THE RECOVERY AND INVESTIGATION OF THE EXPLOSION AT THE ENDEAVOUR COLLIERY

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ABSTRACT

The Endeavour Colliery is operated by Powercoal PTY Ltd. It is located in the Central Coast of New South Wales, Australia. The mine has been in operation for about 30 years, producing around 600,000 tons of export coal annually from two production sections. On June 28, 1995, an explosion occurred underground in the 300 Panel at approximately 9:50 a.m.. There were thirty miners underground at the time of the explosion, all of whom were safely evacuated.

From June 29 through July 10, personnel did not enter the mine. However, gas samples of the mine atmosphere were obtained from underground monitoring stations and analyzed. Samples were also obtained from boreholes that were drilled from an adjacent mine. On July 10, the atmosphere at the underground monitoring locations and at the boreholes appeared stable with minimal risks of combustion occurring underground. Plans were developed to begin the recovery of the underground workings. The recovery of the underground workings was completed on July 13.

The underground investigation of the explosion began on July 14. The investigation was conducted by the New South Wales Department of Mineral Resources. Technical assistance was provided by the United States Department of Labor's Mine Safety and Health Administration (MSHA).

BACKGROUND INFORMATION

Coal is mined by continuous miners and is transported by Joy 15SC shuttle cars to Fox feeder breakers from two production sections. Each section is about 7 kilometers (4.4 miles) from the pit bottom and works three 8-hour shifts per day. Coal is mined from the Great Northern seam which ranges in thickness from 1.8 meters (5.9 feet) to 3.5 meters (11.5 feet) with a normal working height of 2.5 meters (8.2 feet). Overburden ranges from 150 meters (492 feet) to 220 meters (722 feet). A continuous mining method was being utilized for partial pillar recovery at the time of the explosion. The immediate roof is a massive 30 meter (98.4 feet) thick conglomerate. There is no history of spontaneous combustion at this mine.

RECOVERY

Immediately after the explosion, the production crews from both the 300 and 406 Panels made their way to the rail end for transport to the surface. At this time, all underground employees were accounted for. A mine rescue team was contacted and immediately responded. A surface control center was established for continuous contact while men were underground.

A senior inspector for the Department of Mineral Resources, a district check inspector for the United Mineworkers Federation, a mine deputy, the undermanager-in-charge, and the manager were underground at the time of the accident. They proceeded inby from the rail end after the others were evacuated from the mine. They used Drager tubes to determine the extent of the carbon monoxide (CO) contamination. They also attempted to ascertain the extent of the damages in the 300 Panel.

Stoppings were found to be damaged inby the No. 42 crosscut of the No. 3 heading of Buff Left. Good ventilation was present from the Buff Left headings to the turn of the 300 Panel roadway. All stoppings into the 300 Panel appeared to be damaged. Ventilation quantities quickly diminished inby the No. 5 crosscut, where only a small flow of air could be detected traveling into the No. 5 heading. There was very little air movement. Five ppm of CO was detected inby the No. 5 cut-through. At the No. 8 crosscut of the No. 1 heading (return), 10 ppm of CO was detected. There appeared to be very little air movement, visibility diminished to about 20 meters (66 feet), and the smell of smoke became apparent. They decided to retreat to the surface of the mine. At this time, there were no persons remaining underground.

From June 29 through July 10, personnel did not enter the mine. During this period, gas samples of the mine atmosphere were obtained and analyzed. Samples were collected using the multi-point tube bundle monitoring system which gives readings at the surface of CO and methane concentrations from six underground stations. Samples were also obtained from boreholes that were drilled into the 300 Panel from the adjacent Munmorah Colliery. Gas analysis of the borehole samples was performed by the mobile laboratory of the Department of Mineral Resources.

The New South Wales Department of Mineral Resources contacted the United States Department of Labor's Mine Safety and Health Administration (MSHA) for technical assistance. On July 3, MSHA responded by sending two technical representatives from their Ventilation Division in Pittsburgh, Pennsylvania to New South Wales, Australia. MSHA's representatives assisted in the recovery and investigation of the explosion.

