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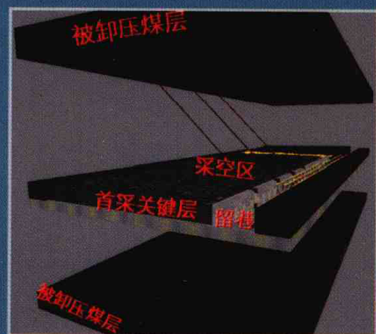

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ABSTRACT

This book, based on innovations and practices of methane drainage in multiseams of low permeability and complicated geology in Huainan mining district, systematically describes theories and key technologies of integrated pillarless coal production and methane extraction with 'Y' type ventilation system in multiseams of low permeability.

Through analyses of deformation, fracturing and failure of rocks around goaf, methane movement and accumulation in and around the goaf are revealed, technologies to retain goaf edge roadways with innovative fill technologies are developed, and technological innovations in methane extraction are made with the retained goaf edge roadways and "Y" type ventilation systems.

This book consists of seven chapters, including theoretical fundamental of integrated pillarless coal production and methane extraction, technologies to control surrounding rocks in goaf edge roadways, fill technology to construct sidewall in retaining goaf edge roadway, methane extraction technologies with boreholes drilled from the roadways, safety assurance system, and case studies.

PREFACE

Methane related accidents have been the No.1 killer in the Chinese coal mines. Between 1950 and 2007, twenty three major disasters occurred in the coal mines, resulted to 3672 fatalities. Of them, methane (coal dust) explosion occurred 21 times or 91.3%, and resulted to 3441 fatalities or 93.7%. Methane control in coal mines is a huge challenge. The Chinese government attaches great importance to prevent occurrence of methane accidents in coal mines. It has long been supported by National Development and Reform Commission, State Administration of Work Safety, State Administration of Coal Mine Safety, the Ministry of Science and Technology, and China National Coal Association through relevant policy amendments, increased R & D funding and technology transfer. National Engineering and Research Centre (NERC) of Coal Methane Control has been established, and NERC has recently held training workshops on methane control to senior management staff and engineers of 45 major state-owned coal companies in China and organised International Symposium on Coal Methane Control and Utilisation Technology.

The concept of integrated coal production and methane extraction has increasingly gained attention and recognition. In most gassy coal mines in China, pre-mining methane extraction with surface boreholes is difficult because coal seams are geologically complicated, of low permeability, of low methane saturation, and anisotropic. Since 1991, Huaibei Petroleum Geological Bureau, China Coalfield Geology Bureau, Xi'an Coal Research Institute, Enron and Texaco have all undertaken coalbed methane (CBM) evaluation in Huainan and Huaibei coalfields. Fourteen wells are drilled, only one of them produced methane at 1000 m^3/d, methane flowrate from the other wells was far less than 1000 m^3/d, and declined rapidly. Furthermore single CBM well costs over RMB5000000 and can only produce up to 42392 m^3 of methane. Therefore, with current technologies CBM development is uneconomical in most gassy coal mines in China.

Statistics show that 70% of the Chinese coal mines are gassy and geologically complicated. Methane explosion often occurs. Huainan is a typical example. Between 1980 and 1997, methane explosion accidents occurred 17 times, resulted to 392 fatalities. In November 1997, two methane explosion accidents occurred and 133 people perished. The accidents almost led to collapse of Huainan Coal Mining Group. Geological conditions in Huainan mining district are very complicated and characterised by deep overburden (400 - 1500 m), multiseams (8 - 15), high methane content (12 - 36 m^3/t), soft coal (f = 0.2 - 0.8), low permeability (about 0.001 md), high methane pressure (up to 6.2 MPa). From a safe mining point of view, seam methane should be drained prior to mining. However the seam methane in Huainan reaches 36 m^3/t. With traditional methane predrainage methods, it may take 10 to 20 years to drain the seam methane to be less than 8 m^3/t. Coal is not replaceable in near future, so it is very important to ensure stable coal production. Huainan is located in the economically advanced area in China and is a major energy supplier to Jiangsu, Zhejiang and Shanghai. Huainan has coal reserve of 50 billion tonnes (Bt) within 1500 m overburden depth. Rapid economic development in China requires a large amount of coal. One cubic meter of methane can generate 3 kWh and one tonne of coal can generate 3300 kWh, energy provided per tonne of coal is 1100 times more than that per cubic meter of methane. Therefore, safe mining of coal resource is of paramount importance in development of national economy in China. Tight coal supply situation caused by the snow storm in the southern China in 2008 proves once again the importance of coal as a predominant energy source. On one hand methane content of coal seams has to be reduced to below 8 m^3/t prior to mining the seams of low permeability, on the other hand we have to produce coal to meet energy requirement to develop the national economy. This leads to development of integrated coal production and methane extraction.

