Methane Drainage at the Minerales Monclova Mines in the Sabinas Coal Basin, Coahuila, Mexico

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ABSTRACT

Minerales Monclova S.A. De C.V. (MIMOSA) operates five underground longwall mines in the Gassy Los Olmos Coals of the Sabinas Basin in the state of Coahuila in Northern Mexico. Because of high in-situ gas contents and high cleat and natural fracture permeability, MIMOSA has had to incorporate a system of methane drainage in advance of mining in order to safely and cost effectively exploit their reserves.

In the early 1990s Resource Enterprises (REI) conducted reservoir characterization tests, numerical simulations, and Coal Mine Methane (CMM) production tests at a nearby mine property in the same basin. Using this information REI approached MIMOSA and recommended the mine-wide implementation of a degasification system that involves long in-seam directionally drilled boreholes. REI was contracted to conduct the drilling, and to date has drilled over 26,000 m (85,000 ft) of in-seam borehole in advance of mining developments, reducing gas contents significantly below in-situ values.

This paper discusses the basis for the degasification program recommended at the MIMOSA mines, and presents the impact of its mine-wide application on MIMOSA's mining operations over the last six years. The paper focuses on the degasification system's impacts on methane emissions into mine workings, coal production, and ventilation demands. It also presents lessons learned by the degasification planners in implementing in-seam methane drainage. The paper presents actual CMM production data, measurements of methane emissions and advance rates at development sections, and mine methane liberations.

KEYWORDS

Mexico, Los Olmos Formation, Methane Drainage, Methane Drainage Efficiency, In-Seam Boreholes, and Degasification.

INTRODUCTION

The five underground longwall mines operated by MIMOSA exploit coals of the Upper Cretaceous Los Olmos Formation in the state of Coahuila in northern Mexico. This region contains Mexico's largest coal reserve, 12.2 Gt (13.4 b tons), of which an estimated 1.5 Gt (1.65 b tons) is recoverable. MIMOSA is presently operating in the Sabinas sub-basin shown on Figure 1, which is one of the three most economically important coal deposits in Coahuila.

MIMOSA's estimated reserves in the Sabinas sub-basin are near 424 M t (467 mm tons).

The Los Olmos formation contains two distinct coal seams (locally known as the Double Seam) which are mined commercially where the rock parting between them is between 0.10 and 0.20 m (4 – 8 inches), for a combined thickness of approximately 2 m (6.5 ft). The coals are medium to high volatile in rank, and for MIMOSA, supply related steel making operations in the city of Monclova.

Coal mining in the Sabinas sub-basin initiated in 1889, with surface and drift mining near outcrops. Mining on MIMOSA's concession in the Sabinas sub-basin initiated in 1950. At that time, the underground mining operations were owned and operated by the Mexican government (SIDERMEX). The mines were purchased in 1991 by Groupo Aceredo del Norte (GAN), a very large steel concern, and are now managed by GAN's wholly owned subsidiary, MIMOSA. The mines are equipped with Joy 4 L810 longwall systems, and develop dual entry gateroad sections with Joy 14 CM and Alpine road heading equipment. MIMOSA's operations presently produce approximately 5 Mt (5.5 mm tons) of coal annually, run of mine.