On July 10, the atmosphere at the underground monitoring locations and at the boreholes appeared stable with minimal risk of combustion occurring underground. Plans were developed to begin the recovery of the underground workings.

The recovery work was completed successfully to the Buff Headings ramp area. Some minor water accumulations were found in the Main South headings. Four ventilation controls in 8 West were found to have sustained severe damage causing considerable air leakage from the intake headings into the right return headings. A door in a ventilation control in Buff Headings was found to have sustained damage causing some air leakage from the intake headings to the left return headings. Air quantity measurements, taken at the 8 West air measurement station, indicated an airflow of approximately 52 cubic meters per second, m^3/s (110,000 cubic feet per minute, cfm), which was a reduction of 38 m^3/s (81,000 cfm) from the last measurements taken at that location in May. The highest concentration of methane encountered during the inspection was 0.9% in the Buff Left return headings.

On July 11 and 12, the atmosphere at the underground monitoring locations and at the boreholes remained stable. A plan was developed to advance the tube bundle gas monitoring location to the No. 12 crosscut in the No. 5 heading and to complete the examination of the 300 Panel. The team was to establish the status of the ventilation in the 300 Panel and evaluate the damage in the panel. They were to withdraw if either signs of continuing combustion occurred, if the methane concentration exceeded 4.0%, or if CO levels exceeded 5,000 ppm.

The recovery work was completed successfully. The tube bundle system monitoring location was advanced in the No. 5 heading to the No. 13 crosscut. The examination of the 300 Panel was completed. Various degrees of damage from heat and explosion forces were reported. No evidence of continuing combustion was observed. The highest methane concentrations in these headings was approximately 2.2%. An inspection in the inactive 304 Panel found over 4.2% methane in the headings adjacent to the gob.

INVESTIGATION

The physical examination of the underground areas of the mine began on July 13 with investigative teams entering the mine to examine and record the evidence. Critical information within the affected area was located and recorded on maps. This information was used to conduct an analysis to determine the causes of the explosion. Mine dust samples were collected in each of the headings and in a representative number of the crosscuts from the face area of the 300 Panel to a location just outby the mouth of the panel. A total of 201 mine dust samples were collected for laboratory analysis to determine the percentage of incombustible content and the presence of coke.

An investigation of the ventilation system was completed, including a pressure/quantity survey of the entire mine. It was necessary to determine the location and condition of the ventilation controls prior to the explosion. This data was used to develop a computer analysis of the ventilation system prior to the explosion.

DISCUSSION OF INVESTIGATIVE FINDINGS

General Mine Ventilation

Ventilation for the mine was provided through the men and materials drift and separate upcast and downcast shafts. The mine was ventilated by a single centrifugal fan on the surface. It exhausted 182.4 m^3/s (386,400 cfm) of air and operated at a water gauge of 108 mm (4.25 inches), as of May 30, 1995. A continuously recording fan pressure chart was not used at this mine.

The intake air was generally coursed to the active sections through two to five parallel headings. From the active sections outby to 8 West, the return air was coursed through three headings located on the left side of the Buff Headings. A single set of overcasts connected the left and right return headings in 8 West at the No. 13 crosscut. Return air was coursed through a single heading and a mined-out area on the left side of 8 West and through a mined-out area on the right side of 8 West. From 8 West to the bottom of the return shaft, the return air was coursed through single headings on the left and right side of Main South and through mined-out areas parallel to Main South.

Both production sections (406 and 300 Panels) used a dual split ventilation system with single return headings on each side of the section. Reportedly, in each production section, the quantity of air available for face ventilation was approximately 20 m^3/s (42,000 cfm) to 25 m^3/s (53,000 cfm).

