

THE LOW CONCENTRATION MINE METHANE SYSTEM

----- APPROACH OF CMM MITIGATION

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ABSTRACT

Although the CMM is recovered certain amount of methane, the mine ventilation system is still the main measure for mine methane dilution. Due to the methane concentration has to be lower than 0.75% in the main ventilation system according to Mine Safety Regulation, and there is some utilization research on the ventilation air methane (VAM) in France, Canada and United States, there is still long way to go for commercialization. It is an important object for the VAM mitigation and utilization. It is tested the 3% methane drainage system in the tailgate of Mine No.3 of Yangquan Coal Group, and got certain experience, with upper limit of 3%. It has laid a base for the low methane drainage system. It is above 30% of the total methane in the tailgate in Mine No.3 of Yangquan Coal Group, especially in seam 12, it is over 40%. The former USSR has tested the 2% methane served as air in the power plant to increase the power generation efficiency 3%. There is studied the power generation genset with the 2% mine methane in Australia. Those has set a base for the utilization of low concentration ventilation methane, meanwhile, it is also bring up a technical measure for further CMM mitigation. Shanxi Asian American Daning Energy Co., Ltd (SAADEC) is a construction mine, it is planned the main gas pipeline of 800mm, with original 370mm pipeline as the mined area low concentration CMM recovery system, to form the high and low concentration CMM recovery systems, and reduce the mine ventilation methane, to achieve the mostly mine methane mitigation.

1. THE PERCENTAGE OF MINE VENTILATION METHANE

Although the methane drainage has played certain role for recovery Coal mine methane since 1950s, the mine ventilation is still playing a very important role of the discharge of mine methane. Take a example of China mine methane is total 6.5 billion m³/y, and from mine ventilation is about 5.5 billion m³/y, while the recovered from methane drainage system of 900 Mm³/y. The methane recovery rate is 16.36%, while the ventilation methane is 83.64%.

In Yangquan Coal Group, though the recovered methane is close to 200

Mm³/y in 2002, the ventilation is still the main measure of methane discharge, as shown in table 1, the ventilation methane is 66.14% of the total methane.

Table 1 The VAM Methane percentage of Yangquan Coal Group in last 5 years

Year	Methane total (Mm ³ /y)	Methane recovered (Mm ³ /y)	VAM (Mm ³ /y)	VAM percentage (%)
1998	342.5025	91.6436	250.8689	73.25
1999	383.7458	119.9787	263.7671	68.73
2000	397.8256	117.3613	280.4643	70.50
2001	430.7082	155.1361	275.5721	63.98
2002	462.3503	198.8151	263.5352	56.99
Average	403.4265	136.58696	266.83954	66.14

For different shaft, the VAM varies a lot. It is analyzed in table 2, the panel methane recovered in Mine No. 5 of YCG reaches 93.49% in average, and the mine methane recovered rate is 65.63% (shown in table 3). While the shafts methane recovery rate of No.2 shaft (seam 3#) and Yugong (seam 12#) of Mine No.3 of YCG is 24.67% and 22.19%, with average of 22.96%.

Table 2 The typical panel methane recovery rate in Mine NO.5 of YCG

Panel No.	Air return methane (m ³ /min)	Methane recovered (m ³ /min)	Methane total (m ³ /min)	Methane recovery rate (%)	Specific methane recovered (m ³ /t)	Mining period
8204	1.65	43.91	45.56	96.38	31.68	Jan. 92 – Jan. 93
4205	3.18	40.16	43.34	92.66	33.98	Sep. 94— May 95
8107	2.30	42.29	44.59	94.84	32.88	Nov. 96 — May 97
8110	4.03	33.82	37.85	89.35	29.76	Jan, 97— Apr. 99
Average	2.78	40.05	42.84	93.49	32.07	

Table 3 The mine methane recovery rate of Mine No.5 of YCG

Year	VAM (Mm ³)	Methane recovered (Mm ³)	Mine total methane (Mm ³)	Specific methane recovered (m ³ /ton)	Recovery rate (%)
1992	3.82	23.807	27.627	23.451	86.17
1993	8.668	30.855	39.523	36.541	78.06
1994	28.651	33.378	62.029	20.859	53.81
1995	25.845	37.688	63.533	25.343	59.32
1996	24.098	42.323	66.421	21.991	63.71
1997	35.014	54.102	89.116	27.006	60.71
1998	28.541	33.735	62.276	32.896	54.17
1999	23.576	45.926	69.502	32.832	66.08
2000	25.192	57.868	82.060	42.551	70.52
2001	27.583	81.41	108.993	53.209	74.69
Average	23.099	44.109	67.208	31.668	65.63

