METHANE DRAINAGE IN RETREATING LONGWALL WITH SINGLE GATEROADS

By
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ABSTRACT

The need to solve the problems associated with spontaneous combustion, system of ventilation and methane drainage in gassy coal mines has brought about the development of mining and degassing methods which has made possible up to 80% gas recovery in retreating longwalls. Beneficial results also were obtained mostly in the double or multiple-entry systems, but for single-entry systems and for a seam thickness exceeding 3 m, gas recovery rate is still very low. With some single-heading systems, such as those where a return roadway is not maintained in the goaf behind the face line, a new methane drainage technology is practiced. Attempts were made to extract methane from roof holes drilled from offsets in the ribside of the longwall block. The inclinations and lengths of the boreholes were planned and designed on the basis of the geological and mining conditions encountered at the time and every second hole was terminated precisely at the point where the previous hole intersected the immediate roof goaf area above the face.

There are mathematical relations appropriate to the design of the above drainage systems to give optimum methane recovery under the given conditions. Some examples of drainage have reached 87% recovery and have attained 94% CH_4 purity.

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INTRODUCTION

Methane drainage has been widely applied in Polish gassy coal mines primarily to reduce the general and local methane hazard. One of the main factors which influences the methane balance in the working areas is the possibility of capturing methane from its various sources of emission. It depends on the mining systems, the driving sequence, the protection and maintenance of mine workings, the drainage of boreholes as well as on the ventilation methods.

Longwall systems with caving are most often used in Polish coal mines. At first, the advancing longwall system was applied where very high gassiness was predicted, to achieve high methane recovery. Beneficial results were also obtained in retreating longwalls, mostly with double entry systems. For single heading system and for a seam thickness exceeding 3 m, methane recovery rate is still very low.

Results of investigations carried out at several collieries show that the same methane drainage methods gave different results when they were applied to different mining systems. Test results have confirmed that in the case of coal extracting work the best degasification results are achieved for the following mining systems:

- advancing along the strike longwall system with roof caving, with the ventilation drift in the goaf area, and
- retreating along the strike longwall system with roof caving and double ventilation drift.

On the other hand, the following mining systems are less favourable to degasification:

- retreating along the strike longwall system with roof caving and one ventilation drift, and
- across the strike longwall systems with caving or hydraulic stowage.

With some single heading systems, such as those where a return roadway is not maintained in the goaf behind the face and for a seam thickness exceeding 3 m, a new methane drainage technology is practised. The attempts which were made to extract methane from roof holes drilled from offsets in the ribside of the longwall block have given satisfactory results, and can be used for lowering gas content of expected gassy extractions.

METHANE DRAINAGE RESULTS ACHIEVED IN RETREATING LONGWALL SYSTEMS

The progress of technology of mining coal seams with higher rates of extraction and increasing depths as well as the problems associated with spontaneous combustion was the reason for using rapidly retreating longwalls with caving in Polish coal mines. In 1980 there were 27 longwalls with degasification systems, 25 retreating and only 1 advancing. Depending on the mining and geological conditions as well as on drilling and drainage possibilities, different results were obtained in these longwalls. Presently, the following methane drainage methods are used in Polish coal mines for degassing retreating longwall faces:

1. Methane drainage of retreating longwalls retreating along the strike with roof caving and single entry systems (Fig. 1) (single entry system has no return roadway maintained in the goaf behind the face line.

Drainage holes are drilled to the roof and to the floor from the entries ahead of the retreating longwall face. The angle of deviation varies from 30^{o} to 45^{o} from the entry direction towards the goaf in order to reach the already destressing zone in the roof and floor. The angles of inclination and the length of standpipe chosen depend on seam thickness, geological, mining and technical conditions, and they vary from 50^{o} to 75^{o}. The length of the standpipes varies from 6 to 20 m. Average length of boreholes is 30 to 80 m. Recovery rate of methane in this system is 30 to 55% for the thickness of seams to 2 m, and 18 to 40% for thickness of seams over 2 m. Results obtained at Jastrzębie Colliery are given in Table 1. Coal production of the longwall commenced in October 1972 and finished in May 1973.

2. Methane drainage of retreating longwalls retreating along the strike with roof caving and double entry systems (Fig. 2) (double entry system has a return roadway with drainage boreholes maintained in the goaf behind the face line).

Drainage boreholes are drilled to the roof and to the floor from the second ventilation drift over (and under) the protecting pillar and they are maintained along the full lengths of goaf behind the line of the longwall face. These holes are drilled at angles of deviation of 45^{o} to 90^{o} from the heading direction towards the goaf. The angles of inclination and spacing of the holes are chosen depending upon gassiness, mining and technical conditions and location of the source of methane, thickness of working seam and pillar width. The range of angles is 10^{o} to 45^{o}, the length of standpipes 6 to 9 m, average length of boreholes 50 to 150 m. Recovery rate in this system is 45 to 75% (maximum 87%). Results obtained at Manifest Lipcowy Colliery are given in Table No. 2.

