Coal mine methane management, Nord-Pas-de-Calais (France)

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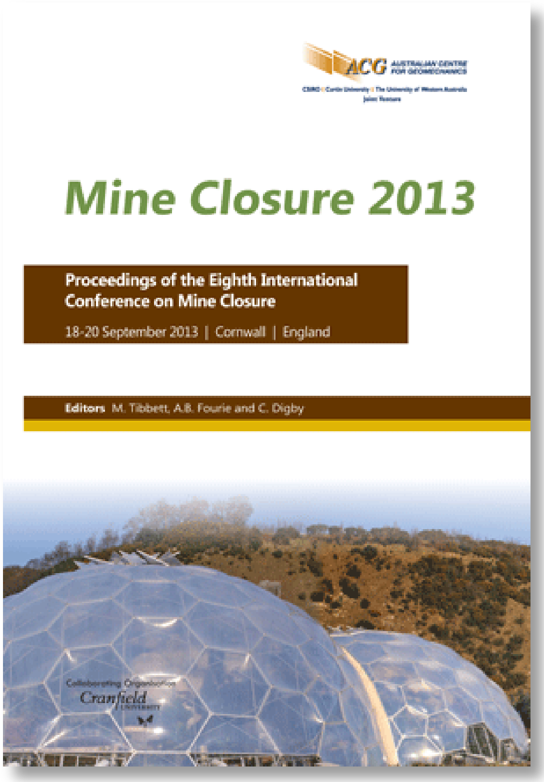

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Abstract

A coal mine, once closed, still 'lives'. Coal beds release methane, which is then trapped in the mine voids by water rising as a result of natural flooding. The consequence is a rise of pressure (a well-known phenomenon in every coalfield), which may be dangerous because gas can migrate directly to the surface.

Controlling mine gas risk is essential for safety reasons, due to methane's highly flammable nature. A control methodology was developed by the original operator, and starting on this basis, geological studies and probability calculations conducted by the BRGM in several French coalfields in the past are today key to improve control.

Methane is bonded on both the internal and the external surfaces of each particle of coal, due to numerous cracks. Gas is released by desorption under specific pressure conditions, defined for each coal by isotherm curves. Desorption occurs naturally into the atmosphere above atmospheric pressure, but gas can also be released beneath by pumping. A whole mine can sometimes turn into a methane reservoir. The definition of risk is then based on two concepts.

For ground gas migration, risk is theoretically defined as 'a cross between the susceptibility of caprock to let methane pass and vulnerability at surface where it might meet sensitive elements such as habitats'. In this context, everything depends on the ground's natural ability to allow migration. BRGM therefore carried out a geological study to identify 'exhaust minimum requirements' and determine where ground constitution, thickness or permeability is insufficient to contain the risk.

BRGM then studied 'the occurrence of the event' pertaining to the mine shafts – i.e., the probability that the gas escapes through some works, and conducted preventative works.

To this end, when mines were closed, a network of galleries was kept open to allow the gas to flow. In some cases, sealing works have been made, while in others, security structures were built before exploitation ended. Decompression boreholes are drilled above higher areas of the reservoir, allowing a 'passive' and continuous decompression. Finally, BRGM makes twice-yearly measurements of pressure, methane content and sealing.

Meanwhile, GAZONOR, a company operating in the Nord-Pas-de-Calais since 1980, is dedicated to the research, extraction, purification and sale of coal mine methane extracted from the former coalfield. The original mission of GAZONOR meets justified and general interest needs of mine gas extraction. Indeed, methane extraction allows limiting potential risk of leaks and spontaneous or accidental explosions, while reducing greenhouse effect by preventing its free movement to the atmosphere.

BRGM and GAZONOR certainly do not have the same goals, one working for people's safety and the other for profit. However, both have the same study object and share a mutual interest in its understanding. In the end, whatever the vision of the reservoir, the purpose is to guarantee the sealing to control the risks while integrating economic and environmental issues.

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1 Introduction

The Nord Pas de Calais coal basin (NPCCB) extends from the Nord department at the Belgian border to Boulogne in the Pas de Calais – over 105 km from west to east and a shorter but variable width of 8 km to the east, 12 km at the centre and 5 km to the west.

The Westphalian coal measures lie beneath an impermeable cover of Cretaceous marls that ensure imperviousness with respect to groundwater aquifers. It is characterised by a large number of coal seams (400), of which only a part (50 at the most) have proved to be workable.

The production of coal ceased at the end of the 1980s. The former shafts and galleries, vestiges of the mining period, today constitute a network of mine voids. The deposit continues however to be 'active', however, particularly via the continuous production of gas by the coal in these mine voids and the effect of the rising water level on the pressure of this gas. Thus the network of mine voids and the geology demarcate several large mine gas reservoirs in the former Nord Pas de Calais coal basin, which includes a major reservoir that we will call RCP (Central Poissonnière Reservoir).

In 2006, the French government entrusted BRGM with a post-mining operational remit. In this respect, BRGM's Mining Safety and Risk Prevention Department (DPSM) carries out monitoring missions within the context of the closure of mining works and the prevention of mining risks. An annual Ministerial Decree sets out the list of installations and monitoring equipment and the prevention of mining risks. These include more than 500 structures monitored on a half-yearly basis, which are linked to the problem of mine gas:

- 75 gas outlets.
- 6 deep piezometers.
- 422 'marked' well heads (location is known).
- 41 'unmarked' well heads (location unknown, in which case, the well head is monitored by nearest marked structures).

The regular acquisition of intrinsic reservoir parameters such as the pressure and the methane content make it possible not just to prevent surface risks but also to monitor their evolution.

In parallel, NPCCB is of considerable economic interest because it has interesting characteristics for mine gas extraction:

- Considerable void volume due to the extraction of 2.5 billion tonnes of coal.
- Initial concentration of methane (CH_4) from 5 to 15 m^3/t.
- Maximum specific flow rate from the mined tunnels of 100 m^3/t – 100 m^3/t for each tonne of coal mined.
- Mining depth between 100 and 1,100 m.
- Numerous open links between sectors and at different levels.
- Imperviousness with regard to the surface ensured by a considerable overburden around 100 m thick with impermeable marls.
- Former shafts (600) filled in with clay or fly-ash.
- Above all, very slow waterlogging (longer than 20 years).

