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Research paper

Mine emissions reduction installations

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HIGHLIGHTS

- Two concepts of an integral exothermic installation intended for a reduction in hard coal mine emissions.
- The combustion of gas obtained from the mine demethanisation process in the ventilation air.
- Generation of superheated steam in a local steam boiler.
- The superheated steam in a turbine set generates electricity, and the backpressure steam.
- The backpressure steam flows into a multi-stage evaporation station where it is used for desalination of the mine water.

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ABSTRACT

This paper presents two installation concepts intended to reduce emissions in hard coal mines: emissions of the gas which is high in methane from methane capture process, emissions of the ventilation air which is low in methane, and emissions of the saline mine water. In one concept, the heat from gas combustion in the ventilation air is used to generate superheated steam in a local steam boiler. The superheated steam in a turbine set with a backpressure turbine generates electricity, and the backpressure steam flows into a multi-stage evaporation station where it is used for desalination of portions of mine water. In the second concept, the stream of gas with a high content of methane is supplemented with hard coal in order to utilise the entire stream of mine water. Mathematical models of the component balance of heat and mass are developed for both installations, and calculations are performed using real emissions data from a selected coal mine. Results are shown in mass flow and energy flux Sankey diagrams. We find that full utilisation of the high-methane gas reduces emissions of mine ventilation air by 2.5% and of the saline mine water by 21%. Also, co-firing with supplementary coal ensures a 100% desalination of the mine water and 10% utilisation of the ventilation air.

An approximate estimate of the economic evaluation and a sensitivity analysis are also presented for both concepts. Results indicate that the first concept is more profitable than the second concept. This is because the payback period (PP) is shorter (7.67 and 9.67 years, respectively), and the rate of return based on cash flows (ARR_{CF}) is greater (13.03 and 10.36%, respectively) at an unchanged load factor of 90% and a 10-year life cycle. Also, the first concept is found to be significantly less risky. Technical and economic analysis of the proposed solutions shows that both solutions are useful; therefore, the most suitable solution should be chosen based on other conditions such as indicators of state environmental policy.

1. Introduction

Hard coal extraction in mines is possible only if the underground part of the coal mine is continuously dewatered and ventilated and if the mine gas, which has a high content of methane, is removed successfully [9–11]. The mine gas and ventilation air have a significant energy potential and a great impact on the greenhouse effect. In most coal mines, approximately 39% of the total quantity of methane released in the headings and brought to the surface (i.e., 45–70%) is captured. This gas is used as fuel for local boilers or in combined heat and power plants as well as for combined generation of heat, cooling, and electricity. The possibilities of utilising methane from coal mines, mostly by burning, are presented in papers [2,23,24].

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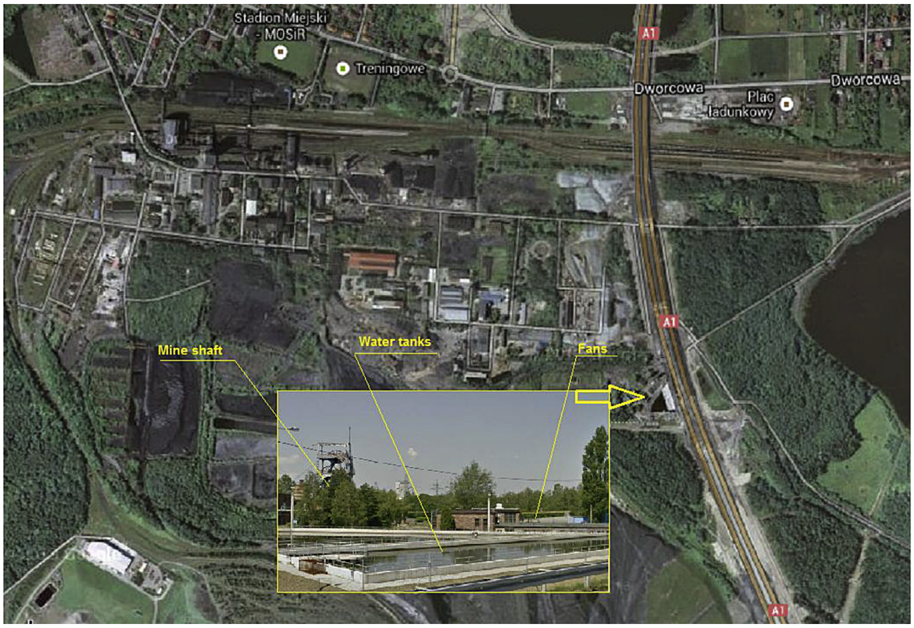

Fig. 1. Location of the ventilation shaft at the mine.