3. Methane drainage of retreating longwalls by help of boreholes drilled from outside the plane of the seam (in the roof or in the floor) (Fig. 3). Drainage boreholes are drilled from roadways

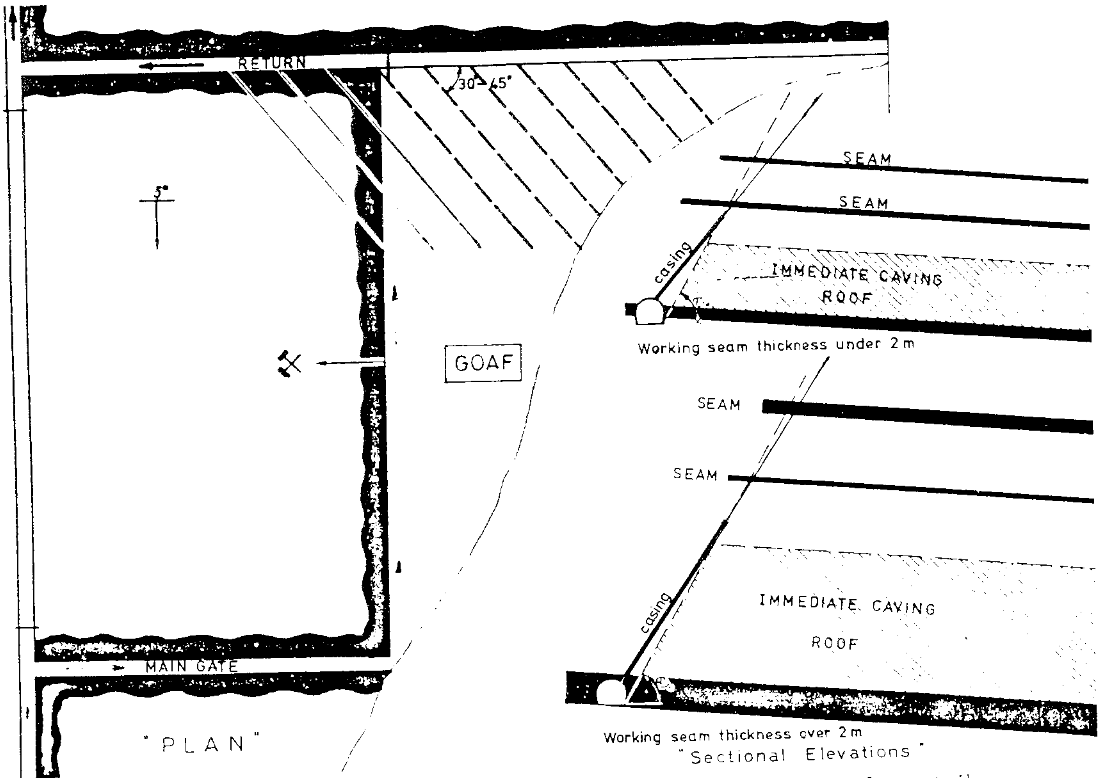

Fig. 1. Single entry retreating longwall with caving - retreating along strike

Table 1

Methane emission, amount of methane captured by drainage and methane drainage parameters in a longwall mined by retreating along-the-strike and single entry system

Year month	Methane emission			No. of productive drainage boreholes	Applied suction	Recovery rate of methane by degasification
	out of this removed by		Total methane make			
	degasification holes	ventilating current				
	m³/min			Number	mm Hg	%
Nov 72	2.9	3.0	5.9	5	27	49
Dec 72	2.6	2.8	5.4	5	36	48
Jan 73	1.2	4.6	5.8	5	32	20
Feb 73	1.1	4.3	5.4	4	24	20
Mar 73	0.9	4.3	5.4	4	16	17
Apr 73	1.1	3.0	4.1	5	8	26
May 73	0.9	3.0	3.9	6	25	23
Jun 73	0.8	1.8	2.6	6	26	30

