



COAL MINE GAS FROM ABANDONED MINES

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Abstract. Coal mine gas usually consists of methane, nitrogen and carbon dioxide. Its appearance is a constant and well-documented concomitant of coal-mining. In the Ruhr Basin, Germany, after the shut-down of the mines, up to 1,000 cubic metres per hour of coal mine gas continue to escape from the pits and get into the atmosphere through special degassing systems. A not insignificant part of coal mine gas migrates in addition diffuse at the surface. Thus, a natural energy carrier is given up for lost. To make matters worse, the methane component of the coal mine gas could form an explosive mixture with air and it is ecologically harmful since it significantly contributes to the greenhouse effect: It is estimated that methane is approximately 21 times more harmful than carbon dioxide.

Since 1994, engineers of the Fraunhofer Institute for Environmental, Safety, and Energy Technology in Oberhausen, Germany, have been working on new concepts regarding:

– the deliberate migrations of coal mine gas also effectively minimises potential dangers resulting from its uncontrolled emission, accumulation and forming explosive mixtures with air;

– the energetic utilisation of coal mine gas from abandoned mines in CHP units (Combined Heat and Power Generation).

Since 1998 UMSICHT operates several sucking-stations the danger defence and for potential inquiry of coal mine gas from abandoned mines. Therefore coal gas is sucked off of boreholes in the surface area (depth < 50 m) and boreholes into old workings of the abandoned mines. A result of the different sucking tests is the minimisation of the diffuse gas migrations. By the direct sucking of the old pit a substantially bigger area could be hold gas free than by sucking off surface boreholes. The sucking off of abandoned coal mines has resulted an increase of the CH₄-concentration from 40% to more than 70% over the testing time independent of the atmospheric conditions. During the time of sucking (more than 3 month) an influence to the pressure in the abandoned mine could not verified. Water ring pumps and roots-compressors in different kinds of operating are tested in the sucking-stations.

Coal mine gas is estimated to be available for a long time. An economic utilisation seems to be possible within the next decades. The gas deposit within the coal mines of North-Rhine Westphalia is enormous: It is considered to amount to approximately 120 million tons of methane per year, most of it energetically utilisable. The utilization of coal mine gas is one way to reach the aims of the Kyoto-Conference. Therefore the energy generation with coal mine gas is supported in Germany by a guaranteed price for the produced electrical energy since 2000. Because of the decreasing coal-prices in many countries a lot of mines were abandoned in the last years. Dezentralized CHP-concepts created by UMSICHT are one way for an effective and quick solution of the problems of these mines.

Key words: coal gas mine, sucking stations, utilization, Germany.

INTRODUCTION

For a long time, coal mine gas has been a known and dreaded aspect of hard-coal mining. The released methane gas mixtures have become more important in the context of the increasing awareness of climatic and environmental problems. According to the decisions of the Kyoto conference, an uncontrolled discharge of coal mine gas into the atmosphere had to be

reduced. The reduction of the methane emissions is of great ecological importance.

Working with methane represents a complex problem with partly contrary issues. Methane represents a safety hazard for underground operation because it can form an explosive mixture in contact with air. The removal of the coal mine gas is therefore essential.

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In former German mining areas, coal mine gas migrations appear more amplified at the surface. The same can be noticed in Poland and the Czech Republic. The migration is both a threat for the residents as well as the climate. A concept for the protection of residents as well as the climate can be realized

through the collection and utilization of coal mine gas for the generation of heat and power.

Following, the utilization of coal mine gas will be described on the basis of examples in Germany. The conceptualization of new utilization options shall be explained.

BASICS OF THE COAL MINE GAS

Methane is one of the products of the geochemical transformation (carbonization) of organic substances to coal. Methane and carbon dioxide produced during the carbonization (starting approx. 300 million years ago) are stored as free gas in fractures, gaps and pores and sorbed at the inner surface of the coal or the surrounding formation.

The share of the free gas of the total gas amount of hard coal is 5 to 10%_{vol}. The main share is sorbed as a mono-molecular layer at the inner surface of the carbon. The total amount of sorbed gas depends among others on the degree of carbonization, which is the carbon content and the water content of the coal.

Differentiation of coal mine gas

One distinctive feature of coal mine gas is the location of release. Three significant locations can be distinguished:

- coal mine gas from unmined deposits,
- coal mine gas from active mining,
- coal mine gas from abandoned mines.