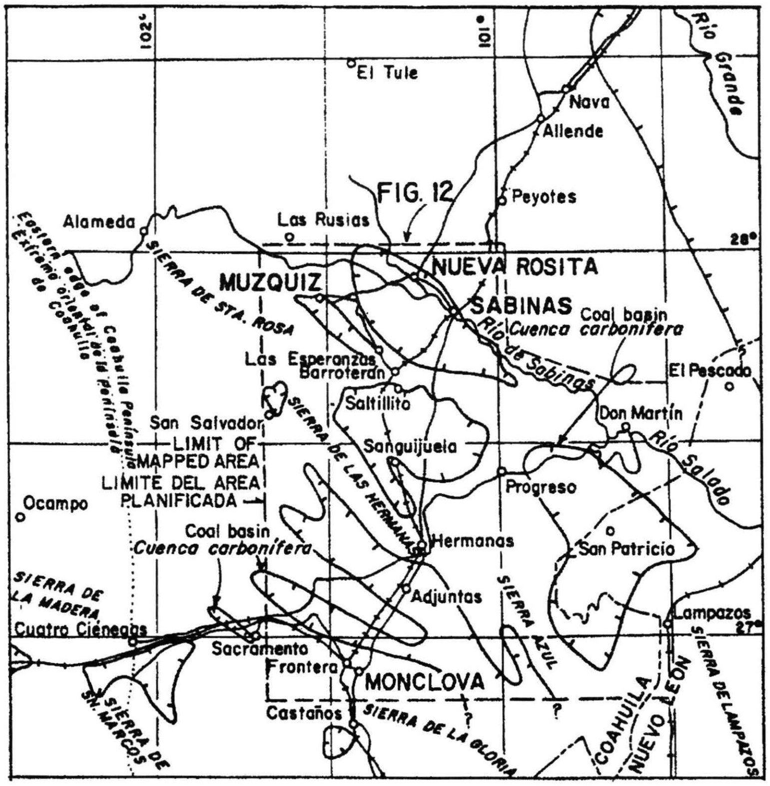

Figure 1. Map of coal bearing area of Coahuila, Mexico (Ojeda-Rivera, 1978).

Underground coal mines at depths greater than 170 m (550 ft) in the Sabinas and neighboring Saltillito sub-basin (due southwest of the Sabinas sub-basin) encounter very gassy coal conditions. Saltillito sub-basin mines in particular, experienced several significant methane related mining disasters (27 explosions between 1889 and 1988 with 1,552 fatalities). In the Sabinas sub-basin, MIMOSA's five longwall operations presently liberate in excess of 400,000 m^3 (14 mmcfd) of methane per day. In order to efficiently longwall mine the Double coal seam MIMOSA has had to implement a system of methane drainage in advance of mining at four of its five operations. Degasification in advance of gate entry development initiated between 1992 and 1993 in Mines I, II, and IV, and in 1997 in Mine V. Todate this program has involved directional drilling of 26,500 meters (87,000 ft) of in-seam borehole. This system has effectively reduced in-situ gas contents in advance of mining and has achieved an average methane drainage efficiency of greater than 30%.

The ensuing sections present (i) the reservoir characteristics of the Double coal seam of the Los Olmos formation as determined by in-situ gas content and reservoir tests; (ii) the basis for recommending in-seam drilling in advance of gate entry development at MIMOSA, and: (iii) the benefits of implementing methane drainage systems at MIMOSA's Mines. Discussions focus on Mines I and II where methane drainage systems were extensively implemented.

BASIS OF IN-SEAM METHANE DRAINAGE AT MIMOSA'S MINES

REI determined gas contents and conducted reservoir tests of the Double coal seam in the Sabinas coal basin from a corehole on property due east of MIMOSA's concession. Testing information was used with a reservoir simulator to predict the effectiveness of methane drainage in advance of mining with long in-seam boreholes. The results of these simulations showed that in-seam drilling could rapidly reduce in-situ gas contents in advance of mining.

Field Tests

In-situ gas content and reservoir tests were conducted at an average depth of 170 m (560 ft). Nine core samples were obtained for desorption testing and two injection tests were conducted to determine reservoir pressure and the ability of the coals to accept fluids.

In-Situ Gas Content. Gas content was determined using the Direct Method. The average in-situ gas content of the composite samples was 8.4 m^3/t (269 ft^3/ton), and on a dry ash-free basis, was 13.5 m^3/t (432 ft^3/ton).

Diffusion. Rapid diffusion parameters were determined. The average value of desorption time (time at which 63% of the total gas is desorbed) for all of the core samples was 56.6 hours. Comparatively, gassy coals in the Warrior Basin typically have desorption times greater than 30 days.

Gas Composition. Results of gas analyses showed 98.97% methane, 1% nitrogen, and 0.03% carbon dioxide.

Rank and Vitrinite Reflectance. Chemical and petrographic analyses determined the coal to be high volatile A in rank with a mean maximum vitrinite reflectance of Ro = 0.99%.

Reservoir Pressure. The injection test data determined that the coals are under-pressured, at 1,191 kPa (172 psi) at 170 m (560 ft).

Natural Fracture Permeability. Interpretation of injection test data estimated natural fracture permeability at 33.6 md. This high level of permeability was supported by fracture description data which recorded average cleat spacings of 1 mm (0.04 inches).

Reservoir Simulations

Reservoir simulations were conducted using the two-phase finite difference reservoir simulator COMETPC 3-D incorporating the parameters presented above, and other necessary reservoir parameters determined from laboratory tests of comparable coals. Simulations were conducted to determine gas production, reduction in in-situ gas content, and reduction in mine face emissions with horizontal in-seam boreholes of differing lengths assuming they are spaced 150 m (500 ft) apart. Results are presented in Table 1 for an in-seam borehole of 460 m (1,500 ft).

