TECHNICAL SESSION - IV

HEALTH AND SAFETY PROBLEMS IN UNDERGROUND MINING

"Mine Illumination Equipment—Hardware Reliability"

by

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ABSTRACT

The recent publication of the Federal Mine Illumination Standards (Parts 75.1719 and 75.1719-1 through 75.1719-4 of Part 75, Title 30, Code of Federal Regulations) has stimulated a renewed interest in available hardware and its reliability. The Bureau of Mines has been engaged in a program by which illumination systems were installed and evaluated in operating coal mines. The results of these evaluations, together with published lamp and ballast mortality statistics, provide a good insight into the expected reliability of today's mine illumination hardware.

INTRODUCTION

To investigate the reliability of any type of hardware, many variables must be taken into consideration. The variables can include a wide spectrum of events and environmental effects, ranging from manufacturing variances to the picks and shovels that find so many uses in our Nation's coal mines. Accordingly, a given luminaire could function without failure for the three years of rated life that many lamps and ballasts claim, or a roof could crush it during its first hour of operation. Therefore, a brief discussion of statistics as applied in determining the expected life of illumination system components will be extrapolated to expected life in the mining environment.

DETERMINATION OF EXPECTED LIVES OF ILLUMINATION COMPONENTS

The major manufacturers of lamps and ballasts assign a rated life to these components. The rated life expectancy is the expected life. It

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is determined in many cases by actually burning a representative sampling of units and determining a statistical average. A typical test procedure is to burn 1, 000 lamps until 50 percent fail; the number of accumulated burn hours at that point is considered the rated life. The graphs displayed in Figures 1-3 show the relative performance of fluorescent, mercury, and high-pressure sodium vapor lamps, three types that are commonly utilized for coal mine face area illumination.

As can be seen, the mercury vapor lamp (Figure 1) is the best performer of the group, with an expected life exceeding 24, 000 hours. However, a point of interest is the relative shapes of the curves. In the case of the fluorescent lamp (Figure 2), the majority will burn 14, 000 hours, and very few will last beyond 20, 000 hours. This type of performance is characteristic of a mature product with tightly controlled manufacturing processes. In contrast, the high-pressure sodium vapor lamp (Figure 3) displaying a finite rate of failure which begins as soon as the test period. This can be attributed to the fact that the sodium vapor lamp is a relatively new device and its production processes are not as refined as those of the fluorescent, causing infant mortalities. However, while the mercury vapor lamp is not as mature as the fluorescent, it possesses a mortality curve with fewer early failures.

This performance will manifest itself in the mining environment. The operator can expect nearly zero failures of fluorescent lamps during the initial 40 percent of rated life, with increasing failures as accumulated hours approach the rating. The high-intensity discharge lamps will display more infant mortalities but a longer average life. The information contained within the mortality curves can often be utilized to define a preventive maintenance program. A group relamping program can be defined by determining an acceptable lamp failure rate, tailored to particular mining conditions.

The three arc discharge lamps discussed all exhibit negative resistive characteristics and, therefore, require an auxiliary ballast to limit the current passing through the lamp. When these lamps are to be utilized on ac circuits, the required ballasts take the form of series inductors or transformers. The technology utilized in the actual performance is dependent on cost vs durability tradeoffs. The ballasts are usually designed to achieve rated life equal to four or five times that of the lamp. This expected performance has not been verified in the actual mining environment because of the extremely long time periods involved (10-15 years). However, experience at the Inherently Safe Mining System demonstration at the Jenny mine, Prestonsburg, Kentucky, revealed an extremely good performance record. A total of 21 ballasts were burned for 6, 000 hours each, with two failures attributed to cut insulation caused by the addition of a poorly placed steel mounting band.

