Table 3: Mining Conditions

Factor	Spontaneous Combustion Potential	Factor Ranking Criteria	Other Factors	Increased Self-Heating Risk	Output
Ambient temperature	high	>19 °C		high	Increased coal oxidation rate due to increased temperature.
	medium	>21 °C		moderate	
	low	>27 °C		moderate	
Coalbed thickness	high	>1.8 m		high	Large-quantities of coal left in worked-out or gob areas.
	medium	>3.1 m		moderate	
	medium	>1.8 m	friability >50	moderate	
Coalbed gradient	high	>5		moderate	Buoyancy and temperature gradient effects in worked-out areas.
	medium	>10		moderate	
Floor heave	high	>30		high	Air and water leakage into sealed areas, exposure of rider beds and pyrite deposits to air and water.
	medium	>30		moderate	
Floor heave potential	high	overburden >457 m	stiff pillar design: y-a or a-y	moderate	Do.
Rib sloughage	high	>30		high	Increased amounts of exposed coal surfaces liable to oxidation.
	medium	>30		moderate	
Rib sloughage potential	high	overburden >305 m	yield pillar design: y, y-y, or y-a-y	moderate	Increased amounts of exposed coal surfaces liable to oxidation.

Mining Practices

Mining practices are the only spontaneous combustion factors that can be directly controlled by the operator. The type of mining (longwall or room-and-pillar), recovery ratio, gateroad pillar design, the rate of advance or retreat, and panel dimensions are all important factors in determining the spontaneous combustion risk of a mining operation. These factors control the amount of coal exposed and the duration that the coal is exposed to air and moisture, and thus liable to oxidation. Other mining practices that affect the self-heating of coal are the face ventilation air velocities and the caving height of the gob. These factors influence the movement of air and moisture in the gob or worked-out area. These factors, their ranking criteria, the degree of self-heating risk, and the program output for each factor are shown in table 4.

Although neither longwall or room-and-pillar mining is inherently more risky than the other in terms of spontaneous combustion potential, longwall mining enhances many of the factors associated with self-heating. This is primarily due to the formation of the gob and its subsequent ventilation while mining the active panel. This can result in a situation where finely crushed fresh coal surfaces are exposed to slowly moving air. Whether a heating develops depends on several other factors, such as the amount of coal left in the gob, the rate of advance, and the reactivity of the coal.

Table 4.- Mining Practices

Factor	Spontaneous Combustion Potential	Factor Ranking Criteria	Other Factors	Increased Self-Heating Risk	Output
Recovery ratio	high	<0.95		high	Increased amounts of coal in gob liable to oxidation.
	medium	<0.8		moderate	
Pillar design	high	y, y-y, or y-a-y	longwall	high	Increased amounts of coal in gob due to pillar crushing, instability of gob seals.
	medium	..do	..do	moderate	
Rate of advance/retreat	high	<9.0 m/day	longwall	high	Build-up of heat behind supports due to longer residence time of gob coal in critical air velocity zone.
	medium	<4.6 m/day		moderate	
Panel dimensions	high or medium	panel width >229 m panel length >2287 m	longwall	moderate	Build-up of heat behind supports due to longer residence time of gob coal in critical air velocity zone.
Face ventilation leakage	high or medium	>0.94 m^3/s	longwall	high moderate	Increased exposure of coal to air due to leakage behind supports, critical air velocity zone pushed deeper into gob.
Caving height	high	>5 times average coalbed thickness mined	longwall	high	Increased air leakage into gob, intra-gob communication paths.
	medium	>7.5 times average coalbed thickness mined		moderate	

The recovery ratio affects the amount of coal left in a gob or other worked-out area, where spontaneous combustion usually occurs. The amount of coal left unmined from the coalbed depends on the coalbed thickness, roof and floor stability, and coal quality. The recovery ratio can be a factor in both longwall and room-and-pillar mining.