Thus, for more than 20 years, well before the creation of the DPSM and surveillance campaigns, the mine gas was worked by GAZONOR (see later discussion) within the deposit and particularly in the RCP.

2 Mine gas

Mine gas, known as firedamp by miners, has its origins in the nature of the vegetal sediments, which are the original constituents of solid mineral fuels.

Apart from superficial zones affected by the migration of methane during geological upheavals, the mine gas is linked to the coal beds and the host rocks, with gas contents that normally reach 10 m^3 or so per tonne of coal in place. The extraction of a coal seam releases the gas from the extracted coal, but also from the expansion zone around the massif, the desorption of which is progressive over time. The specific release resulting from this phenomenon may frequently reach 100 m^3 per tonne extracted. While the coal was being mined, the gas was evacuated from the mine by ventilation of the working faces. The necessity of maintaining the atmospheric content below the regulatory limits led to the development of gas capture in working mines. In this way, it was possible to capture, in certain very favourable conditions, up to almost 50% of the total firedamp released.

This capture is currently generalised in firedamp centres of Western Europe, due to the deepening of mines and the increase in the unitary production of mining sites. When the working of a mine field comes to an end, the atmosphere at the bottom rapidly becomes impoverished in oxygen and the mine shafts are either filled in or shut off, all communications with the exterior being cut. In the case of a firedamp deposit, the methane content becomes important under the effect of the desorption of gas from the coal that has remained in place.

In the working fields of the Nord Pas de Calais coal basin, all of the mine shafts have been closed. The thick overburden with its impermeable marls under the aquifer chalk ensures good imperviousness at the head of old abandoned works. Leak tightness directly in line with former backfilled mine shafts is ensured by filling with clay or fly-ash inside the shaft linings. The idea was therefore conceived, in 1974, to capture the firedamp from old mine workings in the high grade coal deposit of Denain.

Actual firedamp capture in La Naville began in 1978. When local mine gas demand increased, capture from this deposit was increased twofold, in 1985, by an installation on the bank of the former Desirée pit; production was thus increased to 13 million Nm^3 a year (1 Nm^3 equals to 1 m^3 of methane at 20°C and 101,325 Pa). This gas, known as mine gas, is thus captured from shut down mines. It is known as 'abandoned mine methane' as opposed to 'coal mine methane', which is captured from active coal mines, and 'coal bed methane', which is captured from unworked coal deposits. The origin of mine gas goes back to the formation of the coal and the deposition and the transformation of plant debris. At the same time, physical/chemical reactions gave rise to the appearance and the formation of an important volume of gas, a large part of which has escaped with coal mining, although up to 20 m^3/tonne remains in coal.

In the Lens and Courrières regions, but also in other areas of the basin, gas contents of the coal of 10 m^3/t have been measured. During mining work, specific releases of gas of 40–60 m^3/tonne of coal mined have been reported. These values confirm that the mines of the NPCCB were very rich in firedamp. The mine gas is extracted at an average temperature of 25–30°C and under variable pressure, between 300 and 600 mbar. Mine gas is a mixture of several different gases. The concentrations of these gases are highly variable from one seam to the next and according to the depth. The main component of mine gas is methane, which accounts for between 90 and 95% of the total. When mine gas is captured, these methane levels are close to 50–60%, because the mine gas is diluted by the entry of air.

The extracted gas is thus a mixture in which the methane content is a weighted average that results from the permanent regime of desorption from the large number of seams concerned and the circulation of gases that have become established in the many voids of the former mine works.

Mine gas is contained in the ground in two forms:

- Free gas in the fissures and pores of the coal and in the barren rock.
- Adsorbed gas in the coal, on its internal surfaces.

To begin with, methane is an odourless and colourless gas. Its spontaneous ignition temperature is 595°C. Its explosiveness range in air in conditions of normal temperature and pressure is reached at a concentration of 5–15%. Nitrogen and carbon dioxide are, for their part, non-flammable.

At typical, the composition of mine gas is:

- CH_4: 50 to 60%.
- CO_2: 10 to 12%.
- N_2: 30%.
- Alkanes: < 1%.
- Noble gases: < 0.2%.
- CO: < 5 ppm.
- H_2S: traces.

Mine gas is qualified as 'clean' insofar as it does not contain sulphur or sulphur compounds (traces in ppm). It has thus been recognised as a source of recoverable energy.

3 Gas surveillance: the mission of the DPSM

3.1 Typology of gas structures

Some 500 gas structures are installed in the Nord Pas de Calais basin. Some are directly linked to the mining reservoir and are indicators of its absolute pressure. Four types of structure may be distinguished: the (un)marked shaft, the vent hole, the outlet and the deep piezometer.

3.1.1 The shaft

This is a man-made cavity filled in up to the surface and formerly in communication with the mine workings via galleries.

3.1.1.1 The marked shaft

The marked shaft (Figure 1) has, at its summit, an observation well, resting on a concrete plug enabling it to rest on the backfill and isolating it from the latter. Inside the observation well, an inspection hole (known as the 'backfill inspection hole'), constituted of a square tube and a flange with two control tappings, gives access to the backfill and enables the level, pressure and composition of the gas to be measured. The shaft is not necessarily filled down to the bottom; for instance, the lower part of the shaft does not systematically coincide with the base of the backfill. In fact, the shaft is sometimes equipped with a mine dam (a more elaborate type of concrete plug anchored in the enclosing structure) at a variable depth, thereby separating a completely filled upper part from an empty lower part. Generally speaking, the backfill is constituted of slag heap products and/or ash. It only has a filling function and does not play a role in terms of permeability, even if the particle size of the materials used makes it relatively impermeable to the gas.

The observation well is closed off by a concrete slab, with access via a cast iron plate. A building may be constructed around or on a well; if the inspection trap of the observation well is always accessible, then it is said that the shaft is marked in this building.