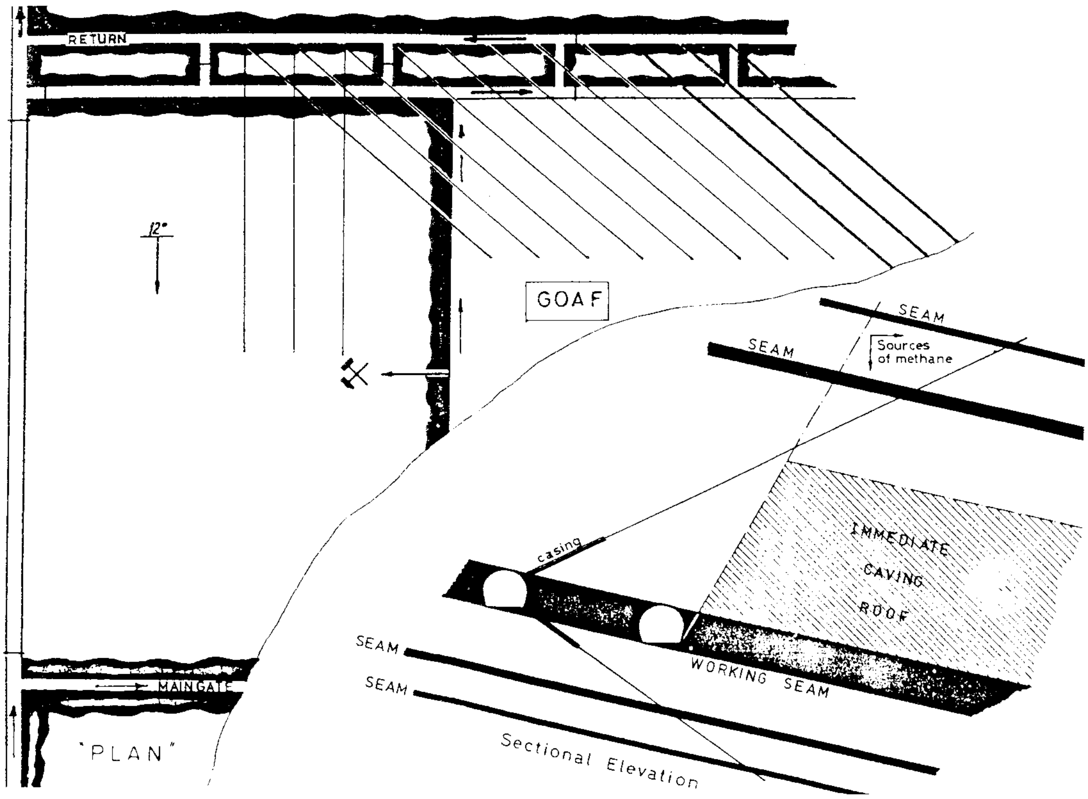

Fig.2. Double entry retreating longwall with caving - retreating along strike

in adjacent levels directly to the source of methane. This method is very reliable because boreholes are not isolated from sources by displacement and local fracture. The application of this method requires drilling of very long boreholes (150 to 500 m) and availability of suitable roadways at other levels. Sometimes this method is used simultaneously with conventional methane drainage methods.

It is evident from these systems that certain problems arise in maintaining boreholes, particularly upholes in the goaf area behind retreating faces with single entry systems. For these reasons, multiple entry systems are preferred where methane drainage is essential for rapidly retreating working and for seams with high methane content. With some single heading systems employing a goaf roadway and "Z" layout in which a return roadway is maintained in the goaf behind the face line, methane drainage can be practised as in conventional longwall advancing districts. From this it is clear that the direction of mining and system of ventilation influence the method of methane drainage. The effectiveness is much less in the case of retreating mining with the single entry system and with collapse of gateroads in the goaf behind the face line and with consequent loss of control of methane drainage parameters from this zone. Though holes are drilled from the entries before retreating longwalling is commenced, practical difficulties are encountered because of low initial methane yield from the boreholes, isolation of boreholes from sources by displacement and borehole local fracture. (Swift, 1970)

Table 2

Methane emission, amount of methane captured by drainage and methane drainage parameters in a longwall mined by retreating along-the-strike end double entry system

Year Month	Methane emission: out of this removed by: degasification holes	Methane emission: out of this removed by: ventilating current	Methane emission: Total methane make	No. of productive drainage boreholes	Applied Suction	Recovery rate of methane by degasification
	m^3/min			Number	mm Hg	%
Jul 72	1.00	3.51	4.51	2	150	22
Aug 72	1.04	3.92	4.96	2	150	20
Sep 72	5.55	5.20	10.75	7	140	51
Oct 72	8.81	4.30	12.21	10	140	72
Nov 72	9.73	3.64	13.37	16	140	72
Dec 72	12.69	5.70	18.39	32	120	69
Jan 73	11.76	7.10	18.86	45	95	62
Feb 73	16.26	7.29	23.54	55	80	69
Mar 73	14.76	9.24	24.00	68	75	61
Apr 73	15.86	11.00	26.86	76	105	59
May 73	18.80	12.00	30.80	83	105	61
Jun 73	21.40	11.80	33.20	95	75	64
Jul 73	26.00	11.40	37.40	115	55	69
Aug 73	26.00	8.70	34.70	128	50	74
Sep 73	24.60	5.90	30.50	138	50	80
Oct 73	23.40	6.60	30.00	145	45	78
Nov 73	21.80	5.00	26.80	151	70	81
Dec 73	18.80	2.80	21.60	160	95	87