The simulations predicted that average daily gas production from in-seam boreholes is generally proportional to borehole length within the range of lengths investigated (305 m to 610 m, or 1000 – 2000 ft). The simulations also predicted that in-seam boreholes could significantly reduce in-situ gas contents and methane emissions from exposed coal faces over short periods of time. This exercise suggested that mining operations in the Sabinas sub-basin could potentially see significant benefits by employing this technique in advance of gate entry development into virgin coal areas. REI presented this approach to MIMOSA.

MIMOSA Mine Methane Drainage Needs

Typical methane emissions in advance of gate entry developments, mine methane emissions, ventilation requirements, and coal production data is presented for MIMOSA mines prior to implementation of in-seam methane drainage between 1992 and 1993.

Gate Entry Development. Prior to implementation of methane drainage, MIMOSA encountered significant methane emissions during gate entry developments in virgin coal areas. For example, in 1992, an airflow of 59 m^3/s (125 kcfm) and an average methane concentration of 1.2%, were measured outby the No. 2 West gate entry developments in Mine I. Methane emissions from this two-entry Alpine

Table 1. Results of numerical simulations with 460 m in-seam borehole.

Parameter	Result of Simulations	Comments
Average Gas Production Per Day	13,450 m^3/day (475 mcfd)	Average over 5 Months
Average Gas Production Per Day Per Unit Length	29.4 m^3/day-m (317 cfd/ft)	Average over 5 Months
Reduction in In-Situ Gas Content after 1 Year	49 percent	For 460 m Borehole
Reduction in Ribside Gas Emissions	30 percent	Reduction Over 305 m of Rib at Day 30

miner section were as high as 60,000 m^3 per day (1.25 mmcfd), impairing gateroad advance. MIMOSA reported average development advance rates as low as 5 m (16.4 ft) per shift when mining in these very gassy conditions.

Mine Ventilation. Ventilation requirements for MIMOSA's longwall operations prior to degasification averaged 120 m^3/s (254 kcfm), based on Mine I and II. Average mine methane emissions were 72,000 m^3/day (2.5 mmcfd). Legal methane concentrations of less than 1% methane were maintained in main return entries and through the main mine fans by dilution.

Coal Production. Average coal production for MIMOSA's single longwall operations (based on average of Mine I and II) prior to implementation of degasificaiton was 1 Mt, run of mine (over a 5 year period).

Following the acquisition of the mines from the Mexican government, MIMOSA planned to substantially increase production from its longwalls (by 65%) and upgraded its face and section equipment. By implementing methane drainage, MIMOSA increased coal production with limited impact to mine ventilation demands and ventilation infrastructure.

APPLICATION OF IN-SEAM METHANE DRAINAGE AT MIMOSA'S MINES

The application of in-seam drainage, borehole gas production rates, and the impact of methane drainage on gate entry development, mine production, and mine ventilation requirements, including mine methane liberations are presented using available data.

Application of In-Seam Methane Drainage

MIMOSA contracted REI to conduct in-seam directional drilling for methane drainage on a contract basis. Borehole placement was determined by MIMOSA and was primarily based on mining schedule, with the intent to reduce in-situ gas contents in advance of gate entry development and subsequent longwall mining. Figure 2 presents drilling patterns and borehole placement in Mine II between 1992 and 1998. The boreholes varied in length from 305 m to 900 m (1000 to 3000 ft) and were generally spaced 150 m (500 ft) apart or less where possible to drain large coal volumes over short periods of time. As shown on Figure 2, multiple boreholes were drilled from single locations to minimize movement of equipment and extending gas collection lines. Gas flow through collection lines and to the surface is facilitated by surface vacuum installations at all mines.

Single Hole Gas Production Rates

MIMOSA engineering personnel obtained methane gas production rates from several individual boreholes for monitoring purposes for periods ranging between 3 and 9 months. These were obtained outby the boreholes in the gas collection lines by measuring velocity pressure with averaging pitot tubes and methane concentration. Figure 3 presents average daily gas production rates for three different boreholes, Numbers 12, 13, and 14, drilled in Mine I at three different locations. These boreholes were all drilled into virgin coal at least 150 m (500 ft) from any entry or borehole and were oriented similarly. The average daily gas production from these three boreholes over an average duration of 5 months on a per length basis is 27.2 m^3 per day per meter of borehole (293 cfd/ft), which compares well with the production rate predicted by the simulations (29.4 m^3 per day per meter of boreholes (317 cfd/ft)).