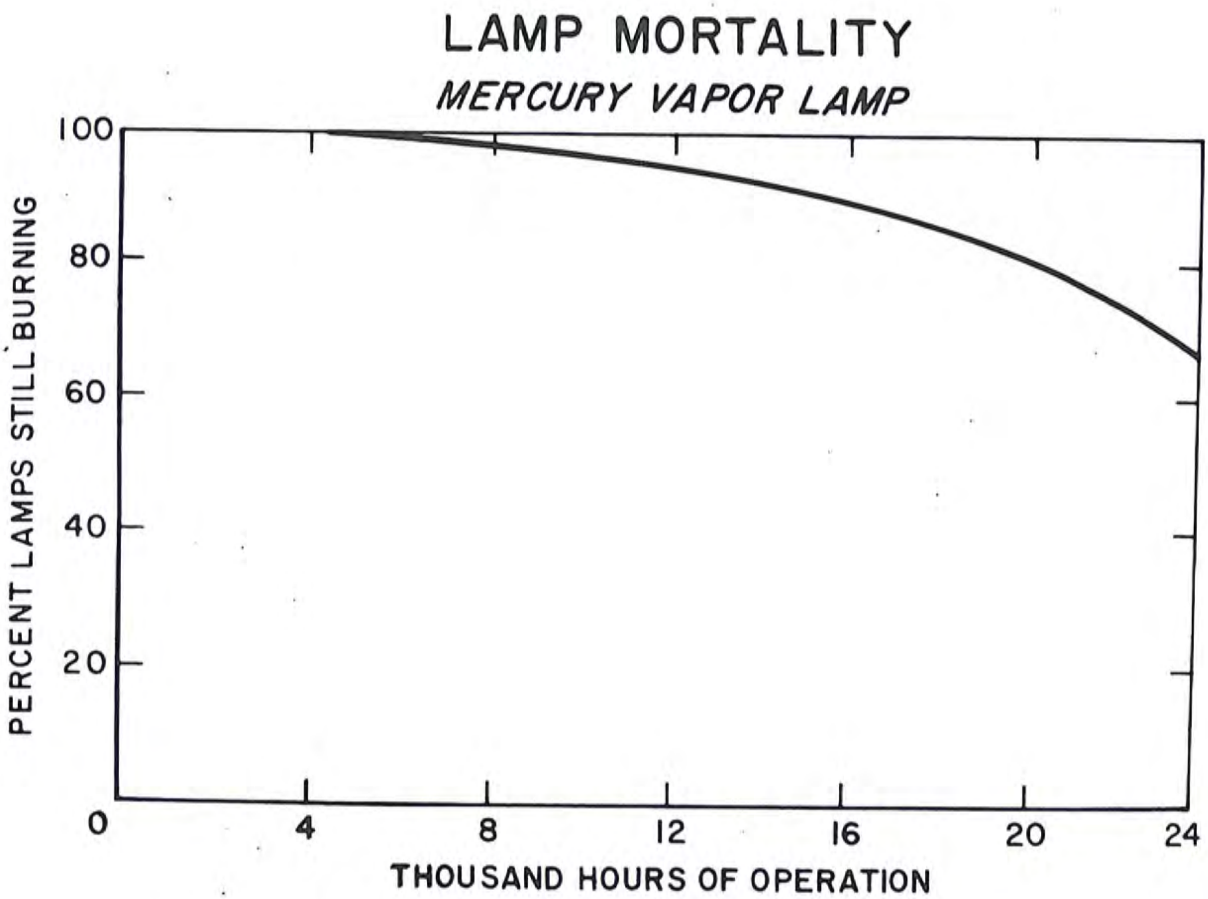

FIGURE 1. Lamp mortality - mercury vapor.