METHANE DRAINAGE OF RETREATING LONGWALLS BY ROOF HOLES DRILLED FROM OFFSETS

In the mining of highly gassy seams many European countries including Poland mostly use single entry layouts of longwall with caving and retreating along the strike with concurrent methane drainage. Considering methods of mining and degasification technology, investigations show that for the retreating single heading system, conventional methane drainage methods are effective only when total methane make of the panel is less than 15 m^3/min (Fig. 4). For seams greater than 3 m thick there are serious troubles in maintaining headings and drainage boreholes in the goaf behind the face line. If the total methane make in a longwall panel area is over 15 m^3/min, different mining systems should be used. However taking into consideration very specific conditions such as spontaneous combustion, bumps, roof conditions, outbursts, strata pressure etc., there are cases where the retreating single heading system must be used in spite of very high gassiness of the area.

A longwall face was designed in Brzeszcze

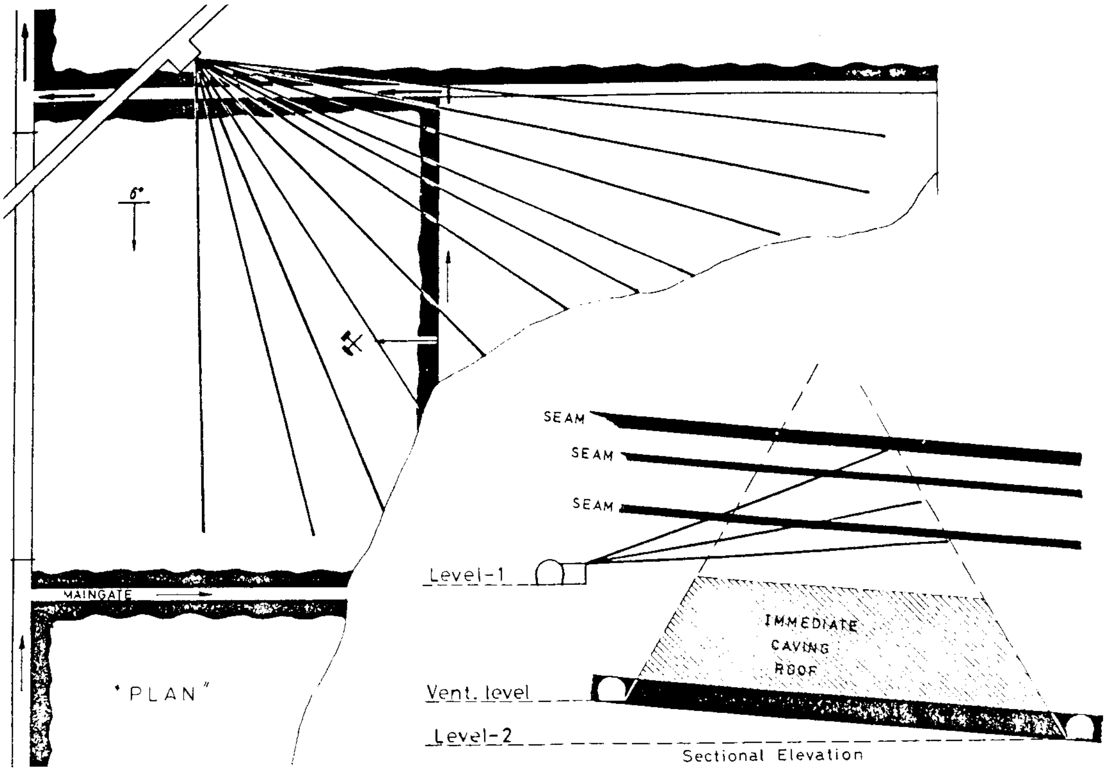

Fig.3. Retreating longwalls drained through boreholes from roadways in adjoining strata (Schmidt, 1981)

