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PROBLEMS OF INCREASING THE RELIABILITY OF AUTOMATIC MINING EQUIPMENT

by

L. G. Mel'kumov
V. B. Ginzburg

Mekhanizatsiya i Avtomatizatsia Proizvodstva, No. 7, pp. 50-52 (1966)

Translated from the Russian

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Discussed are problems of reliability of automation equipment in coal mines. Special emphasis is placed on the actual operating reliability of the equipment, the nature of possible breakdown, and recommendations for improving reliability.

In connection with the extensive introduction of automation equipment in coal mines and its complexity, the problems of reliability acquire a particular importance. Inadequate reliability of the equipment does not favor its introduction, results in idleness of the technological equipment, and increases the use of spare parts and of the cost of operations. In view of this, it is important to determine the actual operating reliability of the equipment, to establish the character of the possible failures to perform, and prepare recommendations for improving the reliability.

In 1963-1965, the Institute Giprougleavtomatizatsiya (State Institute for Planning the Automation of Coal Mining) and its affiliate (with the participation of several scientific research organizations and coal mining enterprises) had carried out a large number of statistical observations of the reliability of mining equipment. The obtained results make it possible to compare the reliability of equipment of different types, to establish the effect of operating conditions on the reliability, to disclose the most unreliable units and parts, to prepare recommendations for improving the reliability of equipment during its designing and production, to obtain a basis for calculating the reliability, and to plan efficiently the application of the equipment, the work of repair service, and the spare part supply.

The observations covered the equipment of 62 types in 160 mines of the Donetskiy, Karagandinskiy, Podmoskovnyy, and other basins involving a total of more than 4000 specimens. At the mines were installed continually acting observation posts to inspect the condition of the equipment.

This resulted in finding the relationship between the operating reliability of the automatic mining equipment and the operating conditions, the working conditions and the loading, the qualification of the servicing personnel, the periods of preventive repairs, the quality of component products, and their production.

An estimate was made of the series-produced automatic mining equipment which is most widely used by the industry, and the generalized actual quantitative characteristics of reliability were disclosed. The latter, which for the first time were obtained for entire branches of industry, will serve as the basis for developing new equipment and will make it possible to estimate the degree of its improved reliability. The use of the obtained characteristics of reliability will make it possible to establish correctly the periods between repairs and the norms for consumption of spare parts needed to maintain the specified level of the operating reliability of the equipment.

In view of the variety of the automatic mining equipment, a special analysis was made to determine the priority of the investigation of the equipment's reliability and the necessary criteria were selected. It turned out expedient to sample the equipment scheduled for a systematic investigation of its reliability in accordance with the following factors: the distribution of the equipment and the program for its output in the near future; the production quality; operating conditions; working conditions and loads; and extent of damage caused by the equipment going out of order.

The observations were arranged for the equipment of the automated conveyor lines (AUK-10, DUKL-2), water-draining units (AVV-3m, AVN-1n), ventilating units (UKVG, ADShV), speed-control units (VIRS-2m, DM, UPDS, VIRS-2s), etc. Beginning with 1965, the observations were also extended to the various contactless equipment of the remote-control systems, safety devices, signaling equipment, etc. It was proven that the probability of uninterrupted work of automatic mining equipment varies exponentially and on this was later based the processing of materials of statistical observations.

For the majority of the types of the series-produced equipment, the observations were carried out simultaneously in different coal basins, i. e., under different operating conditions, and, as a result, the reliability characteristics were quantitatively different for the same type of equipment. The generalization of the data by taking into account their fitness for comparison for the series-produced equipment and its component blocks resulted in obtaining quantitative characteristics of reliability shown in Table 1.

