

# Optimum width of longwall faces in highly gassy coal mines – Part II

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**ABSTRACT:** In Part I of this paper, it was established that the width of longwall faces in highly gassy mines is primarily limited by the volume of air reaching the tail-end of the face. The ventilation air reaching the tail-end of the face should be not only enough to keep methane concentrations below the statutory limits (generally 1 percent) but also enough to prevent any gas layering. The air volume leaking from the longwall face into the gob should also be able to push the explosive methane-air mixture away from the gob area immediately behind the longwall face where active roof-fall is taking place (typically 30-45 m). The second group of variables that also controls the width of the longwall panel consists of (a) the rate of advance, (b) bleeder air quantities, (c) specific methane emissions for the gob area and, (d) efficiency and cost of gob gas capture. This paper will discuss the second group of variables and its impact on the optimum width of longwall faces in highly gassy coal mines.

## 1 Introduction

With the large turnover in the mining workforce, the industry has lost many valuable and experienced employees. The influx of inexperienced workers has created a need for increased emphasis on the efficient and safe mining of coal. Large coal companies, such as CONSOL Energy, the largest producer of underground mined coal, has started a campaign to attain an “Absolute ZERO” reportable accident status in all its mines. Such highly desirable goals cannot be achieved by merely complying with federal and state regulations or their enforcement. It calls for a fundamental change in our approach to mine safety. As a first step in this direction, the following needs to be done:

- (1) Education and training of mine workers to change their behavioral paradigm leading to the adoption of safety as a value.
- (2) Improved engineering design of mines which includes inter alia, methods of mining, mine machinery, methane and respirable dust control, ground control, haulage and electrical equipment.
- (3) Monitoring of air environment, communications, and emergency preparedness and response.

Coal seam degasification and longwall mining are the two most significant engineering innovations in the past thirty years that have led to higher productivity and improved safety in underground mines. Coal seam degasification removes methane from coal seams prior to mining as well as during mining and makes the mines much safer and more productive. Processing and marketing of captured gases can bring in extra revenue that can defray the cost of coal seam degasification. CONSOL Energy pioneered the coal seam degasification techniques, e.g. in-mine horizontal drilling, vertical gob wells, massive hydraulic fracturing of coal seams. CNX Gas, a subsidiary of CONSOL Energy is now developing a technique to drill horizontal boreholes from surface and enhancing coalbed methane production by carbon dioxide infusion. CNX Gas

is the largest producer of methane from coal mines in USA.

Longwall mining is the safest and the most efficient method of mining underground coal. Today a little over fifty percent of underground mined coal in USA is produced by longwall faces. CONSOL Energy is the largest producer of underground mined coal and operates twelve longwall panels in Pennsylvania, West Virginia and Virginia.

In Part I of this paper a case was made for the optimization of the width of longwall panels in highly gassy mines. Merits and demerits of a very wide panel (width  $\geq 300$  m) were discussed. Gassiness of coal seam, optimum ventilation layouts and adequate air quantities were also discussed. The optimum width of longwall panels is determined by two groups of variables: (a) longwall face dependent variables, e.g. total methane emissions, ventilation quantities and air leak off, etc. (b) longwall gob dependent variables e.g. rate of face advances, bleeder air quantities, specific methane emission of the gob and, cost and efficiency of gob gas capture.

This paper will discuss the impact of the second group of variables on the optimum width of longwall panels.

## 2 Origin of Gases in Longwall Gobs

Longwall mining causes overlying strata (containing other coalbeds) to subside and underlying strata to heave. The mine atmosphere acts as a pressure sink drawing all gases to the mine workings. Thus, in post mining phase the gas emission reservoir is considerably expanded.

Figure 1 shows the vertical limits of the gas emission space created by longwall mining and the percentages of gas contents released by various coal seams into the gas emission space as a function of their distance from the mined coal seam. The vertical dimension of the gas emission space is highly dependent on the width of the longwall face. In general, the wider the longwall face, the

greater is the vertical extent of the gas emission space and, consequently, the higher is the specific gob emissions (volume of gas emitted per unit area of the gob).