However, approximately 60% of the estimated total amount of methane released during mining is emitted into the atmosphere through ventilation shafts, exacerbating the greenhouse effect. For example, in Polish mines a single shaft emits between 270,000 and 1,400,000 $m^3{}_n/h$ of an air-methane mixture, usually with a safe methane concentration in ventilation air of less than 0.7%, which corresponds to a power of 18.7 MW–96.9 MW lost to the environment. In addition, it should be noted that burning methane greatly reduces the effect of greenhouse warming, because methane is a greenhouse gas 21 times more potent than carbon dioxide, and since when burned methane turns into carbon dioxide. Previous studies [4,5,25] present analyses and proposals for the removal and utilisation of methane contained in ventilation air from coal mines. Burning fuel in ventilation air from coal mines is indicated as one possibility; it is stressed, however, that this process can rarely be applied in practice.

Annually, up to 0.364 km^3 of water is pumped from Polish coal mines [26], most of which is discharged into surface watercourses directly or after partial use in industrial processes. In 1994, the mines pumped 996,200 m^3 of water per day, 386,900 m^3 of water with mineral content <1 g/dm^3, 252,300 m^3 of water with mineral content of 1.0–3.0 g/dm^3, 288,300 m^3 of water with mineral content of 3.0–70 g/dm^3, and 68,700 m^3 of water with mineral content of >70 g/dm^3. At that time, the discharge rate of chloride and sulphate ions averaged approximately 7069 Mg/d, 72% of which were carried into the Vistula River, resulting in increased mineralisation of water in that river (in Goczałkowice and Dwory) from 0.3 to 3.5 g/dm^3. The currently applied methods of treating mine water include the following: injection of saline water into rock formations, reducing the load of salt in water, hydro-technical protection of rivers against the salinity, desalination, and water recirculation [3,6]. Also, some common desalination methods include the following: thermal [13], thermal–mechanical, mechanical, electrical, and chemical. However, salt production and recovery of brine constituents is not very profitable. This is not only because of high processing costs, but also due to the low marketability of these products.

Environmental hazards posed by emissions of mine gas and ventilation air as well as discharges of saline mine water affect the vicinity of the ventilation shaft, usually at the mine under

Table 1
Data of the reactants of the installation intended for reduction of mine emissions.

				Nominal	Maximum
1	Gas with high content of methane	Mass flow	$m^3{}_n/h$	1,380	
		Methane concentration	vol. %	70.0	
		Temperature	°C	32.0	
		Pressure	bar	1.0023	
2	Ventilation shaft air	Mass flow	$m^3{}_n/h$	41,300	1,830,000
		Methane concentration	vol. %	0.12	
		Temperature	°C	32.0	
		Pressure	bar	1.0023	
3	Mine water	Mass flow	m^3/h	31.75	150.00
		Salt concentration	g/dm^3	12.6	
		Temperature	°C	32.0	

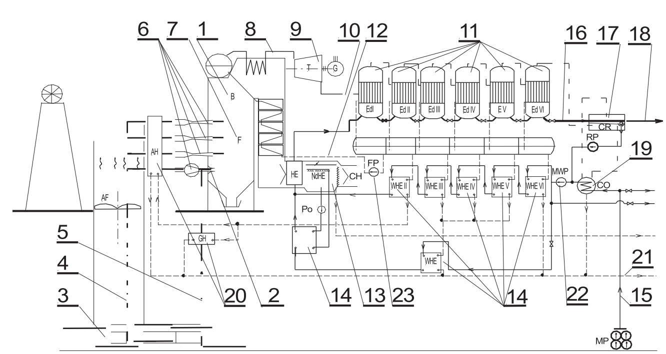

Fig. 2. An installation utilising the entire stream of gas with a high content of methane from the methane capture process. 1 – steam boiler B, 2 – gas burners, 3 – mine heading, 4 – ventilating shaft, 5 – pipeline of gas with a high concentration of methane, 6 – fans, 7 – furnace F, 8 – superheated steam, 9 – turbine generator T + G, 10 – backpressure steam, 11 – multi-stage evaporation station E, 12 – condensate, 13 – set of non-diaphragm- and diaphragm heat exchangers NdHE, HE, 14 – water/water heat exchangers WHE, 15 – saline mine water, 16 – concentrated brine, 17 – salt crystalliser CR, 18 – crystalline salt, 19 – condenser CO, 20 – set of heaters of the mine air AH and of the gas with a high concentration of methane GH, 21 – condensate discharge, 22 – mine water pump MWP, 23 – boiler feed pump FP.