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Present-day requirements for protection against fire in coal mines

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Analysis of statistical data shows that, on an average, about 50% of the total underground emergencies occurring in coal mines in the USSR are due to fires. Great attention is, therefore, paid in our country to the problem of protection against fire in coal-mining undertakings.

Fire protection in mines envisages measures to prevent the emergence of possible sources of combustion, readiness to suppress emerging fires, and to localise fires that have already developed.

At present, protective measures against fire are put into practice in accordance with the requirements of the "Safety regulations for coal and shale mines" and other regulating documents. However, scientific research carried out in recent years at the All-Union Scientific Research Institute for Mine Rescue (VNIIGD) shows that the requirements existing to date are not sufficiently well founded (for example, the standards for the supply of water for firefighting, requirements for mine fire doors, standards for the length of fire-resistant zones in mine workings having wooden supports, etc.).

In connection with this, the unified "Standards of fire protection in coal and shale mines", and "Handbook on fire protection in coal mines" have been worked out by VNIIGD.

The main difference in the new standards lies in making existing requirements more precise and in the introduction of new requirements for fire protection in mines. There are also recommendations on the use of new fire fighting equipment.

As it would take a long time to explain all the standards and give the results of the research on which the selected parameters and values are based, we will just present a few of the more important ones.

Special heated water tanks having a constant water supply must be provided in the yard of all mines. The water volume is determined from the calculation of its delivery for putting out an underground fire over a period of three hours, but is not less than 300 m$^3$ for newly projected mines and 250 m$^3$ for mines already operating. Pumping stations are located near the tanks. The output of fire pumps must correspond to the consumption of water when underground fires are being extinguished, but must not be less than 80 m$^3$/hour.

For putting out underground fires use may be made of the catchment basins
of water drainage installations on upper, operational or non-operational levels. For the fire protection of staple shafts and ventilation shafts that are a considerable distance away from the yard and to which it is not economic to supply water through a special supply line for fire fighting purposes, a fire reservoir with a capacity of not less than 50 m$^3$ must be provided.

At the entrance of vertical shafts and also staple shafts supplying fresh air, spray adapters are fixed to circular pipe-lines, the total flow of water through which is calculated in accordance with conditions of fire extinction in vertical workings:

- $2 \text{ m}^3/\text{hour} (0.55 \text{ litres/s})$ for every $m^2$ of cross-sectional area of a vertical working having non-flammable linings;
- $6 \text{ m}^3/\text{hour} (1.66 \text{ litres/s})$ for every $m^2$ of cross-sectional area of a vertical working having flammable linings.

The total amount of water for one mine shaft must not exceed 80 m$^3$/hour.

As streams of water directed from the ground are not effective for extinguishing fires in shaft headgear, this must be equipped with a dry-pipe pipeline whose purpose is to supply water, in case of fire, to spray adapters so that the sheaves and the platforms under the sheaves may be sprayed at a rate of not less than 15 m$^3$/hour (4.2 litres/s).

In order to deal with fire and dust in underground workings of coal and shale mines, water pipe-lines to be used both for fire and dust suppression are envisaged; these are to be constantly filled with water and to be under pressure. The network of a fire pipeline in underground workings consists of main and district lines whose diameter is not less than 100 mm (independently of the calculated throughput capacity). In stall roads the laying of 50 mm diameter pipes is permitted.

Main lines are laid in vertical and inclined shafts, galleries, shaft bottoms, main and grouped transport roads and crosscuts, and inclines. Where there are two or three parallel inclined workings, the fire pipe-line must be laid in a working equipped with a belt conveyor, fire hydrants to be taken into parallel workings through crosscuts or boreholes.

District lines are laid in transport- (collecting), ventilation- (boundary), and panel (intermediate and extraction) roads. The ends of district pipe lines used for fire fighting and spraying must not be further than 20 m from the faces of development workings and must be fitted with fire hydrants; near these must be kept a box containing a fire hose and branch.