The presence of a marked shaft is always indicated by a warning plate.

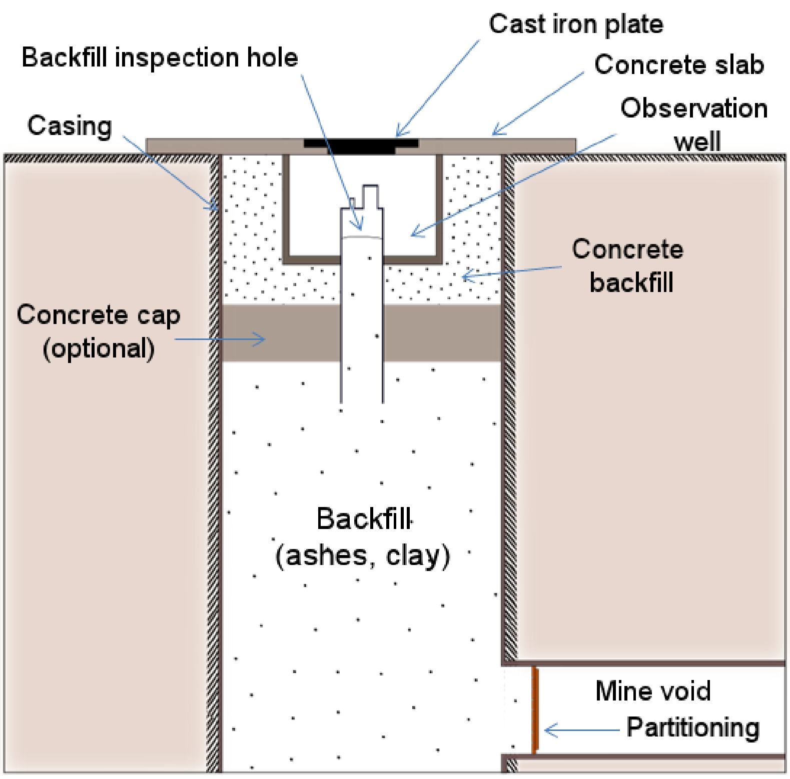

Figure 1 Diagram of a marked shaft

3.1.1.2 The unmarked shaft

A shaft is qualified as 'unmarked' when its geographic location is unknown or when it is inaccessible (concreted observation well, construction of a building). These structures figure all the same in the surveillance list. They are monitored by the nearest marked structures.

3.1.2 The vent hole

A shaft, even if filled from the bottom to the surface, can have a risk of leakage of mine gas. If at the very moment of filling, when closing a shaft, it has been possible to detect methane (CH_4), the operator then knows that a gas hazard exists in the observation well. As a safety measure for the operator, a device must be installed in order to displace the arrival of this gas outside of the observation well. This device is known as a vent hole. CH_4 is expelled into the atmosphere, and regular controls can be carried out without any risk in the observation well.

In certain cases, a well is located in a building. In such cases, a vent that is fixed to the exterior wall of the building (with or without detection of gas) is also systematically put in place.

It should be noted that the well head is not always accessible in the building. It is then necessary to put in place a second observation well on the outside, in lateral communication with the well under the building: this is then known as a 'shifted observation well'. It is worth noting that a shifted observation well can also make it possible to control a well whose head is dematerialised.

3.1.3 The outlet

Outlets are gas structures directly linked to the mine voids. Two types may be distinguished: the conventional outlet, inherited, like the shafts, from the former mine workings, and decompression borings, which are more-recent structures dating from the post-mining phase and intended to manage the positive gas pressure hazard. Outlets, like vents, are equipped with anti-return and flame arrestor valves in order to avoid atmospheric air infiltrating into the reservoir.

3.1.3.1 Conventional outlet

During the closure of certain shafts, the operator has left in place a pipe providing a direct link between the mine voids and the surface. This structure enables the pressure of the reservoir to be monitored and generally, as a piezometer, the rising of the mine aquifer to be monitored. It will also serve as decompression boring in the final waterlogging phase.

3.1.3.2 Decompression borings

One of the direct consequences of the end of mining operations is the progressive rising of the mine aquifer. In the final phase of waterlogging, through a vertical piston effect of the rising water level, the upper mine voids of the deposit are subject to high gas pressure. These pockets of mine gas, under positive pressure, present a real danger. Thus, decompression borings are made in the upper points of the reservoir. At this stage, they also make it possible to obtain a regular piezometric measure to record the rising of the groundwater.

In the particular case of the RCP reservoir, all of the decompression borings and conventional outlets are permanently isolated from the exterior by a ball valve (in the metal casing) that relieves the anti-return valve from the strain imposed by the negative capture pressure. The reservoir is thus ensured not to be polluted by atmospheric air from these sources.

