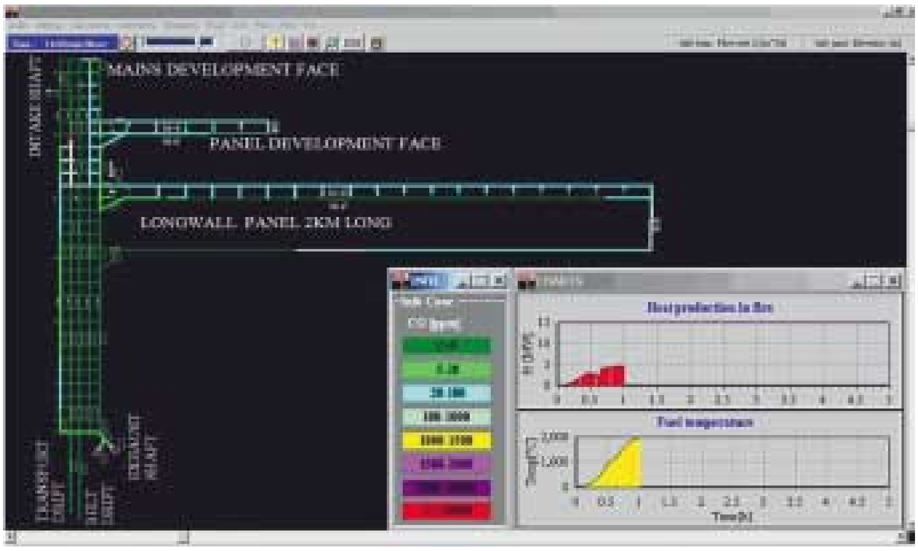


Figure showing a ventilation reversal during a mine fire simulated in a typical Australian underground coal mine layout using longwall extraction method

Coal dust and methane

In the USA, the National Institute for Occupational Safety and Health (NIOSH) does a lot of work and has provided news of interesting new developments. Marcia L. Harris describes an 'Explosibility Meter: "In underground mines, coal dust explosions are prevented by the addition of rock dust sufficient to render the coal dust inert. Federal [US] regulations require 65% and 80% incombustible content in samples taken in intake airways and return airways, respectively, assuming a nominal coal dust size of 20% minus 200 mesh. The Coal Dust Explosibility Meter (CDEM), a hand-held instrument developed by NIOSH uses optical reflectance to measure the explosibility of a rock dust and coal dust mixture." The CDEM is now commercially available.

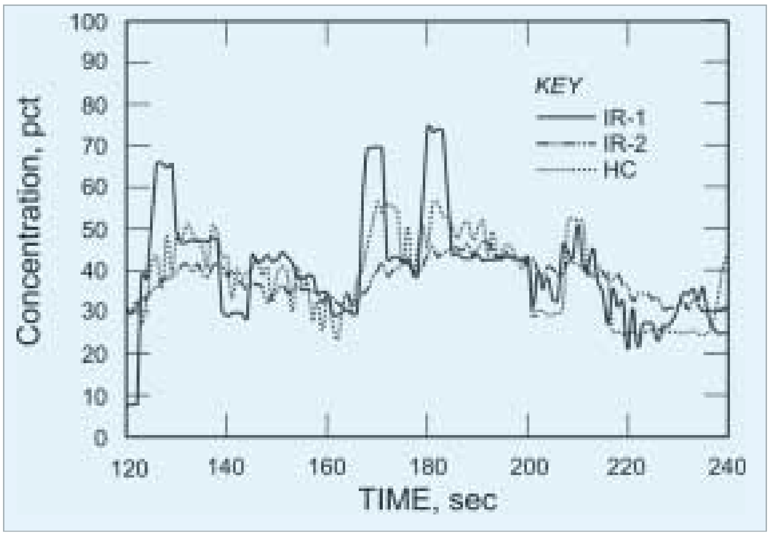
It provides real-time results during rock dust surveys instead of waiting weeks for laboratory results[1]. "With real-time results, the potential for a disaster can be mitigated immediately. The CDEM displays the percent incombustible content as well as a colour indicating the relative explosibility of the coal and rock dust mixture. A red read-out indicates that more incombustible material is required to inert the coal and rock dust sample, while a green read-out indicates that the dust sample is sufficiently inert. When the mixture is marginally explosible, a yellow read-out is indicated. The red-yellow-green output depends upon the particle size distribution of the rock and coal dust mixture with the finer size fraction being more explosible."