Coal mine gas from unmined deposits. There is a considerable amount of methane gas in many coal deposits. This gas isn't significantly mobile and isn't released into the atmosphere in large amounts. In some deposits, the geological conditions (sufficient porosity) allow a gas release independent from coal mining. In 1997, approx. 29 billion m³/a of this so-called "Coalbed methane" (CBM) is extracted and used in the US (State..., 1999). CBM consists of about 90 %_{vol} methane and is used for the most part for the production of heat and steam. However, it is also suitable as a substitute for natural gas in L-gas networks.

In the literature, the expression Coalbed Methane (CBM) is used differently. In this lecture, CBM is understood as gas extracted by day drilling into unmined coal deposits.

In Germany, the conditions for CBM extraction are normally unfavorable. First tests in the northern part of the Ruhr basin have shown this. Presently further tests are carried out on this topic in the context of a research project in the Saar area.

Coal mine gas from active mining. Below ground the released gas is a problem for the coal production, due to methane can form explosive mixtures in connection with air. A removal of the released coal mine gas is therefore of important meaning for the safety of the miners.

The amount of methane released every year by active hard-coal mining can be found in the literature in varying amounts. Reasons for this are, among other things, the various extrapolation methods. For Germany, an area of 0.96 with a

maximum of 2.1 million t CH₄/a are given incl. brown-coal mining, which, however, only contributes a small amount. The German share is 0.18 to 0.4% of the worldwide methane released in context of the hard-coal mining. The share of the hard-coal mining in the worldwide methane issues (515 million t/a) is calculated with 5 to 9% (Drijver, 1997).

The utilization of coal mine gas from active mining has been known in Germany for a long time. The collected coal mine gas is mainly used in power plants and boiler systems.

The amount of collected mine gas depends on the gas content of the extracted seams. Therefore, the collected quantity can differ greatly. The amount of the gas mixture collected ranges from 4.000 m³/h up to 20.000 m³/h. Coal mine gas from active mines stands out due to its oxygen content, which is between 5 and 15%_{vol}. This value differs because of the air share included at the point of collection in the underground workings. Due to the change in pressure volatile changes of methane are typical when being extracted from active mines.

In the Ruhr basin, however, mines are operated without coal mine gas extraction systems since the released gas amounts are so low that they can be blown out by the ventilation systems of the mine. The mine atmosphere isn't energetically utilizable directly since the methane contents usually lie below 1%_{vol}.

Coal mine gas from abandoned mines. The north walk of the hard-coal mining in the Ruhr basin and the ongoing closures of coal mines let a new problem arise in areas of the alto mining. After the abandonment of coal mines, gas is continuous to be released in these areas. Fractures in the formations caused by the mining activities provide new migration paths for the gas. Furthermore, the gas pressure drop caused by the fractures enable desorption of the gas sorbed in the seams and the formation. This effect is comparable with a champagne bottle. If cork is removed, the carbonic acid sparkles until no-more is available. The coal mine gas escapes into the atmosphere through the remaining degassing pipes.

Equally, diffusive gas migration through overlying formations is also well known in the Ruhr basin because the abandoned mines are not sealed tightly enough. The methane containing gas is let out into the atmosphere without being treated.

Mine gas from abandoned coal mines stands out due to its oxygen liberty. The methane content fluctuates between 40 and 80%_{vol}. Carbon dioxide is found at concentrations between 8 and 15%_{vol} and the remaining share is nitrogen. Lane substances like hydrogen sulfide, carbon monoxide or higher hydrocarbons appear in amounts of 50 ppm or less.

An estimation of the released gas amounts or the potentials from abandoned mines is extremely difficult due to a lack of

data. Official data from the department of mines published in 1984 gives an amount of 120 million m³ CH₄/a for the Ruhr basin, in the areas Aachen and Ibbenbüren. Newer collection tests at completed shafts of abandoned mines showed a far greater amount. With further shutdowns the amount of released coal mine gas will increase.

Climate pertinence of coal mine gas

At present, methane (CH₄) represents one of the most important anthropogenic sources of climatic relevant trace gases next to carbon dioxide (CO₂), the CFC and the nitric oxides (NO_x). The climate relevance of the greenhouse gasses is essentially described by two factors:

- specific greenhouse potential — potential to the absorption of radiation; by definition referred to the potential of CO₂,
- atmospheric life time — time till the gas is abolished and cannot absorb any radiation any more.