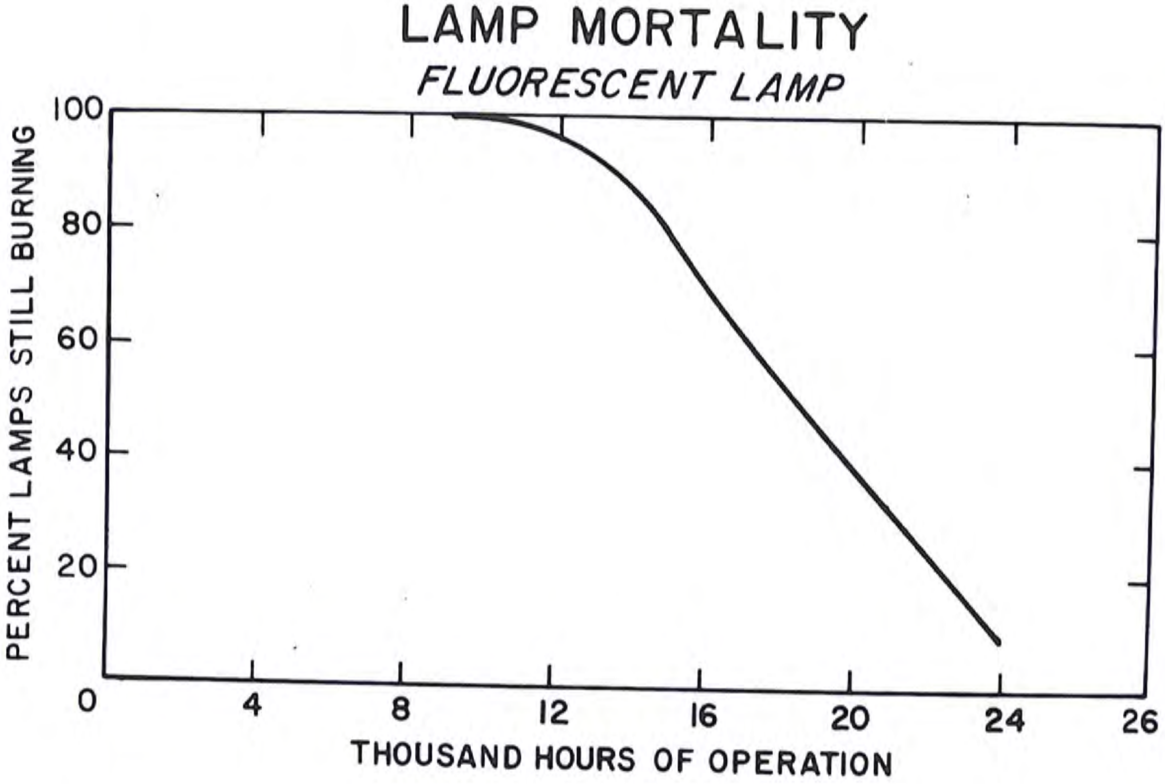

FIGURE 2. Lamp mortality - fluorescent lamp.

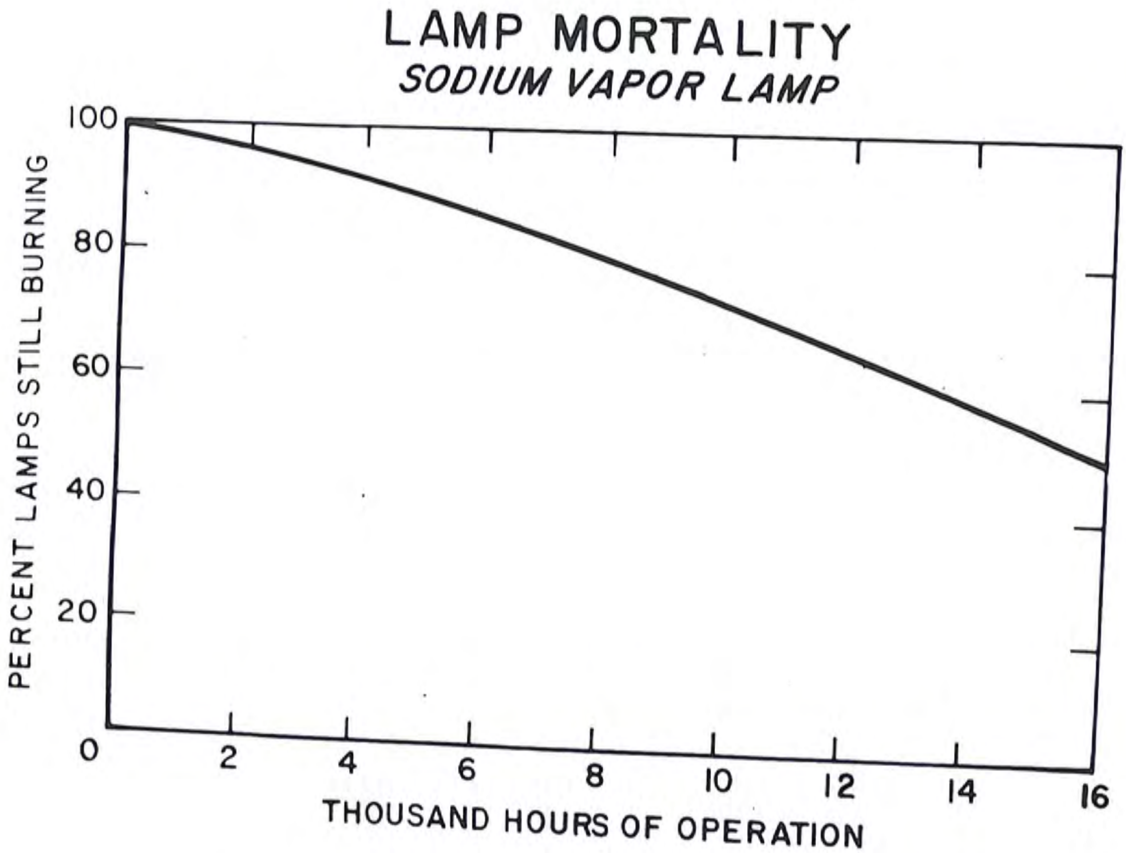

FIGURE 3. Lamp mortality - sodium vapor lamp.