The currently approved method for determining the incombustible content present within an entry in the USA is to collect a band sample and send it to a laboratory for low temperature ashing (LTA). The process, from obtaining samples to reporting the analytical results, typically takes several weeks. Thus, inadequate inerting may exist for some time before the laboratory results could show that additional rock dusting is necessary.

NIOSH personnel accompanied Mine Safety and Health Administration (MSHA) inspectors on routine band surveys in five underground coal mines in southwest Pennsylvania. While underground, they used the CDEM to assess the explosibilities of the dust samples. "The percent incombustible contents determined by the CDEM agreed well with those values obtained later by LTA at MSHA and NIOSH laboratories. Among these intake entry samples, 92 out of 104 had ≥65% incombustible content as required by current regulations. However, the CDEM indicated that 27 of these 92 samples were within the red or yellow bands, suggesting that about a quarter of the samples may have been deficient in incombustible content. Mine areas represented by these samples would most likely not receive additional rock dust since they were compliant with current regulations. Yet according to CDEM analyses, these samples represented areas of the mine where a risk of explosion propagation was present and more rock dust was required. These samples likely had size distributions finer than the 20% minus 200 mesh assumed in the federal regulations and, for this reason, were indicated as potentially explosible[2].

The use of infrared sensors for monitoring methane underground is examined by C.D. Taylor, J.E. Chilton and A.L. Martikainen. They note that "infrared and catalytic heat of combustion sensors are commonly used for measuring methane, but only the latter are currently used on mining

machines in underground coal mines. A series of tests was performed to evaluate the feasibility of infrared instruments for underground use. A test box and a full-scale ventilation test gallery designed by NIOSH were used to compare the performance of one heat of combustion (HC) and two infrared (IR-1 and IR-2) sensors. Response times were measured using the test box. The 90 % response time for the heat of combustion sensor (HC) was 18.5 s and corresponding readings for the infrared instruments, IR-1 and IR-2, were 9.8 and 32.5 s respectively.

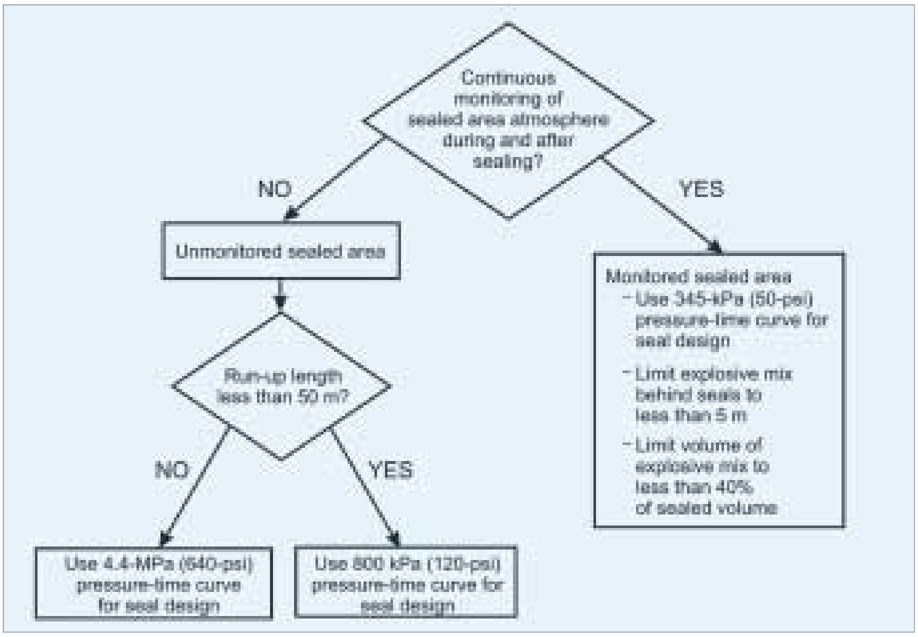


Real-time methane levels obtained on the mining machine

“Further testing in the box showed the large difference in response times for IR-1 and IR-2 was due to the design of the environmental caps. Both caps have plastic baffles to lessen the amount of dust and water reaching the infrared sensor heads. The IR-2 instrument also has a filter material inside the cap to provide increased protection for the sensor. The filter material slowed the diffusion of gas through the cap and was responsible for the increased response time.”