Colliery where the drainage was increased by using a specially adapted drainage system based upon drilling into the roof from offsets in headings. Brzeszcze Colliery lies in the southern part of the Upper Silesian Coal Basin and mines Seam No. 405 of thickness 4 m and dip 10^{o} at depth of 640 m. The specific gas content of the seam was 13 m^3/tonne ash free dry. Because of the spontaneous heating problem, longwall retreating was adopted with a maximum quantity of air of 20 m^3/s. Because of special geological conditions the gateroads had to be caved immediately behind the retreating face. The calculated total gas make for 2,000 tonne/day was 28 m^3/min of CH_4. The planned ventilation capacity could dilute only 15 to 18 m^3/min of liberated gas, while drainage techniques would be required to extract 10 to 13 m^3/min. In the initial stages the conventional method was used for drainage of gas where holes were drilled from the ribside. The holes varied from 60 to 70 m length with direction 45^{o} to the gateroad towards the goaf and inclined at 65 to 75^{o} with the horizontal. However after the first main break the total methane make increased from 14 to 21 m^3/min and the conventional drainage method could cope with only 4 m^3/min of CH_4 - an effectiveness of 19%. Consequently special methane drainage technology was used based upon drilling of holes from offsets in the ventilation roadways. These holes were of fan shape and were designed based upon local mining conditions. From every offset four holes of 65 mm dia. and 100-150 m length were drilled.

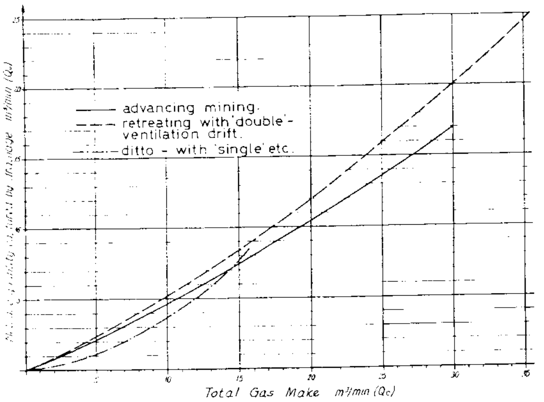

Fig. 4. The effectiveness of methane drainage for various systems of mining (Lunarzewski, 1976)

1. Angle of deviation of the fourth hole (σ_4) was so selected that the hole covered one-third the length of the face, while the first hole was drilled such that the casing lengths are more than zone fractures around the gateroads (Fig. 5). The deviation angles for the first and fourth holes are according to the formulae:

For hole 1

$$\text{Sin } \sigma_1 = \frac{(6-W)}{C} \qquad \text{(i)}$$

For hole 2

$$\text{tg } \sigma_4 = \frac{(1/3L-W)}{2Z} \qquad \text{(ii)}$$

where

σ	=	angle of deviation
L	=	length of the face
Z	=	distance between offsets
W	=	distance of the hole collar from the ribside
C	=	length of the standpipe

The deviation angles for holes 2 and 3 were at intermediate positions.

2. Angles of inclination of holes were selected depending on the distance of the seams in the roof, distance between offsets and height of immediate caving roof. These angles were so selected that successive groups of holes provided continuous cover of drainage sources (Fig. 6).

The angles of inclination are according to the formulae:

$$\text{Sin } \alpha_1 = \frac{6S}{l_{cr}} \text{ for S >2 m} \qquad \text{(iii)}$$

$$\text{Sin } \alpha_1 = \frac{5S}{l_{cr}} \text{ for S} \leq 2 \text{ m} \qquad \text{(iv)}$$

where

α	=	angle of inclination
S	=	mining height
l_{cr}	=	"dead" part of drainage hole

The value of l_{cr}, is calculated graphically as shown in Fig. 6 and is based upon experience gained in mining. For the Brzeszcze Colliery the value of the angles are:

$\sigma_1 = 17^o$ $\sigma_2 = 20^o$ $\sigma_3 = 23^o$ $\sigma_4 = 28^o$

$\alpha_1 = 8^o$ $\alpha_2 = 15^o$ $\alpha_3 = 22^o$ $\alpha_4 = 32^o$

z = 50 m and size of offsets 4 x 3.5 m. Holes were drilled with a pneumatic drill rig of Polish production type WDP-2A, capable of drilling up to 250 m, with maximum thrust of 5,000 kg. It is powered by two motors of 18 and 10 H.P. Offsets were supported by woodenprops which could be removed easily as the face advanced. Standpipes were in two parts, consisting of the steel pipe projecting and rubber or antistatic plastic grouted in.

Use of the above method of drainage resulted in an increase in the effectiveness of methane drainage up to 50% and decrease in the concentration of methane in the return air below the 2% limit required by regulations. Table 3 gives the results when holes from only

