

Early detection of smouldering fire in close proximity of conveyerbelt systems

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Through selected preventive measures it was possible to radically lower the number of fires in the mines at the RAG stock company in Herne.

Nearly all open fires in mines are caused by external supplied ignition. The most frequent sources of a fire are disturbances in active conveyer belt systems. A few examples include stuck, defective wheels, graters, grinding of the belt and slip of the belt or belt misalignment.

In spite of all the security technology currently used in conveyer belt systems, it is still not possible to prevent the ignition of all coal smouldering fire in close proximity to conveyer belt systems. Such a mine fire occurred on march12th 2005 in gate road 4320 of the Prosper Haniel mines in Bottrop. This fire was caused by an ignition of coal smouldering fire below the conveyer belt. Therefore it is of primary importance that smouldering fires are detected and fought at an early stage before developing to an open mining fire.

State of the art

For the early detection of fire, not only a inter-regional CO-monitoring in the whole mining buildings is applied, but additional CO-measuring devices along the conveyerbelt systems. The additional CO-warning devices for short range room control act as early fire detection, especially in drive- and sweep areas as well as transfer stations. Smouldering fire of slack coal shall be identified at a CO-emission of 10 l/min (2). Such a CO-emission is released at a fill of smouldering coal dust of 0,25 sqm (3). Through this CO- concentration is deluted in very high air until below the detection limit. At a CO-emission of 10 l/min the theoretical CO-concentration at an air of 1000 cm/min

about 10 ppm, at an air of 5000 cm/min just 2 ppm (4). This means that a smouldering fire only slightly increases the CO-value in the air

so that it can not be detected as a fire by conventional CO-Measurement. Only at bigger fires a warning is made by the CO-measurement. Therefore a safe early detection of smouldering fire at bigger volumes of airstream is not always for sure. Tests have shown, that fire performance of conveyerbelt systems at a higher airflow are obviously declining and a belt in V-quality can burn down completely. The smouldering fire at the belt changes into combust due to the speed of the airflow of more than 3m/s. Just the use of a stationary measuring unit is not a satisfactory solution of the problem. As there is barely smoke visible at a smouldering fire of slack coal, which is also heavily deluted in a high volume of airstream and the self extinguishing properties of the conveyerbelt system, is no longer fulfilled.

The arising of smouldering fire of slack coal in close proximity of conveyerbelt systems still can not be prevented despite of all safety engineering. That is why it is necessary to find the source of fire at an elementary stage and detect it locally. The GESO Firefinder M is based on the technic of fibre optical distributed temperature sensing and guarantees a complete and continuing detection of any temperature anomalies along the whole conveyerbelt system. Intelligent analysing software differs between normal running variation in temperature and possible fire occurrence. In case of a fire it generates an alarm even with the exact location to a permanent occupied place (mining control stand).

Thermal radiation from a smouldering fire spreads out independent of the ambient medium and therefore independent of the speed of the weather. For this reason a monitoring system is required which is able to detect the thermal radiation of a smouldering fire in close proximity to conveyer belt systems. As conveyer belt systems are enormous constructions a linear heat detector is required which can permanently monitor a system allows for a hot spot to be detected at an early stage.

Measuring system

In the period between Jan. 1st 2002 and Dec. 31st 2003 various commercially available linear heat detectors have been tested for their applicability to detect smouldering fire downhole in coal mines, by the DTM-centre of fire control and safety. Results of this survey verified that two of the tested systems are theoretically applicable for that purpose because of their performance parameters:

- Electric temperature sensing cable system with hybrid circuits along the cable
- Distributed fiber optical system

Both measuring systems have been successfully tested by DTM GmbH in Essen. As they have not been developed for downhole use, they could not meet the requirements for explosion prevention. Because of their evident principle advantages:

- absolutely electric passive cable,
- extrem robust and simple cable construction,
- reachable measuring range (per measuring channel) up to 8000 meters and
- good qualifications to meet the requirements of explosion prevention.

Only the fibre optical temperature sensing system had been progressed.

Measuring concept of the fibre optical temperatur sensing

The measuring principles are based on the OTDR (Optical Time Domain Reflectometry)- method. Light pulses are coupled into the fibre of the sensing cable. The backscattered light contains information about the temperature of the optical waveguide. Besides the wavelength (Rayleigh-Line) the backscatter spectrum consists of a so called Stokes and Anti-Stokes line (Raman effect), which are shifted within their wavelength to the lower or higher wavelength. While the intensity of the Stokes line is nearly independent of the temperature the Anti-Stokes line shows a

temperature dependence (Fig. 1). The quotient of both intensities constitutes an obvious measure of temperature in the optical waveguide.