TABLE 1

Name of Equipment and of Its Component Blocks	Type of Equipment	Quantitative Characteristics of Reliability		
		Accrued Operating Time per Failure, T in Hours	Probability of Uninterrupted Work P (720)	Average Restoration Time, T in Minutes
Speed-control equipment:	VIRS-2M	1800*	0.67	48**
magnetoinductive pickup	DM	3700	0.82	12 (replace)
universal attachment to speed-control pickup.	UPDS	2320	0.73	20
Speed-control equipment	VIRS-2S	1876	0.68	34
Relay of resistance controller . .	IKS-2	4420*	0.85	54**
Tubular electrode-type pickup . .	ET-1	9050	0.92	60
Automation equipment of high-voltage water-draining unit:	AVV-3M	1690*	0.65	87**
control-instrument	AUV-3M	3411	0.81	68**
signaling tableau.	TSV-3	26112	0.97	46**
productivity relay	RPFVI	4896	0.86	48
electrode-type pickup	ED	26112	0.97	55
Automation equipment of low-voltage water-draining unit:	AVM-1N	941	0.47	135
control-instrument	AUN-1	1687	0.65	128
signal-tableau	TSN-1	40481	0.98	20
productivity-relay.	RPFV-1	6747	0.89	58
controlled valve	VU-1	5060	0.867	227
Automation equipment of main valves:	UKVG	5000*	0.87	82**
dispatcher's desk	PD-60	10665	0.93	59**
control station	SU-60	13094	0.046	68**
secondary recording device . .	E-618	234616	0.997	300**

* The data takes into account the comparable values of different coal basins.
** Weighted-average data for basins subjected to observations.

TABLE 1. (Concluded)

Name of Equipment and of Its Component Blocks	Type of Equipment	Quantitative Characteristics of Reliability		
		Accrued Operating Time per Failure, T in Hours	Probability of Uninterrupted Work P (720)	Average Restoration Time, T in Minutes
differential manometer-flowmeter	DEMPM	78205	0.99	187
Equipment to control content of methane:	AMT-2	4300*	0.85	38
signaling device	ASMT-2	78152	0.99	46
pickup	DMT-2	19538	0.96	32
signal tableau	TSM-5	78152	0.99	30
Automation equipment of unbranched conveyor lines:	AUK-10	290**	0.08	87**
control desk	-	3022	0.82	58
control block	-	2862	0.81	159
Automation equipment of branched conveyor lines......	DUKL-2	6000*	0.89	43**
Bearing-temperature control	KTT-1	3080*	0.79	50**
Ditto	KT-2	4400**	0.85	108**
Wiper-type explosion-proof relay	RVShCh-1	3000	0.79	36
Wiper-type pickup	DShCh	12000	0.94	-
Dispatcher's remote signaling ...	DTS-2	4250	0.84	34
receiving-recording device....	APR-3	10913	0.93	41
resonant amplifier block	BRU-1	30684	0.98	34
pickup-generator	DG	75966	0.99	28
single generator	OG	15441	0.95	35
Loudspeaker intercommunication .	PGS-1K	525	0.25	147
Insulation control (1963 model) ..	UAKI-660	2100	0.71	-
Hydroelectric drive	EGP	320*	0.1	95**
drive	-	1490	0.62	110
electric motor	VEG-1	852	0.43	90

* The data takes into account the comparable values of different coal basins.

** Weighted-average data for basins subjected to observations.

As shown in Table 1, the reliability of many types of series-produced automatic mining equipment is comparatively low, and urgent steps must be taken for its improvement.

In accordance with the tentative requirements developed by the Giprougleavtomatizatsiya Institute and adapted by the industry, the automatic equipment and facilities of the mining industry must have the following quantitative characteristics of reliability.

For equipment of the 1st class involving the safety in mines (control of the gas composition in the mine's atmosphere, resistance of the insulation of the mine's electrical network, leakages and resistance of the grounding system, spontaneous combustion of coal, etc.), the average accrued operating time per failure must equal $T_o = 75,000$ hours, the probability of uninterrupted work per month of operations (720 hours) should be $P_{720} = 0.99$. The result of a failure of the equipment to operate may involve considerable damages, idle the mines by exploding methane and fires, and cause body injuries.

For the component equipment of this class, $T_o = 14,500$ hours, $P_{720} = 0.95$, and the average restoration time $T_{restoration} = 0.2$ hours.

