WATER REGIME CONTROL IN MINES AND QUARRIES IN THE USSR COAL INDUSTRY

M. S. Gazizov

USSR

ABSTRACT

The paper briefly reviews the mine water problems associated with coal mining industry in the USSR. Statistics regarding quantities of water discharged from surface and underground coal mines are given together with the pumping heads, range of water problems at a coal face and the quality of mine water. Ground water control systems are described which include surface preventive measures, surface mine water control techniques and underground mine dewatering methods. Recommendations for further investigations for solving a variety of mine water control problems are included.

INTRODUCTION

The current techniques of surface and underground coal mining are influenced by the following hydrogeomechanical processes and phenomena :

- disturbance of the geostatic equilibrium of a rock mass, its deformation with partial or complete breakage of the structure, formation of geomechanical transformation zones, and occasionally surface subsidence and caving;
- disturbance of the natural underground water regime with establishment of hydraulic connections between aquifers, water inflow into mine workings and formation of mine water;
- lowering of underground piezometric level and formation of cones of depression around mines and quarries, depletion of underground and surface fresh water reserves, dessication of water intake installations, soil consolidation and surface sites;
- semi-underflooding of populated areas and industrial sites, flooding and bogging of surface subsidence trough, the possibility of water and mud inflows into mine workings;
- pollution and contamination of surface water flows, reservoirs and underground water during diversion of mine water with high mineralization and bacteria content.

Coal mining affects the geological medium, the hydrogeological, hydrological and hydrochemical conditions as well as the landscape.

SOURCE OF MINE WATER INFLOW

The main source of mine and quarry water inflow includes underground water, that of abandoned mine workings, surface water flows and reservoirs, and atmospheric precipitation. Water is delivered into mine workings through: the natural regions of water recharge, geological disturbance zones (karst and tectonic, endogenic and exogenetic fissure system), rock mass geomechanical transformation zones (stoping zones, growth of water-conducting breaks, smooth subsidence of rock mass layers, marginal fissures in the subsidence trough), exploratory and operational boreholes, pits and other mine workings.

QUANTITIES OF MINE WATER DISCHARGED

Most water is pumped out of coal mines and open pits as compared to the other branches of the industry in the country. Each mine or quarry pumps out from 20 to 2000 m^3 of water per hour and even 5000-12000 m^3/hour during rainy seasons. For all coal output about 25000 million m^3 of water is pumped out every year. The mine water-saturation coefficient varies from 0.5 to 10.0 m^3/t and for the coal industry it is 3 m^3/t on average.

Water inflow will increase every year due to heavier coal mining and larger goaf areas. The coal industry pumped out about 1870 million m^3 in 1970 and 2438 million m^3 in 1979. In 1985 the inflow is expected to rise to 2700 million m^3, or by approximately 10 per cent.

Pumping Heads

In the future the mining depth is expected to increase as well as the energy required for water pumping. In 1970 the average depth of pumping was 360 m, in 1980 it was 460 m (and over 1000 for several mines), in 1985 it is expected to reach 500 m. The energy consumption for water pumping will increase from 3000 to 6000 million kwh per year over the same period. The greater depth will complicate the pumping scheme.

Range of Water Problems

With the powerful pumping installations available at mines according to the Safety and Production Codes and reliable power supply, the total water inflow can be pumped out of the mines without any special difficulties. Most trouble is caused by water inflow at coal faces (especially those with mechanized complexes), sudden inrushes of water, depletion of fresh water sources, and mine water contamination. For example, out of 2600 coal faces inspected in 1979, 82 per cent of them were having small water inflows (less than 5 m^3/hour), 10 per cent medium inflows (5-10 m^3/h), 3-4 per cent heavy inflows (10-15 m^3/h) and 4-5 per cent very heavy inflows (over 15 m^3/h). The permissible water inflow on Donbass coal faces with strong floor rock (sandstone, siltstone) is 7-8 m^3/h and 3-3.5 m^3/h for those with weak clay floor rock (mainly argillite) (provided the rate of coal face advance exceeds 3.5-4 m per day to avoid support sinking in the floor). Every year there are 30-40 water and mud inflows in Moscow basin collieries. It takes 40-70 thousand roubles to deal with the consequences of a single inrush.