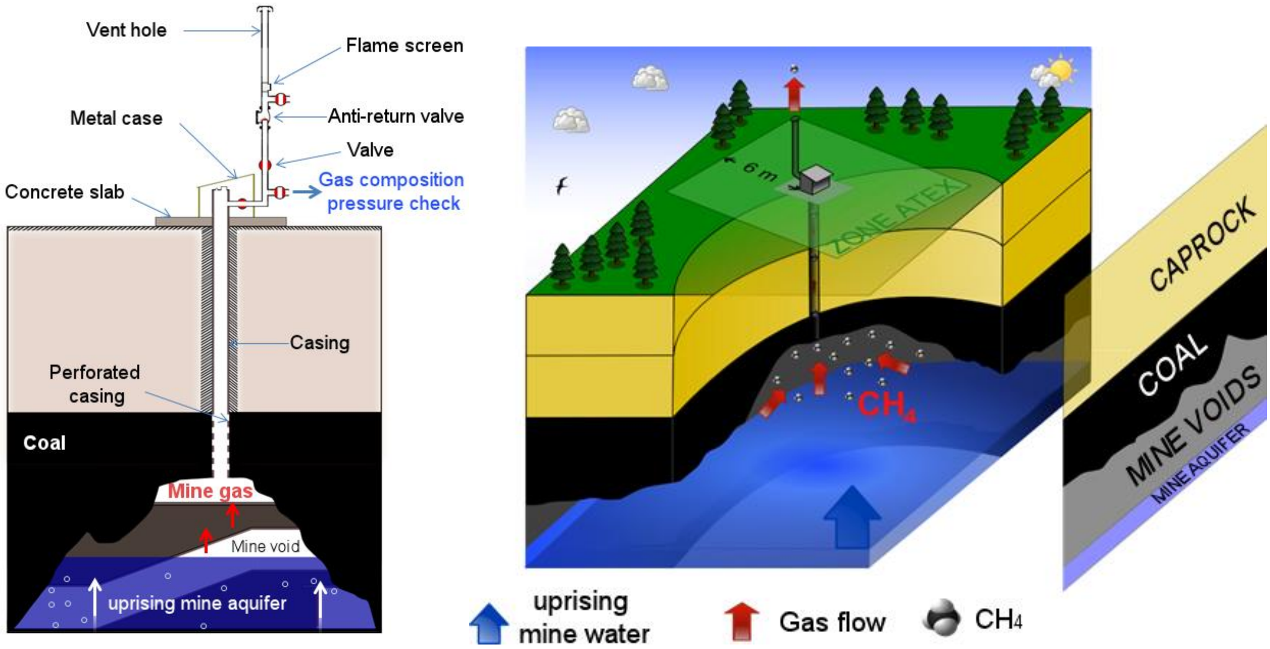

Figure 2 Diagram of a decompression boring (left: sectional, right: perspective)

3.1.4 The deep piezometer

Deep-lying piezometers are intended to record the rise in groundwater levels and the waterlogging of the deposit. Even though they were not designed for it, they provide, like the outlets, a measure of the pressure in the mining reservoir, providing the water level has not risen past the highest works. Nevertheless, classed as piezometers, they are not provided with a safety device (type A, B, C vents) as defined in the Instruction Exutoires de Gaz de Mine (mine gas outlet instructions) (Guise, 2009).

3.2 Gas structure surveillance methodology

3.2.1 First step

The first step in the surveillance of a structure, whatever it is, is verification of its integrity. The accessibility and the visibility of the site may be compromised by natural events (subsidence) or anthropogenic events (building works, vandalism).

3.2.2 Materialised wells

3.2.2.1 The opening of the observation well

Controls begin in the backfill observation well, at the head of the well.

The first and the most important measure is the pressure above the backfill (P). This is systematically compared with atmospheric pressure (AP). A pressure differential is then recorded, noted ΔP and expressed in millimetres of mercury (mm Hg) or water column (mm CE) for the lowest pressures, with:

$$\Delta P = (P - AP) \quad (1)$$

These measures are accompanied by an observation of the path taken by smoke diffused into the observation well backfill (entering, neutral or escaping) as well as simple listening, which sometimes makes it possible to detect a hissing noise bearing witness to an escape of firedamp or the entry of air. In certain cases, the perception of the characteristic odour of the mine bottom (H_2S in particular) is a supplementary tool.

Three scenarios may thus be distinguished:

- $\Delta P = 0$: the pressure in the backfill is equal to the AP. This is the reference value, providing confirmation of the leak tightness of the backfill.
- $\Delta P < 0$: the pressure in the backfill is less than the AP. The flow (materialised with smoke tracer) is called entering.
- $\Delta P > 0$: the pressure in the backfill is greater than the AP. The flow is called escaping.

Note that for low values (less than 5 mbar), around zero, the differential pressure could be a consequence of atmospheric pressure variations. In these cases, the shaft is open to set the differential to zero. Once closed, pressure is recorded once again to confirm that its rise is not influenced by atmospheric pressure variations. Beyond 10 mbar, it is assumed that there is an actual leakage from the shaft.

Second, the backfill level is recorded. There are two phenomenon causing the backfill to drop down: its compaction or a collapse at the base of the well. In both cases, backfill is completed in order to return to the initial backfill level.

3.2.2.2 Additional observations

In the cases where the ΔP is positive or negative in a well, the situation is abnormal. One suspects, respectively, escapes of mine gas or air entering into the well. It is then necessary to extend the radius of the surveillance zone. Smoke is vaporised into the observation well and in the 15 m protection zone around the well by the boring of a micro well (diameter 10 mm, depth 1 m) in order to identify entering or escaping flows. It is worth noting that, at the present time, escaping flows are difficult to perceive with the smoke technique around the well bore (surface air currents).

In the case of an escaping flow, the composition of the mine gas is determined with a Dräger™ X-am® 7000 multi-gas analyser (CH_4, H_2S, CO, CO_2, O_2), but other methods and equipment exist.

3.2.3 Outlets and deep piezometers

These structures, by their construction, are directly linked to the mining reservoir. Thus, at any instant, the pressure recorded at the outlet must be equal to the pressure in the reservoir (until the piezometer response zone is covered by groundwater). The expected values are thus not the same over the whole of the basin.

RCP is worked for the capture of mine gas by GAZONOR and it is at negative pressure – that is, below atmospheric pressure. In their present state, the vent holes of the outlets have no role to play. They are never required to open. The role of the non-return valve is to open and not to maintain a negative pressure. Consequently, it was decided to install a ball valve at the base of the vent holes, so as to ensure the leak tightness of the structure (Lemal, 2012).

The reservoirs formerly worked for gas capture are always at a pressure below atmospheric pressure. Nevertheless, as the reservoir is no longer put on suction, this pressure is rising, tending towards equilibrium in the more or less long term (several years to several decades). Negative pressure is thus not abnormal in the structures concerned but, unlike RCP, the flap gates of the vents are not isolated by a ball valve.

Finally, in the sectors that have never been mined, the outlets play a conventional role. The gas is at positive pressure and the flap gates are thus free to open.

Any outlet in the basin showing a pressure different to the real pressure of the reservoir, in accordance with the aforementioned rules, is identified as malfunctioning.

