CAPTURE AND USE OF METHANE FROM OPERATING AND ABANDONED MINES IN GERMANY

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An overview is given on the current status of combined heat and power (CHP) generation from coalmine gas in Germany. Starting with some general words on hard coal mining in Germany and a summary of the history of coalmine gas utilisation, the potential and current utilisation of Coalmine Methane (CMM) for power production in Germany are outlined. After that, mobile containerised CHP units are presented being the most favourable concept for the utilisation of CMM from both operating and abandoned mines. An analysis of the operational experience gathered in the first plants of this kind leads to a general conclusion.

1 G.A.S. ENERGIETECHNOLOGIE GMBH

G.A.S. Energietechnologie GmbH is a German pioneer in power production from coalmine gas. Being founded in 1985, the company originally concentrated on landfill gas utilisation in gas engines. Today, the portfolio of G.A.S. covers project development, own and operate projects, planning, construction, and full service of CHP plants for landfill gas, biogas, sewage gas, and coalmine gas.

2 HARD COAL MINING IN GERMANY

In Germany, there are four major areas of hard coal deposits (see Fig. 1). Although production and utilisation of indigenous hard coal is continuously decreasing, there is still significant mining activity around Ibbenbüren, in the Ruhr area, and the Saarland. Contrarily, hard coal mining in the surroundings of Aachen has been abandoned.

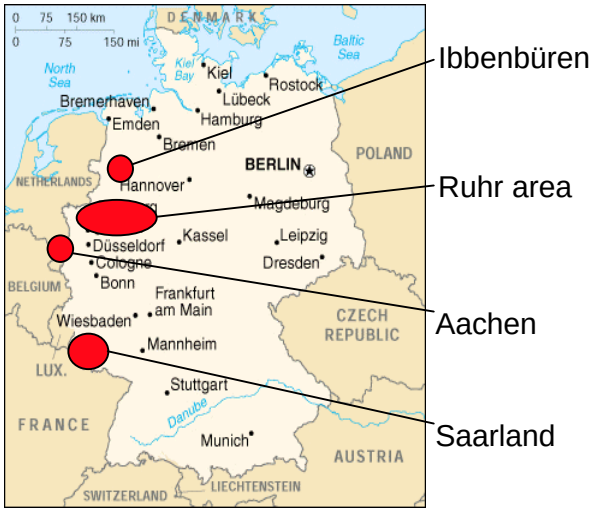

Fig.1 Areas of Hard Coal Mining in Germany

Concerning the availability of CMM, the Ruhr valley and the Saarland are most relevant. These areas offer a high potential for the utilisation of CMM from both active and closed mines. On the other hand, Ibbenbüren offers a small potential of CMM from active mines on top of what is utilised already, and the availability of CMM in the surroundings of Aachen will be limited to several years due to an increasing ground-water level.

3 HISTORY OF MINE GAS UTILISATION

Until the 1950s, coalmine gas was primarily regarded as a hazard for miners and hardly used for power production. Starting with the shutdown of several large coal mines in the 1960s, attention was also drawn on CMM escaping from earth's surface. The gas even accumulated in cellars of private buildings causing serious explosions in some cases. It became evident that as much CMM as possible must be collected and released under controlled conditions.

In the Saarland, a pipeline network was established in the 1950s and continuously extended to today's length of about 100 km. During the last decades, mine gas from both active and abandoned mines was mainly used in boilers for district heating and co-firing in fossil-fired power stations. In the recent past, more than 20 MW_{el} of CHP stations have been commissioned. Another 16 MW_{el} will be commissioned by the end of 2004.

In 1978, the first pipeline for the removal of CMM was installed in a coalmine before being closed (coalmine "Mont Cenis"). At first, the CMM was not used for energetic purposes but released to the atmosphere.

It was not until the late 1980s that public attention was drawn to the emission of greenhouse gases and the resulting danger of climate change. When methane became known to be a greenhouse gas being 21 times more harmful compared to CO_2, release of CMM to the atmosphere became unacceptable. Instead, the utilisation of the CMM for power production or CHP production became desirable.