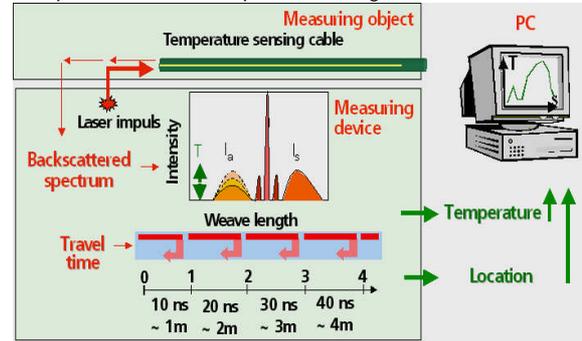


Fig. 1

It is the average temperature of that section from which the backscattered light is originated in a certain time slot. The analysing unit links the intensity measurement with the duration measurement of the laser light in the optical waveguide. That's how it is analysing the temperature values of each section x ; to the time t_n : $T(x; t_n)$.

Components of the system

The measuring system consists of 2 main components. The sensor cable with optical waveguide and the opto-electronic analysing device. The sensor cable is a fibre glass cable, similar to cable being used in the telecommunication industry.

Fig. 2 shows a schematic diagram of a fibre optical measuring system for long monitoring distances. Optional extendable by simply adding a measuring device.

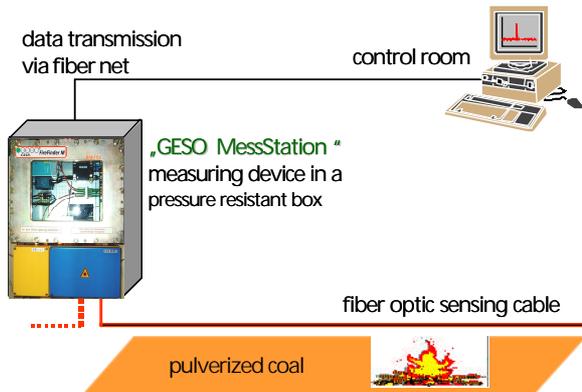


Fig. 2 scheme system components

As a cost effective alternative to the shown separate sections of transmission, separate fibers from the temperature sensing cable can be used for data communication.

The actual sensors, the fibres in the sensor cable are immune to electromagnetic influences and therefore applied in special hazardous areas (explosion-risk areas). Due to the design of the sensor cable, corrosion is prevented. Through experiences with conventional underground cables, it is deducted that the lifetime of fibre optical temperature sensing cables are at least 20 to 30 years. The temperature sensing cable is laid along the distance to be monitored. Basically the direction of the cable depends on the local conditions and expected temperature effects.

Automatic triggering

Variation in temperature which arise e.g. from fire, differ from other temperature changes because of the very local area and the continuous timing. These effects are filled out with the triggering. An alarm is set when the customized temperature gradient or a preset threshold value is exceeded. The algorithm works automatically; the results can be integrated in the superior process control system. The data transfer is made by standard systems alternatively by the temperature sensing fibre cable. For this purpose an extra fibre can be integrated into the cable.

Development of the system for coal mining

Ever since the availability of the first commercially utilisable fibre optical temperature sensing devices in the early 1990's it was in practical use in a wide range. Since 1993 GESO GmbH in Jena offers a customized application of this technology to different industrial sectors and can refer to a variety of references. In doing so, it showed that detailed knowledge and strict observation of the specific application from the user is most important for successful application of the installed system.



Fig. 3

As the tested devices in the year 2003 from DMT (Centre of fire control and security) had not been developed for usage in coal mines, series of tests had to be done, to prepare the devices for the special requirements in coal mining downhole.