4 Gas capture

4.1 History of GAZONOR

Mine gas, the mixture of gases mainly composed of methane, needs to be captured:

- First, to ensure safety, at the bottom of the mine and for the miners.
- Second, to distribute as an energy source and to commercialise.

The beginnings of the capture of this gas date from 1978 in the Nord Pas de Calais basin. The Houillères du Bassin Nord Pas-de-Calais (HBNPC) formed, with Gaz de France, on 22 December 1987, the GIE (economic interest group) Methamine to suck up and compress the mine gas captured from pits 5 of Lens and 7 Bis of Liévin and to inject it into the Artois artery of Gaz de France's distribution network.

In 2007, GAZONOR filed for and successively obtained:

- An application to extend the Poissonnière concession to cover the real zone of influence of its captures; the extension was granted by Ministerial Decree of 14 January 2009.
- An application for an exclusive exploration permit on the Valenciennois, an independent and unworked gas deposit between the Valenciennes conurbation area and the Belgian border; the permit was granted by Ministerial Order of 10 September 2009.
- An application for an exclusive exploration permit in the zone known as Sud Midi, covering part of the Nord and Pas de Calais. This perimeter is located to the south of the Poissonnière concession. This permit was granted by Ministerial Order of 16 June 2010.

Before the dissolution of Charbonnages de France, GAZONOR became on 28 December 2007 a 100% subsidiary of the firm EGL SAS, the French subsidiary of the Australian group EUROPEAN GAS LIMITED (EGL); following an operation on convertible financial bonds, since 5 May 2011 GAZONOR has belonged to the TRANSCOR ASTRA GROUP.

4.2 The gas reservoirs of the NPCCB

4.2.1 RCP

RCP, situated in the central part of the basin, represents the largest mine gas reservoir in the NPC basin (Figure 3). This zone is demarcated at the western edge of the Divion reservoir, and at the eastern edge it is demarcated from the Desirée reservoir and the Valenciennois by a series of faults.

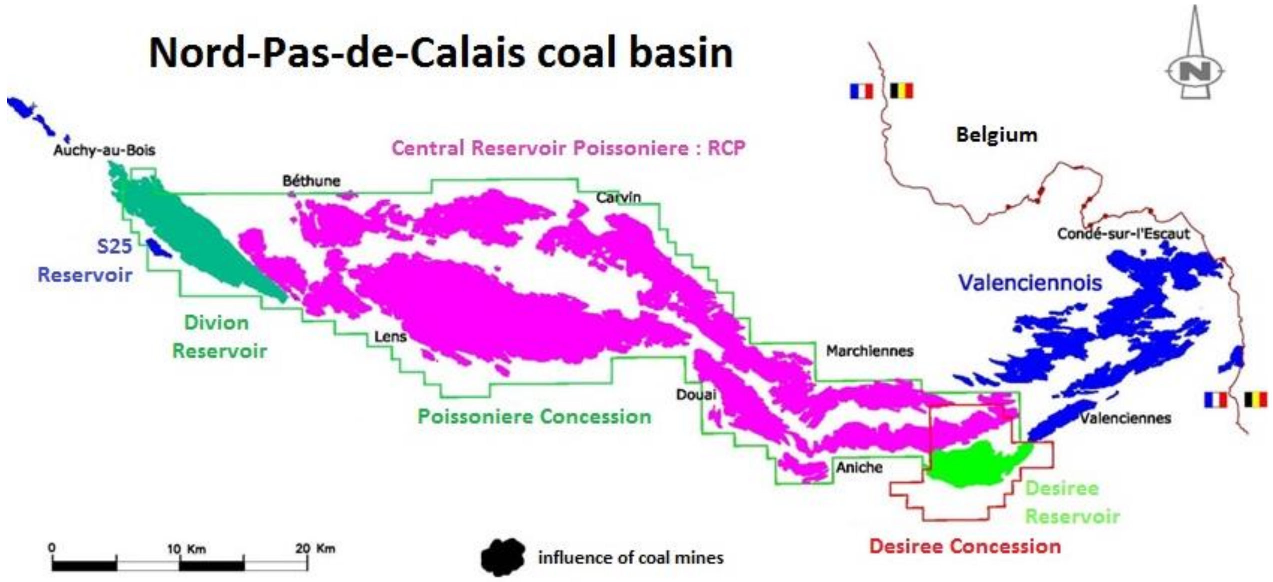

Figure 3 Mapping of influence of coal mines in the NPC and gas reservoirs

For over 20 years this site has been capturing gas from two wells in which mine dams made of reinforced concrete were installed during the closure (pit 5 of Lens at 176 m and pit 7bis of Liévin at 151 m). Each mine dam is traversed by two pipes (Ø300 and Ø250) that collect the gas from the part of the well that has remained void and is connected to the reservoir. In addition, a boring was drilled into the former mine workings near to pit 5 of Lens to offset any loss of gas on this well.

Given a tonnage of coal estimated at 2,500 billion tonnes and a desorbable gas potential of around 2.3 m^3 per tonne, the gas potential of RCP, at the start of operations, has been estimated at 5,750 billion m^3 of pure CH_4 (i.e. 33,000 GWh).

In 2012, all of GAZONOR's mine gas production was from this single site via the extraction stations 5 of Lens and 7bis of Liévin. The annual production was 74.90 million Nm^3 with an average CH_4 content of 49.7% and corresponds to an energy value of 412.3 GWh.

Although the extracted volume is practically equivalent to that of 2011 (74.40 million Nm^3), the energy value produced in 2012 was 4% less than in the previous year (429.70 GWh) due to the observed drop in the average higher heating value (HHV, equal to 11.06 KWh for 1 Nm^3 of pure (100%) methane). HHV dropped from 5.78 KWh/Nm^3 in 2011 to 5.50 KWh/Nm^3 in 2012.

It should be noted that this downturn intensified in the first months of 2013 (HHV between 5.10 KWh/Nm^3 and 5.35 kWh/Nm^3).

