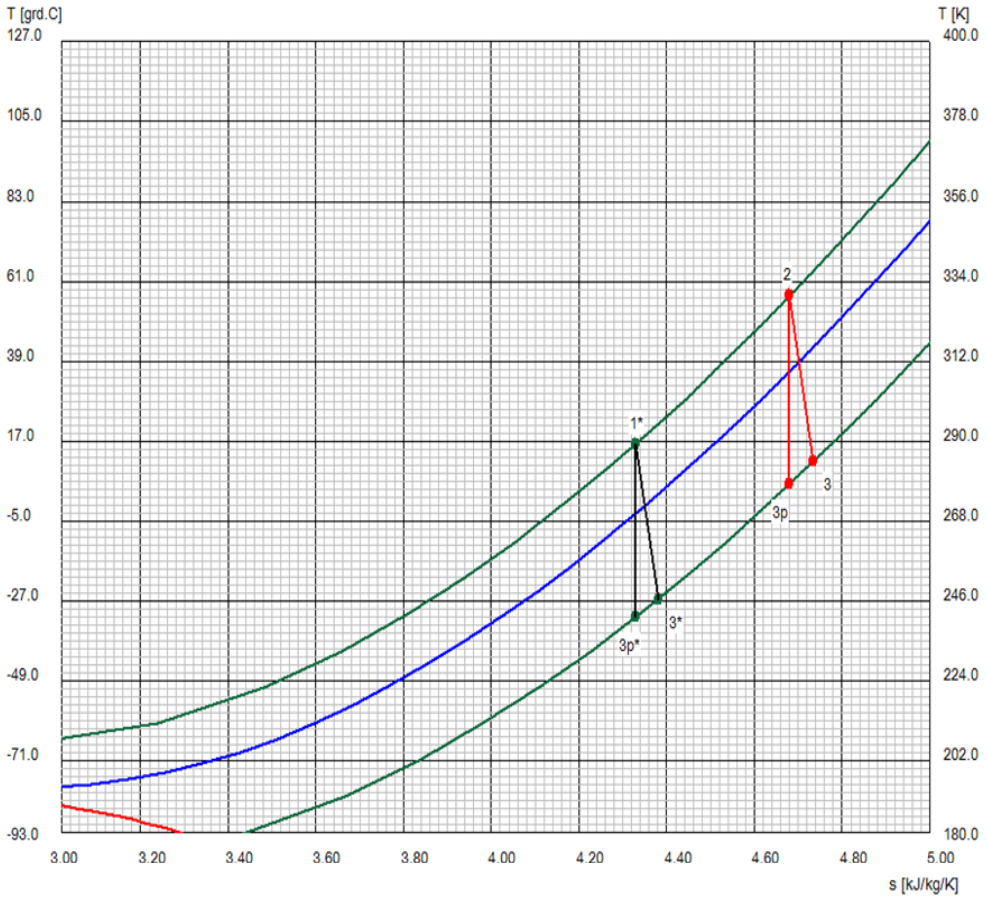

Fig. 4. Diagram of the thermodynamic processes in a one-step turboexpander

Table 6. Parametric values defined in the expansion process with pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Densitate [kg/m³]
1	60	327.8	928.439	4.661	37.767
3p	30	276.0	827.492	4.661	22.500
3	30	282.2	842.634	4.715	21.875
Recovered power 8482.247 kW					

Two-step expansion. It is accomplished within a pressure range of 53-39.87 bar (step I) and 39.87-30 bar (step II), according to the diagram in fig. 5. The parametric values defined in the expansion process taking place with and without pre-heating in the turboexpander, are shown in tables 7 and 8.

Table 7. Parametric values defined in the expansion process without pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Densitate [kg/m³]
1*	53	285.0	823.207	4.376	40.059
3p*	39.87	264.7	786.926	4.376	32.473
3*	39.87	266.9	792.368	4.396	32.103
5p*	30	247.8	758.279	4.396	25.966
5*	30	249.8	763.392	4.417	25.669
Recovered power 2064.114kW (step I) + 1939.342 kW (step II)=4003.456 kW					