A middle dwell time of 10 years (CO₂) arises in the context of an assessment of methane: 5 to 10 years and a specific greenhouse potential, which lies around 20 to 30 times higher than that of CO₂.

A part of the methane sorbed in the coal and in the formation is released during mining activities. It is either released into the atmosphere with the ventilation of the mine or collected by a sucking station and transported for further utilization.

Coal mine gas from abandoned mines is released into the atmosphere from fractures cavities, and columns. Until now coal mine gas usually isn't collected and, therefore, it can fully unfold its greenhouse effect.

Endangerment from coal mine gas at the surface

Coal mine gas from abandoned mines migrates diffusely through the overlying formation into the atmosphere, if the gas

isn't completely collected by degassing systems. These diffuse migrations are weather dependent and change with the air pressure. The released gas represent a source of danger for the population since it can come form combustible and explosive mixtures with air.

There is already an acute threat particularly in the western part of the city of Dortmund and in parts of Bochum (Hollmann, 1999). Here, local sucking stations are already operating to guarantee sufficient safety for the population. Gas migrations are also known in other parts of the Ruhr basin for instance in the cities of Herne, Duisburg and Moers.

In coal basins like the Ruhr area and the Silesia area, the number of places with diffuse methane migrations have increased in the last years and different accidents due to mine gas have occurred. Experiences made in former mining areas in the Ukraine and in Czechia (e.g. City of Ostrava) show the source of danger from diffuse gas migration at the earth's surface.

Coal mine gas deposits in Germany

Coal mine gas is found in all hard coal areas in Germany that is in the Saarland in the Aachen coal-mining area, in the Ruhr district, and in the Ibbenbürener mining area.

Mine gas released from old mines is found in many former coal mining areas. Gas occurrences are, thus, found in big amounts of the southern Ruhr basin.

There aren't any more active mines in the Aachen area. However, many places are affected with gas releases here.

The gas released in the abandoned mines of the Saar basin is collected and pumped to a gas distribution system. The gas is used in power plants and in a steel mill. In the shut down parts of the Ibbenbürener mining area, no gas leading seams have been dismantled. However, considerable gas releases aren't known in this area.

TECHNICAL, ECONOMICAL AND LEGAL BASES FOR THE UTILIZATION OF COAL MINE GAS FROM ABANDONED MINES

For coal mine gas utilization two fundamental variants, the material and the energetic use, are possible. The energetic use can in addition be differentiated in gas fuel burner systems and in CHP-units (Tab. 1).

In Germany the variants of the material use of coal mine gas described in the Table 1 aren't in use till now. Nevertheless a material use could be economical interesting at locations with special basic conditions.

The utilization of coal mine gas as an additional fuel in power station plants is well known. The positive burning qualities and the missing of emission relevant trace substances improve the specific exhaust emissions of the plants.

Occasionally coal mine gas is used as an additional or substitute fuel in industrial heating and drying installations.

In the past coal mine gas fired plants are mainly used for heat and steam generation. Meanwhile an increase of

cogeneration plants for the combined heat and power generation can be recognized. Cogeneration aggregates represent an interesting solution for an gas utilization of sources with capacities less than as 1,000 m³/h. Gas engines, gas-diesel engines

Table 1

Coal mine gas utilization

Material utilization	Energetic utilization	
	as fuel burner	CHP-units
Substitute of natural gas	additional firing	gas engine
Methanol production	mono firing	gas-diesel engine
LPG production		gas turbine
LPG production		fuel cell

and gas turbines are the favorable driving elements for those cogeneration plants.

Coal mine gas is already used as fuel for gas engines in various places. The customization of the engines and particularly of the control units are quite sophisticated. The efficiency factor of mine gas driven units is corresponded to cogeneration sets operated with natural gas. Gas engines with a performance of 1 MW_{el} or more reached an electrical efficiency higher than 40%. The combined utilization of the heat of the cooling water and the exhaust gas enables total efficiency factors of 90%. Gas engines for cogeneration sets are offered in a range of electrical power from a few kW to 5 MW.

Diesel gas engines work unlike the former listed IC gas engines as self ignition motors. At the end of the compression phase an ignition oil, normally diesel fuel is injected to ignite the gas air mixture in the cylinder. These engine types also run easily with coal gas out of active mines for some years. Primarily the machines are used with an electrical performances higher than 3 MW. Their electrical efficiency factor is about 40%.