Lumen Maintenance

All three of the arc discharge lamps discussed exhibit a decrease in lumens of output as accumulated hours increase. This characteristic in fluorescent lamps can be attributed to changes in phosphor and the deposition of electrode material onto the glass envelope. Mercury vapor lamps deteriorate in much the same manner, with the electrode material coating the arc tube walls and also, in color-corrected lamps, the degradation of phosphors. Lamp manufacturers have determined the lumen degradation as a function of accumulated burning hours. The details presented as "lumen maintenance curves" (Figures 4-6) show lumen maintenance curves for typical fluorescent, mercury vapor, and high-pressure sodium vapor lamps.

The information presented in these curves must be considered when an illumination system is being designed to a performance specification, such as the Federal Mine Illumination Standard of 0.06 ft lamberts (ftL). As can be seen by reviewing Figures 4-6, an illumination system must be designed with an initial margin to insure proper illumination as lamps age. Consider the design of a fluorescent illumination system, to be utilized in a mine whose coal surfaces possess a reflectivity of 2 percent. An illumination level of 3 ft candles (ftC) would be required to provide an initial luminance level of 0.06 ftL. However, a margin of 30 percent would be required to insure sufficient luminance levels as the lamps age. Therefore, the system should be designed to provide an initial 3.9 ftC.

Mine Illumination System Performance in the Mining Environment

The Bureau of Mines has pursued a Mine Illumination program which has produced two permissible illumination systems and has contributed to the development of several more systems that are currently under review by Mining Enforcement and Safety Administration (MESA) Approval and Certification Center. Another facet of the Bureau's program evaluates these illumination systems in operating coal mines, acquiring data concerning both attained illumination levels and product reliability. The program to date has been restricted to the evaluation of the two systems that have been approved. However, the performance of future systems which utilize standard, commercially available components can be predicted by examining the published mortaility and lumen maintenance data.

Existing and proposed illumination systems can be grouped into two categories for the purposes of this paper: (1) Systems that utilize standard lamps and ballasts and (2) systems that utilize solid state or other newly developed devices which are characteristic of intrinsically safe power distribution techniques and dc devices.