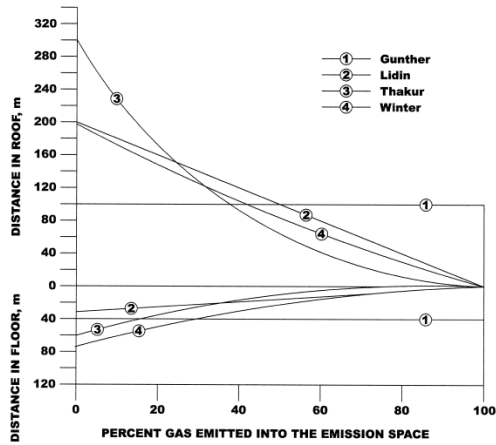


Figure 1. Vertical limits of the gas emission space.

For optimum methane capture, the specific gob emission for the longwall panel must be calculated from Figure 1 and, subsequently verified by directly measuring post mining gob emissions.

A highly gassy coal seam is usually underlain and overlain by equally gassy, but generally non-mineable coal seams. Longwall mining fractures them all, and their gas contents are released into the mine. Specific gob emissions can be as high as 2 Mm<sup>3</sup>/hectare of the gob area, but it depends on the following variables:

- Total thickness, gas contents, and proximity of other coal seams to the mined coal seam in the gas emission space,
- Width of the longwall panel,
- Presence of geological disturbances, e.g. lineaments, faults, etc.,
- Thickness and properties of non-coal strata above and below the mined coal seam.

### 3 Gob Gas Control Technology

Besides the specific methane emission of the longwall gob discussed above, the other parameter that has the greatest influence on the total gob emission per day is the rate of longwall face advance/day. Gob emission rates are linearly proportional to the rate of face advance. Total gob emission is the product of specific gob emission in Mm<sup>3</sup>/hectare and face advance per day multiplied by the face width. In highly gassy U.S. coal mines, longwall faces can be 200-300 m wide and can advance 15 to 20 m/day. The specific gob emissions can range from 1-2 Mm<sup>3</sup>/hectare. Hence, the gob emissions can range from 0.4 to 0.9 Mm<sup>3</sup>/day. This methane emission rate is so high that it cannot be handled by the bleeder ventilation alone. Bulk of this emission (70-80%) must be removed from the mine

atmosphere. At present, the only methane drainage technique that can cope with this emission rate is the use of vertical gob wells (Cervik 1981, Thakur 1981).

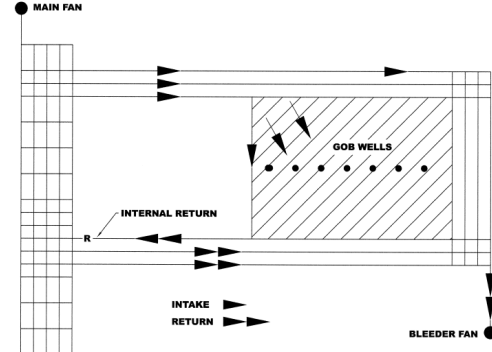


Figure 2. A typical ventilation layout for a longwall face with vertical gob wells.

Figure 2 shows a typical longwall ventilation layout with vertical gob wells. The diameter of these gob wells vary from 100 to 381 mm. Completion techniques for these gob wells are described elsewhere (Davis 1973, Mazza 1977).

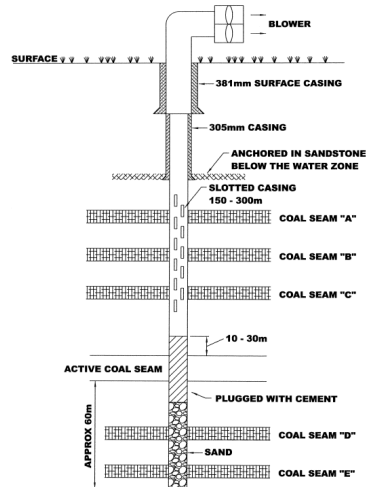


Figure 3. Vertical cross-section of a typical gob well.

Figure 3 shows a typical vertical section of a modified gob well. It is designed to capture gases from both overlying and underlying strata to minimize floor emissions on the longwall face (Thakur, 2005). The first gob well is usually installed within 30-40 m from the set up entry. When the longwall face retreats 30-40 m, the first main roof fall takes place releasing a large volume of methane. Sometimes, it is necessary to have two gob wells in parallel near the set up entry to cope with the onrush of strata gases. Location of other gob wells on the panel must

be done in an optimal manner to capture the maximum percentage of total gob gas emissions at the minimum cost.

