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Remote Fiber Optic Methane Detection System

Technical Paper

METHANE PROBLEM IN MINES

Methane gas is generated during the mining process and must be controlled to levels below 2% for worker safety. This methane emitted from various sources such as the mine roof or floor can populate active or remote areas, build to dangerous levels, and then migrate with air movement undetectable to mine operations. Sensing systems used in coal mines today can provide point data for methane levels via handheld gas detectors and remote point sensors but all these methane detection systems require electrical power at the sensing unit and periodic calibration, making them impractical for use in the remote and closed areas of the mine.

METHANE SENSING SYSTEM OVERVIEW

RSL Fiber Systems developed a self calibrating, fiber optic based system that can be used for coal mine-wide remote methane monitoring, significantly increasing safety and reducing workload by eliminating the need for a miner to travel the mine and take manual methane concentration readings on a regular basis. In addition, the ability to sense in the mined-out sealed areas of the mine can generate data on methane emissions to be used in anticipating the ventilation demands of the mine.

A remote fiber optic methane detection system from OptoSci Ltd., Glasgow, Scotland, used in landfills and tunnels to monitor methane and natural gas was adapted by RSL for use in coal mines under a National Institute of Occupational Safety and Health (NIOSH) Research project. The system performed flawlessly in the lab and during the In-Mine trials. Despite long-term exposure to a very demanding environment, there was no system degradation or failure. The field trials verified that the system is unaffected by common mine conditions including high humidity, anaerobic conditions, and the presence of other non-target gases which can cause erroneous readings with many other sensor types. Other system features include:

- Methane detection levels sensitivity from 0.05% to 100%.
- Tolerance to dust contamination and full functionality at signal losses of up to 90%.
- Remote self calibration before each sensing measurement.
- Hundreds of sensing points at distances of up to 20 km from a central control unit.
- Low power (10mW) diode laser with a distributed single mode fiber network.
- Individually addressable ruggedized optical sensor modules.
- Intrinsically safe within the mine environment.

The fiber optic remote methane sensing system can be combined with a mine wide monitoring system to detect the formation, movement, and concentration of methane clouds, and provide a display on the Human Machine Interface (HMI). This will alert the mine operators to the presence of methane and allow the operators to monitor the methane levels and flow as it is being ventilated from the mine.

SYSTEM DESCRIPTION

The Remote Fiber Optic Based Mine Wide Methane Gas Monitoring System is based on three (3) technologies:

- Remote fiber optic methane sensors;
- Distributed fiber optic network;
- Mine wide control system.

Remote Fiber Optic Methane Sensors

The remote fiber optic methane sensors are connected to a central control unit (CCU) via a single mode fiber optic network to provide real-time, all-optical, methane gas monitoring at hundreds of points, up to 20 km from the CCU. This remote sensing technology is based on Tunable Diode Laser Spectroscopy (TDLS). On each scan, the narrow linewidth laser sends the optical sensor a signal "tuned" at a wavelength within the methane absorption range as well as a signal at a wavelength outside the methane absorption range for referencing purposes. As the laser is tuned through the gas absorption line, the light is absorbed in proportion to the gas concentration and analyzed at the CCU. The system provides high methane gas sensitivity with a wide measurement range (0.05% to 100%), exceptional gas selectivity, no gas cross-sensitivity, rapid response (<2 seconds to update readings from 100's of sensors simultaneously); is unaffected by anaerobic conditions, catalytic poisoning, other non-target gases, and excessive humidity. The very low power laser signal (10's of microwatts) transmitted through each sensor makes the system inherently safe for use in coal mines.