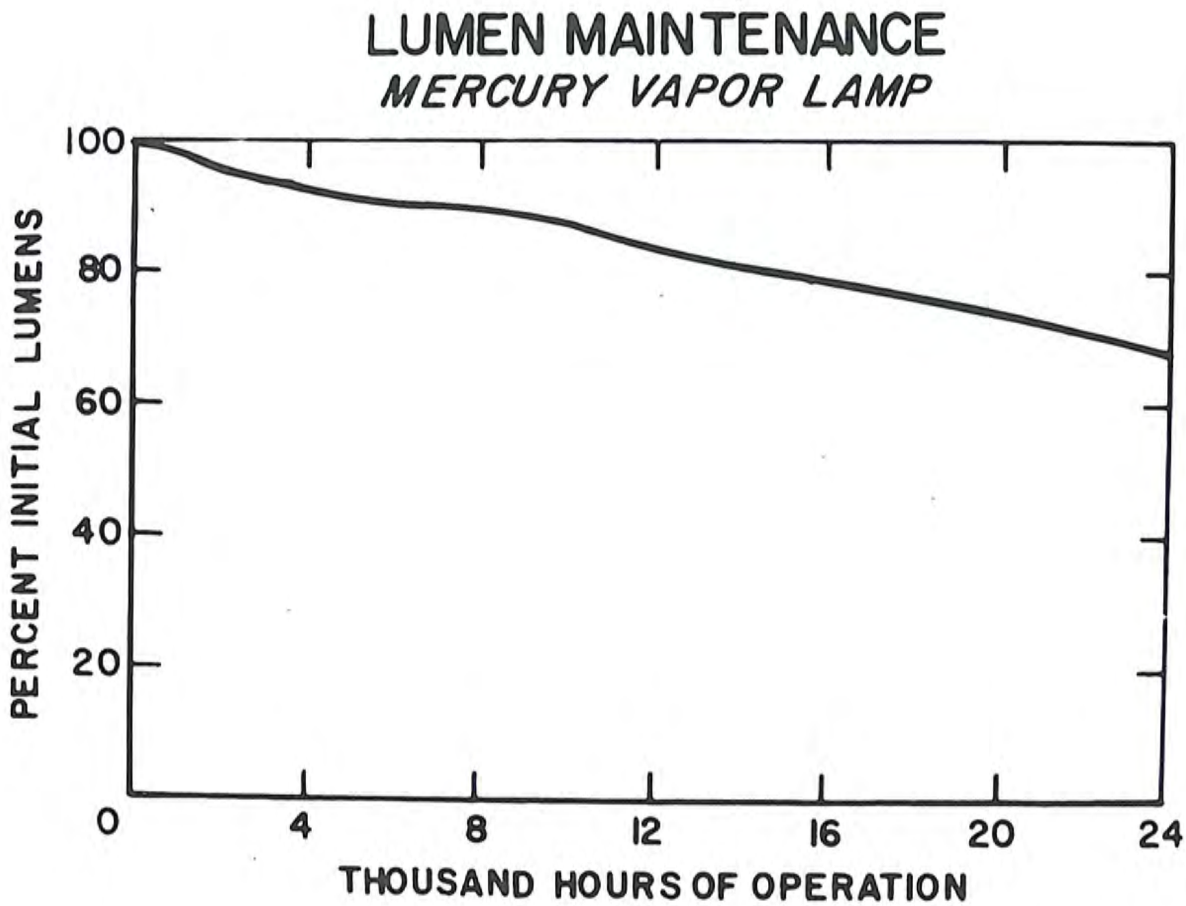

FIGURE 4. Lumen maintenance - mercury vapor lamps.

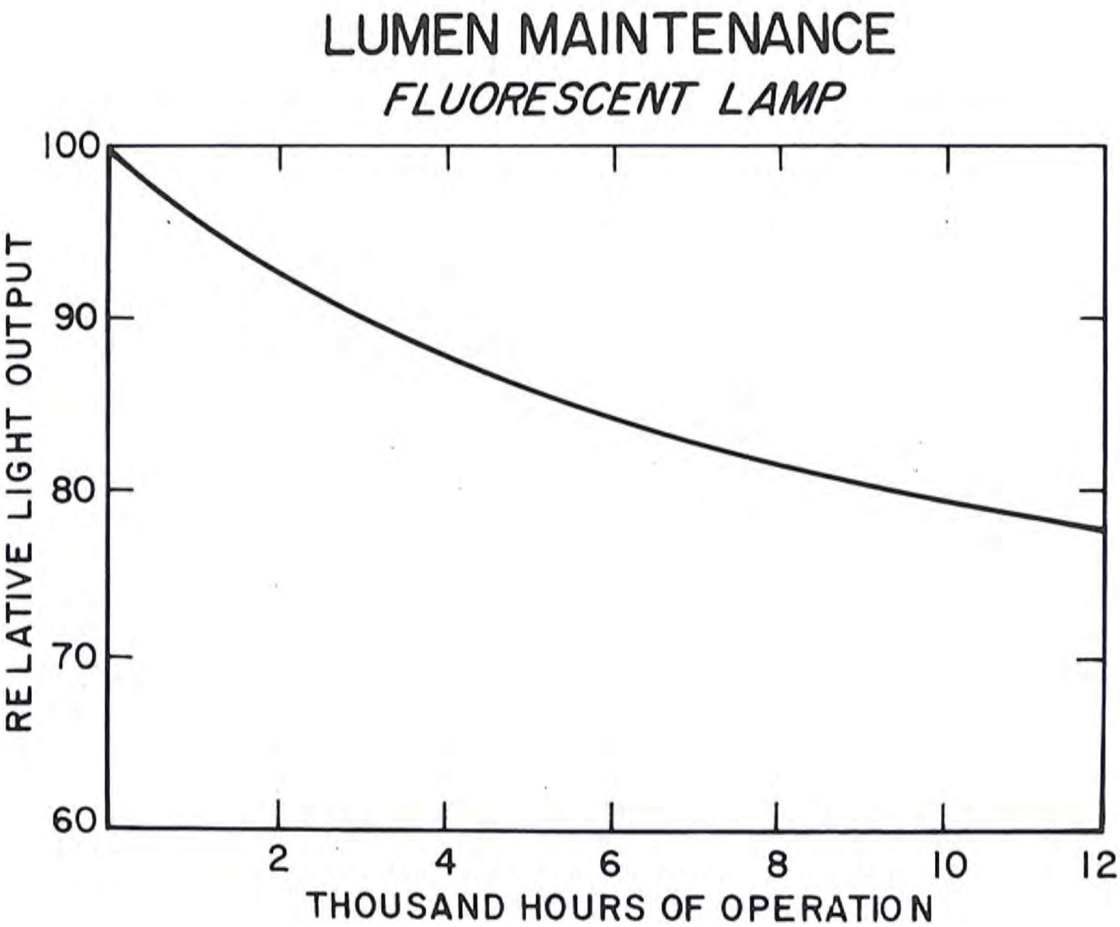

FIGURE 5. Lumen maintenance - flurorescent lamp.