For the functional protecting blocks of the equipment belonging to the 2nd class, which provides normal working conditions in the mines, protects the technological objects against accidents, and provides the emergency signaling (protection of the lifting, ventilating, and water-draining units, electrical substations, etc.), it should be $T_o = 14,500$ hours, $P_{720} = 0.95$, and $T_{restoration} = 0.2$ hours, while for the components of the equipment of this class it should be $T_o = 7200$ hours, $P_{720} = 0.9$, and $T_{restoration} = 0.25$ hours. A failure of this equipment to operate may idle for a long time the technological units and the mine, inundate mining workings, and cause considerable damages.

For class 3-A equipment employed for automation of the technological processes and equipment without a margin of productivity, whose idleness is inadmissible (automatic equipment of loading, skip, and cage lifts, main conveyor lines, etc.), it is $T_o = 7200$ hours, $P_{720} = 0.9$, and $T_{restoration} = 0.5$ hour. Failures of this equipment may result in considerable damages measured by the loss of mined coal, cost of repairs, or cost of replaced equipment. As an example, one hour idleness of the main conveyor line costs, on the average, 60 rubles and for the skip-lift it is 190 rubles.

For the class 3-B equipment, $T_o = 4500$ hours, $P_{720} = 0.85$, and $T_{restoration} = 1$ hour. This equipment is used for automation of the technological processes having a margin of productivity for which a short idleness is admissible (automatic equipment for lifts carrying loads and people, auxiliary lifts, hoists for tailings, sectional conveyor lines, equipment near shaft-doors and of above-mine buildings, etc., which do not operate at full load).

A failure of this equipment may cause a material damage resulting from the loss of mined coal when the idleness is longer than admissible, and also from the cost of restoring or replacing the equipment.

For class 4 equipment used for automation of auxiliary processes and for which long idleness is admissible, it is $T_o = 2500$ hours, $P_{720} = 0.75$, and $T_{restoration} = 1.5$ hours. The damage resulting from the failure of this equipment to operate is insignificant and involves the cost of restoring it.

As indicated by statistical investigations, the intensiveness of failures of typical elements used in automatic mining equipment is increasing due to the difficult operating conditions (effect of unfavorable surroundings and lack of protection against its action, vibrations, low level of preventive service, incorrect working conditions, etc.).

In Table 2 are shown the experimentally obtained data on the intensiveness of failures of typical elements serving as components of automatic mining equipment; also the tabular intensiveness of failures of the same elements of the equipment commonly used by the industry.

The average intensiveness of failures of elements to operate was calculated by taking into account the average by-type distribution of the elements among the automatic mining equipment and it is as follows: $\lambda_{average} = 0.34 \times 10^{-5}$ for minimum value of intensiveness and $\lambda_{average} = 4.2 \times 10^{-5}$ for maximum values of intensiveness.

As indicated by observations, for most of the types of automatic mining equipment, the restoration time is within 15-280 minutes and the most typical time required to restore the equipment is within 45-60 minutes.

The time required to restore the equipment depends on the structural features of the equipment, availability of spare blocks, assemblies, suitable tools and devices for detecting faults, and on the qualification of the servicing personnel.

Table 2

Name of Element	Intensiveness of Failures λ (10^{-5} 1/hour) Tabular Data	As Per Statistical Observations	Average Restoration Time, T_r, (minute)
Relays:			
RKN	1.0	4.65 to 7.0	86
MKU-48	0.25 to 2.0	4.0 to 6.5	86
RP-4	0.4	35.0	104
RP-5	0.4	43.0 to 48.0	104
Semiconductor devices:			
D-205	2.5	6.6	90
P-202	2.2	4.05	102
Elements of switching equipment:			
RB block disconnectors	1.5	10.0	60
tumblers	0.3	0.68	60
switches	0.64	1.5	60
MP-1 pushbuttons	0.5	6.4	60
feeding transformers	1.2	4.45 to 8.9	120
plug-type connectors	5.0	7.0	60
SD-2 motors	1.1	4.55	96

In case of technological objects for which a short idleness is admissible, a gain in reliability can be obtained as the result of a shorter average time required to restore the equipment (in the final analysis it amounts to reducing the idleness of the equipment). This gain will be a function of the ratio between the allowable idle time and the average time required to restore the equipment for its duties (the probability of restoring the equipment within the specified time). Consequently, the main causes of inadequate reliability of automated mining equipment are: structural defects, low quality of products, and unsatisfactory operation.