Since 1998, Huainan, assisted by some coal producing companies, research organisations and universities, has carried out some challenging research and development in methane control technologies, developed a number of technological breakthroughs, ensured safe and efficient coal mining, and achieved significant social and economical benefits. Coal production in Huainan has increased from 10 to 60Mt, fatality rate per 1 Mt of coal output has reduced from 4.01 to 0.1, methane extraction has increased from 10 to 150 Mm^3/y, and methane utilisation ratio has jumped from 3 to 7%. These technological breakthroughs, in combination with new management structure and concept of methane control, have produced significant impact in coal industry. A number of field workshops have been convened by the national governments and the Chinese coal industry to promote the innovative methane drainage technologies. This has resulted in wide applications of the technologies in many gassy coal mining districts in China. Methane extraction in Yangquan, Jincheng, Huainan, Songzao, Panjiang, Shuicheng, Jixi, Huaibei, Ningmei and Fushun has all exceeded 100 Mm^3/y. Methane extraction from the Chinese coal mines have reached 4.4.Bm^3, an increase of 2.6 Bm^3 or 140% since 2004. However, because of complicated geological conditions of coal seams, some technologies applicable in shallow coal seams such as those with methane drainage tunnels to destress and extract methane from overlying and underlying seams, have started to show significantly negative impact on mine layout in deep coal mines. Deep coal mining have some serious issues, including outburst, support in soft strata, abutment pressure in narrow pillars, high overburden pressure, high strata temperature, complicated geology, low permeability and high methane content. These issues pose huge challenges to safety, economics and technologies of deep coal mining.

It is widely recognised that there exist some technological difficulties in extract methane from deep coal seams of low permeability. This book aims to reveal fracture evolution and methane movement in pillarless mining and describe innovative technologies to retain goaf edge roadways, pre-mine key strata, drain methane with boreholes drilled from the retained roadway. Goaf edge roadways are retained with new support and fill technologies, and pillarless panels can be realised with the retained roadways. The key strata (rock or coal) are carefully selected and mined to destress their overlying and underlying strata and increase strata permeability by hundreds and thousands times (in Huainan, the key strata are often coal seams of no or low risk of outburst). Through studies on fracture evolution and methane movement in roof and floor strata during pillarless coal mining, methane-rich zones in goaf, roof strata and floor strata are identified, methane extraction is maximised with optimum layout of methane drainage boreholes, methane content and outburst risk of the destressed seams are reduced, and extracted methane is utilised. Key technologies have been successfully developed over the last five years to integrate pillarless coal production and methane extraction with retained goaf edge roadways and 'Y' type ventilation system in multiseams of low permeability.

During my writing of this book, I am deeply grateful to academicians Chang Yinfo, Qian Minggao, Zhou Shining, Song Zhenqi, Hong Boqian, Xie Heping, and Peng Suping for their advice and help. I am also grateful to Prof. Zhang Nong, Prof. Cheng Hua, Prof. Liu Zegong, Prof. Xue Junhua, Prof. Sun Daosheng, Prof. Lu Ping, and Prof. Cao Shuxiang for their valuable information. I would also like to express my sincere thanks to NERC of Coal Methane Control, Huainan Coal Mining Group, China National Coal Association, and China Coal Industry Publishing House for their support.

As coal mining depth increases in Huainan, issues such as high methane content, high strata stress and temperature become increasingly serious. This book merely summarizes some achievements in integrated coal production and methane extraction, and clearly a lot more research work need to be done.

Yuan Liang

September 2008

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CHAPTER 1 INTRODUCTION

1.1 Introduction

China is the biggest coal producing country in the world and accounts for 37% of world coal production. Coal is a major energy source in China and accounts for 76% primary energy production and 69% of primary energy consumption. It was stated in "National Medium to Long Term Energy Development Plan (2004-2020)" that China would stick to coal and electricity as its main energy sources, and in the mean time develop oil, gas and other new energy sources. Clearly coal will be a major and irreplaceable energy source in China for a long period of time.