A use of coal mine gas in gas turbines is principally possible. The variation of the calorific value are the main problem of the turbine burner system. To prevent overheating damages to the turbine shovels and turbine stators a gas delivery with a constant calorific value has to be guaranteed or a decrease of performance and efficiency has to be accepted. Additional energy intensive side facilities for a gas pre-compression are necessary for the turbine operation. The electrical efficiency factor lies with an amount of 30% (performance class of 2 MW_{el}) clearly under those of performance equivalent gas engines. As a benefit the high exhaust gas temperatures allow a steam production with a connected steam turbine for power generation.

Microturbines and fuel cells are future variants of the decentralized combined heat and power generation with mine gas.

Using the pit ventilation as burning air for heating and turbine plants is one further variant of the coal mine gas use. At this the contained methane (share lower 1%_{vol}) is utilized.

The use of coal mine gas from active mines is already for a long time stand of the art. The application of gas out of abandoned mines wins however at meaning since the last years. Causal among other things are the diffuse methane migrations in former mining areas. The resulting problems of the gas migrations get more and more important by the progressive shut down of coal mines.

A solution to the problems danger defense and climate protection is the use of coal mine gas from abandoned mines. A gas utilization enables a limitation of diffuse methane migrations and a consumption of the gas coming out of the degassing systems.

Regarding the pretended conditions and under consideration of using an efficient and reliable technology decentralized CHP-units are the technique of the choice for an combined generation of heat and power. For this kind of the cogeneration IC gas engine units are economically interesting.

In the following chapter the conditions of application should be described.

Application conditions of coal mine gas from abandoned mines

The named conditions can be divided in four parts:

- locale conditions,
- technical conditions,
- legal conditions,
- economical conditions.

Locale conditions. A fundamental precondition for the use of coal gas is the existence and the possibility of extraction. It can be assumed that in many abandoned mines methane is released from not dismantled coal seams and eventually from the formation. The amount of released methane will be various locally and depends in the essential on the geological conditions. Profound knowledge of the amount of gas are not existing till now. Therefore exact statements of the gas potential at interesting locations couldn't be made. Conclusions made by measuring of the "natural degassing" at the degassing systems are limited usable.

For using the released coal mine gas it has to be suck off out of the abandoned mine workings. The sucking off of methane can be distinguished in three ways depending on the place of extraction:

- degassing systems in abandoned mines,
- drillings in abandoned workings,
- drillings near by the surface.

For a controlled degassing of the abandoned mines degassing pipes were constructed in the shafts before back stowing. These pipes frequently represent a good connection to the old underground mine working. If the preconditions of the surface location are given, then this pipes offers itself as gas supply line. By using this pipes the previous task, the secured removal of the gas has to be guaranteed. In addition it has to be ensured that only gas is extracted out of the pit and a sucking of the surrounding air is impossible.

At locations where no degassing pipes are available in old shafts the entry to the gas leading underground workings can be reached with a drilling. These drillings become into a dismantled coal seam or to an underground roadway. These roadways should be in the upper floor of the old mine to suck off the gas striving to the earth's surface.

Drillings near by the surface end in the overburden layers and have no direct connection to the old underground mine workings. They are used at locations where drillings into the underground workings of the abandoned mines are impossible e.g. if water fills the whole mine workings. These kind of drilling in combination with a sucking station is also used to prevent diffuse methane migration at the surface. The gas quality is in comparison to the other to kinds of gas extraction substantial worse.

At the bottom of the sucking pipe water free and gas mobility conditions are necessary. For an effective sucking off the gas mobility are important. Gob wells open or only loose filled road ways enable a wide sucking off area in the underground. By such conditions gas pressure levels can be installed in the mining claims and the gas streaming up from deeper floors could be sucked to extraction points. If a pressure level below atmospheric pressure can be maintained permanently in