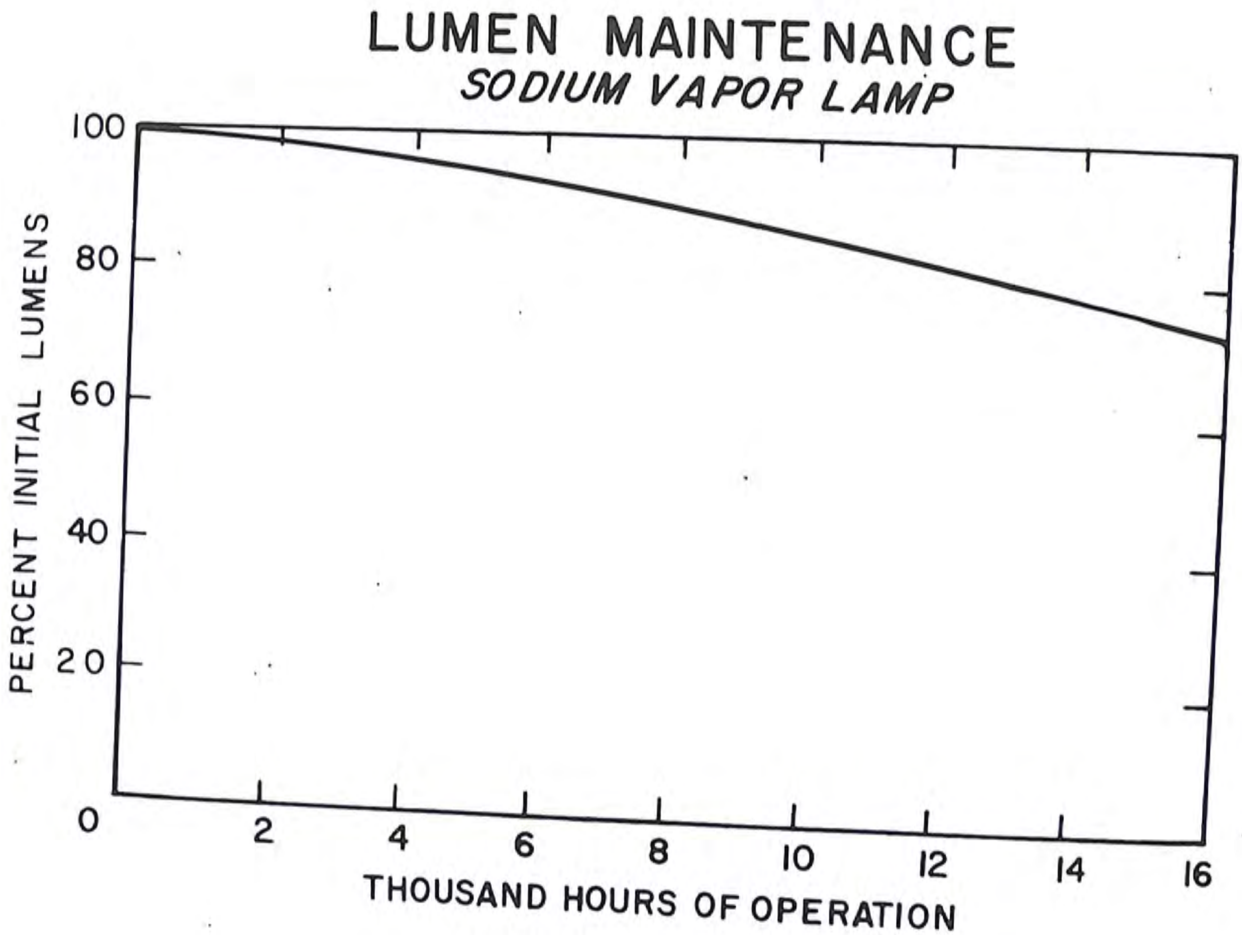

FIGURE 6. Lumen maintenance - sodium vapor lamp.

The first group, utilizing long-proven hardware, should perform as per published data. In-mine evaluations of the Control Products System,[2] which utilizes standard fluorescent, mercury vapor, and high-pressure sodium components, have shown this to be true. Typical experience at the Jenny mine demonstration was related earlier in this paper.

The prediction of reliability in the second group, which utilizes relatively new technology, is not as easy. Newly developed power supplies and ballasts operate lamps in unconventional modes; the resulting expected component lives could be longer or shorter than those of standard equipment. A representative of this group is the Ocenco illumination system, which consists of a power supply that accepts mine power as input and provides 12 vdc intrinsically safe power to flurorescent luminaires that include a solid state inverter ballast. This hardware has been extensively evaluated by the Bureau of Mines.