The water pressure in the pipe-line for fire fighting and spraying is to be from 60 to 150 m water column (at the prescribed consumption rate for extinguishing fires). When the water is to be used for spraying purposes the required
pressure is produced by means of special apparatus. The upper pressure limit in a combined pipe-line laid in inclined workings is 200 m water column (on the high side of the hydraulic reducer).

The parameters of the main pipe-line laid in a shaft, in workings near the shaft bottom and in crosscuts up to the point where the pipe-line branches into the principal workings along which coal is transported from both sides of the mine, are calculated from the total consumption of water required for the production of mist curtains, for the direct extinction of a fire with a solid jet from one branch with a nozzle diameter of 19 mm (flow through the branch, 30.0 m³/hour or 8.3 litres/s) and for technological requirements (half the calculated consumption).

The parameters of the main pipe-line laid in trunk- and grouped transport roads and inlines are calculated only from the total water consumption for mist curtains used as fire protection and for direct extinction of fire by means of a solid jet from one fire branch. The total water consumption is to be not less than 60 m³/hour (22 litres/s) independently of the calculation.

The parameters of district pipe-lines, laid in transport-, ventilation, and panel (intermediate and extraction) roads, are calculated only from the water consumption for mist curtains for fire protection but are not to be less than 50 m³/hour (13.9 litres/s).

The water consumption needed for a mist curtain to stop a fire from spreading in district workings with wooden supports is determined in accordance with the cross-sectional area and the speed of the ventilating air stream. Per m² water consumption for a mist curtain must be not less than 6.6 m³/hour at an air speed of 1 m/s;

7.7 m³/hour for an air speed of 2 m/s;
9.0 m³/hour for an air speed of 3 m/s.

Fire pipe-lines connected to water drainage ranges must be fitted with distributing and pressure-regulating devices which must be consecutively numbered and recorded on the plan of the water-pipe system, together with indication of the order in which they are to be used.

The whole of the pipe-line for fire fighting and spraying purposes in the mine is to be painted red for identification.

The disposition of primary manual and automatic, fixed and portable means of fire extinction, the installation of fire doors and arches, and the arrangement of fire-resistant supports in workings, are all subject to fire protection standards.

The automatic UAK-1 appliance has been developed by VNIIGD for the extinction of fires in belt conveyor drive heads in horizontal and inclined workings. The
appliances consists of a system of pipes and fittings, a filter, booster and automatic valves, a manual operation valve, a system of cables with heat locks and a final "off" switch. The appliance can extinguish a fire over an area of 40 m². The spray density is 0.1 litres/s per m². The output of the appliance is more than 30 m³/hour when the water pressure in the pipe-line is 4 kgf/cm². The appliance is automatically switched on and the conveyor drive automatically switched off when the temperature in the area where the heat locks are located reaches 72ºC.

The UAP-W appliance has been designed to extinguish fires in rooms containing electrical machinery and including oil-filled equipment. Fires are extinguished by means of low-expansion air-mechanical foam. The appliance consists of pipes and fittings, a filter, a metering tank, an exotherm and an automatic valve, a manual operation valve, a system of cables with heat locks and a final "off" switch assembly. On operation of the activating mechanism, the appliance produces up to 20 m³ of low-expansion foam for 3 to 4 minutes, enabling a fire to be extinguished over an area of 100 m².

Manual fire extinguishers are distributed (two at a time) along the whole length of mine workings according to the following standards:

in workings with belt conveyors (independently of the kind of supports), every 100 m;

in workings with flammable supports (wooden supports, combined supports with wooden lagging), every 300 m.

The institute has developed the type OP-8 powder extinguisher for mine fires in the initial stage involving wood, coal, conveyor belts, methane, oil and electrical equipment of up to 660 V.