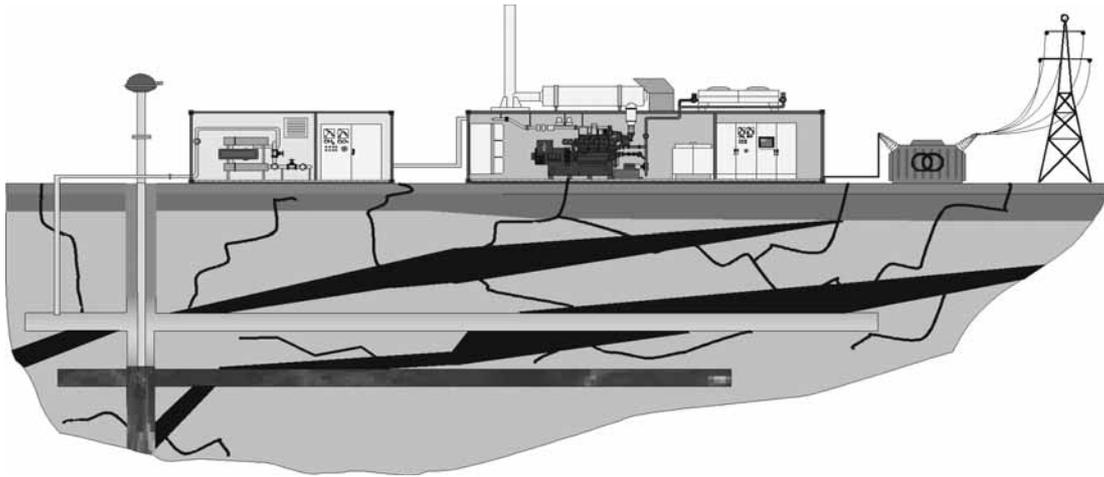


Fig. 1. CHP-unit with sucking station (after Wörsdörfer, 1999)

the system a gas migration into the atmosphere can be excluded.

Are there active mines in the neighborhood the sucking off of coal gas from abandoned mines has to be coordinated with the operator of the active colliery to prevent negative aspects like sucking off inleaked air or an uncontrolled ventilation of shut down underground districts.

As risk factor for the gas utilization the gas extraction has to be listed. Strong fluctuations of the extractable gas amount can come by changes in the abandoned underground workings. Therefore an adjustment of the performance becomes necessary or the generation has to be stopped and a new promoting location (e.g. a new drilling into the abandoned underground working) with economical operating conditions have to be found (Fig. 1).

To these questions a considerable research effort is still necessary. Due to this reason, only a limited use time you can put for certain for a location at present.

The performance of the power production with coal mine gas depends on pressure influence in the abandoned mine workings produced by the sucking station. Depending on the location gas quantities are expected that enables a power performance from 0.5 to 2 MW_{el}. For a practical use of these coal gas potentials a decentralized technology in corresponding size has to be installed. A waste heat recovery could be installed if there are clients for a heat supply otherwise the heat is given to the atmosphere.

Technical conditions for CHP. The main fuel for IC gas engines is natural or bio gas (sewage gas, landfill gas), however in the last time coal mine gas gets more and more important. For raking the usability of different gases for IC engines characteristic parameters are used. Next to the combustibility of the gas the stability of the relevant characteristics are important.

Important parameter for an evaluation of gas are the methane number, the calorific value and the laminar flame velocity. For an optimized energy conversion the mentioned key numbers have to be regarded.

The calorific value specify the energy contends of a gas. The calorific value of coal mine gas from abandoned mines

runs from 14 to 30 MJ/m³ therefore a trouble free operation can be expected.

A knocking combustion (uncontrolled combustion) could destroy an engine immediately. The methane number is the specific parameter for an evaluation of the knocking stability of a gas. It is comparable to the octane number of gasoline and named the methane-volume ratio of a methane-hydrogen mixture that shows in a test engine under defined conditions the same knocking characteristics like the tested gas (Schneider, 2000).

Methane with a methane number of 100 and the high contend of CO₂ and N₂ guarantees a methane number of 100 to 130 for coal mine gas. Therefore coal mine gas is usable for IC gas engines because a knocking combustion isn't expected.

Table 2 presents the primarily parameter of coal mine gas, natural gas, sewage gas and landfill gas.

Based on the mentioned parameters the combustion properties and the engine design for the coal mine gas utilization is basically comparable with the natural gas operation. However the alteration of the CH₄ concentration and the very high rela-

Table 2

Gasparameter (after Schneider, 2000)

Kind of gas	Density [kg/m ³]	Caloric value [kWh/m ³]	Methane- number	Flame velocity [cm/s]
Hydrogen	0.899	2.996	0	302
Methane	0.717	9.971	100	41
Propane	2.003	26.000	33	45
Carbon monoxide	1.250	3.510	75	24
Natural gas	0.798	10.140	80	41
Coal mine gas (abandoned mines)	0.986	6.960	110	34

tive humidity of coal mine gas appears additional measures at the engine and the plant.