Coal resource in relation to its overburden depth is shown in Figure 1-1-1. Up to a depth of 2 km, coal resource is estimated to be 4.5×10^3 Bt. Coal resource increases by 225 Bt with every 100 m increase of depth. In depth between 1.5 km and 2.0 km, coal resource increases by 250 Bt with every 100 m increase of depth. At present mining depth in the Chinese coal mines is about 400 m and there are at least 80% of the coal resource to be mined and utilised. Development of deep coal resource will remain with us for a quite long period of time.

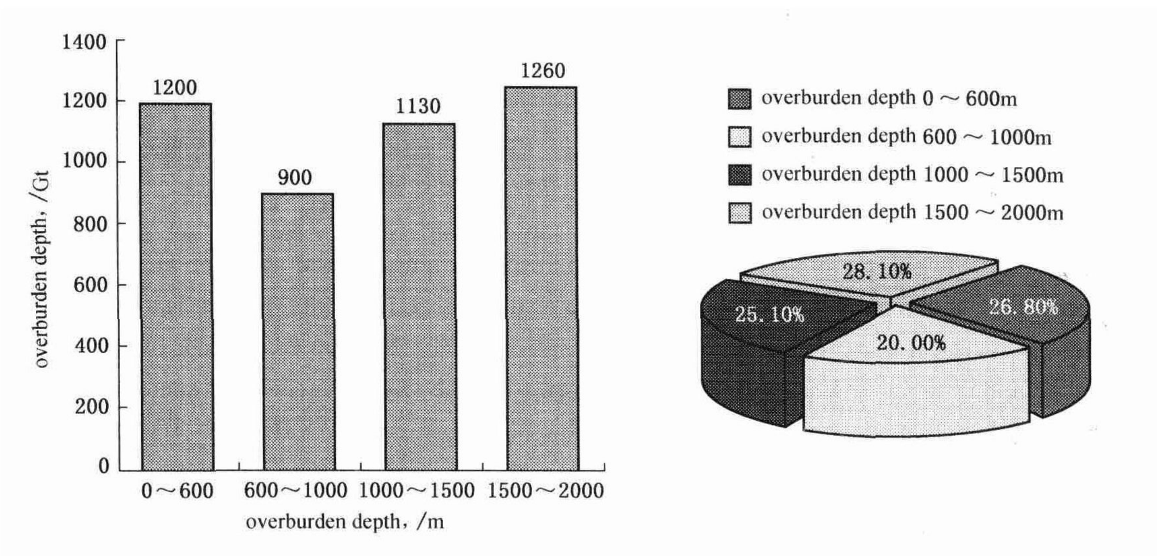

Figure 1-1-1 Coal resource vs overburden depth

Coal mining districts in the eastern part of China is an important coal energy base. Coal seams in the districts are within Carboniferous-Permian strata. The coal seams are stable and their sulphur content is less than 1%. Coal resource in the districts is close to 100 Bt. Huainan has 50 Bt coal resources and accounts for 50% of the total resource in the districts. The coal resource in Huainan also accounts for 74% of total resource in Anhui province. There are a number of large coal mining companies in the districts, including Huainan, Huaibei, Xuzhou, Yanzhou, Xinwen, Pingdingshan, Yongcheng and Jiaozuo. These companies produce 200 Mt of coal per year and value of their coal output exceeds RMB100 billion. Because the mining districts are located in the area of rapid economic development, adjacent to China Eastern Sea on eastern side and European-Asian continent on western side, they are strategically and geographically located. Sustainability of coal production in the districts is a key in the national energy development plan. In recent years, ten new coal mines at a cost of RMB30 billion, have been constructed or under construction in the districts, adding 50 Mt coal output per year. That investment represents 53% of total national investment in coal mines. However, Tertiary strata in the districts are very thick, coal seams lie very deep, seam floors are water-bearing Ordovian strata, deep coal resource (overburden depth is over 700m) accounts for 67% of total coal resource in the districts. In addition, the districts have been intensively mined and will extract coal seams of 1000 m deep. Most new coal mines in Juye mining district extract coal seam of 500 to 1000m deep. In Huainan mining district, there are 15 operation mines, 12 of them extract coal seams of 700 to 1000 m deep, and one mine extracts coal from seams of over 1000 m deep.