The gateroad entry stability also plays an important role in determining the spontaneous combustion risk in a longwall operation. Yielding designs create fresh coal surfaces as a result of pillar crushing, increasing the spontaneous combustion risk. In addition, yielding designs can affect the integrity of gob seals and lead to air leakage into the gob. In general, stiff designs reduce the risk of self-heating by minimizing pillar crushing. However, these designs can lead to rib sloughage and floor heave.

The rate of advance or retreat is critical in controlling self-heating in a longwall operation. During longwall mining, the leakage of air behind the roof supports may expose a zone of fresh coal surfaces to slowly moving air, depending on the amount of coal left in the roof or floor, resulting in oxidation and the generation of heat. In general, leaving large amounts of coal in the worked-out area increases the risk of self-heating, by providing the fuel source exposure to the slowly moving air. As the face advances or retreats, this zone

moves with it, preventing the buildup of heat in any specific area. However, if the rate of advance or retreat is slowed or stopped, a buildup of heat leading to spontaneous combustion may occur.

The size of the longwall panel, particularly the width, is an important parameter in the rate of face advance or retreat. The wider the longwall face, the slower the rate of advance, and the longer the coal in the area being ventilated behind the face supports is exposed to the airflow.

The amount of air leakage behind the face supports depends on the caving characteristics of the gob and the face ventilation rate. Very tightly consolidated gob restricts the flow of air through the gob material, reducing the risk of self-heating behind the face supports. Large caving heights can lead to the establishment of intra-gob communication paths, which can allow air and water migration to sealed areas.

SUMMARY

The SPONCOM expert system was developed by the USBM to aid mining operators, regulatory bodies, and consultants in the assessment of the spontaneous combustion risk of an underground mining operation. To develop the program, information was gathered and correlated with the USBM's experimental studies to form the knowledge base for the program. The program is designed to obtain information from the user on the coal properties, geologic and mining conditions, and mining practices. The program determines the coal's spontaneous combustion potential and what effect the coal properties, geologic and mining conditions, and mining practices have on the spontaneous combustion risk of the mining operation.

REFERENCES

Anon. American Society for Testing and Materials. Standard Classification of Coal by Rank. D 388-82 in 1983 Annual Book of ASTM Standards: Section 5, Petroleum Products, Lubricants, and Fossil Fuels: V. 05.05, Gaseous Fuels; Coal and Coke, Philadelphia, PA, 1983, pp. 240-244.

Banerjee, S. C. A Theoretical Design to the Determination of Risk Index of Spontaneous Fires in Coal Mines. J. Mines, Met. and Fuels, August 1982, pp. 399-406.

Battacharya, S. K. 'D' System Classification of Coals in Respect of Spontaneous Combustion. J. Mines, Met. and Fuels, April 1982, pp. 185-186.

Feng. K. K., R. N. Chakravorty, and T. S. Cochrane. Spontaneous Combustion--A Coal Mining Hazard. CIM Bull., v. 66, No. 738, 1973, pp. 75-84.

Kim, A. G. Laboratory Studies on Spontaneous Heating of Coal: A Summary of Information in the Literature. BuMines IC 8756, 1977, 13 pp.

Pomroy, W. H. and A. M. Carigiet. Analysis of Underground Coal Mine Fire Incidents in the United States From 1978 Through 1992. BuMines IC 9426, 1995, 25 pp.

Singh, R. N. A Practical System of Classifying Coal Seams Liable to Spontaneous Combustion. J. Coal Quality, July 1986, pp. 108-113.

Singh, R. N., B. Denby, and T. Ren. A Knowledge-Based Expert System for Assessing Spontaneous Combustion Risk in Longwall Mining. Min. Sci. and Tech., v. 11, 1990, pp. 45-54.

Smith, A. C., and D. G. Richard. An Expert System for the Prediction of the Spontaneous Combustion Potential of Coal. Paper in Proceedings of the 9th Conference, International Coal Testing Conference (Lexington, KY, Mar. 17-19, 1992). Stand. Lab., Inc., Ashland, KY, pp. 63-67.

Smith, A. C., and C. P. Lazzara. Spontaneous Combustion Studies of U.S. Coals. BuMines RI 9079, 1987, 28 pp.