The alteration of the CH₄ concentration can be compensated by dynamic system for the automatic performance and combustion controlling. Dynamic gas air mixer and optical on-line supervision of each combustion chamber are main parts of those systems.

The high humidity at a relative high gas temperature can cause condensate in gas valves and regulators of the engine. To prevent malfunctions steam traps and if necessary gas heating or drying systems have to be installed.

For an utilization of coal gas in IC engines emission limits are fixed in the German TA-Luft (Clean Air Act, Tab. 3).

Table 3
Emission limits for gas engines
in Germany

Gas	Limit TA-Luft [mg/m ³ _{i,N}]
NO _x (as NO ₂)	500
CO	650
NMHC	150

based on 5% O₂; dry exhaust gas

On the one hand inner motor measures and on the other hand a treatment of the exhaust gas are two ways offered for a reduction of the exhaust gas emissions of IC gas engines.

The catalytic exhaust gas cleaning is the favorable system for the exhaust gas treatment. Due to the alteration of gas quality a oxidation catalytic converter for HC and

CO oxidation is used as a reliable and economical system (Schneider, 2000).

On reason of the previous experiences stand times of the catalytic converter utilization with coal mine gas are similar to those of natural gas utilization. The low pollution content in the coal mine gas proved the oxidation catalyst with regard to the stand time as negligible till now.

The combination of engine features like lean burn combustion and the utilization of catalysts enables the compliance of emission limits.

Due to coal mine gas from abandoned mines could be set oxygen free roots compressors with rotating pistons made of steel are an alternative to normally used water ring pumps. The compressor can operate under the usual conditions to gas transportation. Extensive experiences with such machines in the area of the landfill and sewage gas use show the operational safety of roots compressors for the transportation of special gasses. The lower investment and operating costs in comparison to water ring pumps let an increase of operation for the coal gas sucking be expected.

Legal conditions. For the extraction of coal mine gas a permission of the responsible mining authority is necessary due to the gas is a natural resource. For active coal mines the license for coal extraction includes the gas license. For the use of coal mine gas from abandoned mines the license has to be applied by the user or someone who delivers the user with gas.

The approval procedure and the legal conditions are the same as those for energy generation plants powered with natural or bio gas.

Economical conditions. The technical feasibility of the gas utilization from abandoned mines in block thermal power stations was already led to the end of the 1990s years. A consolidation of technology threatened to fail however since the

prices of electricity are as far as sunk in the deregulated market (Liberalization of the German current market in 1998). Therefore local energy supplier or industrial clients calculate prices far lower 4 cents/kWh. Even if the generated heat and power could be sold completely the decentralized use of this gas normally wasn't profitable.

For the sake of protecting the environment and managing global warming as well as guaranteeing a reliable energy supply, the German Federal Government and the German parliament — in agreement with the European Union — have set themselves the objective of at least doubling the percentage share of renewable energy sources in total energy supply by the year 2010. This objective is related to the envisaged commitment on the part of the Federal Republic of Germany to reduce greenhouse gas emissions by 21% by the year 2010 in the framework of the European Union's burden sharing as laid down in the Kyoto Protocol to the Framework Climate Convention of the United Nations; and this objective is linked to the German Federal Government's objective to reduce carbon dioxide emissions by 25% by the year 2005, relative to 1990 (Bündnis..., 2000).

In order to attain this objective, it is necessary to mobilize the so-called new renewable energy sources. In spring 2000 a law called the Act on Granting Priority to Renewable Energy Sources (Erneuerbare-Energien-Gesetz (EEG)) was enacted. The act gives a removal guarantee for the generated electrical energy and intends a minimum price settlement.

The use of mine gas for electricity generation will improve the carbon dioxide and methane balance, relative to the release of these substances into the atmosphere without utilizing them. For this reason, mine gas was included in the scope of application of this act (Bündnis..., 2000).

For the coal mine gas utilization the following payment results:

- Electrical Performance ≤ 500 kW 7 cents/kWh,
- Electrical Performance > 500 kW* 6 cents/kWh.