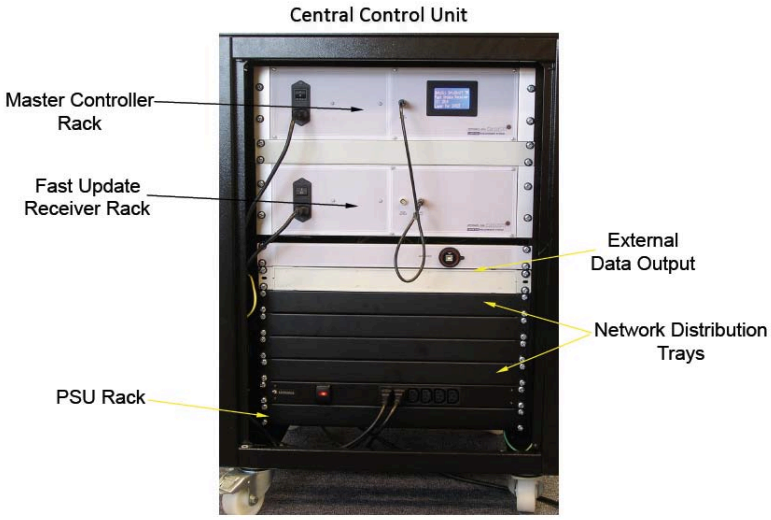

Figure 1: Remote Fiber Optic Methane Sensor Central Control Unit

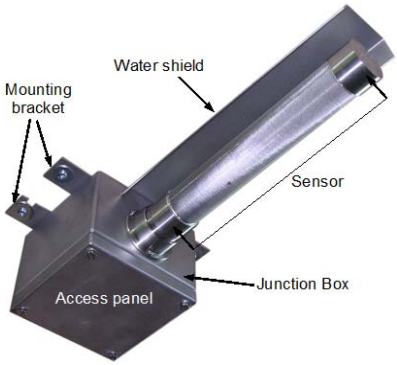

Figure 2: Remote Optical Methane Sensor and Junction Box

As only optical signals are transmitted through the optical network and sensors, the system is totally electrically passive outside the CCU (located in the mine control room). The gas sensing technique is self-referencing, providing inherent calibration stability, requiring a single, one off calibration at the CCU and never requiring calibration at the remote sensors location. An automatic system self-checking function at the CCU gives advanced warning of any potential controller, network, or sensor problems and allows a predictive maintenance protocol to be established.

The plug-in modular format allows for ease of component replacement and rapid system expansion. The system has undergone full testing & certification to IECEx and ATEX requirements.

Distributed Fiber Optic Network

A fiber optic network is used to split and transport the laser signal to potentially hundreds of remote sensors and transmit the return signal back to the CCU. The network uses standard communications grade single mode optical fibers. The system's cables and the interconnect components are of a construction that minimizes the losses to allow for the long distance between CCU and sensors whilst maintaining the accuracy of the signals.

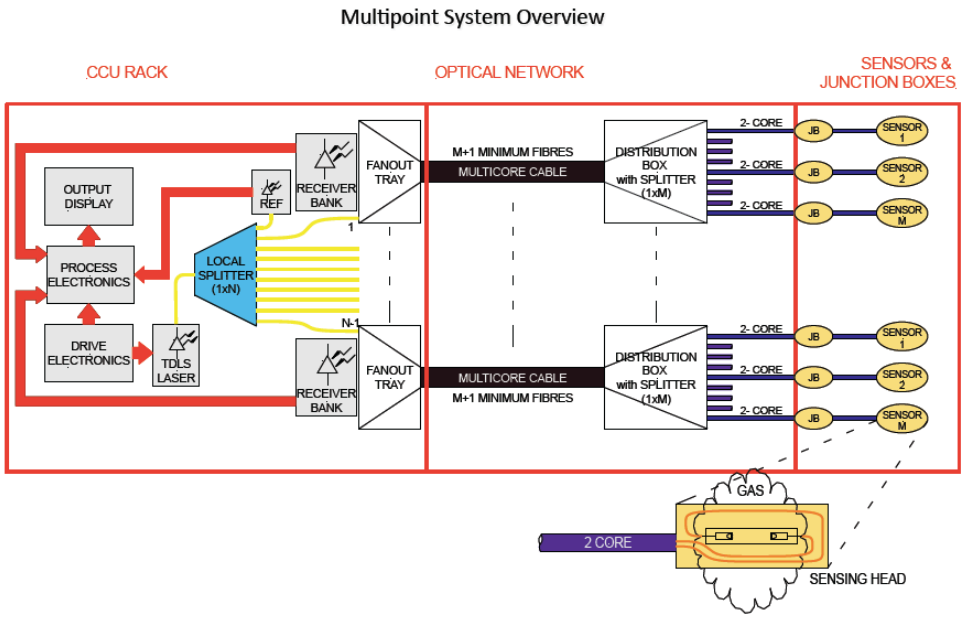

Figure 3: Methane Detection System Architecture

Mine Wide Control and Monitoring System

The methane detection system is designed to be integrated into the mine wide control and monitoring system, providing near real time information on the conditions of the mine environment and the mining equipment via a HMI in the mine control room and at other remote locations. Alarms can be programmed if certain conditions occur, prompting the mine operator to take the required actions. The mine wide system integrates multiple controls and data signals into one single system and display, with the ability to obtain more detailed information on any function being monitored and for specific areas of the mine.

SYSTEM BENEFITS SUMMARY

The remote fiber optic methane sensors do not require electricity to operate and are calibration stable, addressing the key drawbacks with the sensing technologies currently in use in coal mines. Multiple sensors can be placed at different locations including closed off, inaccessible areas of the mine. The information provided by the sensors to the CCU can be displayed on the mine wide control and monitoring system to track the formation and movement of the methane cloud. Figure 5 shows the possible placement of sensors in the Longwall area.