Table 4 The methane recovery rate of mine NO.3

Mine name	VAM (M ³ /min)	%	Recovered (M ³ /min)	%	Total (M ³ /min)
Shaft No.2	28.36	75.33	9.29	24.67	37.65
Yugong Shaft	65.86	77.81	18.79	22.19	84.64
Average	47.11	77.04	14.04	22.96	61.15

The Shanxi Asian American Energy Co., Ltd (SAADEC) is still in the construction period, the recovered methane is 35.59 m³/min in average, with recovery rate of 66.9% ; while the VAM is only 17.61 m³/min, with percentage of only 33.1%. In 2005 , while the longwall panel put into operation, the VAM rate will increased certain percentage, and the recovered methane will still over 50%, while VAM rate under 50%.

Mr. Karl Schultz from EPA of US analyzed the international VAM (mine methane) discharged, the methane discharged worldwide is 43.4 billion m³, [*1] (shown in table 5) . Among which , the VAM discharged reaches 16.2 billion m³ , which is 37.33% of the total. Therefore, the mitigation of VAM (mine methane) is significant for the worldwide methane mitigation.

Table 5 Countries Analyzed and 2000 VAM Emission

Country	2000 Methane Emission (Bm ³)	Percent of World total (%)	Total 2000 VAM Emission (Bm ³)	Total 2000 VAM Emission (MMt CO ₂ e)	Percent of Study total (%)
China	19.1	44.0	6.5	92.3	45.6
US	6.1	12.4	2.5	36.0	17.8
South Africa	2.8	6.4	0.4	5.8	2.8
Russia	2.2	5.1	0.6	9.2	4.6
Ukraine	2.0	4.5	2.0	28.3	14.0
Australia	1.4	3.2	0.6	9.1	4.5
Poland	1.0	2.4	0.3	4.1	2.0
Germany	1.0	2.4	0.1	1.3	0.7
India	0.8	1.9	0.3	4.0	2.0
UK	0.4	1.0	0.2	2.4	1.2
Kazakhstan	0.4	0.9	0.3	4.5	2.2
Czech -	0.4	0.8	0.2	3.3	1.6
Mexico	0.2	0.4	0.1	2.1	1.0
Study total	37.8	57.2	14.1	202.5	100.0
Other countries	5.6	12.8	2.1	29.7	
World total	43.4	100	16.2	232.2	

It is thoroughly analyzed, though certain mines recovered comparatively high rate CMM, as national-wide, the VAM is still over 83%. Mine ventilation is still the main measure of mine methane discharge, how to collect and utilize the ventilation methane, is significant to effectively fulfill the VAM mitigation.

2. TEST OF LOW CONCENTRATION METHANE DISCHARGE

2.1 THE EFFECT OF TAILGATE IN THE MINE METHANE DISCHARGE

Beside the air return, the main measure for treat the panel methane is the tailgate in YCG, Which is under 3% CH₄. It has obvious effect of the tailgate, shown in table 6, it discharged 42.8% of panel methane, which is significant for discharge the panel methane.

It is analyzed the mine methane distribution, beside the panel methane, mined area methane is also the important source of the mine. It is shown that with the mine methane distribution analysis, the mined area methane percentage takes 22.96% of the mine total methane. Normally, it is discharged by mine ventilation system, with perfect seal stoppings, the methane concentration can be as high as 20-30%, those are the important mine low concentration source.

Table 6 The panel tailgate methane discharge result

Panel name	Air return quantity (m ³ /min)	%	Tailgate air quantity (m ³ /min)	%	Methane recovered (m ³ /min)	%	Methane total (m ³ /min)
721011	3.71	18.36	6.9	34.14	9.6	47.50	20.21
721006	3.18	14.27	8.49	38.09	10.62	47.64	22.29
721007	4.43	24.01	6.6	35.77	7.42	40.22	18.45
K7206	4.27	17.11	12.51	50.14	8.17	32.75	24.95
K7207	4.53	15.96	14.58	51.37	9.27	32.66	28.38
平均	4.024	17.65	9.756	42.80	9.016	39.55	22.796

Table 7 Mine methane source analysis of YCG

Shaft	Longwall panel	%	Road heading	%	Mined area	%	Others	%
No.2 shaft	21.75	57.46	3.355	8.86	12.75	33.67		
Shujing shaft	9.26	74.29	0.58	4.62	2.00	16.04	0.63	5.06
Yugong shaft	41.03	48.46	7.52	8.88	16.23	19.16	19.89	23.49
Average	24.01	53.36	3.82	8.49	10.33	22.96	6.84	15.2

2.2 LOW MINE CONCENTRATION METHANE DISCHARGE TEST

In 1980s, there are 3 panels, as 71703 in No.1 shaft, 72407 and 72408 in No.2 shaft of Mine No. 3 of YCG tested the low concentration panel methane discharge test. Certain experience have been gained (shown in table 8). It is explained above that the tailgate played a important role in mine methane discharge. The low concentration methane discharge test is conducted in mine No.3 of YCG, it is sealed the tailgate and installed the centrifugal fan with special explosion-proof treated. The concentration upper limit is 3% , the test result is shown in table 8. Low concentration methane discharge is 96.13% higher in average than tailgate ventilation.