Test installation in the mine Prosper Haniel

For an expertise a fibre optical temperature sensing system for early detection of smouldering fire at conveyer belt systems had been installed in the mine Prosper Haniel in Bottrop in Feb. 2005. Above all, the possibility to install fibre cable at a conveyer belt and permanent operation under practical conditions had been tested. A fibre optical sensing cable about 3500 m long had been mounted left sided at the lower run in direction if the conveyer belt. At that time the opto electronical analysing system including the control PC had to be installed at the controll centre as it was only permitted outside the ex-safety area. Fig. 3 shows one alternative to fix the fibre cable to the lower run. Until Jan. 2006 three different commercial utilisable opto electronical analysing systems had been tested at the same fibre cable. As a result of these tests it had been established that the fibre optical temperature sensing system by GESO is applicable in principle. It is recommended to install the system additionally, securing the conveyer belt distances with a weather speed of >3m/s (6).

The following points had to be optimized:

- construction of the cable
- laying of the cable especially downhole (Basic distance)
- measuring regimes (measuring time measuring frequency)
- parametrization of fire detection (temperature gradients, threshold values)
- installation of the measuring system downhole (ex-safety area)

Screening test

Experimental fires had been realised in the small fire drift of the DMT site for fire protection in Dortmund. To ascertain the detection parameters especially the maximum range of detection of a smouldering fire. The temperature gradients affected by the developing smouldering fire and the acquired threshold values at the fibre.

Breadboard construction

For define installation the fibre cable was looped back and forth above the smouldering fire and fixed to a steel cable in the fire drift and then guided into the control room. The distance between the sensing position and the smouldering fire or respectively among one another arises out of Fig. 4.

Like shown in Fig. 5 the analysing unit consisting of temperature sensing device and measuring PC were placed next door in the control room. To simulate additional length of sensing cable, more cables of an LWL cable had been spliced between the analysing device and the real sensing fibre. The complete length of the installed measurement distance was approximately 3200m. The area of the installed sensor in the fire drift was between 3026m and 3101m at the start measuring device. The smouldering fire construction to cause the smouldering of coal dust, was made of two electrical lab hot plates with 2 kw each. On top placed a copper-plate for a better heat transfer and a frame of perforated metal plate with the dimensions 0,50m x 0,50m x 5cm to collect the coal dust. Fig. 6 shows the experimental arrangement in the small fire drift

Carrying out the test

The coal dust smouldering fire was inflamed by the lab hot plates. During the test the smouldering fire had been controlled by a thermographic camera. The electric heat was turned off after the coal dust had reached a surface temperature of 270 °C and visible smoke with first zones of smouldering fire showed. Then the smouldering fire progressed until the whole area was completely taken. The temperature of the smouldering fire came up about 450 to 500°C. The temperature in all five fibre cable positions with weather speeds of 1,2m/s, 3,0m/s and 4,5m/s had been acquired.

Results

Under these test conditions the presented measurement system proofed the detection of a coal dust smouldering fire with an area of 0,5 x 0,5m (=0,25m²) and a distance of 1,8m (Distance between surface of smouldering fire and sensing cable) at a weather speed of up to 4,5m/s. In the report dated May 10th 2006 of the measurements done April 25th 2006 at DMT was finally established:

- Due to the results it is assumed that the presented fibre optical linear heat detector, in view of its measurement parameters for early detection of fire, is applicable at conveyerbelts in coal mines. It must be assumed that if the fibre cable is fixed right below the supporting structure of the conveyerbelt system, the source of smouldering fire at all regular weather speeds is detected for sure (5).

System configuration

GESO FireFinder M

The ATEX product instructions 94/9 EU laid down the rules for products placed in the market which are installed in explosion-

hazardous areas. The purpose is to protect persons who work in such areas.

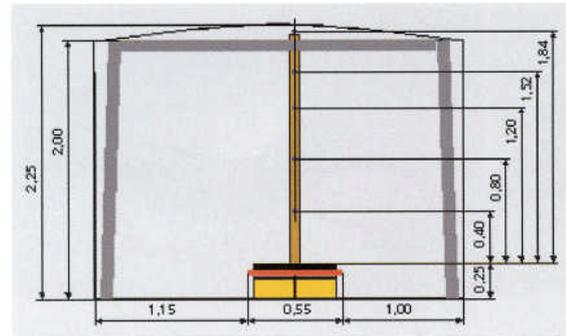


Fig. 4 cross section of a small fire drift with sensor cable system

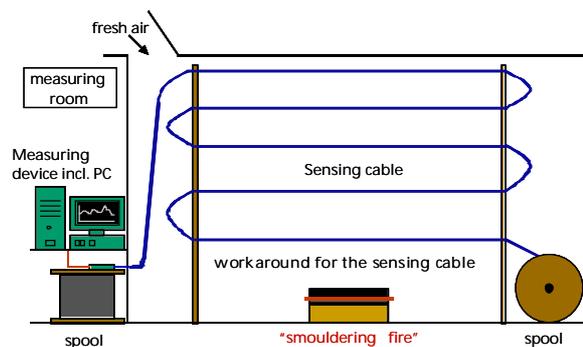


Fig. 5 longitudinal section through the breadboard construction including measuring system