In 1998, the first CHP plant on CMM from a closed coalmine was commissioned at the coalmine "Mont Cenis". One year later, G.A.S. Energietechnologie GmbH erected its first containerised CMM power plant (374 kW_{el}) at the coalmine "Minister Achenbach".

Since 2001, mine gas is included in the German EEG-law guaranteeing a fixed payback tariff for the period of twenty years (6.6-7.7 cent per kWh_{el}, depending on the plant size) for at least 20 years. Since then, the number of CMM power plants from both closed and active mines has sharply increased.

Currently, the EEG-law is under discussion. It is planned that, from 2005 on, the fixed payback tariff for electricity from coalmine gas installations will be decrease by 2 % per year for new installations. The payback tariff will depend on the year of commissioning but will be maintained for the period of 20 years. It is expected that in 2004 a considerable amount of installations will be commissioned to take advantage of the highest possible payback tariffs.

4 POTENTIAL AND USE OF MINE GAS IN GERMANY

In Germany, the utilisation of coalmine gas is limited to CMM from both active and closed mines, whereas CBM is not (yet) used due to unfavourable geological conditions. However, research on availability and utilisation of CBM is ongoing. In Table 1, the annual amounts (1998) of the most relevant sources of CMM are summarised.

Table 1 Annual Amount of CMM in Germany in 1998 [DMT, 1999]

Draining of operating mines	372 million m_n^3/a
Ventilation of operating mines	469 million m_n^3/a
Losses during coal transportation	49 million m_n^3 /a
CMM from closed mines	180 million m_n^3/a
Total amount in 1998	1 070 million m_n^3/a

CMM from the draining of operating mines has been used to a great extent (1998: 77 %) for a long time, mostly in industrial boilers for the production of heat or both electricity and heat to cover the needs of the coal mines. Due to the favourable payback tariffs for electricity from coalmine gas, feeding of the electricity to the public grid recently became an attractive alternative. Therefore, CHP projects with a high power-to-heat ratio based on gas engines are currently under development.

The highest share of CMM (469 million m_n^3/a) is included in the ventilation air of operating mines. Due to its low amount of methane (normally < 1 %), it can only be used as combustion air with a certain calorific value or by using a fairly new technology, thermal oxidation. The losses of CMM during transportation (49 million m^3 (V_n)/a) cannot yet be used at all.

The utilisation of CMM from closed mines for CHP production started only 4 years ago. It is expected that, within the next 1-2 years, almost the total amount (estimated at 180 million m_n^3 per year) will be used for decentralised CHP production.

Among the three fundamental ways to use CMM for energetic purposes

- utilisation in boilers for heat or electricity production via a steam cycle,
- production of secondary fuels, e.g. conversion to methanol or upgrading towards natural gas quality, and
- CHP production in prime movers (mainly in gas engines, maybe in gas turbines or fuel cells in the future),

only options 1. and 3. are currently used (with a clear preference for CHP plants), whereas the production of secondary fuels is not yet considered economically viable.

One of the main driving forces for CHP plants was the decision to include coalmine gas in the German law for the support of renewable energies (EEG). Although coalmine gas is only considered renewable to a limited extent, its utilisation is desired because of the strong impact of methane on climate change. The guaranteed payback tariff of helps decreasing the investment risk for a coalmine gas fired CHP plant.

In the past three years, more than 35 (CH)P-projects on CMM from closed mine have been realised with a total capacity of more than 60 MW_{el}. It is expected that another 30-50 MW_{el} on CMM from both closed and active coal mines will be installed in the near future.

The necessary permissions for such coalmine gas power plants mainly involve mining law, building law, and environmental law. The emission limits for gas engines as defined in the German emission law "TA Luft" are given in Table 2.