4.2.2 The DIVION reservoir

The DIVION reservoir is situated to the west of the NPC basin. It is isolated from the S25 reservoir, to the southwest, by the Marqueffles Fault and from the RCP reservoir, to the east, by the Ruitz fault. The extraction of mine gas from this reservoir by Charbonnages de France began in November 1979. Five short borings (120–220 m) positioned on the former bank of pit 5 of Bruay (commune of Divion) were used for the capture. Historically, the capture-compression installation supplied the Drocourt coke works with mine gas. When this coke works was shut down, modifications were made to supply another client, the Société Artésienne de Vinyle (SAV) in Mazingarbe, via a buried pipe 21 km long. In 2007, following a commercial dispute with SAV, capture on the DIVION reservoir was stopped.

The evolution of the pressure of the reservoir is shown in Figure 4. It can be seen in this figure that the pressure is well below atmospheric pressure, that it has been steadily rising since capture was stopped but that it is not yet stabilised.

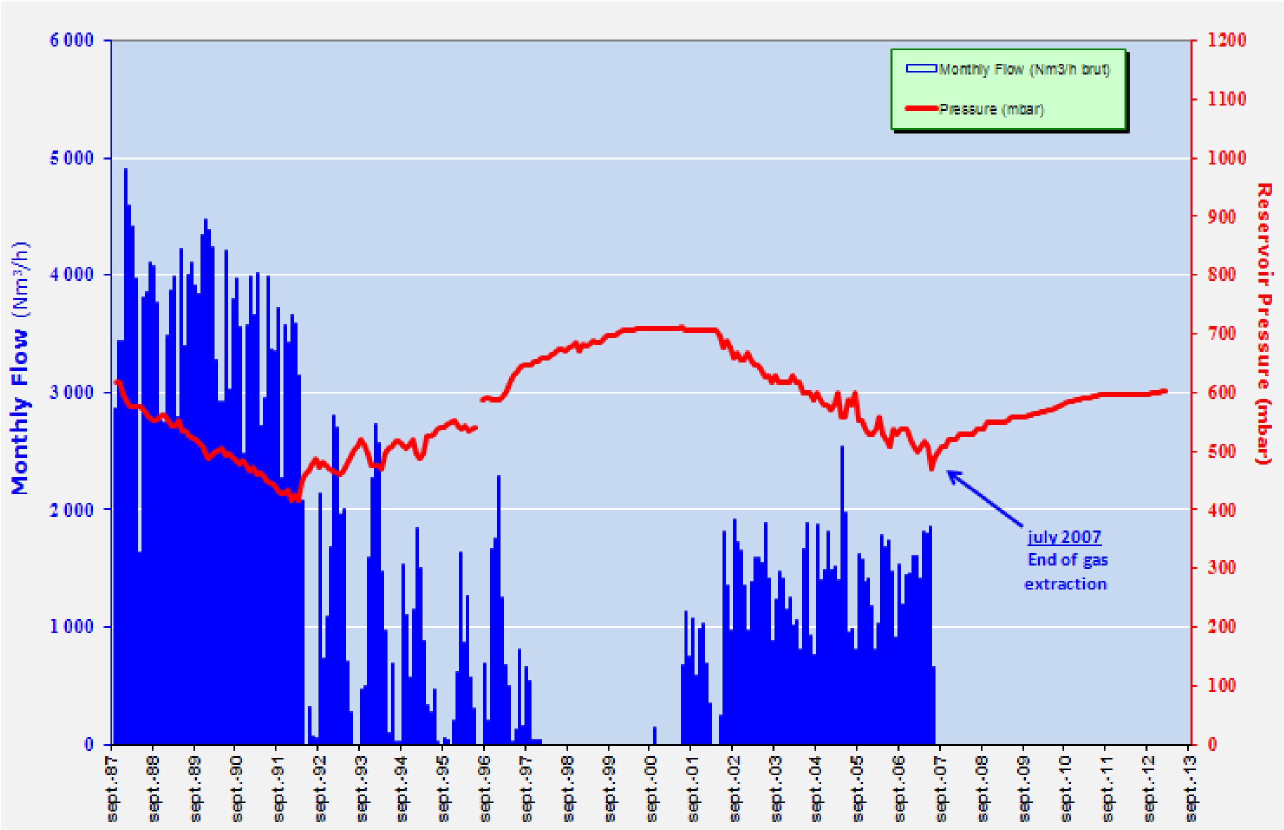

Figure 4 Pressure and flow of DIVION Reservoir between 1979 and 2012 (Source: GAZONOR)

4.2.3 The Desirée reservoir

The DESIREE reservoir is located in the southeast quarter of the BHNPC, separated from the Valenciennois by the Hérin Fault and from RCP by the Midi d'Abscon Fault. Mine gas was captured starting in January 1978 by Charbonnages de France. Four borings on the La Naville site and two borings on the Desirée site, linking the surface and the former works, enabled the deposit to be worked. The actual implementation of capture at La Naville dates back to 1978. As local demand for mine gas increased over the years, capture was doubled, in 1985, by an installation on the bank of the former Desirée pit; the production thereby reached 13 Nm^3 per year. This capture-compression installation supplied the ash dryer of the firm SURSCHISTE in Hornaing via a buried pipeline 8 km long. Since the needs of SURSCHISTE fluctuate with the seasons, a connection with the nearby power plant was constructed so that it could benefit from the excess of gas supplied by DESIREE. This agreement came to an end in 2006, when the power plant switched over to natural gas operation. Later, in 2010, the operation was stopped, as production costs were greater than the profits made from the sale of gas.

Figure 5 represents the life of the reservoir, from the start of capture up to its shutdown. Since this is relatively recent, the reservoir still has a considerable negative pressure (current pressure of the order of 1,000 mbar).