According to the New South Wales Department of Mineral Resources, return airway maintenance was generally considered less than desirable. It was noted that the last accurate reading of ventilation quantities available in the 300 Panel were taken at least a month before the explosion. The readings apparently were only being taken to satisfy statutory requirements and not at more frequent intervals.

300 Panel Gob

A review of the map of the Endeavour Colliery indicates that a bleeder system was generally used in most areas where pillars had been recovered. However, a bleeder system was not being used in the 300 Panel. The lack of a bleeder system in the 300 Panel would have allowed methane, liberated during pillar recovery, to accumulate in the unventilated gob area adjacent to the working section. The accumulation and movement of any methane-air mixture in the unventilated gob area would be dependant on factors such as barometric pressure, elevation, temperature, roof falls, and the airflow from the active section. The ventilation system used in the 300 Panel was dependent on adequate airflow along the gob fringe to remove methane accumulations as they were released from the unventilated portions of the gob.

Concerning the absence of a bleeder return, the New South Wales Department of Mineral Resources reports the following:

1. Despite some extraction panels having been ventilated without bleeders, it was common practice at the colliery to ventilate gob areas with bleeder returns.
2. The pillar extraction area worked prior to the 300 Panel and in the

same region of the mine had been ventilated over and through the gob.

3. There was a change in the ventilation practice at the colliery from "through the gob" to "gob edge" ventilation for the period in which pillar extraction occurred in the 300 Panel, with a consequence absence of a bleeder return capable of maintaining the gob free of methane accumulations.
4. The approved plan indicated that formation of bleeder returns for a limited area of 300 Panel, outby the explosion site, was intended by cutting into the Buff headings.
5. Direct connection to the Buff headings proved not to be possible due to an accumulation of water.
6. An attempt to skirt around the water accumulation by driving extra roads outby was prevented by poor roof.

Ventilation History of the 300 Panel

The 300 Panel was located approximately 7 kilometers (4.4 miles) from the intake and return shafts. A dual split ventilation system was used in the 300 Panel. The right return heading was open from the mouth of the panel to the No. 22 crosscut and was unregulated. The left return heading was open from the mouth of the panel to the No. 18 crosscut. It was regulated by a partial check curtain between the Nos. 4 and 5 crosscuts. Air entered the left return from the gob at the No. 18 crosscut. The accessible portion of the gob between the Nos. 21 and 22 crosscuts and between the Nos. 18 and 19 crosscuts was partially filled with stow. The portion between the Nos. 19 and 21 crosscuts was partially blocked with roof falls.

A review was conducted of the Ventilation Officers Report and Measurements of Air Quantities and Methane Content record book for a one year period prior to the explosion. The record book refers to the 303 and 304 Panels. These panels are located on the right and left side, respectively, of the inby end of the 300 Panel. This review indicated that the airflow available for the 303 and 304 Panels ranged between 13.4 m^3/s (28,400 cfm) and 25.2 m^3/s (53,400 cfm). There were no significant trends during that time. The last intake air measurement in the 303 Panel, 25.2 m^3/s (53,400 cfm), was taken on May 31, 28 days prior to the explosion. Return air measurements indicated that this airflow was split evenly between the left and right section return headings, 12.4 m^3/s (26,300 cfm) and 12.8 m^3/s (27,100 cfm), respectively.

Measurements taken during the ventilation survey on June 28 indicated that the airflow available for the 300 Panel was approximately 30 m^3/s (63,600 cfm). The pressure differential between intake and return headings near the mouth of the 300 Panel was approximately 0.04 kpa (0.16 inches of water). At the time of the ventilation survey, the damaged ventilation controls in 8 West and in Buff Headings had been repaired. Temporary ventilation controls had been established into the 300 Panel. This resulted in an increase in airflow to the 300 Panel from that measured in May.

A higher quantity of airflow was present in the panel in the right return heading, 15.6 m^3/s (33,000 cfm), than in the left return heading, 7.5 m^3/s (15,900 cfm). Reportedly, the airflow in the panel was changed since the air measurements were made in May, with the airflow reduced in the left return heading. The restrictions in the left return inby the No. 18 crosscut may have also contributed to the change in airflow.