Table 8 The comparison of low concentration blower discharge with tailgate ventilation

Panel	Tailgate ventilation			Low concentration discharge			Comparison (Low concentration / ventilation)	
	Air quantity (m ³ /min)	Content (%)	Methane (m ³ /min)	Air quantity (m ³ /min)	Content (%)	Methane (m ³ /min)	Methane (m ³ /min)	%
71703	125	1.27	1.59	167	1.98	3.31	1.72	+108.18
72407	150	1.5	2.25	155	2.9	4.49	2.24	+99.56
72408	145	1.1	1.60	150	1.9	2.85	1.25	+78.12
Average	140		1.81	157		3.55	1.74	+96.13

2.3 THE WET VACUUM PUMP METHANE DISCHARGE TEST

There adopted the KWB-40 wet vacuum pump for underground methane discharge test in mine No.3 of YCG. It solved the upper corner methane problem. Due to the wet vacuum pump is not limited by the methane concentration, is gained the experience of low concentration methane discharge. While start mining of panel 8905 in seam 15# of Shijing shaft, it is significant of the gas emission, there laid 1700m pipeline, the methane is drained with KWB-40 wet vacuum pump, the mixed gas quantity is 30 m³/min, the concentration of 3 – 30% with average of 18%. It is calculated pure methane 1 – 8 m³/min with average of 3.67 m³/min , it drained 10 days with actual drained methane of 52848 m³.

In panel 81004 in seam 15# of Shijing shaft, the start mining is also with significant gas emission, there laid 800m pipeline, the methane is drained with KWB-40 wet vacuum pump, the mixed gas quantity is 35 m³/min, the concentration of 3 – 35% with average of 17.68%. It is calculated pure methane 2 – 6.5 m³/min with average of 3.25 m³/min , it drained 8 days and 16 hours with actual drained methane of 40560 m³.

The methane drainage with KWB-40 wet vacuum pump test has accumulated certain technical experience of low concentration methane discharge system.

3. THE COAL MINE METANE DRAINAGE SYSTEM SCHEME OF SAADEC

It is situated southeast Shanxi province, 16 km north of Yangcheng county. The coal bearing strata is Taiyuan formation of upper Carboniferous Period, Shanxi formation of lower Permian Period, with total thickness of 151m, and 10-22 coal seams. Among which seams 3# and 15# are minable in all area, and seams 6# , 7# , and 9# partially minable. The geological reserves is 673.5 Mt, among which seam 3# industrial reserves of 286.7 Mt. The designed capacity is 4Mt, with service life of 84.9 years. Among which, the service life of seam 3# is 30.7 years. It is predicted that the designed capacity is reached at end of 2004.

The geological structure is comparatively simple in the mine field, it is a single dipping structure, and the dipping angle is less than 10 degree. Folding is mainly in the east part, and fault fracture is developed in the west part. There is no non coal column (Karst structure) observed in the mine field. The gas content is comparatively high, the in-situ gas content is 6.05 – 17.46 m³/t of seam 3# with average of 12.27 m³/t.

The mine started construction in 1996, which is constrained by gas problem and developed very slow. In 2000, a agreement is reached with Asian American Coal Co., Ltd, to form a Joint venture company as Shanxi Asian

American Daning Energy Co., Ltd. In May 2002, Asian American Coal Co., Ltd has invested on the SAADEC project, it is started the joint venture operation. Due to the coal production is constrained by the gas problem, therefore, it is determined general scheme of pre-degasification and degasification while mining. From 2002 to May 2003, it is completed 498 boreholes with total drilling of 81936m. it is drained 19221358 m³ from July 2002 to may 2003 (11 months). The average monthly methane drained is 1747396 m³. foe average per meter borehole drained CMM 234.59 m³/m. Fig 1 shows the methane drainage effect. The drained methane is increased from 6.86 m³/min in July 2002 to as high as 51.78 m³/min in first half of 2003, the recovery rate is increased from 28.88% to above 65%.