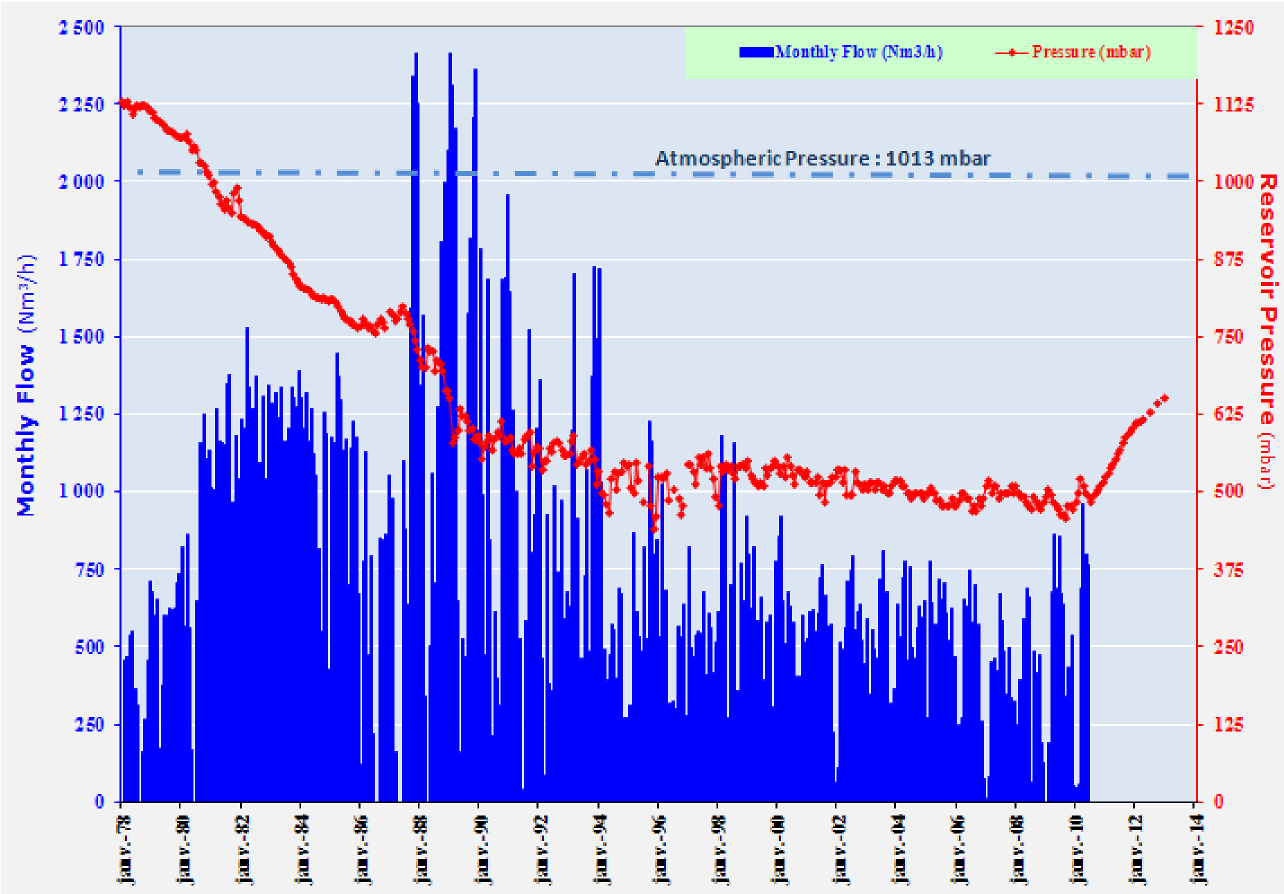

Figure 5 Pressure and flow of DESIREE Reservoir between 1978 and 2012 (Source: GAZONOR)

4.2.4 Sectors never exploited for gas

The S25 reservoir is located at the western edge of the NPC coal basin and isolated from the DIVION reservoir by the Marqueffles Fault. This reservoir, which is at positive pressure, has never been mined to date on account of insufficient volume.

The Valenciennois should be considered as a 'sector' and not a 'reservoir' because the rise in the groundwater level of the coal basin is progressively isolating an indeterminable number of upper mine voids and in all likelihood crossing positive pressure zones. The Valenciennois should therefore be approached as a sector composed of independent micro-reservoirs. The Valenciennois sector is separated from the DESIREE reservoir by the Hérin Fault. It does not suffer any effects from capture from the RCP deposit because it is isolated from it by the Barrois Fault (Becq-Giraudon, 1983). Finally, it is worth underlining that the coal seams worked in this sector extend beyond the French-Belgian border.

5 Surveillance – capture interaction

The Central Poissonnière Reservoir, still being worked for abandoned mine methane extraction at the present time, covers two-thirds of the Nord Pas de Calais coal basin. There are 544 well heads and 55 decompression borings in this same zone. Thus, although the government and the operator do not work together, surveillance and capture issues are completely linked.

5.1 Different sensitivities

At first sight, the government and the operator have different objectives: while one aims to protect the public by ensuring that the gas remains trapped in the reservoir, the other aims to optimise its output by maximising the quantity of gas extracted while ensuring that the mixture is as rich as possible in methane.

From the operator's point of view, the quality of the mixture is essential (as little nitrogen as possible). Ground depressurisation due to the gas suction does not hinder monitoring in any way. Quite the opposite, maintaining constant depressurisation in the reservoir allows the operator to avoid any risk of gas escaping to the surface. But even if it may be thought that no molecule of CH_4 can escape from the reservoir, none of the monitored shafts (or even the ground) is designed to be sealed in a strong depression (450 mbar). Consequently, they represent potential air inlets. This air mixes with the mine gas, decreasing the HHV at a critical point where the gas cannot be sold.

5.2 The keys to harmony and understanding

Although their objectives are different, it has to be accepted that the two parties have essential common needs: an understanding of the reservoir and the guarantee of its leak tightness. Understanding is entirely possible, and the pooling of resources can only be beneficial. The government and the operator therefore need to assure the attainment of their objectives while not harming the needs of the other. To do this, two notions need to be properly grasped.