A review of the comments of the survivors indicated that there was good airflow on the section prior to the explosion, but no airflow measurements were recorded since May 30.

The remanents of all the temporary ventilation controls or brattices, inby the No. 21 crosscut, were discovered during the investigation, except the brattice in the No. 1 heading. The condition of these controls prior to the explosion could not be determined from these remanents. However, all of these temporary ventilation controls were reported by mine officials and check inspectors to be intact and in good condition prior to the explosion. Staples found on the posts in the No. 1 heading near the No. 22 crosscut tend to support these reports. These controls were important to dilute and render harmless methane liberated from the active face and to carry away methane liberated from the gob edge in this type of system. These controls have impact on the ventilating current and the methane levels along the fringes of the gob.

Methane History in the 300 Panel

It was reported that methane at this mine can be given off from the coal seam as it is mined. It can also be present from blowers in the roof or floor strata, or it can be associated with dykes and faults. Reportedly, in development work, the normal concentration of methane in section return airways is 0.3%. The methane concentration increases with pillar extraction and can reach 0.5%. The Ventilation Officers Report and Measurements of Air Quantities and Methane Content record book indicated the methane concentration in the return headings of the 300 Panel ranged between 0.2% to 0.8% for the one year period prior to the explosion. The last record in May, 1995 indicated 0.4%.

Reportedly, this mine does not have a history of sudden extensive releases of methane during mining operations capable of overwhelming the ventilation system. Typical evidence associated with these types of extensive releases of methane were not observed during the investigation.

Two days prior to the explosion, methane was encountered while driving a pillar split. This de-energized the continuous miner. In subsequent mining (and on more that one occasion) the methane monitor indicated 1.0% or greater when extracting a lift. On the shift before the explosion, the miner was withdrawn from the lift to prevent excessive concentrations of methane from de-energizing the machine.

After the explosion, statements were obtained from the survivors. George Gain, deputy, stated that he did not detect any methane and that the ventilation was good during the shift. However, he stated that it was possible to get 3% - 4% methane behind the brattice in the left hand gob.

Prior to the recovery, a number of boreholes were drilled from the Munmorah Colliery into the Endeavour Colliery in an attempt to determine the atmosphere inside the 300 Panel prior to recovery efforts. The results of samples taken from these boreholes indicated methane levels between 2% and 76%. Although some of these samples appeared to have been contaminated with strata gas liberated from the boreholes, methane had accumulated in the 300 Panel gob.

During the recovery efforts, methane concentrations of up to 2.0% were detected throughout the unventilated 300 Panel. In addition, concentrations of methane in excess of 5.0% were detected in the open headings adjacent to the 304 Panel gob.

During the investigation, ventilation was re-established in the 300 Panel using brattice stoppings up to the No. 18 crosscut. Methane concentrations were reduced in the 300 Panel to less than 0.2% On July 19, a roof fall in the gob occurred inby the No. 22 crosscut. Methane was pushed from the gob into the working places of the 300 Panel. Investigative team personnel in the area encountered methane concentrations approaching 2.0% in the No. 21 crosscut.

Ventilation Survey

From July 17 through July 20, a mine pressure - air quantity survey was conducted at the mine.

The survey was conducted as a joint effort of all parties involved in the investigation. The raw data collected during the survey was analyzed and balanced. The balanced data, coupled with data points from the characteristic curves of the main mine fan, was used to produce a mine ventilation network file. This is known as the trial balance.

The trial balance indicated that the main mine fan was operating near the upper end of its characteristic curve at 159.3 m^3/s (337,500 cfm) and 1.06 kpa (4.25 inches of water). The airflow inby the 8 West area was 98.0 m^3/s (207,700 cfm). The intake airflow at the mouth of the 300 Panel was 29.7 m^3/s (63,000 cfm). The airflow in the panel in the left and right return headings was 7.4 m^3/s (15,600 cfm) and 12.8 m^3/s (27,100 cfm), respectively. The available pressure differential at the mouth of the 300 Panel was 0.04 kpa (0.16 inches of water).