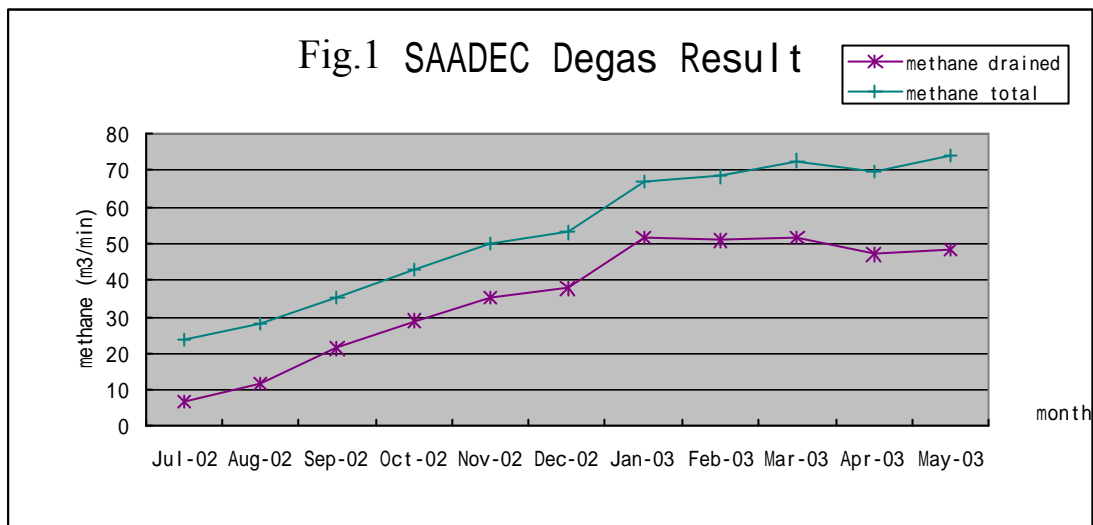


Fig 1. The mine methane recovery result of SAADEC

Due to there are drill rigs of domestic MKD-5S, directional Fletcher from US, directional VLD from Australia, it is capable to combine the straight borehole and directional borehole with branches. After years practice, the directional boreholes can be drilled in gob area instead of only leave pipe in the seal stoppings. It provide the technical measure for set up the mine low concentration methane system.

4. THE FEASIBILITY OF THE MINE LOW CONCENTRATION METHANE DISCHARGE SYSTEM

Based upon the above analysis, it is feasible to set up mine low concentration methane system, it mainly shows in the following aspect:

4.1 CERTAIN EXPERIENCE IS GAINED AFTER SEVERAL TIMES TEST

In section 2, it is described the test of low concentration methane discharge and result. The average recovered mine methane concentration is 2.26% in tailgate, and 18% in wet vacuum pump system, and recovered low

concentration mine methane is around 3.25-3.67 m³/min.

4.2 THERE IS CERTAIN INTERNATIONAL EXPERIENCE AND EQUIPMENT FOR LOW CONCENTRATION CMM UTILIZATION

For the low concentration mine methane application, the combustion research Institute of former USSR has tested 2%CH₂ served as atmosphere to the power plant and increased combustion efficiency of 3%.

Recent years, US, France and Canada all search the utilization of VAM methane, which is mainly the heat exchanger type utilization of VAM methane. It is still in the LAB test stage. There is still a way to go before commercial use. The EDL Company has done much on the utilization of low concentration mine methane. First of all, there is VAM added power plant. Recent years, it is developed the gas turbine which can combust the low concentration mine methane[3*]. Fig 2 is the principle drawing and actual power generation set.

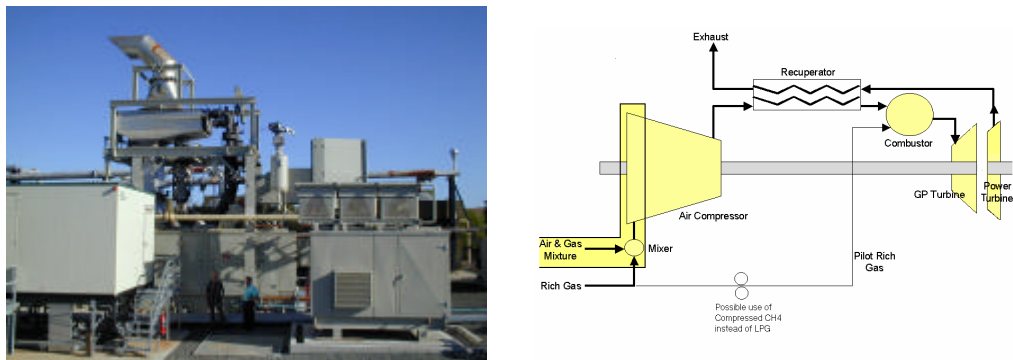


Fig 2. The Lean Combustion gas turbine manufactured in Australia which takes low concentration mine methane
Left: actual machine Right: principle drawing