SYSTEMS OF MINE WATER CONTROL

Water protection of the mines and open pits is carried out mainly by drainage of the coal measures aquiferous rocks by the mine workings and pumping out of the drained water with pumping installations (passive method), as well as by intensive drainage of aquifers with surface and underground dewatering installations (active method). However, in the Moscow basin the moduli of underground and surface run-off, hydraulic and hydrochemical regimes and water temperature have changed because of the operation of pumping installations with a total output of about 30000 m^3/h, of several hundred dewatering boreholes with a total discharge of 34000 m^3/h, and of water intakes of over 8000 m^3/h for an area of about 3000 km^2.

QUALITY OF MINE WATER

Underground water usually is neutral or alkaline in composition. The deeper water has less SO_4, Ca and Mg ions and more Na, Cl and HCO_3 ions. Mine water in the goaf is contaminated which cause changes in its chemical composition, similar to those of underground water as the depth increases.

So, drainage of great volumes of coal mine water leads to: the formation of depression cones around workings over an extensive area; changing conditions of inflow; movement and runoff of underground water; depletion of their sources; irregularities in the natural hydrological, hydrogeological and hydrochemical regimes of an entire area; mine, surface and underground water contamination during water pumping and drainage; rock deformation, land subsidence and landscape changes.

As far as the conservation of water resources and the environment as a whole are concerned, the widely used method of drainage of rocks surrounding an excavation during mining operations obviously cannot be considered rational. The mixing of fresh surface and underground water with mine water is intolerable. Many years of experience in the development of saturated deposits have proven the expediency of water regime control in mines and quarries. By this the author refers to the system of complex means and measures to: reduce the affect of hydrogeomechanical processes and phenomena in mining; prevent or limit the inflow of surface, underground and mine water providing the pre-set water level in country rock; provide for the safety of the given mining system; combine effective mining with environmental control and prevent water sources from depleting and contaminating. The water regime control is one of the main aspects of mining hydrogeology connected with mining geology, hydrogeology, geomechanics, mining technology and ecology.

TECHNIQUES OF MINE WATER CONTROL

Surface Preventive Measures

Means and measures to control the surface water regime providing the protection of mine workings from water, include the following: capture of the slope run-off water (on its way to the zones of surface subsidence and open pit workings) by means of surface water-protective installations (upland drainage trenches, dams); screening of stream beds by cementation, argillization, concreting, etc. within the limits of the depression cones; diversion of water by trenches and pumps from reservoirs and flows outside the development zone of depression cones; cementation of subsidence fissures on the mine field surface with argillaceous and other materials, or levelling and packing of cauldron margins; diversion of rainy water from cauldrons with floating pumps or by the underground drainage method (according to the connected vessels principle thus reducing electric power consumption for drainage); resorting to mining systems with partial or complete stowing without any pillars.

Underground water control in mines and open pits can be carried out by intensification of coal-bearing strata drainage, or by limiting the water inflow with the help of barrages (water-proof and anti-filtration), or their rational combination, or by choosing a technique providing protection of coal faces from water. The drainage of water-bearing levels is aimed at dynamic flow interception (i.e. to intercept the majority of inflow into the workings) and pumping it out, lowering the water level (head) to the required mark and minimizing the static water reserves within the mining areas. For barrages the mine workings are screened against dynamic flows while the static reserves of underground water are drained only within the limits of the mining operations area. In both cases the drainage water is directed to collecting pipelines to be supplied to water consumers.

Mine Dewatering Techniques

By their site and method of construction the drainage installations are subdivided as surface, underground and combined. Surface drainage installations include: dewatering and absorbing holes, horizontal drains, well point installations on benches and advanced trenches. Underground drainage installations include: water entries, through filters, raise bore holes, dewatering wells and advanced workings.

The combined installations include both surface and underground drainage workings. The drainage installations are subdivided according to their layout in plan (as cluster, linear, marginal, and net-like) in cross-section (as unihorizontal, multihorizontal, collector and collector-free), the time of their construction (advanced, parallel and overlapping), and their service (stationary and sliding).

Surface Mine Water Control Techniques

Barrage installations, widely used for hydrotechnical construction, provide for waterproof screens around quarries (or on their benches) mostly down to 50 m deep (rarely to 100 m) which limits their application in mining. Nevertheless, in several coal fields under shallow water-bearing sands the application of barrage screens is considered rational.