Effectiveness in Gate Entry Developments

In-seam boreholes have had a significant impact on the development of gate entries in advance of longwall mining. Because of the high permeability of the cleats in the coal, the in-seam boreholes rapidly shield development activity from methane emissions. This is illustrated in Figure 4 which presents methane emissions and section advance rates during development of the 2 West gate entries prior to and after drilling an 884 m (2,900 ft) in-seam borehole adjacent to the projected rib of the entry in advance of mining in Mine I. The figure indicates that after deployment of the in-seam borehole, methane emissions into the entry decreased by 30% (from maximum) in two months, enabling MIMOSA to reduce ventilation requirements to the section by an equal amount, and increase advance rates by 78%.

Impact on Mine Ventilation and Coal Production

Implementation of degasification systems enabled the mines to achieve MIMOSA's coal production objectives after equipment modernization. For example, MIMOSA increased coal production by 48% from Mine II after 1992. This increase in production and the implementation of methane drainage increased total mine methane emissions by 43%. The degasification system served to decrease methane emissions diluted by the ventilation system by 6 %. To sustain the increased production and increase in methane emission rates mine ventilation demand increased by 17%. Note that all comparisons are based on data between 1988 and 1997. In 1997 Mine II was expanded by connection to workings of Mine I. Figure 5 illustrates the effects of methane drainage and increased coal production on mine airflow demand for Mine II during this period.

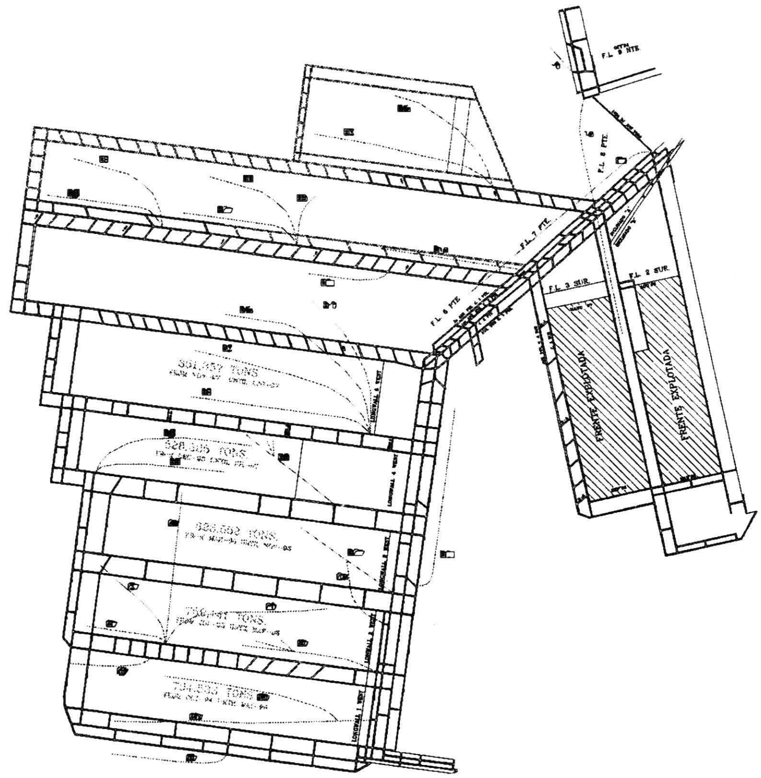

Figure 2. Program of degasifcation at MIMOSA's Mine II.