After June 30th 2003 it is no longer allowed to place products on the market without keeping the ATEX-product instructions. The selection of the components for a downhole installed GESO measuring system was therefore under the aspect to strictly comply with the ATEX-product instructions for mining. For all downhole installed systems, components had been chosen, with "pressure-resistant enclosure" as a precaution in case of explosion.



Fig. 6 Test situation in the small fire drift

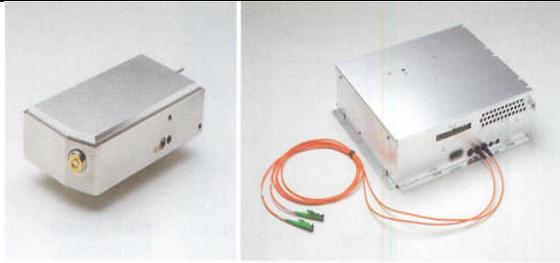


Fig. 7 Agilent's hermetically sealed opto-block (left); Compact measuring device (right)

Opto-electronic control unit (DTS)

The opto-electronic control units have been proofed within the limits of the above described test installation. The only tested unit which is applicable is the DTS - Distributed Temperature System, Outdoor Series (N4386A) of Agilent Technologies Manufacturing GmbH & Co. KG in Böblingen.

The decisive advantages for the allocated applications are:

- highly integrated, solid construction of the actual measurement device ("card-cage") (291mm x 323mm x 89mm)
- very large operating temperature range (-10 to +60°C)
- guaranteed function in the additional enclosure at high temperatures downhole
- very low energy expenditure of 15W nominal (<40W max.)
- little energy input in the additional enclosure
- very low laser energy in the fibre (17mW)
- complies in accordance with the integrated laser watchdog the ATEX requirements for downhole use

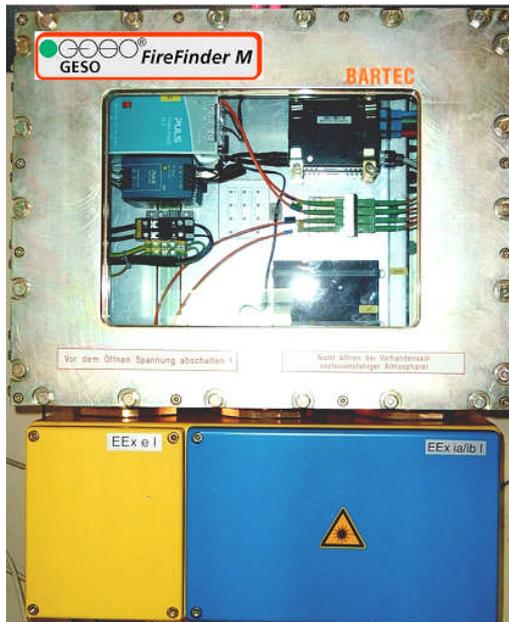


Fig. 8 GESO measuring station in pressure resistant enclosure

GESO measuring station in pressure resistant enclosure

To keep the requirements of explosion prevention the Agilent-DTS as well as the assemblies of the data communication and the power supply had been placed in a pressure resistant enclosure. Typ dSD05M with two attached junction boxes below of the ignition protection type "increased security" and IP54 of the BARTEC security switchgear GmbH in Menden (Fig.8).

Sensing cable system

The sensing cable system consists of pre ready-made fibre cables which ensure easy connection between the cables with a special plug-in connector. Cables with different lengths are in the delivery contents. At both ends of the cable sets are plug-in connectors, each containing one fibre glass. During transportation and laying out process these connectors are protected by retracting them with a grommet. To ensure the cable splicing between the sensor cables, as well as fast exchange of damaged sensor cables (repare of the monitoring distance), each cable set has its splicing box were it is connected.