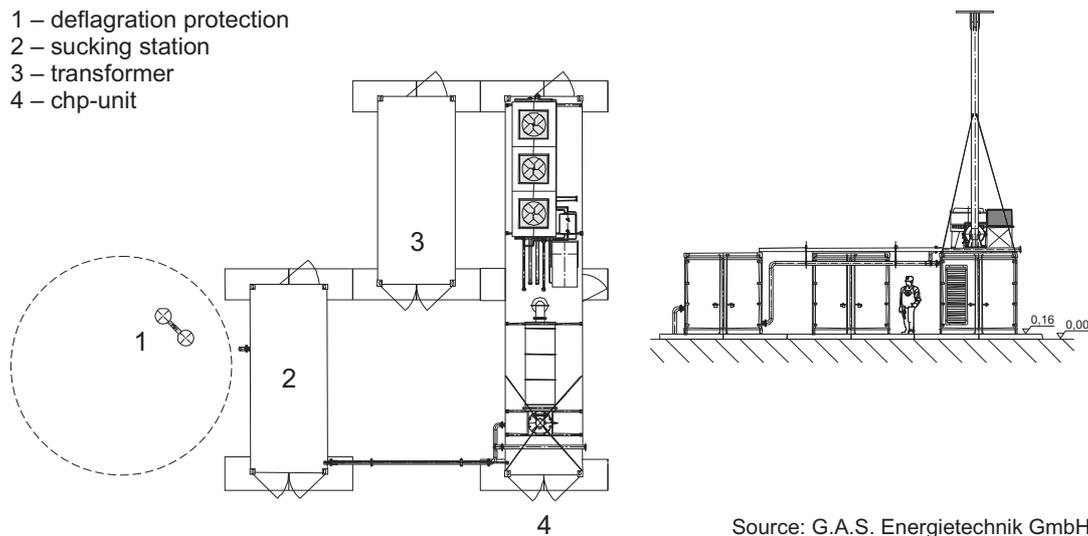
The listed rates have a positive development of the use of coal mine gas from abandoned mines in Germany expected.

CHP with coalmine gas at the Technology Center LÜNTEC

The Minister Achenbach mine in the city of Lünen in the Ruhr district was shut down in 1990. 37.5 km² of underground pit mines altogether were abandoned. All shafts were filled and the degassing systems were partly installed. The pipes of the degassing systems ended below the filled part of the shafts.

The pipe of the degassing system at the site Technology Center LÜNTEC in shaft 4 has a diameter of 250 mm and ends at a depth of 500 m. At the top, the system has a deflagration protection and a pressure control system (Fig. 2). The shaft valve opens regularly to the atmosphere if the gas pressure in the shaft is higher then the atmospheric air pressure. Therefore, a penetration of air into the shaft is impossible.

A connection to the degassing pipe was installed between the top of the shaft and the shaft valve. Over a quick acting valve and a deflagration protection unit, the gas is compressed



Source: G.A.S. Energietechnik GmbH

Fig. 2. CHP unit Technology Center Lünen (after Sporer, 2000)

with a roots compressor to a pressure of 10 kPa. Intake pressures with a maximum of 6 kPa are on the intake side of the compressor that vary depending on the atmospheric air pressure. The utilized type of compressor is a construction that is used by many landfill gas collection stations. The collection station at LÜNTEC used a roots compressor for sucking coal mine gas from abandoned mine for the first time in Germany. Since 1998 the compressor has proved itself successful.

The compressed mine gas is supplied to the CHP unit. The utilization of the methane in the installed IC gas-engine-generator-set enables the simultaneous generation of electricity (374 kW) and heat (538 kW). The generated electrical energy is fed into the grid of the local energy provider using a transformer station (0.4/10 kV). The heat (70/90°C) will be used once the district heating network on the customer side is in-

stalled. At the moment, the heat is given off to the atmosphere by a cooling system. The installation of the CHP-unit was supported by the German Environmental Foundation (DBU, Deutsche Bundesstiftung Umwelt; Fördernummer: 08545).

Since starting plant in winter 1998 no coal mine gas specific problems appeared. The methane content increased from an initial 50%_{vol} to about 65%_{vol} (Fig. 3).