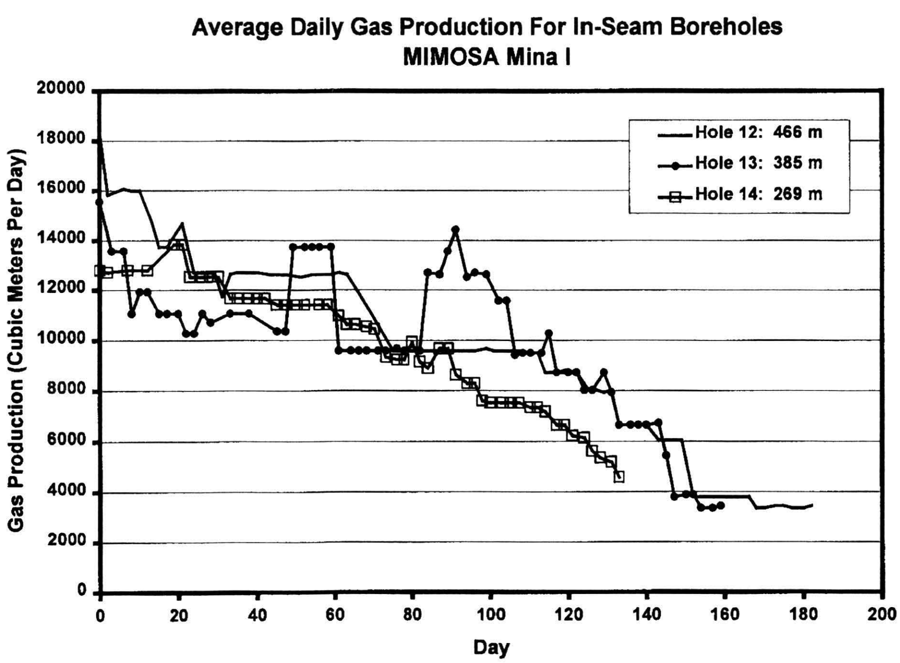

Figure 3. Average daily gas production from three boreholes drilled in Mine I.

Degasification Efficiency

The methane drainage systems implemented in Mines I and II recover approximately 33% of total methane emissions from these mines, or over 32.5 Mm^3 (1.14 bcf) of methane per year. Drained gas is vented to the atmosphere at each mine at average concentrations of over 85% methane in air. The gas is diluted slightly by air contamination through the collection system which is operated under vacuum.

CONCLUSIONS

Since 1992, MIMOSA has implemented over 26,500 m (87,000 ft) of in-seam borehole to reduce methane contents in advance of mining at four of its five mines. Applying this system in advance of gate entry developments has enabled MIMOSA to increase development advance rates, and reduce development ventilation requirements. In conjunction with new, modern longwall and section mining equipment, MIMOSA has been able to increase coal production at its gassiest mines by 55%.

Lessons Learned

MIMOSA has gained invaluable experience with in-seam degasification systems, including planing of borehole locations, gas collection system requirements, and coordination with mining operations.

Borehole Locations. From the initial reservoir simulation analyses, and supported by field measurements and experience, long in-seam boreholes are very effective at reducing in-situ gas contents over short periods of time. This lead to implementation of drilling activities just outby active mining sections for immediate relief. This impacts drilling productivity (sharing of utilities, etc.) and reduces the effect of the in-seam boreholes because of reduced drainage time. Mining personnel now realize the benefits of planning drilling operations significantly ahead of any mining activity where possible.

Also from experience, mine personnel have determined borehole spacing requirements based on time available for degasification. For immediate results and short degasification times, spacings of less than 150 m (500 ft) are used. Additionally, to improve drilling productivity and the time required to put a borehole on production, MIMOSA selects drilling locations where more than one borehole can be installed. This minimizes time and coordination efforts with mining operations for equipment movement and installation of gas collection pipeline.

Gas Collection Systems. MIMOSA personnel recognize that safety systems on methane collection equipment with valves to shut-in boreholes or sections of gas gathering line are imperative to mine safety. Breech of collection systems can release high volumes of methane into mine ventilation return entries. MIMOSA personnel are installing a pneumatic wellhead shut-in and pipeline safety system.

Coordination with Mining Operations. MIMOSA personnel have learned that proper coordination and communication with mine operations personnel are vital to achieving desired methane drainage system efficiencies and methane drainage benefits. Because of utility and personnel demands during drilling, and personnel demands for equipment relocation and pipeline installation and maintenance, and changes to coal production plans, MIMOSA methane drainage personnel appraise coal production personnel of all activities and together coordinate methane drainage plans. MIMOSA has learned that a close working relationship with mine production personnel is necessary to implement an effective system of in-seam methane drainage.

Future Plans

In 1998 MIMOSA implemented a program of coalbed methane exploration involving vertical production wells. Pending results of this program, MIMOSA plans on producing methane in advance of mining at its concessions in the Sabinas and Saltillito sub-basins, possibly for power generation. MIMOSA is looking at use alternatives and is aware of the deleterious affects of venting methane from its mines. Coalbed methane use options will incorporate the methane drained from the underground mines.