Tests were conducted in the ventilation test gallery to determine how different response times would affect methane measurements made on a continuous miner. A model machine was located at the gallery face. The instruments were placed side-by-side on the top of the machine, 2.6 m from the face. Intake and machine scrubber flows were varied to provide six different test conditions. For each of the ten minute tests, the average readings obtained with the three instruments were approximately the same. However, the concentrations varied considerably during each test. The figure shows real-time instrument measurements obtained during part of one test. “In general, the faster the instrument response time, the faster the concentrations changed and the higher the peak values measured.

“Concentration patterns measured one foot from the face of the gallery were similar to those measured on the machine except that the peak and average concentrations at the face were much higher. It was not possible to correlate the changes in concentrations occurring at the face and on the machine. However, it is likely that the fastest response instrument (IR-1) provided the best estimates of real-time changes in concentration at the face. Long-term underground testing is necessary to determine if the faster response instruments (IR-1 and HC) provide adequate protection for the sensor heads or if the improved protection of the IR-2 environmental cap is required when using a sampling instrument on a mining machine.”



Flowchart for selecting design pressure-time curve for new seals.

R. Karl Zipf, Jr is a NIOSH Senior Research Mining Engineer, Michael J. Sapko is Principal Research Physical Scientist (retired) and Jürgen F. Brune is Principal Research Mining Engineer. They consider NIOSH Information Circular–9500: *Explosion Pressure Design Criteria for New Seals in U.S. Coal Mines*. Seals are barriers constructed to isolate abandoned mining panels or groups of panels from the active workings.

Historically, mining regulations required seals to withstand a 140-kPa explosion pressure. The Mine Improvement and New Emergency Response Act (MINER Act) required MSHA to increase this design standard. MSHA published the new design standards Sealing of Abandoned Areas; Final Rule on April 18, 2008." The NIOSH Information Circular published July 2007 provides the scientific and engineering justification behind the three-tiered explosion pressure design criterion in the new design standards. It is available at http://www.cdc.gov/niosh/mining/pubs/pdfs/2007-144.pdf.

"NIOSH engineers considered the explosive atmospheres that can accumulate within sealed areas and used thermodynamic calculations and simple gas explosion models to estimate worst-case explosion pressures that could impact seals. Three design pressure-time curves were developed for the dynamic structural analysis of new seals under the conditions in which those seals may be used: unmonitored seals where there is a possibility of methane-air detonation or high-pressure non reactive shock waves and their reflections behind the seal; unmonitored seals with little likelihood of detonation or high-pressure non reactive shock waves and their reflections; and monitored seals where the potentially explosive methane-air volume is limited. The diagram below is a simple flowchart that illustrates the key decisions in choosing between the monitored or unmonitored seal design approaches and the three design pressure-time curves.

"For the first condition, an unmonitored seal with an explosion run-up length of more than 50 m, the possibility of detonation or high-pressure non reactive shock waves and their reflections exists. The recommended design pressure-time curve rises to 4.4 MPa and then falls to the 800-kPa constant volume (CV) explosion overpressure. For unmonitored seals with an explosion run-up length of less than 50 m, the possibility of detonation or high-pressure non reactive shock waves and their reflections is less likely. A less severe design pressure-time curve that simply rises to the 800-kPa CV explosion overpressure may be employed. For monitored seals, engineers can use a 345-kPa design pressure-time curve if monitoring can ensure that (1) the maximum length of explosive mix behind a seal does not exceed 5 m and (2) the volume of explosive mix does not exceed 40% of the total sealed volume. Use of this 345-kPa design pressure-time curve requires monitoring and active management of the sealed area atmosphere.

"NIOSH engineers used these design pressure-time curves in the Wall Analysis Code from the US Army Corps of Engineers to develop design charts for the minimum required seal thickness to withstand each of these explosion pressure-time curves. These preliminary analyses show that seal designs to resist these curves can be achieved using common seal construction materials at reasonable thickness. Successful implementation of the seal design criteria and the associated recommendations in this report for new seal design and construction should significantly reduce the risk of seal failure due to explosions in abandoned areas of underground coal mines.

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1. Sapko, M. J., and Verakis, H., 2006. Technical Development of the Coal Dust Explosibility Meter. SME 2006 Annual Meeting, St. Louis, MO, March 26-29, 2006, Preprint 06-044.

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