Structural defects are the result, in many cases, of the inadequate training of designers and incorrect accounting of the equipment's operating conditions. In such a manner, general-purpose elements are used which are not adjusted for work under mining conditions, incorrect loading conditions are selected, the shells of the equipment are not adequately moistureproof, etc. In this category, too, is the equipment's low fitness for repairs due to the limited use of joints, removable and easily accessible to inspection and repair of blocks.

The low quality of products is due to the lack of necessary inspection of materials and elements received from neighboring enterprises, inadequate outgoing inspection, and violation of technology; also, poor quality of pouring and impregnating, poor soldering, violation of the manner of impregnating and drying of windings, etc.

The unsatisfactory operation of the equipment includes the noncompliance with the dates and number of preventive repairs, lack of necessary measuring and special instruments, use of "homemade" parts for the equipment, and lack of properly trained repair crews and operating personnel. It was established statistically that, even when the equipment is protected against errors made by servicemen, the personnel are responsible for 10 to 20 percent of the failures.

The results of the experimental investigations carried out at the enterprises of this branch of industry made it possible to prepare the measures that must be taken to improve the technical level of designing, production, and operation of automated mining equipment and, as a result, to improve its reliability and to prolong its service life. Generally, these measures are reduced to the following.

In planning the equipment it is necessary to assure the use of highly reliable elements and correctly selected loading conditions; to meet the calculated reliability; to improve the fitness of the equipment for repairs by block-type assemblies by using plug-type connectors, and easily removable covers, by introducing into the design inspection jacks and inspection push-buttons; to protect the mining equipment and its individual blocks against the action of dust and moisture (tar-pouring, use of dust-, moisture-, and explosion-proof shells; and to coat the parts with moisture-proof varnishes, etc.).

In manufacturing the equipment it is necessary to assure the inspection of the quality of employed materials and elements, to follow the technology, to check thoroughly the tested specimens for reliability, and to try them in operation.

In operating the equipment it is necessary to carry out a systematic and high-quality preventive inspection and repair in accordance with a carefully prepared program that takes into account the failures to perform of the equipment's elements under actual operating conditions.

It should be noted that the requirements for the equipment provided by the existing standards and departmental norms do not assure the production of highly reliable equipment. This pertains to the parameters of the surrounding conditions and of outside mechanical actions, etc. The specifications for certain elements serving as components of the equipment do not correspond to the specifications for the production of the equipment. The existing guiding manuals which are effective in this field must be reviewed in the near future.

As a result of the work carried out by Giprougleavtomatizatsiya, its coworkers, and the plants manufacturing the automated mining equipment, there were prepared specific recommendations for the replacement of the most unreliable assemblies and parts. Thus, as a result of the investigation of the reliability of the speed-control equipment of the type-VIRS-2M conveyors, there were found assemblies and parts which frequently go out of order (the polarized relay, DM-pickup, MKU-48 relay, etc.). The compliance with the recommendations for replacing the least reliable assemblies assures a 20 percent improvement in the reliability of the equipment by increasing the cost by 11 percent. As a whole, by complying with the recommendations, the Dnepropetrovskiy Plant of Automatic Mining Equipment obtained an annual saving of about 90,000 rubles.

In 1963-1965, the steps taken to improve the reliability of products made by the Konotopskiy Plant "Krasnyy Metallist" (Red Metalworker) improved by 10-30 percent the reliability of the AVV-3M equipment for automated draining of water, of the PRSh-1 starter, VKV-380 switch, etc. It prolonged the service life of the EBG electric bore, SER-19m electric drill, and others, and their guaranteed service life was increased from 6-8 to 12 months. For this plant, the economic gain from taking these steps amounts to 300,000 rubles per year.

The realization of the steps aiming to improve the reliability of the equipment will make it much easier to automate the mining processes and make them more effective. The work for improving the reliability of systems and automatic mining equipment must be developed in all directions: in manufacturing plants, planning and designing organizations, and in coal-mining enterprises. The next task is the creation of scientifically based optimum standards of equipment reliability, norms for preventive repairs and for consumption of spare parts.

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