The airflow for the 300 Panel was found to be virtually unregulated. The regulator in the left return headings was constructed of brattice nailed to posts and had a negligible pressure differential across it. Minor changes to the ventilation system, such as roof falls, routine ventilation changes due to mining, and deteriorating ventilation controls could impact the ventilation of the 300 Panel.

The computer analyses indicated that the available pressure differential at the mouth of the 300 Panel was 0.04 kpa (0.16 inches of water) or less before the explosion. The condition of the ventilation controls in 8 West prior to the explosion would have significant impact on the available pressure differential in the 300 Panel. The available pressure differential is due in part to mine design and the distance between the 300 Panel and the intake and return shafts. The pressure differential across the ventilation controls, particularly at any check curtains in the Nos. 1 and 2 headings between the Nos. 21 and 22 crosscuts, would have been less than that available at the mouth of the panel. The pressure differential and airflow in this area affects the ability of the ventilation system to dilute and render harmless any outflows of contaminants from the unventilated gob.

The New South Wales Department of Mineral Resources interprets the principle findings of this survey to be as follows:

1. The colliery has a relatively high resistance to air flow.

2. The majority of the high resistance areas lay in the outby (older) half of the colliery.
3. Major return airways are so restricted that mine air seemed to flow through gob areas rather than through the design path.
4. The pressure available to ventilate face areas was small.
5. There was little reserve in the system to cater to abnormal conditions.
6. Roof falls were allowed to remain in the returns.
7. Gob areas were used as main returns.
8. Gob areas were allowed too close to vital ventilation roadways.

Ventilation Controls in 8 West

During the recovery efforts and the subsequent investigation, some of the ventilation controls between the intake and the right return headings in 8 West, located between the No. 6 crosscut and the No. 11 crosscut, showed various degrees of damage. The damage ranged from cracks on the Nos. 6, 9, and 10 controls to large portions being dislodged on the Nos. 7 and 11 controls. This allowed substantial quantities of air to leak from the intake headings directly into the return headings.

The review of the Ventilation Officers Report and Measurements of Air Quantities and Methane Content record book indicated no significant trends or reductions in the airflow at the 8 West measuring stations. The last measurement, 88.94 m^3/s (188,400 cfm), was taken on May 31, 28 days prior to the explosion. Simulation 1 indicated an airflow of approximately 96.5 m^3/s (204,400 cfm) at that location with the controls in 8 West in good condition. A measurement taken during the investigation totaled 51.6 m^3/s (109,300 cfm). This indicates that there was some leakage through the controls in 8 West when the air measurements were made in May. Reportedly, no maintenance was completed on these controls from May until the time of the explosion.

Survivors working in 8 West at the time of the explosion reported minor effects following the explosion. The No. 1 crosscut of 8 West is approximately 1800 meters (5,900 feet) from the last observable damage to controls in the 300 Panel. The overpressures in the 8 West area were not large enough to adversely affect ventilation controls maintained in good condition. This is evidenced by the number of unaffected controls in the area outby the 300 Panel. Rock dust barriers located at the mouth of the Buff Headings were unaffected by the forces of the explosion. There was no other explosion damage in the 8 West area. Therefore, the very poor condition of the ventilation controls in 8 West prior to the explosion allowed them to be adversely affected by small overpressures.