In general, methane content in a coal seam increases with its depth. Methane resource within 2000 m of overburden depth is estimated to be $3.1\times10^{13}m^3$ in Chinese coalfields and the methane resource is ranked the second in the world, and it accounts for 51.94% of total methane resource (natural gas and coal seam methane) in China. Since 1990, methane emission from coal mines in Huainan mining district has increased by 100 m^3/min annually, and methane content in the coal seams has increased by 4.61 m^3 with 100 m increase in overburden depth.

CBM is a clean energy and its development and utilisation has gained attention and recognition. On one hand it is one of major safety hazards in coal mines, on the other hand it is a clean energy, valuable chemical material and important alternative energy. In 2006 China coal production was 2.38 Bt and drainage methane was about 1.4 Bm^3 from the major state-owned coal mines. Based on assumption that coal contains 8 m^3 of methane per tonne, then 12.8 Bm^3 of CBM is ventilated into air every year. CBM is classified as a clean energy in recently announced national energy policies. Therefore, development and utilisation of CBM is of very important significance.

Geological conditions of coal seams in China are very complicated. Methane emission from the coal mines in China is over 12 Bt. Of major state-owned coal mines, the number of gassy and outburst prone mines accounts for 49.8%, coal production from these mines accounts for 42%, the number of coal mines prone to coal dust explosion accounts for 87.4%, the number of coal seams prone to sponcom accounts for 51.3%. In such complicated geological conditions, Chinese coal mines are prone to accidents, particularly those gassy coal mines. In 2005 methane related accidents account for 12.13% of total accidents, however number of fatalities resulted from these methane related accidents accounts for 36.5% of total fatalities. Of accidents resulted to more than three fatalities, the methane related accidents account for 59%. Of accidents resulted to more than ten fatalities, methane related accidents account for 69%. Since 1949, of 22 accidents resulted to more than 100 fatalities, 20 accidents or 91% were caused by methane explosion, and number of fatalities resulted from the 20 accidents account for 94% of total fatalities. Methane related accidents are the most deadly. Therefore, prevention and control of the methane related accidents is of the most importance in coal mining.

Mining depth in Chinese coal mines increases by 10 to 30 m per year. With increase in mining depth, methane pressure and strata stress and temperature also increase, and risk of occurrence of natural accidents also increases. Methane pressure increase by 0.1 to 0.3 MPa per year and methane emission increases by 1.5×10^9 m^3 per year. In 45 major state-owned coal companies, number of gassy and outburst prone coal mines increased by 10 % between 2004 and 2005. In Huainan mining district absolute methane emission increased from 473 m^3/min in 1997 to 1000 m^3/min in 2005 and over the last three years three more coal mines have been classified to outburst mines. Furthermore, number of coal mines with rockbursts and heat hazards also increases dramatically. The rockbursts have occurred in 102 coal mines in China and 70 coal mines face serious threat from the heat hazards.

The main purpose of methane control in coal mines is to prevent methane accumulation, eliminate outburst risk, and control explosion of methane and coal dust. Main methods to prevent the methane accumulation include reduction of the methane emission into mine openings and dilution of methane concentration in the opening. Methane drainage is an effective method to reduce the methane emission and mine ventilation is an effective method to dilute the methane concentration. The main method to eliminate the outburst risk is to destress coal and rock strata. Other methods to control methane hazards include control of underground ignition sources and development of safety assurance systems of explosion prevention, isolation and suppression, personal protection and methane monitoring. Main methods to control underground ignition sources include use of explosion-proof electrical apparatus, use of static resisting and fire retarding materials, use of mine-safe explosives, effective control of sponcom and exogenous fire hazards.

With technological development of coal mining industry, methane drainage technologies have been significantly improved. Development of the methane drainage technologies in China can be divided into four stages, as described below.

(1) Methane drainage from coal seams of high permeability

In 1950s, inseam methane predrainage was successfully used in extra thick coal seams of high permeability in Fushun mining district. This method was also trialied in coal seams of low permeability and was not successful.

(2) Methane drainage in adjacent seams

In late 1950s, cross-measure methane drainage was successfully used in Yangquan mining district. It solved its high methane emission problem encountered while first coal seam of multiseams was mined. Importance of methane drainage in adjacent seams was recognised. This method has since been widely used in coal mines of multiseams environment.

