METHODS OF IMPROVING THE EFFICIENCY
OF MAIN MINE VENTILATION PLANTS

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Mining operations entail release of toxic substances, and the only way to create safe comfortable working conditions is to dilute them and carry them off to the surface. In gassy pits the ventilation conditions are determined by the emission of methane, because calculations of the quantity of air according to the methane give the highest values, which are used in choosing the ventilation system.

Design of ventilation systems for new pits and new horizons in existing pits must be based on prediction of the gas levels and proposed development schemes. Present methods of prediction enable us to predict, to some approximation, only the mean expected gas level, and do not permit us to take account of inequalities in gas emission or in the dynamics of development of mining operations during exploitation. It is also impossible to predict the order of development of the mining operations throughout the service life of the pit. Therefore the aerodynamic and gas-dynamic parameters of the pit ventilation system during exploitation deviate from those adopted (predicted) during the planning stage, and as a consequence the operation of the ventilation plant is so much altered that its efficiency is much reduced.

Research on the operation of 100 main ventilation plants in the Kuzbass showed that the over-all efficiency of the plants varies from 0.05 to 0.57, and the weighted mean over all the Kuzbass plants is $\eta_{av} = 0.35$, i.e., only 35% of the electric power is usefully used by the ventilators. Every year, the main ventilator plants in the Kuzbass pits use 526 million kWh of electric power. If we consider that 65% of this is wasted, it becomes obvious that the economic losses from the working of inefficient ventilation plants is quite considerable.

A main ventilation plant is a complex, consisting of the fans which feed air to the pit, and the ventilation ducts which connect the fans to the atmosphere and to the ventilation shaft. Losses in the plant can be divided into hydraulic and bulk losses in the ducts and internal losses in the fans [1].

Hydraulic losses are mainly due to local resistance in the ducts (turns, narrow sections, and wide sections in the ducts), and are characterized by the hydraulic efficiency

$$\eta_H = \frac{H_m}{H_{st}},$$

where $H_m$ is the static pressure in the mouth of the ventilation shaft in N/m$^2$, and $H_{st}$ is the static pressure created by the fan, in N/m$^2$.

Bulk losses are due to air leakage in the ducts and are characterized by the bulk efficiency,

$$\eta_Q = \frac{Q_m}{Q_f},$$

where $Q_m$ is the quantity of air fed to the mine in m$^3$/sec, and $Q_f$ is the output of the fan in m$^3$/sec.

Internal losses in the fan are characterized by the static efficiency $\eta_{st}$ of the fan, and are due to its mode of operation.
In the Kuzbass, losses in the ventilation ducts constitute on average 35.3% of the power expended by the fans. A large part of these losses is due to inleaks and outleaks of air through the seals of the ventilation plant at the points where the valves and airlocks adjoin the support frames. The mean value of the inward and outward leakage of air in the main ventilation plants of Kuzbass pits is 18.6%, and in Gornaya Shoriya pits 17.8% [2] of the fan outputs. The unavoidability of this type of loss is due to the engineering systems of existing ventilation plants with systems of ducts, airlocks and valves. This is confirmed by planning practice: in planning the ventilation of pits, the amount of air to be pumped at the surface is taken as 10% of the amount required to ventilate the pit.

The presence of ventilation ducts of complex geometrical shapes, with turns, narrow parts, and wide parts, which have poor aerodynamic quality, leads to high hydraulic losses, the average value of which in Kuzbass pits is 20% of the pressure developed by the fans. Losses in the ventilation ducts (bulk and hydraulic) can be minimized by simplifying the ducts themselves. From this viewpoint, the best system of ventilation plant is that in which the fan is directly above the ventilation shaft (in a vertical working position), and reversal of the ventilation stream is effected aerodynamically (without bypass valves and airlocks). If we introduce reserves by an operative exchange of fans at the working site, we can completely dispense with ducts, valves, and airlocks in the ventilation plant. The absence of ventilation ducts enables us to avoid hydraulic losses, and the absence of valves and airlocks enables us to minimize bulk losses, which in this case will be caused only by air leakage through the seals at the point where the fan joins the shaft, i.e., it becomes possible to work the ventilation plant with over-all efficiency close to the maximum attainable value for the fan, so that $\eta_{\Delta H} = 1$ and $\eta_{\Delta Q} \approx 1$.

The static efficiency of present-day axial fans of the VOD series reaches $\eta_{s} = 0.82$. Consequently, the overall efficiency of a ventilation plant with synchronous drive ($\eta_{el} = 0.95$) can be brought up to $\eta_{tot} = \eta_{s}\eta_{el} = 0.78$, which is more than twice as great as the efficiencies of existing ventilation plants in Soviet pits [1, 2].

Increasing the static efficiencies of fans involves difficulties and cannot appreciably affect the efficiency of existing ventilation plants. Therefore further improvement in the main ventilation plants must primarily be made, not by improving the static efficiencies of the fans, but by creating new engineering ventilation systems.

The high losses in the fans themselves (29.7% of the power consumed) are due to the fact that they work in uneconomic conditions with low static efficiencies owing to deviation of the equivalent pit orifices from those assumed in the planning stage. Because the service life of a ventilator fan is long (up to 20 years), the characteristic of the ventilation network due to the development of the mining operations will vary over a wide range, and in practice in most cases the fans work with $\eta_{st} < 0.6$ (according to present norms, the static efficiency of projected ventilator plants should not be less than 0.6). In Table 1 we give the results of an investigation of the operation of the main ventilators in Kuzbass pits and Soviet ore mines, from which we see that only 28% of these plants operate at $\eta_{st} \approx 0.6$.

Losses in the fan can be reduced only if it works in nearly optimal conditions when the characteristic of the network passes through the zone of highest efficiency. For this purpose, in the planning stage it is necessary to choose the fan so that in the initial period of development of the mining operations it shall work with maximum efficiency. As the mining operations develop, the parameters of the ventilation network will alter, and the operating conditions of the fan will leave the zone of maximum efficiency. When the parameters of the ventilation network alter so that the efficiency of the fan falls to its lowest permissible value, the fan characteristic must be altered so that its mode of operation crosses into a zone with maximum efficiency (see Fig. 1), i.e., it is necessary to make the plant adaptable to changing equivalent apertures of the pit ventilation network by changing the fans to those with the nearest parameters. This involves large additional construction expenses, both in the plant and in the fans, which must be replaced without closing down the plant. The desirability of changing the fan and the ventilator efficiency at which this becomes necessary must be calculated on a sound economic basis.

Besides stable changes in the characteristics of the ventilation network due to the development of the pit, there are continuous changes in the aerodynamic parameters of the network and in the gas emission. It is known that, even with steady working conditions in the pit and normal output, the gas flow will alter during a day. Therefore it is possible to increase the ventilation efficiency and satisfy the stringent safety requirements with minimum costs only on the basis of continual redistribution and alterations in the quantity of air fed to the pit, which means continuous regulation of the fan operating conditions.

Thus a main ventilation plant must satisfy the following requirements. It must be possible to continuously regulate the throughput of the fan without stopping it, to a sufficient extent to keep it in the zone of economic operation. It must be possible to reverse the ventilation flow without additional structures (bypass ducts, airlocks, etc.) in a limited time with the necessary output in the reversed mode. The reliability must be at least up to the