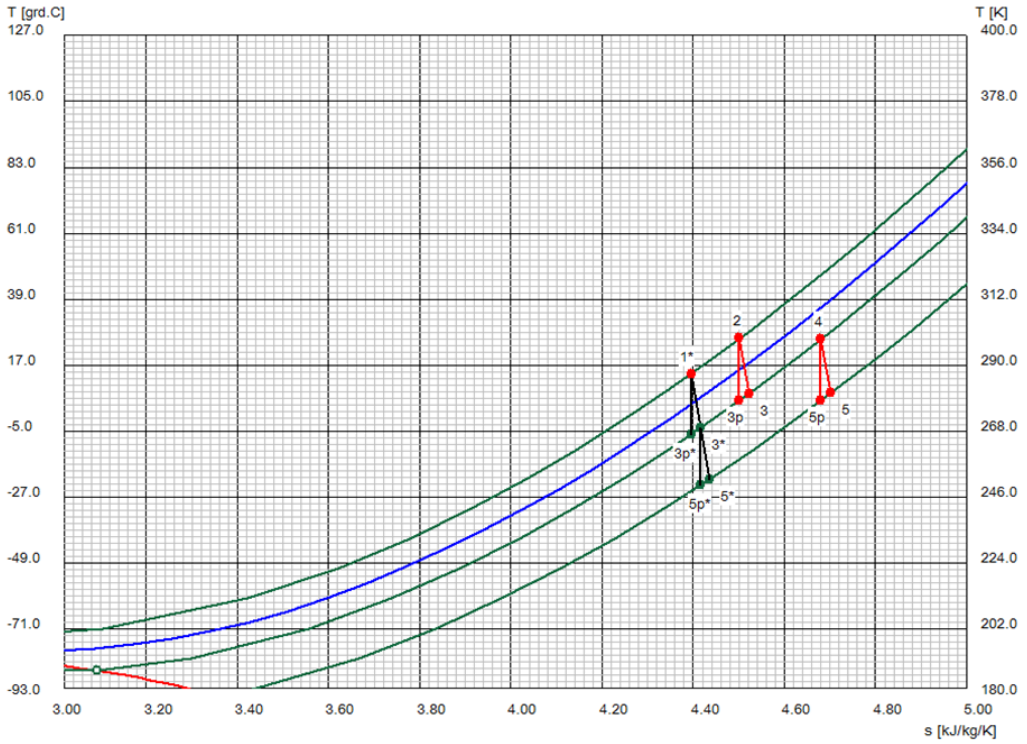

Fig. 5. Diagram of thermodynamic processes in a two-step turboexpander

Table 8. Parametric values defined in the expansion process with pre-heating

Point	P [bar]	T [K]	Enthalpy [kJ/kg]	Enthropy [kJ/kg/K]	Densitate [kg/m³]
1	53	285.0	823.207	4.376	40.059
2	53	296.8	853.990	4.481	37.814
3p	39.87	276.0	815.550	4.481	30.627
3	39.87	278.3	821.316	4.502	30.284
4	39.87	296.4	866.795	4.661	27.853
5p	30	276.0	827.492	4.661	22.500
5	30	278.4	833.387	4.682	22.252
Recovered power 2186.890 kW (step I) +2236.013 kW (step II) = 4422.903 kW					

Recovered Energy

The maximum power that can be recovered corresponds to the first extraction day and amounts to 7,999.503kW. Consequently, three turboexpanders of 3000 kW each are required. We suggest that the power be recovered in a two-step turboexpander with the gas heated up before each step due to the advantages presented by this gradual expansion and despite the fact that the power recovered from a one-step turboexpander is bigger. The total energy recovered by expanding the gas from the pressure held upon its extraction from the underground storage facility at Bilciureşti until it gets to the measurement point at Butimanu compression station, over the 72 days of operation, amount to 10732 MWh. To heat up the gas an average flow of 780 m^3/h is required. The results are as indicated in fig. 6 while the layout of the three turboexpanders is presented in fig. 7.