A review was conducted using the information from the computer analysis of the ventilation system and from the mine monitoring system. This review indicated that airflow at the upcast shaft increased approximately 9.7 m^3/s (20,600 cfm) as a result of the explosion. The concentration of methane at the upcast shaft shows a marked decrease. The airflow and methane concentration from the left returns in Main South increased slightly after the explosion. The airflow from the right returns in Main South increased and the methane concentration decreased significantly after the explosion. The airflow and methane concentration at the other sampling points remained relatively unaffected. The airflow and methane concentration in the left return headings of the Buff Headings would have decreased significantly after the explosion. The airflow from the left return headings of the Buff Heading splits with a portion coursed over the 8 West overcasts to the right return headings of Main South and the balance going to the left return headings of Main South. With the 8 West controls generally intact prior to the explosion, slightly over fifty percent of the air in the Buff Headings would have been coursed over the 8 West overcasts. Subsequent to the explosion and with the controls in the condition observed during the investigation, only about five percent of the air would have coursed over the 8 West overcasts.

It is concluded that the decrease in the methane concentration at the upcast shaft is a direct result of the short circuits to the ventilation system caused by the explosion, both in the 300 Panel and in 8 West. The decrease in the methane concentration at Stations 2 and 6 is due to the short circuit in the ventilation system caused by the failure of the ventilation controls in the 8 West area.

In summary, the condition of the controls in 8 West had an effect on the amount of airflow and pressure differential available to the 300 Panel. Prior to the explosion, these controls were generally intact but in very poor condition and leaking.

Methane Movement

Methane can accumulate in unventilated areas of underground coal mines. Except for the fringes, the gob area in the 300 Panel was unventilated. Due to the elevations within the panel, methane would tend to migrate towards the face where it would mix with the return air and be carried from the mine.

During a roof fall, methane was pushed from the gob into the working places of the 300 Panel. The ventilation system did not prevent the inrush of methane onto the section and it was not capable of diluting this methane to below explosive levels. During the roof fall, the restrictions in the left return inby the No. 18 crosscut would have caused a greater amount of displaced gases to flow through the temporary ventilation controls or brattices in the Nos. 1 and 2 headings into the No. 21 crosscut.

Barometric Pressure

The barometric pressure was obtained from a recording barometer maintained in the mine office. A drop in the barometric pressure occurred in the hours prior to the explosion. This may have increased the methane liberation and the likelihood of methane migrating from the gob toward the faces of the 300 Panel.

Coal Dust, Loose Coal, and Rock Dust

The New South Wales Coal Mines Regulation Act of 1982 presents regulations governing the application of rock dust in underground coal mines. Seams are designated as either Class A seams or as Class B seams depending on the occurrence of methane in the return airways. If the general body of air contains more than 0.1% methane, then the seam receives a Class A designation. The Great Northern seam at Endeavour Colliery is classified Class A.

Mine dust samples, taken during the investigation, were subjected to an incombustible analyses. Additionally, the coal was determined to be an explosive, medium-volatile, bituminous coal dust.

Extent of Flame and Forces

The extent of flame and the magnitude and direction of primary forces were determined. This information was used to determine the ignition source; the total quantity, concentration, and location of methane accumulations involved in the ignition; and the likelihood that coal dust contributed to the development and continued propagation of the explosion.

the incombustible content of many of the 201 mine dust samples were below 65%. All of the 201 mine dust samples were also analyzed for coking by means of the Alcohol Coke Test which indicates the presence or lack of coke in each particular sample. The results of the Alcohol Coke Test show that the only large quantity of coke existed in the No. 21 crosscut between the Nos. 1 and 2 headings. Additional large quantities of coke would be expected at inby locations if the explosion had originated in the gob. Therefore, these results indicate that the No. 21 crosscut was a likely point of origin of the explosion.

During a roof fall, methane was pushed from the gob into the working places of the 300 Panel. Ignition of approximately 6 cubic meters (200 cubic feet) of methane diluted to between 6% and 7% could result in the flame and forces experienced in the 300 Panel during the explosion.

In the Nos. 1 and 2 headings, flame involved a distance from the 300 Panel gob to a point just outby the No. 20 crosscut. A portion of the mine dust samples taken throughout this length of each heading or crosscut showed areas where sufficient incombustibles existed for extinguishment of the flame. There was apparently no flame propagation in any of the remaining headings. Similarly, flame did not reach the face area. The miners in that area did not report the effects of flame even though the incombustible content of the mine dust samples were insufficient in this area to prevent the involvement of coal dust in the explosion.