(3) Intensive methane drainage in coal seams of low permeability

In coal seams of high methane content and outburst risk, conventional methane technologies described in (1) and (2) didn't perform well. Since 1970s, a number of methane control technologies were developed and trialled. These include high pressure water infusion, hydraulic fracturing, loosening blast, controlled pre-split blasting, drainage with boreholes of large diameters, and cross layout of boreholes with small spacing. Because of operational difficulties and poor practicality of these technologies, only cross layout of boreholes with small spacing was applied in some coal mines.

(4) Integrated methane drainage

Since 1980s, methane emission in panel faces increases dramatically with introduction of longwall mining, in particular Longwall Top Coal Caving (LTCC) mining. To control the high methane emission, integrated methane drainage methods have been used. In terms of timing, the methods include methane predrainage, drainage during mining, and goaf methane drainage. In terms of spacing, the methods include drainage from mining seam, drainage from adjacent seams, and drainage from surrounding strata. In terms of operation, the method includes drainage with borehole and tunnel, drainage in underground and from surface, and conventional and intensive drainage. With the integrated methane drainage method, the methane emission was basically controlled.

In late 1990s, Pingdingshan mining district developed new methane predrainage technologies. They include inseam methane drainage with long (between 200 and 500 m) horizontal boreholes and controlled pre-split blasting. Methane drainage ratio increased by 20%.

In early 2000s, Huainan mining district undertook intensive research and development in prediction, prevention, monitoring and control of hazards associated with methane and coal dust. A number of technologies were developed to drain methane from coal seams of low permeability. For example, high pressure water jet technology was developed to enlarge inseam methane drainage boreholes. Conventional methane boreholes of 70 mm in diameter were enlarged to between 200 to 300 mm, even 619.9 mm in one occasion, with the water jet technology. Methane drainage efficiency was significantly improved.

Development of the integrated methane control technologies in multiseams of complicated geology was listed as a key research program in the Tenth Five-Year Plan. Major achievements include detailed understanding of effect of mining protective seams on protected seams and development of new methane control technologies to solve high methane emission in mining the protective seams. These technologies include surface goaf drainage and use of tunnels excavated in overlying and/or underlying strata and cross-measure boreholes drilled from the tunnels to drain methane from the protective and protected seams. These technologies was successfully applied to mine a protective seam with an overlying seam (protected seam) located up to 70 m above it and methane drainage ratio from the protective seam was up to 62%. The technologies have been applied to many coal mines in China and lead the world.

Development of surface inseam methane drainage in China is still at early stage. In 1970s, in order to solve methane problems, 40 surface wells were drilled in Baisha, Fushun, Jiaozuo and Yangquan mining districts. The wells were hydrofractured, methane production from the wells was low and drilling cost was too high. In 1992, United Nations Development Programme (UNDP) sponsored CBM development in China and CCRI Xian carried out CBM evaluation. Both surface and underground trials were conducted in Kailuan, Tiefa and Songzao. Results from the trials show that three surface wells drilled into goaf in Tiefa produced 747 m^3/d methane over two and half years; three surface wells drilled into virgin seams in Kailuan produced little methane and underground methane drainage system was improved in Songzao. In 1995, China Ministry of Coal Industry and U.S. Department of Energy signed an agreement on CBM recovery and utilisation. At the same time, China Ministry of Coal Industry collaborated with Enron, Amoco and Texaco to develop CBM in Huainan, Huaibei, Sanjiao, Pingdingshan and Jincheng. In 1996, China United Coalbed Methane Co. Ltd (CUCM) was established by the Chinese government to undertake exploration, development, transportation, marketing and utilisation of CBM, and it was given an exclusive right to undertake relevant international collaboration. In January 1998, CUCM and Texaco collaborated to develop CBM in Huaibei with planned investment of US $500M. In the same year CUCM, BP and Chevron Phillips jointly developed CBM in Shanxi Hedong Coalfield. Up to now, 100 CBM wells have been drilled in 10 mining districts. The highest methane production from a single well is more than 10,000 m^3/d, however methane production from 90% of the wells is less than 1,000 m^3/d. With current market price of methane, it will take more than 10 year to recover investment if methane production is around 3000 m^3/d per well. These trials conclude that CBM development with surface wells is not economically viable.