Table 2 Emission Limits for Gas Engines According to TA Luft

CO	650 mg/m_n^3	@ 5 % O_2
NO_x	500 mg/m_n^3	@ 5 % O_2
NMHC	150 mg/m_n^3	@ 5 % O_2

5 MOBILE CHP PLANTS IN A CONTAINER

Due to the insecurity related to the amount and duration of coalmine gas availability, mobile CHP plants in a container have turned out to be the most favourable concept, see Fig. 2. The modular approach allows easy adjustment of the capacity of the plant to the (changing) availability of coalmine gas. Additionally, the concept of mobile containers leads to a minimisation of investment risks, space requirements, and duration of project execution.

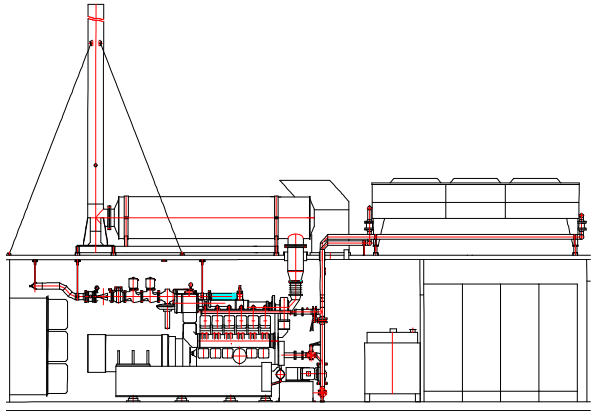

Fig. 2 Mobile CHP Plant in a Container

In the following, three examples of our container concept for CHP from coalmine gas are presented, see Figures 3-6.

5.1 MINISTER ACHENBACH SHAFT IV

The coalmine "Minister Achenbach" in the Ruhr area was closed in 1990. A total of 37,5 km^2 shafts were dumped. All the mines were filled and partially provided with degassing pipes that were finished underneath the backfilling. In the grounds of the Technology Park "LÜNTEC", a degassing pipe with a diameter of 250 mm ends at shaft IV of the abandoned mine. A pipe down to a depth of approximately 500 m is acting as the removal route of the CMM into the atmosphere. It is provided with a deflagration protection and a mine flap that opens if the pressure of the shaft is above atmospheric pressure. Therefore, penetration of air into the old mine is avoided.

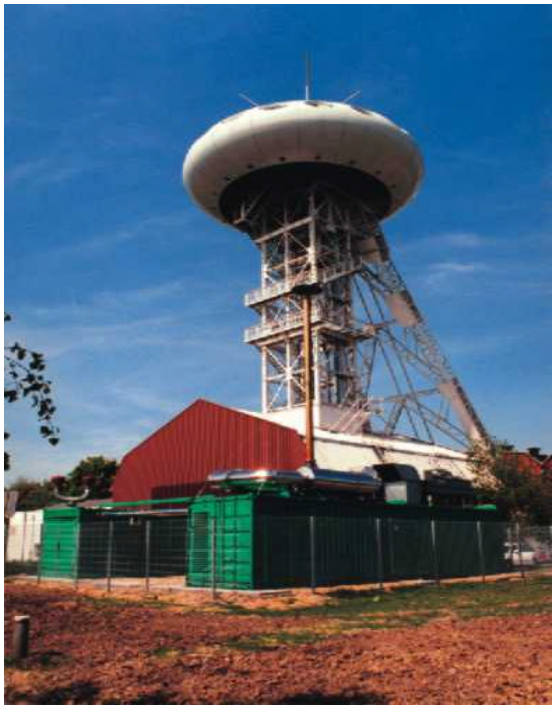

Fig. 3 Plant “Minister Achenbach Shaft IV”

A branching for partial use of the coalmine gas was installed between the shaft’s outlet and the mine flap. Behind a rapid action valve and deflagration protection the gas is compressed by an rpm-regulated rotary compressor up to 90 mbar(g). The coalmine gas is fed into a cogeneration plant of 374 kW_{el}/538kW_{th} and recently upgraded to almost 1 MW_{el}.