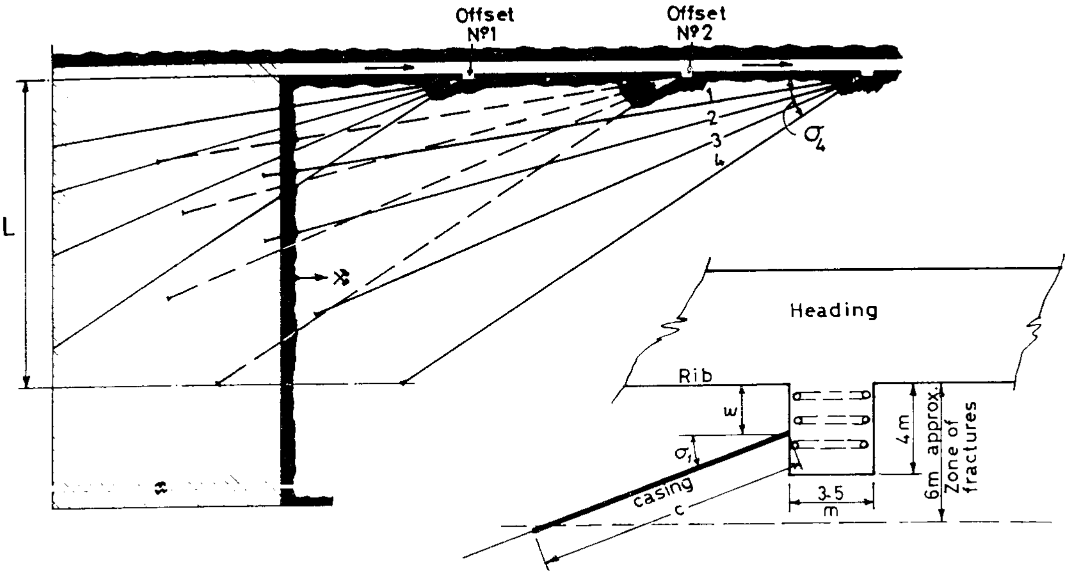

Fig. 5. Plan of drainage holes from offsets in tailgate - Brzeszcze Colliery

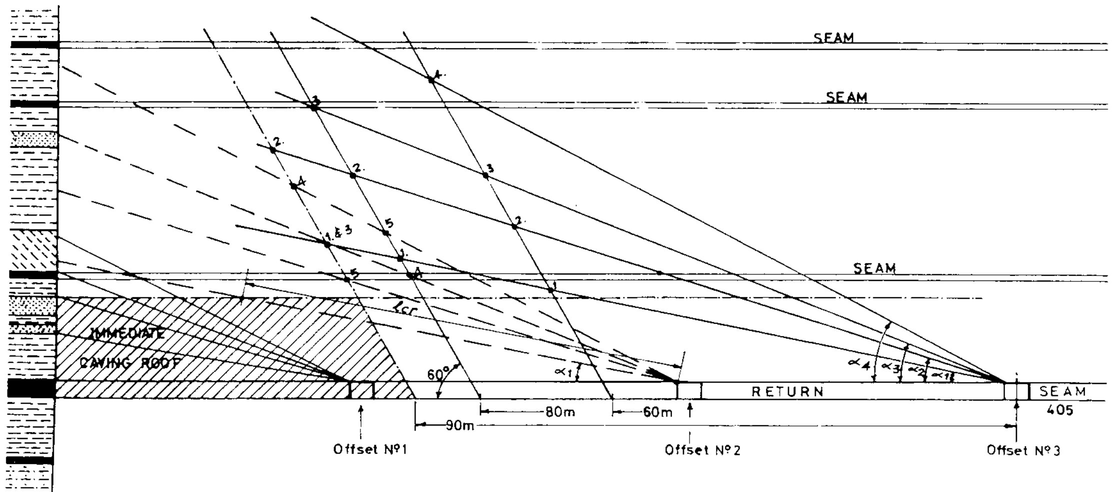

Fig. 6. Elevation of drainage holes from offsets in tailgate - Brzeszcze Colliery

one offset at 100 m from the face were in operation. Optimum values both for methane drainage and ventilation were obtained when the offset was 70 to 35 m from the face. This gave parameters for the future location of the offsets. Table 4 gives the results when holes both from three offsets and the conventional drainage were in operation from the gateroads.

It is found that if the longwall face is at the distance of 90 m from offset No. 3 then three holes are operational from offset No. 2 and two from offset No. 3. At the distance of 80 m from offset No. 3 two holes are operational from offset No. 2 and two from offset No. 3. At 60 m distance four holes are operational from offset No. 3.

TABLE NO. 3

Methane drainage and ventilation results when only one offset was in operation

Test No.	—	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Methane captured by degasification		-	-	-	1.0	1.2	3.1	3.5	5.2	5.5	5.8	6.5	6.9	5.7	3.8	4.4	3.7	1.8
Gas percentage in the return (% CH_4)		1.9	1.9	1.7	1.6	1.5	1.5	1.4	1.4	1.4	1.2	1.1	1.0	1.1	1.3	1.2	1.5	1.6*
No. of productive drainage boreholes		-	-	1	2	3	3	3	3 to 4	4	4	4	4	3	3	3 to 2	2	1
Gas percentage in drainage boreholes % CH_4	1	-	-	50	50	40	15	20	20	20	25	24	20	10	-	-	-	-
	11	-	-	-	-	-	40	40	42	50	65	67	50	40	15	10	-	-
	111	-	-	-	-	50	52	55	56	65	80	85	55	50	40	30	20	15
	V	-	-	-	-	-	40	42	50	60	71	81	93	94	94	94	92	85
Distance between offset and longwall face (m^3)		95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15