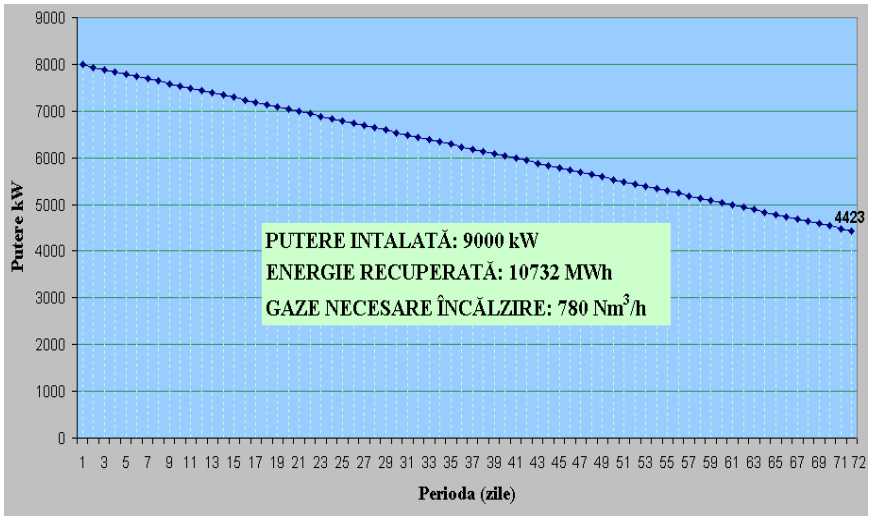

Fig. 6. The energy recovered at Butimanu

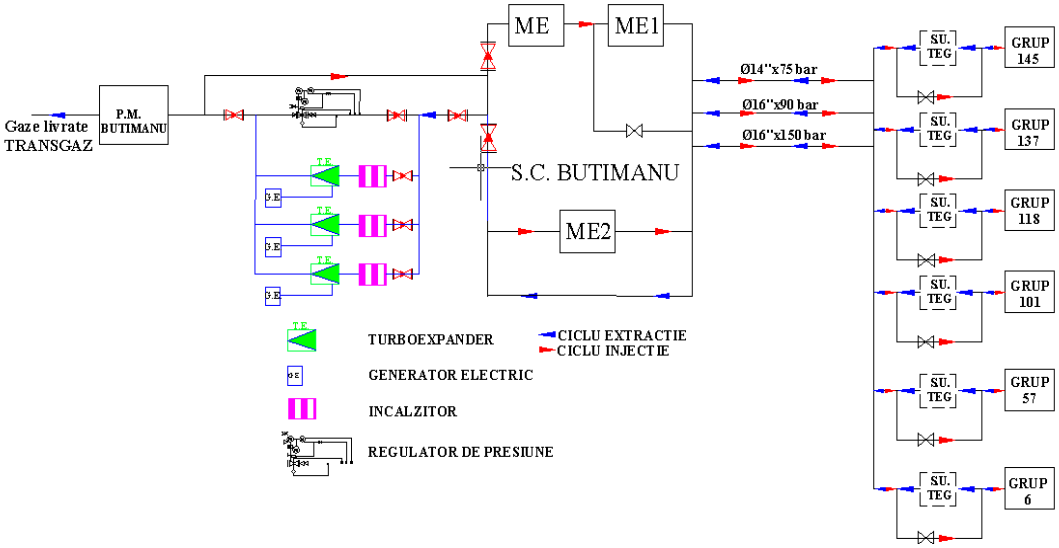

Fig. 7. Layout of the three 3000-kW turboexpanders at Butimanu

	Technical data			**Economical data,** Euro			**Economic efficiency**	
	Installed capacity kW	**Recovered energy** MWh	**Gas flow** Nm^3/h	**Investment**	**Electric power**	**Gas consumption**	**Profit** EUR	**Recovery time** years
Storage	9,000	10,732	780	4,500,000	1,098,957	256,090	842,866	5.33

Conclusions

Gas energy can be recovered via a group of turboexpanderes installed inside the measurement point. The turboexpanders will operate starting with day 1 when the overall gas flow from storage is of 11.965.000 Nm^3/day (98,855 kg/s) and reaches Butimanu with a pressure of 60 bar and a temperature of 14 ^oC, until day 72 when the flow gets to 8.101.000 Nm^3/day, gas pressure at Butimanu is of 53 bar and the temperature 12 ^oC. The gas in the turboexpanders is processed until it reaches 30 bar.

The technical data of the solution are as follows:

- Day 1. Maximum flow rate of the gas extracted:11 965 000 Nm^3/day at a temperature of 14.6^oC. Two-step expander with 2 pre-heatings by 40^oC (in total) before each step, recovering 8000.0 kW;
- Day 72. Minimum flow rate of the gas extracted: 8 402 000 Nm^3/day, a temperature of 14.6^oC. Two-step expander with 2 pre-heatings by 40^oC (in total) before each step, recovering 5 617.4 kW;
- Technical solution proposed: **three 3000 kW turboexpanders, laid out in parallel formation**;
- Total energy recovered in 72 days: **10 732 MWh**;
- Average gas consumption for heating: **780 Nm^3/h**;
- Estimated investment: **4 500 000 Euro**;
- Value of produced electric power: **1 098 957 Euro**;
- Cost of the gas used up for heating: **256 090 Euro**;
- Estimated annual profit: **824 866 Euro**;
- Estimated investment amortisation: **5.33 years**.

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Studiul posibilității de recuperare a unei părți din energia pierdută prin procesul de laminare a gazului pe Structura Bilciureşti la punctul de măsurare Butimanu

Rezumat

Lucrarea prezintă un studiu realizat pe Structura Bilciureşti referitor la posibilitatea recuperării unei părți din energia gazelor naturale ce se pierde prin procesul de laminare din regulatoarele de presiune din punctul de reglare şi măsurare Butimanu. Pentru recuperare se propune utilizarea turboexpanderelor amplasate în incinta punctului de reglare şi măsurare Butimanu.