A relationship between the methane content and the atmospheric air pressure couldn't be verified. Before starting the IC gas engine low caloric gas is ventilated during long standstill periods at high atmospheric pressure. Gas analyses characterized the gas to be very suitable for gas engines as well. The materials don't show any striking corrosion appearances that could be caused by pollutant components like fluorine, chlorine or hydrogen sulfide. Analysis of the engine oil don't show

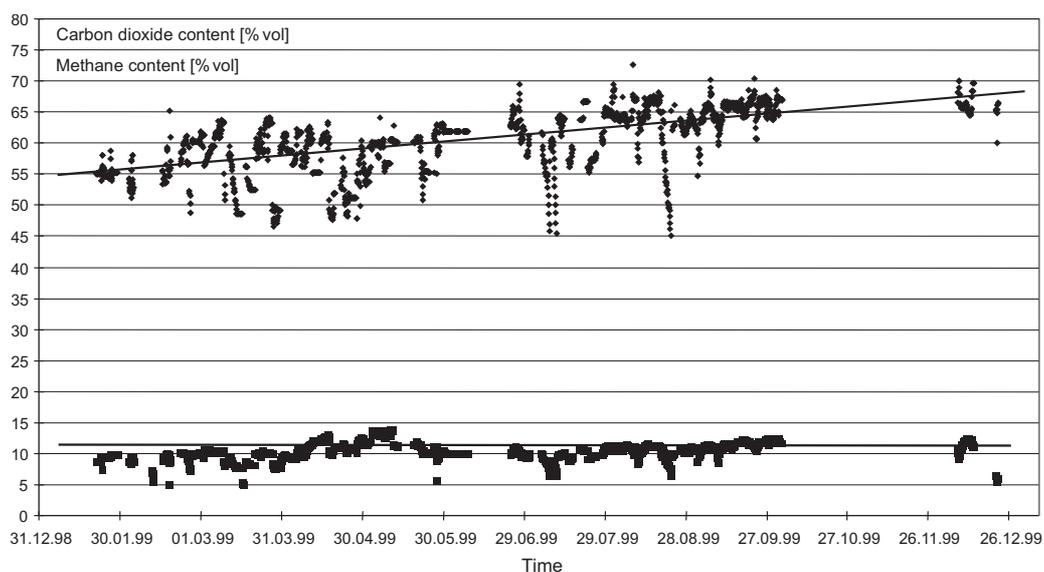


Fig. 3. Trend of methane and carbon dioxide content in Lünen

any considerable concentrations of pollutants and verify the statements of the gas analysis.

In Lünen the plant components compressor, gen-set and transformer station are built in ISO norm steel containers. This guarantees a uniform style for low specific place requirements and low building costs.

Due to the positive experiences gained in the operation, the gen-set was replaced with a container with an electrical performance of 941 kW in June 2000. The advantage of the prefabricated and standardized container solution can be seen here. The standstill of the plant due to the replacement took less than two weeks.

CONCLUSION

The high production cost based on the difficult extraction conditions and the low world market price for coal cause to more and more abandoned mines in Europe. For the coal mine regions in West and Central Europe the use of coal mine gas becomes interesting. The released methane gas mixtures have become more important in the context of the increasing awareness of safety, climatic and environmental problems. Available or being set up degassing systems can be used for the extraction of coal mine gas from abandoned mines. Exact estimates of the available potentials can be carried out on reason of a lack of data very difficult.

First results of pilot plants using coal mine gas from abandoned mines however let themselves be seen positive results to the quality and quantity of the used gas.

The official guidelines will be decisive for the use of coal mine gas under the point of view of danger defense. The installation of degassing systems on several floors and an ongoing dewatering on a reduced depth enables a combination of the aims climate protection and danger defense possible by using the coal mine gas.

The legal basic conditions are an additional aspect at the use of coal mine gas. Since the Act on Granting Priority to Renew-

able Energy Sources (Erneuerbare-Energien-Gesetz (EEG)) was enacted an economic use of coal mine gas from abandoned mines for generating heat and electrical power is possible. Any negative changes are not expected because the protection of climate and resources and the support of renewable energies is established in the programs of all parties.

The standard technology for an economical generation of heat and power is the implementation of CHP-units with IC gas engines powered with coal mine gas from abandoned mines. Containerized units show the best flexibility.

New technical solutions for the power generation with coal mine gas are the use of hydrogen fuel cells and microturbine. A pilot project with a PEM fuel cell (Polymer electrolyte membrane) and a microturbine is realized at Fraunhofer UMSICHT in Oberhausen. The units are installed for a combined heat, power and chiller generation.

Additionally emission trading can be a new source of income. For the EU the start of trading is planned in 2005 and the worldwide trade should start in 2008.

For companies working in the area of the hard-coal mining or energy plant construction new business fields are opened where their know how can be placed.

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