A typical performance record was obtained at a longwall installation in the York Canyon mine, Raton, New Mexico. The illumination system consists of 122 Model 20M luminaires and 15 20-amp power supplies. The illumination system has operated for approximately 340 shifts (2, 720 hours) during an 8-month period. A total of 12 luminaires were replaced, and 21 power supply failures were experienced. Eighteen of the power supply failures were attributed to a circuit board utilized within the supply to regulate voltage and limit current. The circuit boards are plug-in modules and are quickly replaced. The performance of the luminaires at York Canyon is representative of other installations. However, the failure rate of the power supplies is not; at other evaluation sites power supplies have operated for over one year with no failures. Again, the performance is a characteristic of a relatively young product and is steadily improving as the hardware matures.

Another major factor in luminaire mortality is mounting and guarding techniques. No presently produced luminaire can survive the impact forces encountered when massive mining machines collide with each other or with coal ribs, and it is highly unlikely such a device will be developed in the near future. Therefore, the need for proper guarding of the hardware cannot be overemphasized.

Several good examples of utilizing machine architecture to provide luminaire protection have been displayed during the Bureau's in-mine evaluations. One such example was the modified Long-Airdox coal drill at the Jenny mine. The sheet metal which formed the top surface of the machine was cut to accept a 175-watt mercury vapor luminaire. The mounting location, as shown in Figure 7, places illumination on the floor,

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[2]Use of company names is for identification purposes only and does not imply endorsement by the Bureau of Mines.

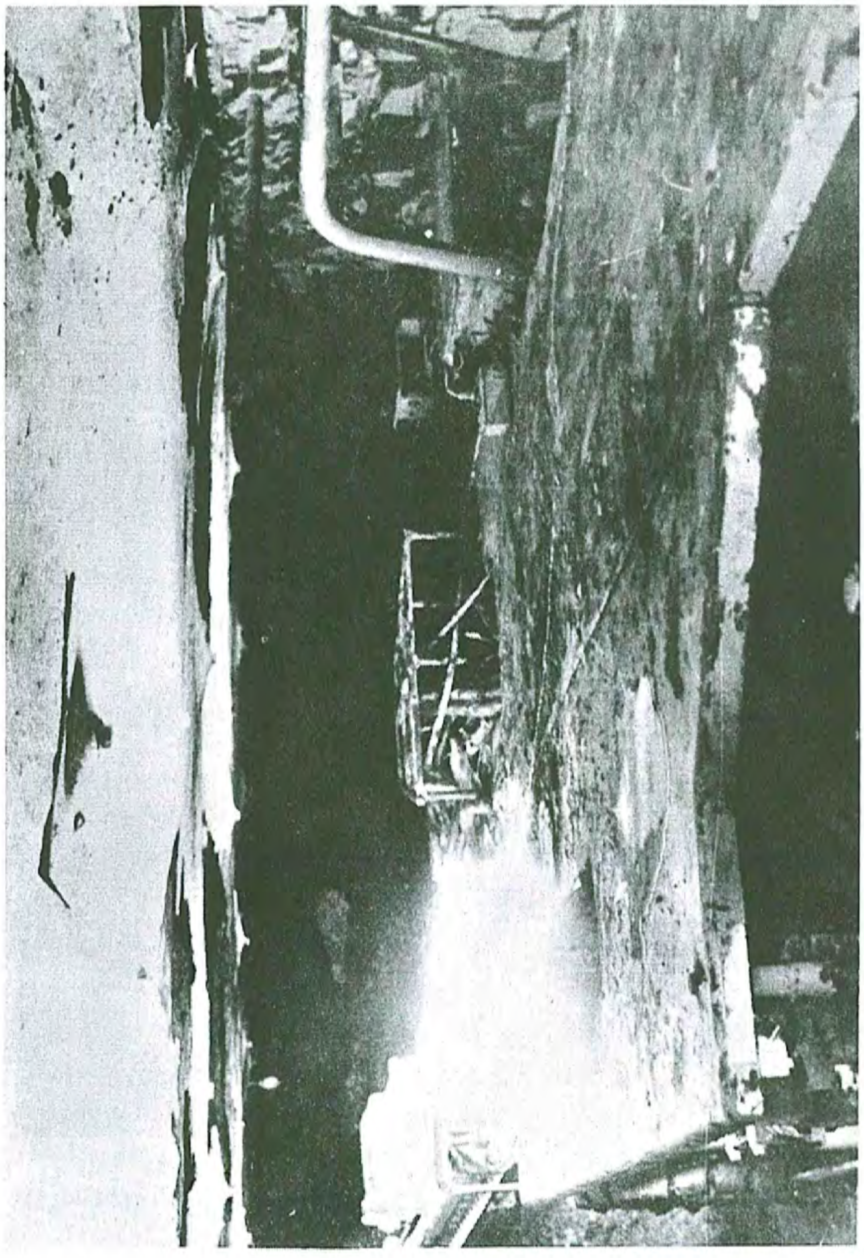

FIGURE 7. Protective luminaire mounting location on a Long-Airdox coal drill.

rib, and roof while providing good protection. The luminaire was in operation for 21 months without damage or downtime.