The plant has been erected by G.A.S. Energietechnologie GmbH under the scientific guidance of the Fraunhofer Institute UMSICHT and with financial support from DBU, a German foundation for environmental research and is now being owned by EnD-I Grubengas GmbH, a joint venture of EnD-I AG and G.A.S. Energietechnologie GmbH. After more than one year of satisfactory operation, the aggregate was exchanged against a container plant with 941 kW_{el} in summer 2000. The required space for the plant remained unchanged which showed the advantage of the prefabricated and standardised container solution. The period of shutdown of the plant due to rebuilding was below 2 weeks.

5.2 BOCHUM-GERTHE

In 2002, EnD-I Grubengas GmbH started operating another 5100 kW_{el} coalmine gas fired power plant in Bochum-Gerthe, avoiding CO_2 emissions of approximately 200 000 tons per annum.

Due to the fact that the installation is located in a residential area, the installation had to be in compliance with strong demands related to architecture and noise emissions. The best solution was to erect a building in which the four CHP containers are arrayed.

The necessary equipment for heat utilisation is currently under construction. From 2004 on, 5600 kW_{th} will be fed into the district heating net operated by the local cityworks, Stadtwerke Bochum.

Fig. 4 Plant “Bochum-Gerthe”

5.3 KURL SHAFT III

In May 2001, Minegas GmbH, a joint venture between RAG AG, G.A.S. Enrergietechnologie GmbH and LAMBDA GmbH, started the operation of its first three cogeneration plants “Kurl shaft III” at the site of the former coalmine of Gneisenau in Lünen. The three modules have an output of 1 358 kW_{el} each which are fed to the public grid corresponding to the electricity requirement of ca. 9 700 households. Until today, Minegas GmbH has realised another 14 projects, 35 power plants with a total installed capacity of 50 MW_{el}.

Fig. 5 Plant “Kurl Shaft III”

5.4 DORTMUND-DERNE

In November 2001, a 5 400 kW_{el} CHP in Dortmund-Derne was converted from natural gas to coalmine gas operation. Due to decreasing electricity prices and increasing gas prices, economic operation of the plant had become more and more difficult. Fortunately, sufficient coalmine gas for the partial operation of the plant was nearby available from the closed coalmine “Gneisenau”. The coalmine gas is owned by Minegas GmbH, compressed on site and then delivered, via a pipeline of 600m length, to the CHP plant owned and operated by Grüne Energie Derne GmbH, a 100% subsidiary of G.A.S. Energietechnologie GmbH.

Fig. 6 Plant “Dortmund-Derne“

6 OPERATIONAL EXPERIENCE

During the first four years of operation of CHP plants running on CMM from closed coalmines, we have gathered the following experience:

- Operation of the engines is strongly depending on the quality of the coalmine gas but definitely positive.
- Reliable operation and availabilities up to 96% are achieved.
- Oil change intervals vary between 500 and 2 000 hours.
- A high amount of sulfur in the coalmine gas can cause corrosion in the flue gas heat exchanger.
- Condensation in the gas train must also be avoided.
- The long-term availability of coalmine gas on a certain location is difficult to assess.
- For each project, a unique authorisation procedure is required due to differing local circumstances. This has delayed the implementation of mine gas power plants in Germany.

7 CONCLUSION

In Germany, power generation from CMM is still booming. More than 60 MW_{el} on CMM from closed coalmines were realized, another 30-50 MW_{el} will soon be installed running on CMM from both active and closed coal mines.

Contrarily, CBM is not (yet) used in Germany due to unfavourable geological conditions.

One of the important driving forces for CHP from coalmine gas are the payback tariffs of 6.6-7.7 € ct per kWh_{el} being guaranteed in the German EEG-law.

Among the different concepts for the utilization of coalmine gas, mobile CHP plants in containers turned out to be the most favourable concept. Operational experience is strongly depending on the gas quality but definitely positive.