4.3 THERE IS LOW CONCENTRATION SYSTEM CONSTRUCTION CONDITIONS UNDERGROUND

In SAADEC, after the completion of schemed 800mm pipeline system, the original 370mm drainage system can serve as the low concentration mine methane system. And the VLD directional drill rig also provide the technical measure for ensuring low concentration mine methane drainage system. Fig 3 and Fig 4 show the directional boreholes with branches drilled by VLD drill rig.

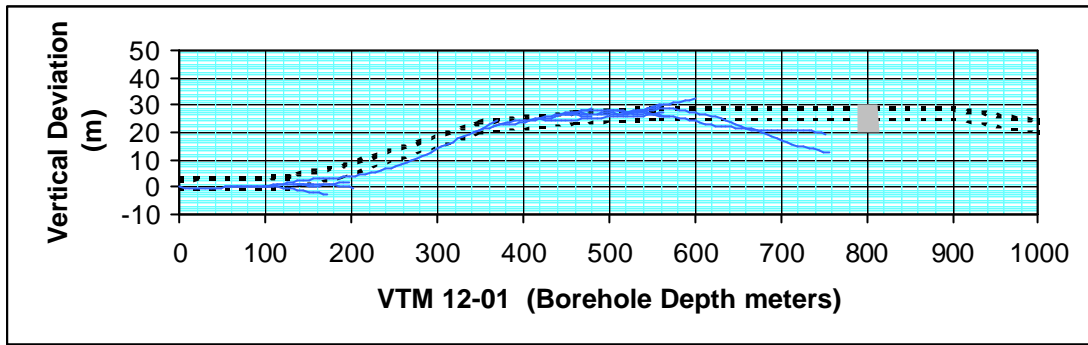


Fig. 3 A example of 750m directional borehole with branches drilled by VLD drill rig

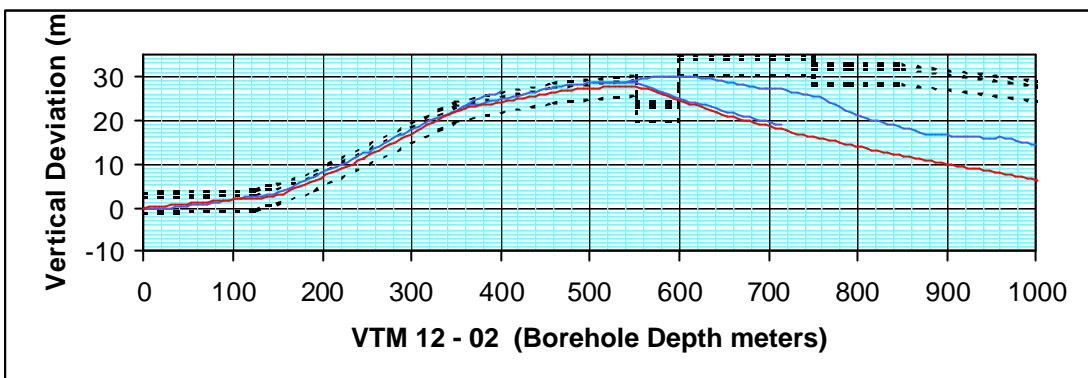


Fig. 4 A example of 1000m directional borehole with branches drilled by VLD drill rig

5. CONCLUSION AND SUGGESTIONS

Based upon above analysis, Yangquan Coal Group has accumulated certain experience on the underground low concentration mine methane recovery. And there is much research on utilization of low concentration mine methane. Therefore, it is feasible to set up the mine low concentration methane system. It is suggested as follow:

- a. To set up the mine low concentration recovery system instead VAM.
- b. After the completion of main pipeline system, the original methane recovery system serves as low concentration recovery system.
- c. After there is experience gained of the low concentration recovery system, it is introduced and spread to other mines worldwide, and significant CMM mitigation result will be gained.

Based on the test in Yangquan Coal Group, low concentration can partly replace the original tailgate, and some of the gob area VAM, which may recovered 42% - 50% more the VAM. Counted 338.5416 m³ CMM as 1 t CO₂ equivalent, the low concentration recovery system can get significant CMM mitigation effect.

Due to it may vary a lot of the low concentration recovery system recovered methane concentration(YCG tested 3 –30%CH₄), it is suggested to adopt the wet vacuum pump for the low concentration recovery system.

References

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