Control-PC

The control PC is installed in the control stand of the mine. It does:

- control the test sequence
- metrological configuration of the sensors
- surveillance of the function of the DTS
- organizing and analysing measurement data
- forwarding of the results

These functions will be realized by the firmware of the DTS manufacturer and the GESO application software.

System software

The following main functions are guaranteed by the systems software:

- Configuration of the GESO Firefinder M within activation
- Data acquisition, data editing and automatic data evaluation in view of the explicit alarm criteria (alarm-trigger) in the automatic monitoring process
- Allocation of selected data from the monitoring process for the operator (system status, temperatures and alarms)

ATEX-Approval

Through the certification authority DEKRA EXAM GmbH in Bochum an EU individual certificate has been given for the first GESO measurement station. It certifies that the unit meets the basic security- and health requirements for the conception and construction of the device and protective

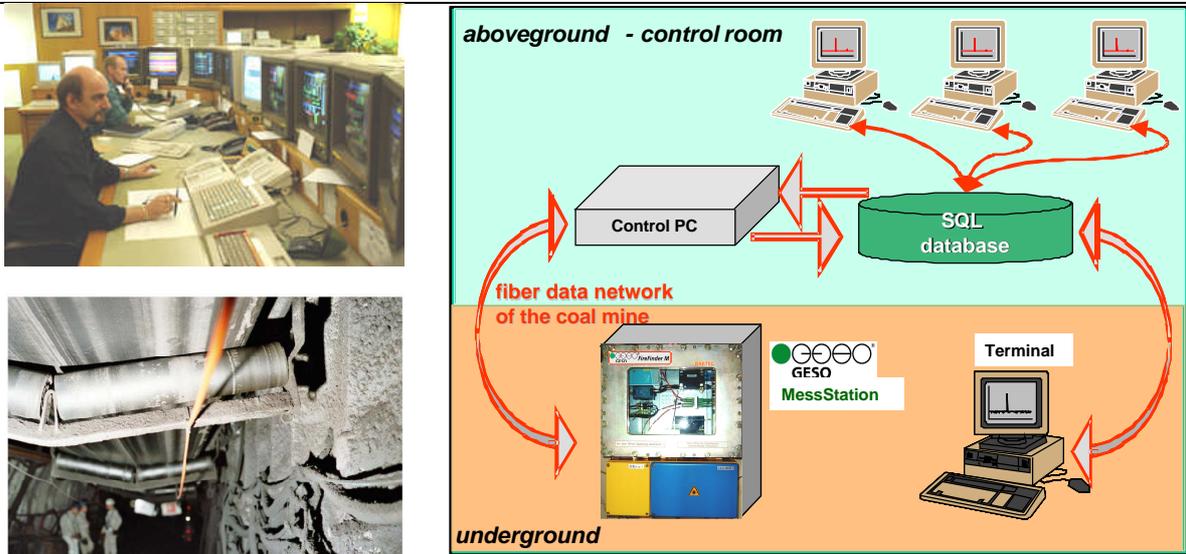


Fig. 9 The GESO Firefinder in the communication system of a mine

systems as intended use in explosive area as supplement II of the ATEX directives. The identification of the measurement station obtains the following information:

- The specified "special conditions" are kept, respectively realized as stated in the EU individual certificate.

Integration of the GESO Firefinder M into the communication system

The GESO measuring station as the hardware main component of the system has to be installed downhole at the monitored conveyer belt section. The control PC is situated above ground in the control stand of the mine. The bidirectional data flow between those two components takes place by using their own glass fibre network. Therefore each of the components has its own IP-address.

Fig. 9 shows schematically the internal data flow of the GESO Firefinder M and its embedding into the data system of the mine. The central "nodal point" of the data communication is a SQL database as interface between the GESO Firefinder M and the data system of the mine. This concerns especially:

- read access of all connected (authorized) terminals.
- write access with defined, if necessary temporary authorisation.

With this all authorised persons can carry out the required entries from all connected terminals. Especially for activation of the system, reactivation, after changing the monitoring section or after repairs.

All results of measurements which have been reported to the data base of the control PC are also available at anytime and anywhere for future use (average values, results, warnings, alarms).

Stand and future perspectives

The first complete system of a GESO Firefinder M had been installed downhole at the mine Prosper-Haniel at a conveyer belt section and is being tested since the beginning of the year 2007.

It is scheduled to report further more about the experiences at the downhole installation of the GESO measuring station and the fibre optical sensor cables as well as analysed results and conclusions.

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