Mobile OP-500 m fire extinguishers are located on transport levels of each extraction field of the mine for the extinction of underground fires in their early stages of development. This extinguisher consists of a tank for the foam-producing solution and two chemical reactors mounted on a mine-car platform. An air-foam branch and fire hoses are kept in a special box beside the tank. The mobile extinguisher has a range of 8 to 10 m and can deliver 4500 to 5000 litres of foam in 12 minutes, enough to extinguish an area of 60 m² of wooden supports. It is recommended for inclusion in mobile hydraulic power packs and fire trains.

The OS-200 stationary air-foam extinguisher has been developed for extinguishing fires in rooms containing electrical machinery; this design has already undergone trials.

These extinguishers are kept in surface buildings, at the bottom of shafts taking in fresh air, and in winch rooms, near the working place of the...
mon on duty.

With this fire extinguisher it is possible to produce low-expansion foam (8 to 10). It consists of a 200 litre tank for the foam-producing solution and a reactor containing sulphuric acid and bicarbonate of soda. The extinguisher delivers 2000 litres of foam in 5 minutes.

In addition to fire extinguishing appliances VNIIGD is developing means of localising underground fires. Apart from mist curtains these include fire doors, fire-resistant zones, etc.

The main purpose of fire doors is to localise fires. They also act as ventilation devices, and in emergency conditions they restrict the entry of fire gases and explosion products. The main qualitative indices of fire doors during emergency conditions are air-tightness and the limit of fire resistance. The designs of fire doors at present in use do not fulfill their purpose.

It is practically impossible to make existing designs of fire doors air-tight, and air leaks reach 30%. A metal fire door becomes deformed under the action of high temperatures and loses its air-tightness; as a result of this its limit of fire resistance sets in quickly, usually after 10 to 15 minutes. In addition, the metal doors, heated up to 530 to 580°C are themselves a source of ignition. For this reason metal fire doors must be installed in a section of the working with non-flammable supports extending for at least 10 m on each side of the door.

The use of non-flammable materials with low heat conductivity that do not buckle under the influence of high temperatures must be considered as the best way of increasing the fire resistance of fire doors.

We have worked out a method of calculating the resistance of fire doors under the influence of high temperatures. As a result of solving a differential equation of the heat conductivity for an infinite plate, heated on one side (non-symmetrical problem), it has been established that the thickness of doors whose fire resistance limit is not less than 4 hours may be determined from the formula

\[ l = \lambda \left[ \frac{T_1 - 150}{\alpha_2 (150 - T_2)} - \frac{1}{\alpha_1} \right] \]

where \( l \) is the thickness of the door, m;
\( \lambda \) is the coefficient of heat conductivity of the material of the door, kilo-calories/m hours.degrees;
\( T_1 \) and \( T_2 \) are, respectively, the temperatures of the ambient medium on the side of the heated and the un-heated surface of the door, °C;
\( \alpha_1 \) and \( \alpha_2 \) are, respectively, the coefficient of heat transmission on the side of the heated and the un-heated surface of the door, kilo-calories/m² hours.degrees.
The limit of fire resistance above four hours is selected on the basis of investigations of the development of an exogenous fire. Calculations show that a metal fire door having a layer of heat insulating material 60 mm thick may resist a fire for 4 hours or more, whereas a non-protected metal door stands up to a high temperature for only 10 to 15 minutes.

In order to localise fires in workings with flammable supports, fire-resistant zones up to 20 m long are used. Zones of this length cannot act as reliable means of localisation as they do not cool fire gases to a safe temperature. For example, a fire-resistant zone capable of cooling fire gases from 1200 to 300°C, depending on the air speed and the cross-sectional area of the working, must be from 200 to 730 m long. The temperature reaches 1200°C when wooden supports are burning in a length of working several tens of times shorter than the length of the fire-resistant zone, other conditions being equal.

It is, therefore, better to use non-flammable materials for the support of the whole length of workings having a large cross-sectional area and high ventilating air speeds.