Practical experience shows that coal mining causes movement of surrounding strata. If there are some coal seams within the surrounding strata, permeability of these seams can be increased tens or hundreds or thousands times, and this leads to methane movement and provides an opportunity for methane to be extracted. Coal seams in China are characterised with complicated geology, multiseams, low permeability, high methane content and prone to outburst risk. These characteristics dictate that coal seams have to be destressed prior to methane drainage from the seams. Methane drainage boreholes should be drilled from underground roadways and into destressed or permeability-enhanced zones resulted from coal mining activities. Development of innovative technologies is required to achieve integrated coal production and methane extraction.

1.2 Technological Problems in Mining Deep and Gassy Seams

Deep mining has been an important research topic in the world mining engineering. In 1983, the former USSR scholars proposed to carry out special study to mining coal seams of over 1600 m depth. The former West Germany once built an extra large physical model to specially simulate 3D stress conditions in 1600 m deep mines. In 1989, Society of Rock Mechanics convened an international conference to discuss "deep rock mechanics". Over the last 20 years, investigations have been carried out in rockburst prediction and control, large deformation and support in soft rocks, prediction of water inrush into tunnels, and methane control in deep mines. The investigations have produced some significant results. In some countries with deep mining, such as USA, Canada, Australia, South Africa, Poland and Russia, governmental organisations, relevant industries and research organisations have teamed up to undertake fundamental studies on theory and technologies in deep mining. Since July 1998, African government, universities and industry have started a "deep mine" research program. The program aims to solve some key problems in deep gold mining. Canadian Federal and Provincial governments and mining industry have undertaken deep mining studies for over 10 years. The studies have made significant achievements in computer modelling of rockburst prediction, support system in rockburst-prone zones, and risk assessment of rockbursts. Deep mining study has been investigated by Idaho University, Michigan Technical University and Southwest Research Institute. University of Western Australia has also carried out a lot of research in deep mining.

In late 1980s, China started to undertake studies in deep mining. Some universities and research institutes studied theory and technology in deep mining, and made some significant achievements. The studies cover support in soft strata, rockburst prediction and information-based mining. A lot of research and practice have been undertaken by tunnelling industry, China Coal Research Industry, China University of Mining Technology (CUMT), Central South University, Northeastern University, Chongqing University, Tongji University, Southwest Jiaotong University and Anhui University of Science and Technology.

Huainan coalfield contains coal-bearing strata of Carboniferous-Permian age. Shanxi and Shihezi groups in the Permian strata are main coal-bearing strata. Thickness of the mineable coal-bearing strata is 340 m and the strata contain 9 to 18 mineable seams. Total thickness of the seams is between 25 and 34 m and averages about 30 m. C_{13-1}, B_{11-2}, B_8, B_6, B_4 and A_1 are main mineable seams, thickness of each seam varies between 2 to 6 m. Huainan coalfield is geologically complicated, seams dip between 0° to 90°, and there are 1900 faults of over 5m fall or 1.1 faults per 1 km^2 on average. Geological structures are closely associated with abnormal seam methane conditions, large geological structures often control distribution of seam methane, and many methane accidents are related to these geological structures.

Coal seams in Huainan are quite gassy, their methane content is between 12 and 36 m^3/t, methane pressure is up to 6.2 MPa; the seams are soft (f = 0.2 - 0.8) and their permeability is very low (about 0.001 md); and main mining seams C_{13} 、B_{11}、B_8、B_4 are prone to outburst. Mining depth increases by 20 m every year, methane emission increases by 100 m^3/min per year and is expected to reach 1500 m^3/min in 2010. Many new mines in Huainan are deep and depth of their first mining panel is between 700 to 1000 m and it increases by 25 m per year. Unfortunately there is little research carried out in deep coal mining technologies.

1.2.1 High Methane Content and Outburst Risk

Methane control in coal mines is a worldwide problem. Methane explosion in coal mines has occurred in many coal producing countries such as USA, UK, Australia, Germany and Russia. Coal seams similar to those in Huainan, which are characterised with high methane content, high strata stress and temperature, won't be mined in USA, Australia and not even in Europe.