The completion technique for a gob well as shown in Figure 3 assumes that there are non-mineable coal seams in the overlying and underlying strata. In a typical completion of 305 mm gob well, a surface casing of 381 mm is set to a depth of 30-50 m. A 343 mm borehole is drilled to a depth about 10-30 m above the working coal seam making sure it intersects all coal seams in the overlying strata. A 305 mm casing is set in this borehole, anchoring it in a good sandstone well below the water-bearing horizons. The part of casing below this anchor is not cemented but slotted with vertical slots to let the gases flow in.

If there are coal seams in the floor of the working coal seams, a 254 mm borehole is drilled to a point about 60 m below the working coal seam, making sure that it intersects all the underlying coal seams. The bottom of this “rat hole” is filled with sand and a 15 m cement plug is put across the mineable coal seam as shown in Figure 3.

When longwall face mines by the gob well, the floor heaves breaking down the cement plug. Floor gases have an easy access to the gob area well behind the longwall face and the vertical gob well captures this gas as it does the gases from overlying coal seams.

#### 4 Optimal Design of Gob Gas Drainage

Optimum gob gas drainage depends on the following:

- The size of the gob well and its production capacity
- Distance of the gob well from the tail gate
- Spacing of the gob well on the longwall which is a function of the width of the longwall panel and the rate of mining
- Cost of installing a gob well.

##### 4.1 The Size of Gob Well and Production Capacity

Coal industry in USA uses gob wells with diameters ranging from 100 mm to 381 mm. Moderately gassy mines use 100-178 mm diameter casings but highly gassy mines use bigger casings. The most popular size is 305 mm in diameter. J55 or K55 casings are more than adequate for the job. The cost of drilling larger diameter gob wells increases exponentially.

All gob wells are assisted in gas production by a well-designed blower. Lampson blowers (Series 600, 800 & 1200) are commonly used blowers and have a good track record. Operating at a pressure of approximately 24 Kpa, the gas production volumes are as follows:

Casing Diameter	Gas Production
229 mm	0.07 to 0.09 Mm <sup>3</sup> /day
305 mm	0.13 to 0.14 Mm <sup>3</sup> /day
381 mm	0.21 to 0.23 Mm <sup>3</sup> /day

Assuming an average of 70% methane in the gob gas, a 305 mm diameter gob well can remove 0.09 to 0.10 Mm<sup>3</sup>/day of methane from the gas emission space.

##### 4.2 Distance of Gob Wells From The Tail Gate

For best efficiency, all gob wells must be located between the centerline of the longwall panel and the tail gate. On an average, best results are obtained when the gob wells are located about 30 m from the centerline towards the tail gate as shown in Figure 4.

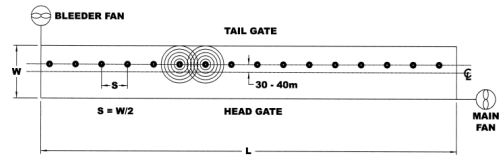


Figure 4. Optimum layout of gob wells on a longwall face.

Gob wells located on the headgate side of the longwall gob produce significantly lower amount of gas and thus, are very inefficient.

##### 4.3 Gob Well Spacing on the Longwall Face

Figure 1 showed the vertical dimension of the gas emission space. The width of the gas emission space is limited to the width of the longwall face. In deep, gassy mines, chain pillars get crushed, and there is little movement of gases from one longwall face to the next. The length of the gas emission space is limited by the subsidence of the overburden strata. Figure 5 shows that the gob is fully subsided (up to the thickness of the coal seam) when the face retreats from the set up entry by 1.3 x depth of the coal seam (Holland, 1973).

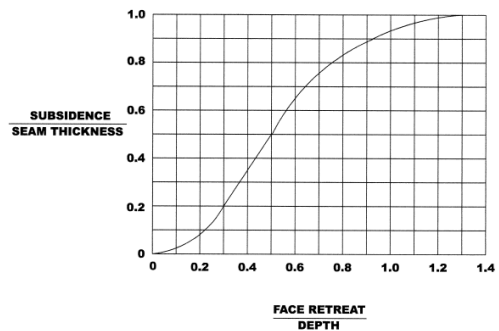


Figure 5. Subsidence over the gob as a function of length of gob/depth.