According to the methods of construction and materials used barrage installations are subdivided as infusion (flooded, filled), injection (pumped), cryogenic (icerock) and sheet piled. The infusion installations are constructed in water-bearing clay and sandy rocks as as trenches or holes filled with clay or clay-cement mortar, and with rolled synthetic material covered with shifted rock, etc. and inter-crossed holes filled with clay, clay-cement, sand-cement and other mortars. The injected installations are constructed both in clay and sandy rocks and in stone rocks by pumping cement, clay, bitumen, water glass, synthetic resin or several of them sequentially. The cryogenic barrage installations are created by freezing water concentrated mainly in clay and sandy rocks. It is provided by circulations of different brines (ammonia, brine and other cooling media) as well as natural cold accumulators in holes (columns). The sheet piled installations are flat piles (concrete, timber, metal) driven into clay and sandy rocks.

Underground Techniques

The inflow of underground water in coal faces can be sometimes reduced without resorting to drainage and barrage, but with the help of a rational sequence of mining areas and corresponding mining method, i.e. grouping of the mine districts simultaneously in operation; retreat or flat-back mining with storage of mineralized mine water in goaf; retreat mining of pillars; choosing areas for mining near the worked-out (and therefore drained) areas; choosing of the initial mining areas in the path of dynamic underground flows to intercept them and to reduce the inflow in the adjacent areas ("drainage faces"); cut-and-fill mining to reduce roof subsidence and the height of water-conducting system of cracks and fissures, etc.

In order to protect the workings from mine water it is necessary to prevent sudden water inflow from flooded workings and to regulate the run-off of mine water. The protection from accumulation of water in abandoned workings is carried out in the following way: natural over-flow of flood water into the main water accumulation reservoir or pumping it directly to the surface with submersible pumps (in mines) or directing water run-off (in quarries); leaving reliable protective pillars around the flooded workings in case they are situated above coal faces; or stowing.

The run-off of mine water is controlled by: a mining direction deviated from the dip of the coal seam floor which allows diversion of the mine water from coal faces into the goaf or adjacent workings; continuous advance of the coal face to minimize the water and coal-rock surface and to reduce water inflow in the coal face area; portable pumps for timely removal of water from swallies near the coal faces.

Drainage means direction of water to the main water sump, pumping it to the surface, clarification of mine water and utilization of both drainage and clarified mine water for technical and drinking water supply, direction of surplus water to the surface-stream flows and reservoirs out of the drainage zone.

In some cases a reduction of underground water head in the bearing rocks with the help of the intercepting boreholes leads to avoiding any formation of acid mine water.

GROUND WATER INVESTIGATIONS

Usually the data from exploratory boreholes is enough to protect the water-protection system for deposits with simple mining conditions, but for the deposits with complex conditions some additional research is carried out while taking into account the mining and stripping systems and resorting to experimental methods (observation and instrumental measurements in analogous cases and simulation in laboratories) and analytical methods using modern computer means.

At present the technique, technology and calculation methods for drainage in mining have been sufficiently developed, while they are not adequate for barrages.

In future the development of theory and practice of water regime control will depend upon carrying out the following basic and applied research :

- A review of world experience in mining mineral deposits with complex hydrogeological conditions, and classification of the deposits according to the degree of their saturation, the conditions of water regime control and protection of the environment;
- carrying out combined hydrogeomechanical research including studies of the structural features and filtration anisotropy of the rock mass, and the hydraulic and hydrochemical regimes of underground, surface and mine water in mining areas with complex hydrogeological conditions;
- developing the theory of hydrogeological calculations and simulation of drainage systems and especially of barrage screens, and the hydrochemical and biochemical conditions for pollution and contamination of underground, surface and mine water;
- improving the technology of mining operations to avoid hydro-geomechanical processes and phenomena, depletion, pollution and contamination of underground water, surface flows and reservoirs, as well as for protection of the geological environment as a whole;
- improving the present and developing new efficient means of water regime control of mining enterprises with complex hydro-geological conditions using new technical means and technology for construction and operation of drainage and barrage screens, clarification and utilization of mine water, as well as the control means for their operation.

CONCLUSIONS

The development and introduction of efficient means of water regime control, provided in future they are rationally combined with the drainage systems and barrage screens and a rational technology of mining operations, will allow preservation of the natural hydraulic and hydrochemical regime of underground water of mineral deposits; no or minimal depletion, pollution and contamination of surface and underground water; and utilization of mine water for technical and drinking water supply. Realization of these scientific and technical tasks will make it possible to reduce the negative affect of mining enterprises on ecological systems and to obtain a great economic effect.