*Limit required by regulations = 1.5% face and 2% main return

TABLE NO. 4

Methane drainage results when three offsets were in operation

Test No.	—	1	2	3	4	5	6	7	8
Drainage boreholes from offsets	Gas flow m^3/min	6.5	6.0	6.0	5.2	5.8	6.8	7.4	7.2
	No. of productive b'holes	5	4	4	4-3	4	5	5	5
Drainage boreholes from heading	Gas flow m^3/min	2.0	2.8	2.6	2.1	2.2	1.6	2.2	2.6
	No. of productive b'holes	3	4	4	3	3	2	3	4
Total gas flow by degasification m^3/min		8.5	8.8	8.6	7.3	8.0	8.4	9.6	9.8
Gas flow in ventilating current m^3/min		10.8	10.0	10.5	12.2	11.8	11.5	9.4	9.0
Methane drainage recovery %		44	47	45	37	40	42	51	52

These results confirm that drainage holes from offsets - drilled at appropriate angles and directions during all phases of the advance of the longwall face had this same number of holes operational continuously as drilled from a single offset. Therefore it is important that both the distance between offsets and the length of the holes be so selected depending upon the predicted total methane make and the location of its sources.

CONCLUSIONS

The new type of methane drainage technology appeared completely successful on faces retreating with a single ventilation heading and with seam thicknesses exceeding 3 m. A combination of conventional boreholes and roof holes drilled from offsets in the ribside of the longwall block is in many cases the only way to degassing retreating longwall panels with single heading system with such high gas emissions.

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DISCUSSION

R. KING (Bureau of Mines, U.S.A.):
Dr. Lunarzewski has consulted with the Bureau of Mines in the United States utilising this method. It has now been tried on four different panels in the U.S.A. and three have now been mined. There has been upwards of 55-60% recovery of the methane from the goaf area using this technique. Another example would be as was stated in the main bleeders - main returns - where gas content can go as high as 2% CH_4. One of the examples had around 0.8% in the returns and when the suction system utilising Dr. Lunarzewski's gob drainage holes was used the gas in the returns went down to 0.1%. This system has been found to be very successful and Dr. Lunarzewski had been working with the U.S.B.M. until he came here on this project.

K. NOACK (Westfalische Bergbauforschung):
Referring to Figure 1 which was the simple single entry retreating longwall system, what is done with the part of the tailgate behind the face. If it is maintained, how is it ventilated, or if it is caved, what happens with the boreholes?

L. LUNARZEWSKI (Visiting Polish Methane Drainage Specialist to BHP Steel Division Collieries): In Poland in the longwall system with single headings usually the tailgate is not maintained behind the face, because it is a caving area. If the thickness of the seam is not very high, for example up to 2.5 m, sometimes the props are left behind the face. From the resultant spaces left in the goaf area the capture of methane is attempted for as long as possible, but unfortunately additional gas mains have had to be used for this purpose. It is only a 100 mm gas main, and on the floor and sometimes protected by rock lumps or other available material. The capturing of gas from behind the face line is possible only whilst the concentration of methane is 30% or more. But if leakage is high so that the concentration of methane is below 30% (in special circumstances - 20%) the capturing of gas from behind such dams must be stopped.

C. JEGER MADIOT (CERCHAR, France): Regarding Figure 1, which is the normal length of the casing? On this figure, the casing seems quite long.

L. LUNARZEWSKI: It depends on seam thickness. It depends on local geological conditions and mining conditions. It varies. It would average from 9 to 15 m for longwall retreating.

C. JEGER MADIOT: Are downwards boreholes also used in this case, that is drainage from the lower seams?

L. LUNARZEWSKI: In the floor? Yes, not very often but there are about 10 or 12 cases when methane drainage is used both for the roof and for the floor.

C. JEGER MADIOT: What are the necessary conditions to have success with drainage from the floor?

L. LUNARZEWSKI: For Polish conditions the optimum depth to which it is possible to capture gas from the floor is about 15 m, but it depends on permeability and other factors. If gas content, permeability and in seam pressure are high enough, it is possible to capture methane from floor even from 30 up to 60 m.