Thus, in a mine with the depth of 600 m, the length of the gas emission space is approximately 780 m. The flow of gob gases into a gob well is assumed to be isotropic and radial. Almost all gob gas is produced in this dynamic gas emission space. Even though, about 20% of the gob gas is removed by bleeder ventilation, it is not taken into account here to provide a little reserve capacity for the gob wells to handle peak emissions. Assuming the gob well production capacity to be 0.13 Mm<sup>3</sup>/d, the number of producing gob wells in the gas emission space can be calculated by simply

dividing the total emissions by 0.13 Mm<sup>3</sup>/d. The total number of gob wells for the panel can be calculated by prorating this number by the ratio, the length of panel/the length of gas emission space. Table 1 shows the specific gob emissions as observed for different widths of longwall panels.

Table 1. Specific emissions for longwalls.

Width of Longwall Face (m)	Specific Gas Emission (Mm <sup>3</sup> /hectare)
135	1.77
180	2.12
225	2.34
270	2.55
315	2.83

The optimum width of a longwall panel is the width where gob wells are most efficient in draining the gob gases and the total number of gob wells for the panel is the minimum. The most efficient gob drainage is reached when the spacing between the two adjacent gob wells (s) is equal to half the width (w) of the longwall panel. To illustrate this point, spacing of gob wells for longwalls with different widths but the same tonnage of extraction is calculated. The following assumptions are made for this calculation:

1. The rate of extraction is the same for all longwall panels, 0.4 hectare/day.
2. The longwall face is 3000 m long and needs two gob wells near the set up entry.
3. A gob gas capture ratio of 70-80% will be achieved.

Table 2 shows pertinent data for various widths of longwall panels.

Table 2. Number of gob wells versus longwall width.

Width of Face (m)	Number of Gob Wells	Spacing/Width (s/w)
135	24 + 2	0.93
180	26 + 2	0.64
225	28 + 2 *	0.48
270	32 + 2 *	0.35
315	36 + 2 *	0.26

\* Total number of gob wells could be slightly higher because of declining capture efficiency.

Figure 6 shows a plot of s/w against longwall face widths. The most efficient capture of gob gas is obtained when s/w = 0.5 or the longwall width is 210 m. Since the gob wells are offset from the center line by 30 m, the optimum width where gob gas drainage is most efficient is in the range 210 to 240 m.

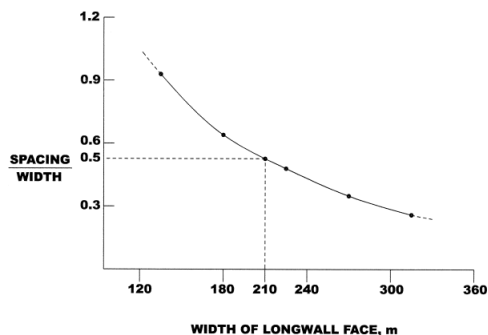


Figure 6. Optimal spacing of gob wells on a longwall face.

It is advisable to recheck this calculated optimum width of a longwall face by the criteria laid out in Part I (Thakur, 2006) of this paper. The minimum quantity of air at the tail gate to prevent gas layering was calculated to be 1400 m<sup>3</sup>/min. for a face emission of 15m<sup>3</sup>/min. A desirable quantity of air at the tail gate would be 30-50% higher than this to handle peak methane emissions. Assuming 60% leak-off on the face, the intake air at the longwall face should be 4500-5200 m<sup>3</sup>/min. This is well within the capability of modern mine fans using a four-entry development to carry the intake air to a longwall face.

## 5 Summary and Conclusion

- A. Optimum width of longwall panels in highly gassy coal mines should be calculated using both the longwall face dependent and longwall gob dependent variables.
- B. Vertical gob wells, with a diameter of 305 m, are optimal for very gassy coal seams. Bigger gob wells are very expensive.
- C. Gob wells begin to lose their gas capture efficiency when the spacing (s) between the gob wells is less than half-width (w/2) of the longwall face. Number of gob wells per panel increases and costs/t increases proportionately. The optimum is reached when gob well spacing equals half-width of the longwall face.
- D. When longwall face methane emissions exceed 15 m<sup>3</sup>/min and specific gob emissions are higher than 2.1 Mm<sup>3</sup>/hectare, the longwall face width should be limited to 210 to 240 m to sustain a mining rate of 0.4 hectare/day with most efficient capture of gob gas and safe dilution of methane emitted on the longwall face.

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