At present, depending on their function, mine workings are supported by materials of specific flammability. However, it has been shown in practice that it is not sufficient to subdivide mine supports solely on the basis of one quality - flammability.

In order to evaluate supports for workings, a concept of the degree of fire resistance of the material and of the design of the support is accepted that includes the category of flammability and the limit of fire resistance. In this way indication is given not only of the possibility of ignition of mine supports in a stream of heated fire gases, but also of the period during which a heated support does not lose its carrying capacity and stability.

Three degrees of fire resistance of supports have been introduced, depending on location in the mine: maximum, medium and minimum.

**Degree of fire resistance of mine supports**

<table>
<thead>
<tr>
<th>Designation of workings or parts of workings</th>
<th>Degree of fire resistance</th>
<th>Flammability category of support components</th>
<th>Material of supports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Entrance to vertical, inclined shafts, galleries, also entrances to short shafts supplying fresh air to the mine, to a distance of 10m from the surface. Vertical</td>
<td>Maximum</td>
<td>Non-flammable</td>
<td>Cast-in-situ concrete, etc. supports, mixed supports: walls of stone (concrete, brick, concrete blocks), canopy - metal beams with concrete arches; reinforced c</td>
</tr>
</tbody>
</table>
shafts. Junctions of vertical and inclined shafts, galleries, also of short shafts supplying fresh air to the mine, with workings of horizons at shaft bottoms. Entrances to inclines and passages near them, and also their junctions with workings for a distance of not less than 10 m in each direction.

Inclined shafts and galleries supplying fresh air to the mine, main crosscuts, main and grouped transport roads. Rooms containing electrical machinery, rooms containing sub-stations and high voltage distribution points, central underground electrical sub-stations, transforming sub-stations and explosive stores with a life of one year or more. Workings to a distance of 5 m in all directions from rooms containing electrical machinery and from the location of fire doors, air compressors, conveyor drive heads and oil-filled hydraulic equipment.

Workings at the shaft bottom. Workings with belt conveyors. Main inclines, inclines and passages near them, inclined ventilation shafts

<table>
<thead>
<tr>
<th>Maximum</th>
<th>Non-flammable</th>
<th>Non-flammable</th>
<th>Reinforced concrete props with reinforced concrete or metal roofbars, metal special-profile with reinforced concrete or metal lagging, prefabricated reinforced concrete.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Non-flammable</td>
<td>Slow-burning</td>
<td>Metal special-profile with plastic or wooden lagging, impregnated or coated with fire-proofing compositions.</td>
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</tbody>
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short shafts, district transport and ventilation roads, district inclines and passages
near them, staple shafts, inclines

VNIIIGI has developed the "Horizon" system; an experimental prototype of this is undergoing operational trials. The system is designed for the automatic detection of open sources of fire in mine workings, for the telemetering of methane concentration in mine atmospheres, of the quantity of air passing through workings and of the information that the critical methane concentration has been exceeded. The system consists of sensors for temperature, quantity of air and methane concentration, equipment for monitoring and measuring points, communication lines and control point equipment.

Temperature sensors and monitoring point equipment are set up in workings having flammable supports and belt conveyors, in rooms containing electrical machinery, and in other locations with a high potential fire danger. The air quantity sensors, the methane concentration sensors and measurement point equipment are set up in accordance with the gas protection system of the mine. The control point equipment is located on the surface, in the mine control room.

Signals from a fire and mine atmosphere parameters are reproduced on a display panel with a figure chart and a plan of the mine ventilation.

The system is based on standard components (of the state system of instruments) from the "Spectro" unit and meets with the requirements of the "Regulations for the manufacture of explosion-protected and mine electrical equipment", and the "Safety regulations for coal and shale mines".

In conclusion it should be noted that the number of underground fires has gone down considerably, thanks to preventive work by the mine rescue service, better supervision of the state of fire protection in coal mines, adoption of the results of research and design work, and the creation and rational distribution of the means of protection against fire in mine workings.