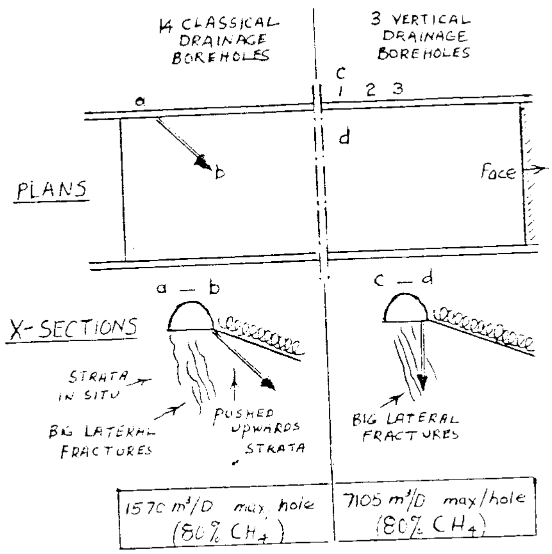

Fig. 1. Drainage from floor

C. JEGER MADIOT: In several trials concerning drainage from the floor in France, there were very different results depending on the direction of the boreholes downwards and on the length of the casing. It is possible to have good results with drainage from the floor firstly when there is a way for easy evacuation of water (flowing in the cracks along the slope and pumped at a convenient place); and secondly if the direction of the boreholes is such that they encounter the lateral fractures of the strata under the goaf. In the past, only small flows of gas were obtained from long boreholes drilled downwards under the goaf. Recently, by using short vertical boreholes, the flow of gas was 5 times more, as shown in Fig. 1. In this configuration, the gas can flow very easily in the big lateral fractures, which constitute collectors and this gas is collected just at the bottom of the casing (Fig. 2). Only a few metres of free borehole under the casing is sufficient to collect the gas. Also in France there were dificulties in trying to use the same upwards boreholes in the roof used in Poland when there are two roadways; when drilling such boreholes from the second roadway beyond the lateral pillar, these boreholes are very often crushed because of strata over-pressures. Is it frequently so in Poland?

L. LUNARZEWSKI: It depends on local and geological conditions. Probably the only problem for capturing gas from the floor is water.

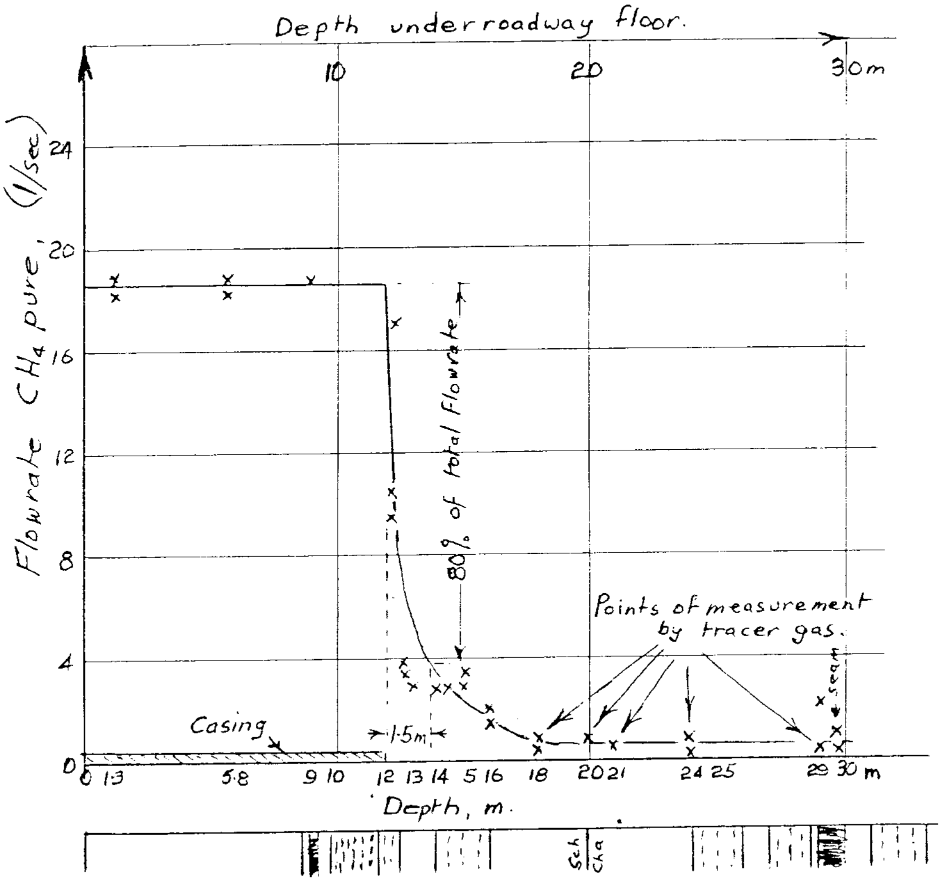

Fig. 2. Level of flow in vertical drainage boreholes downwards in the floor.