In Huainan, methane content and outburst risk increase significantly as mining depth increases to over 600 m. All operation mines in Huainan are classified as outburst mines. In 2005 an outburst occurred in development heading #66108 of Xinzhuangzi mine. In 2006 an outburst occurred in shaft sinking of Wangfenggang mine. These outbursts resulted to fatalities. In 2006 two panel coalfaces (one in Xinzhuangzi mine and another in Dingji mine) suddenly moved forward, and these were accompanied by a large amount of methane emission into the panel faces, resulting in sudden methane accumulations in the faces and nearly leading to accidents. Methane pressure of as high as 6.2 MPa was measured in B11b seam at -860 m level in Wangfenggang mine. Outburst control becomes No.1 problem in deep coal mining in Huainan.

In deep coal mines, due to high methane emission, conventional ventilation systems are incapable of controlling methane concentration at panel return corners. In case of multiseams, methane emission in mining first panel can reach 90 to 120 m^3/min and 60% of that is from adjacent seams. Most panel faces in Chinese coal mines use "U" type ventilation system (Figure 1-2-1). This system is simple, economic and suitable to panel faces of low to moderate methane emission. Problems associated with the system include: (1) in a panel face with high methane emission, a large amount of methane tends to accumulate in goaf; (2) with high methane emission, panel air intake is high, pressure difference across the panel is high, resulting to large air leakage (about 20%); and (3) methane concentration in panel return corner can exceed statutory limits.

Methane control measures used in mining shallow coal seams are not applicable or difficult to implement in mining deep coal seams. Firstly, methane drainage with roof and/or floor tunnels in a panel can only drain 50 to 60 m^3/min of methane; it is simply not enough and leaves too much methane to be diluted with panel ventilation system. Secondly, methane drainage with inseam boreholes can induce bursting while the boreholes are drilled, it is a safety concern. Thirdly, methane drainage with "destressed mining", i.e. a protective seam is firstly mined to destress adjacent seams or protected seams, has largely prevented outbursts from occurring, however outbursts do occur in abutment stress zones of the protected seams, which is resulted from the coal pillars left in mining protective seams. Outburst risk in the abutment stress zones increases with mining depth, so mining in the zones shall be avoided. Finally, because of high stress in deep strata, development of roof tunnel or floor tunnel is slow and very expensive.

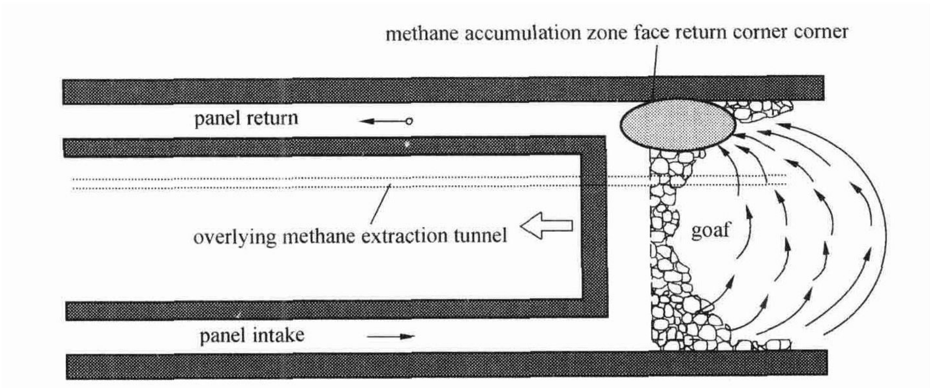

Figure 1-2-1 "U" type ventilation system

Huainan was plagued with methane disasters in the past. After more than ten year's research and development in methane control, Huainan has developed theories and technologies of "integrated coal production and methane extraction" and "destressed mining", advanced "methane control – 20 concepts", and summed up "50 pieces of methane control experience" and "50 methane control technologies". Methane control is more proactive and comprehensive. Huainan has carried out a major national R & D program, i.e. development of technologies to predict, prevent and control methane and coal dust explosion, and developed a set of methane control technologies such as "destressed methane drainage technologies in soft and thick coal seams of low permeability", "technologies to mine overlying protective seams to control outbursts of adjacent seams", "technologies to drain methane from roof of mining seams", and technologies to drain goaf methane with surface boreholes". Most of these technologies have been widely accepted and applied in the coal industry, and they are leading the world.

Guqiao and Wangfenggang mines in Huainan were designated as demonstration and experimental mines to control high methane, high strata stress and temperature respectively by the Chinese