MIMOSA plans to continue implementation of in-seam efforts to solve immediate methane problems at its underground mines. This system is presently under implementation at MIMOSA's newest operation, Mine V.

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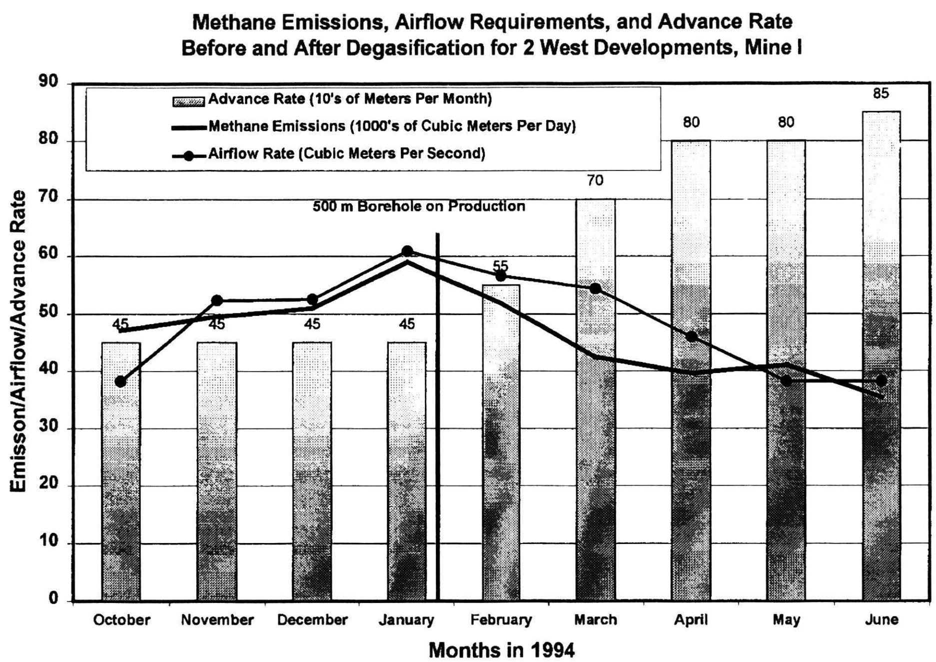

Figure 4. Impact of a 884 m (2900 ft) borehole on gate entry developments in Mine I.

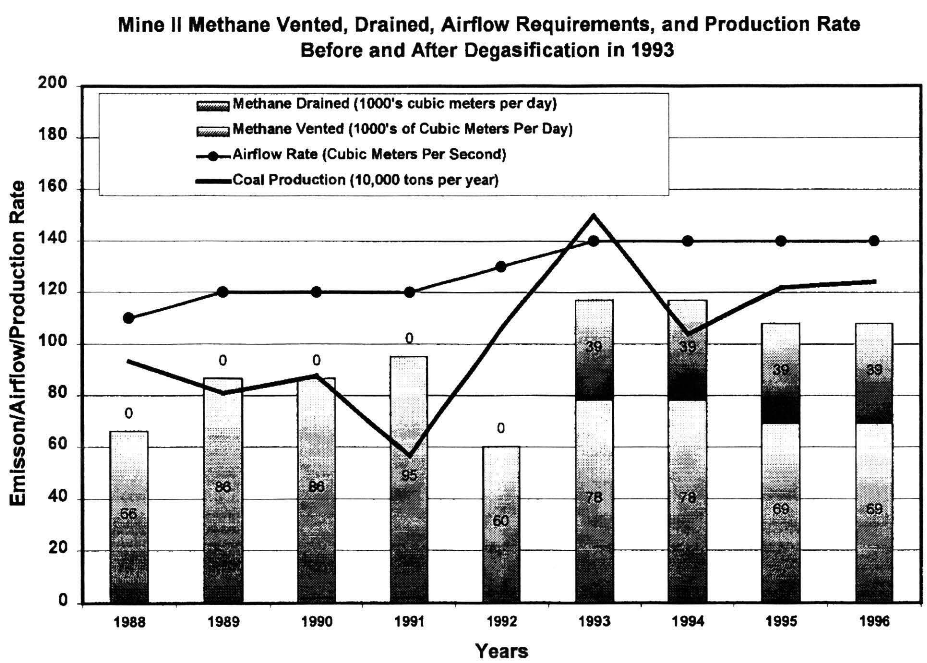

Figure 5. Impact of methane drainage and equipment modernization on coal production and mine ventilation requirements for Mine II.