A second example of providing good luminaire protection is shown in Figure 8. A mercury vapor luminaire is mounted on a 15RU cutting machine utilizing the existing machine configuration and as such required no machine modification.

DC Illumination

Several devices have been developed to power various luminaires, utilizing the mine's dc trolley line as a power source. Two such devices have "come of age" and are now displaying acceptable lives.

Ocencȯ, Inc., has developed a power supply which accepts power from the 300-vdc trolley and supplies 12 vdc as an output. The power supply has exhibited a mean time between failures exceeding one year.

A second device is the FMC dc mercury vapor lamp ballast. The ballast will also accept 300 vdc and will operate one 175-watt or 100-wall mercury vapor lamp. These ballasts have also exhibited lives exceeding one year.

CONCLUSION

In conclusion, the reliability of illumination systems is determined by the components and the mounting methods utilized during the initial installation. However, experience has shown that the major cause of downtime is damage due to machine collision resulting in crushing of components. Therefore, proper protection of the hardware will be provided if reasonable service is expected—it must be protected to survive.

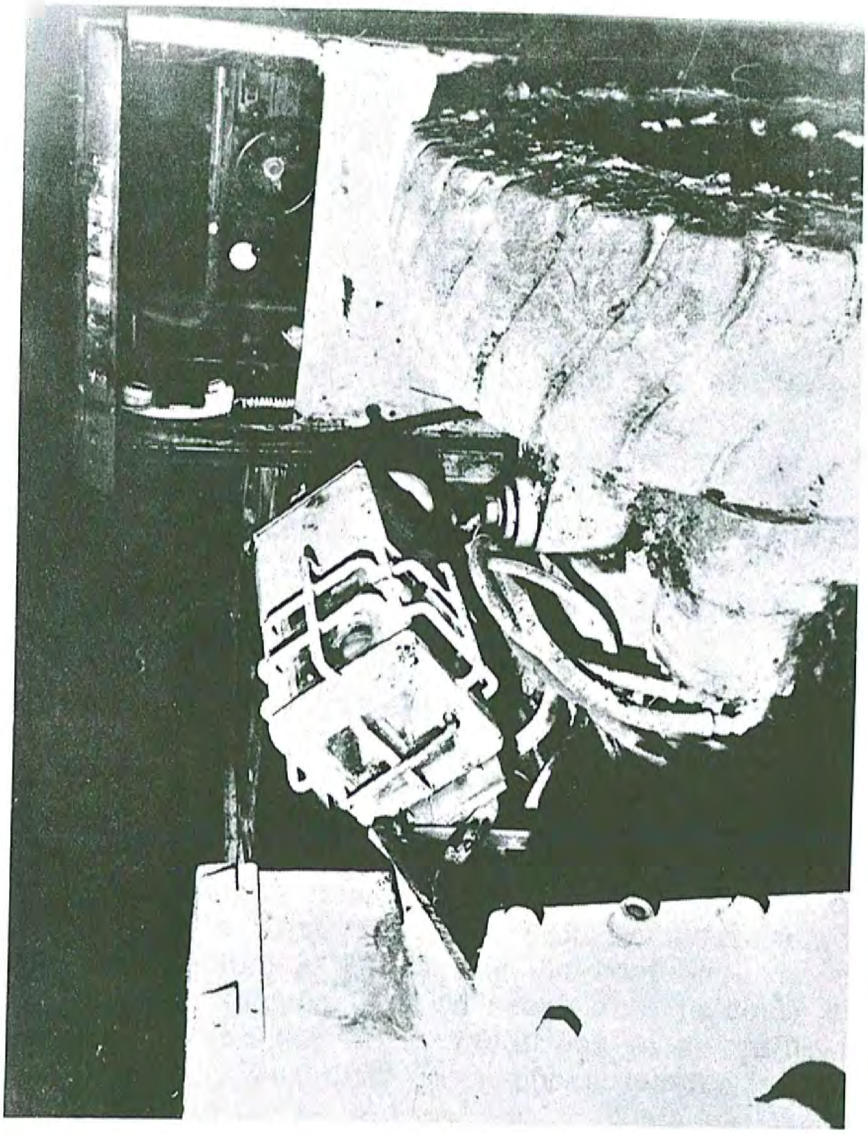

FIGURE 8. Protective luminaire mounting location on a Joy 15RU cutting machine.

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