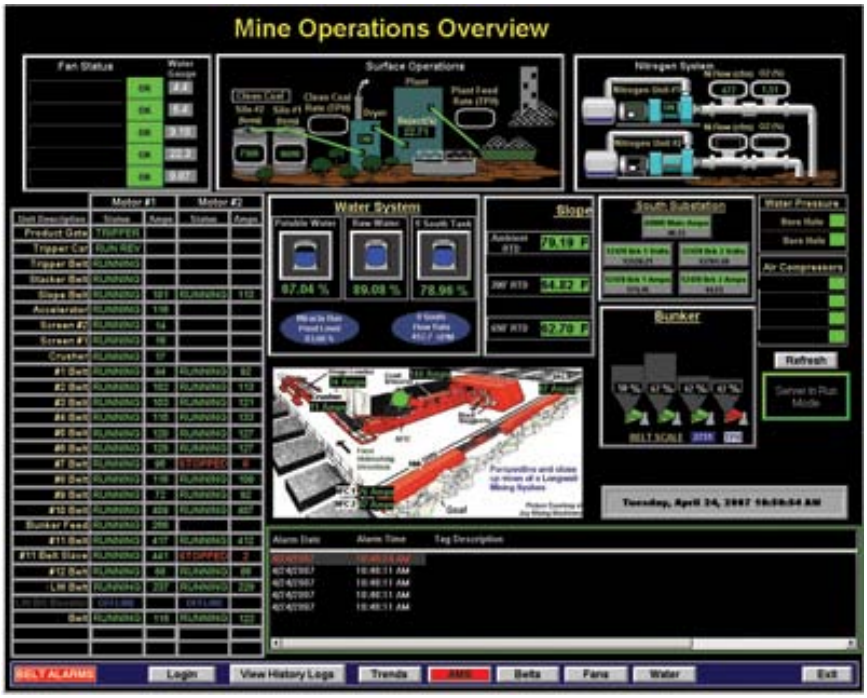

Figure 4: Typical Mine Wide Control and Monitoring System – HMI (© Pillar Innovations)

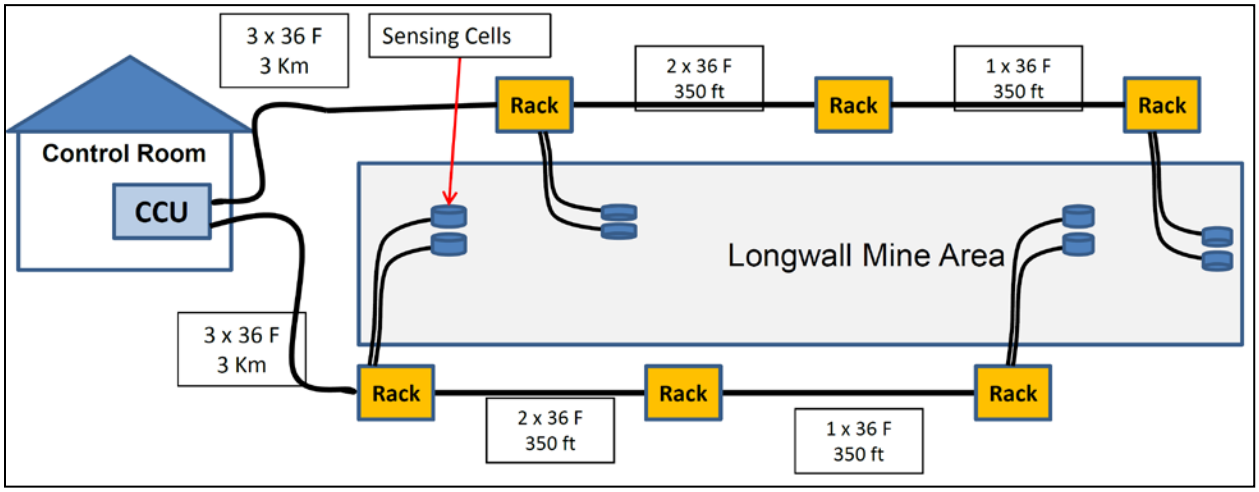

Figure 5: Methane sensing system in Longwall Mine

RSL Fiber Systems, LLC develops, manufactures, and integrates, advanced fiber optic systems for challenging illumination and sensing solutions. RSL is the recipient of multiple grants from the US Navy Office of Naval Research and is the sole source provider of the topside lighting system for the US Navy DDG 1000 stealth destroyer class. The Company recently completed the development and adaptation of remote fiber optic methane sensing and temperature sensing systems for use in coal mines through a grant by the National Institute of Occupational Safety and Health.