Flame involved a significant portion of the No. 21 crosscut in that it propagated from near the 304 gob to a point between the Nos. 3 and 4 headings. Also, the No. 20 crosscut experienced flame from the No. 1 heading to the No. 3 heading. Very limited flame extension occurred outby or adjacent to the No. 21 crosscut between the Nos. 1 and 3 headings.

During the propagation of the flame, the available methane at the ignition source was readily consumed. Also, several locations near the fringe of the flame zone contained enough incombustible material to prevent the involvement of additional fuel. These two factors prevented further propagation of the explosion. The extent of flame is consistent with the explosion originating in the No. 21 crosscut.

A determination concerning the magnitude and direction of primary forces was made after considering all force-related evidence located throughout the 300 Panel including but not limited to; damage to ventilation controls, deposition of dusts, the location of brattices, and the reported affects on the miners; and statements provided by survivors along with their physical condition following the explosion.

An explosion originating in the No. 21 crosscut would have caused forces on the brattices in the Nos. 1 and 2 headings in the inby direction. This indicates a point of origin outby the gob.

Although the surviving victims experienced the effects of the explosion, none suffered severe physical trauma. Some were reportedly knocked down by the forces. Evidence indicates that explosion pressures were about 27 kpa (4 psi) in the 300 Panel and about 4 kpa (0.5 psi) in 8 West. The evidence from the evaluation of the forces is consistent with the point of origin of the explosion being located in the No. 21 crosscut.

Potential Ignition Sources

The most likely ignition source was located in the No. 21 crosscut approximately between the Nos. 1 and 3 headings. The trailing cable and an associated coupling device from the No. 465 shuttle car were located in this area. This coupling device was located approximately 3 meters from the No. 3 heading in the No. 21 crosscut. The trailing cable and coupling device were taken during the investigation and was subjected to an electrical analysis by the New South Wales Department of Mineral Resources.

A large roof fall in the gob of the 300 Panel occurred prior to the explosion. The men working in the face area reported a windblast from the roof fall. The start switch on the No. 465 shuttle car became engaged causing the pump motor to start. The operator switched "off" the pump motor. He said that a blast came from an outby direction and propagated toward the gob.

The Electrical Investigation Report stated that "...findings are inconclusive as to the cause of the methane ignition,...".

Several faults were found on the cable from the No. 465 shuttle car, but these were not in the immediate vicinity of the Nos. 2 to 3 headings in the No. 21 crosscut. This included a broken earth conductor in the No. 3 heading. Also, a coupling device in the No. 21 crosscut near the No. 3 heading was found to be in non-flameproof condition. This coupling device appears to be the most likely ignition source.

Potential ignition sources in the gob include spontaneous combustion and roof falls. The mine has no history of spontaneous combustion. There was no evidence discovered to indicate the presence of spontaneous combustion in the 300 Panel.

Ignition of a methane accumulation results from the frictional heating that could occur during the roof fall or from piezoelectric discharges associated with the fracture of crystalline structures during a roof fall. The mine has no history of the ignition of methane from roof falls, however, its potential cannot be eliminated from consideration.

CONCLUSIONS

A bleeder system to remove hazardous accumulations of methane from the 300 Panel gob had not been established. The lack of such a bleeder system allowed methane to accumulate in the gob. During a roof fall, methane was pushed from the gob into the working places of the 300 Panel. The ventilation system did not prevent the inrush of methane onto the section and it was not capable of diluting this methane to below explosive levels. This explosive mixture of methane was most likely ignited in the No. 21 crosscut approximately between the Nos. 1 and 3 headings. The non-flameproof condition of a coupling device in the shuttle car cable appears to be the most likely ignition source. The ensuing explosion resulted in damage to portions of the 300 Panel, the 400 Panel, and in 8 West.