5.2.1 Negative pressure: the paradox of the operator

Air inlets may lead the operator to act in a counterproductive way. Sometimes (as shown on Figure 6), the operator increases the depression so as to extend the capture influence radius and speed up desorption in order to mitigate the gas mixture degradation. Unfortunately, this increases the air flow inside the reservoir and may even create new air inlets. Figure 6 shows pretty well, from early 2009, how decreasing pressure influences the calorific value (HHV).

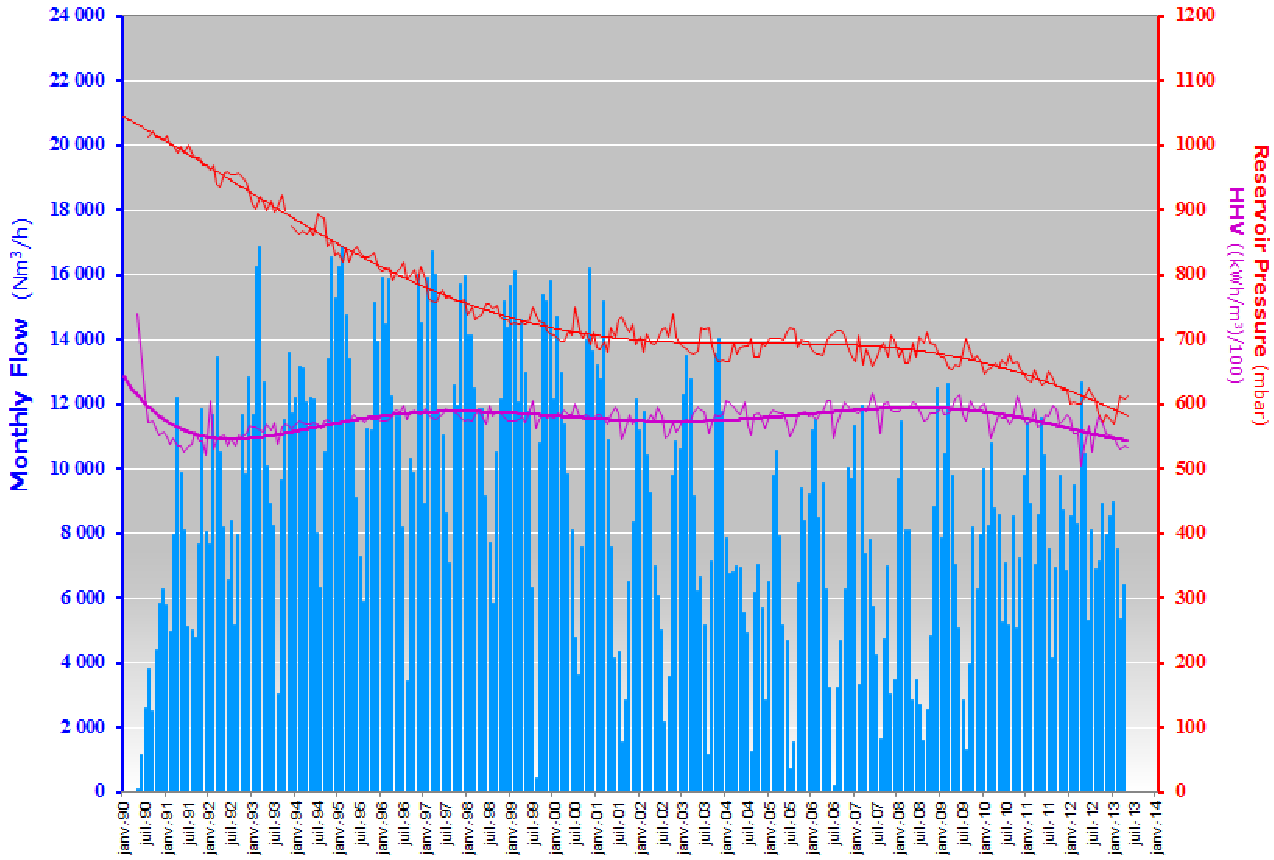

Figure 6 Influence of negative pressure on gas quality and calorific value (HHV) (Source: GAZONOR)

5.2.2 The spatial-temporal scale of surveillance

The operator has few data relative to the number of extraction sites he manages. The government, for its part, has a large amount of time-based data, spread within the whole reservoir. These data should be valued. The key to understanding the phenomena lies in extending the scope of study. The entirety should be considered, not just one site. Thus, monitoring must be transcended, so as not to focus just on the state of a site when measurements are recorded but, quite the opposite, to feed conceptual and phenomenological models of reservoirs every time new data are acquired. The idea is no longer to remedy a critical situation (gas leak, incoming air) but to be able to anticipate its occurrence.

Above all, this long-term view of the reservoir must also consider that gas capture will not go on forever. Thus it should not be forgotten that stopping gas suction would quickly lead to new emission issues at the surface. Today's air inlets are tomorrow's mine gas outlets.

6 Conclusions

Thirty years after the end of coal mining in the Nord Pas de Calais coal basin, the coal seam is still active. Methane builds up naturally in the mining voids. Its recovery is not a source of controversy, because this firedamp is produced by the coal exposed by the former mining operations and because it is recycled as fuel, while at the same time ensuring that it is not released into the atmosphere (which limits contributions to greenhouse gas emissions). In this way, GAZONOR can extract significant quantities of methane that has been emitted from the former coal mines for several decades.

However, the aquifer level of the coal basin is tending to re-equilibrate, and the water that is rising into the mining voids is increasing the gas pressure in the former galleries and mine shafts. For this reason, the government has entrusted BRGM, through its post-mining department, with responsibility for monitoring former mining sites, particularly for the control of gas hazards. The wells, which have been filled, are equipped at the well heads with tappings for controlling leaks. Decompression borings are drilled at strategic points of the reservoir, such as valves, to decompress the reservoir.

Two entities with different aims share an interest in the Nord Pas de Calais coal basin. Nevertheless, neither can live without the other or ignore its activities. The experience in the north of France shows that the two roles are complementary and that mutual understanding is the guarantee of leak tightness of the reservoir. It ensures, in the long term, the optimisation of production and the protection of individuals.

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