Illumination of Mines

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In preparing this paper the object has been to set forth facts relating to illumination problems, which, judging from the results realized in the iron and steel and other industries somewhat similar to mining, will tend toward furthering safety, production, and contentment of employees, as well as economy of operation in mines. By applying the principles of illumination with the assistance of modern appliances, the full benefits in efficiency may be derived from improvements already made in other details of mine operation.

The lighting of a typical coal mine may be divided into four distinct parts: 1, The lighting of the buildings about the top; 2, the lighting of the working faces; 3, general illumination at the bottom; and 4, special applications of lighting.

The lighting of buildings about the top may be treated in the same manner as that of any other industrial plant, for we have a boiler room, an engine and generator room, a forge, a machine shop, and a hoist room. These can be well and efficiently lighted by the use of 100-watt tungsten-filament multiple lamps with proper reflectors so spaced and suspended that a power consumption of from \( \frac{1}{4} \) watt per square foot in the boiler room to 1 watt per square foot in the machine shop is obtained. The methods that apply to this kind of lighting have been ably treated by a number of authors,\(^1\) and for this reason a detailed discussion is unnecessary.

The lighting of the working faces is usually done by means of portable lamps, of which there are four types in use: The oil torch, the acetylene lamp, and the oil and the electric safety lamps. The different types have been fully described in numerous papers and articles and will not be covered here, although a few figures on the cost of operation will no doubt be

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Numerous papers on the various phases of industrial lighting have appeared in the Transactions of the Illuminating Engineering Society.
of interest. In attempting to obtain cost figures, one is impressed with the fact that apparently very few such data have been obtained in this country. It would seem that such data would be of particular benefit at this time, with the advent of the electric safety lamp.

The oil torch is without question the cheapest source of light. The acetylene lamp, at a cost of 6c. to 10c. per lamp per week, gives far superior illumination, but the characteristics of this source of light as well as any other open-flame lamp will bear careful consideration in view of the ever-present desire for industrial efficiency and safety. It is the opinion of many that the greater percentage of disastrous explosions in this country have resulted from the use of open-flame lamps in the so-called non-gaseous mines. This question of safety, of course, merits serious consideration.

The oil safety lamp has a distinct advantage in that it gives an indication of the presence of gas. Its development marked one of the greatest advances in mine lighting, although in most cases at the present time it is not considered a guarantee against explosion when in the presence of gas. Figures obtained from foreign countries indicate the cost of using oil safety lamps is from 7c. to 9c. per lamp per week.²

The electric lamp gives a steady and readily directed light, free from gases, soot, and frequent outage. A large proportion of the generated light is directed on the working face. It is sometimes considered a disadvantage that the electric safety lamp does not give an indication of gas as does the oil safety lamp. The trend of opinion in England, however, is toward choosing a lamp for the light it gives and to use some other means for gas indication.³ There is no question that an electric lamp passing the tests of the U. S. Bureau of Mines will give more light on the working face than any of the three previous illuminants, because it has been scientifically designed with that end in view.

Foreign practice has shown that electric light costs from 12c. to 17c. per lamp per week. This cost is about twice that of the oil safety lamp. The light on the "face," however, is materially increased by the use of the electric lamp. One foreign electric-lamp manufacturer places the cost of electric light at 2½c. per lamp per shift.³ This figure, though it seems low, can well be realized in this country with a large installation and proper care. In this connection, it is very necessary to have proper housing and proper attention for electric lamps—more so than with the oil safety lamps. It has been found in foreign practice that this care and

² William Maurice: Electric Handlamps for Collieries, The Electrician, May 12, 1911.
attention is very little, if any, more expensive than the attention that is
given to oil safety lamps, even though more expensive help is needed, be-
cause fewer men are required to care for the electric outfits. This country
has been slow in taking up the electric lamp. It has been said that in
Belgium alone there are 12,000 outfits in use. The excellent work done
by the U. S. Bureau of Mines to obtain the highest efficiency for this new
source of illumination has accomplished what years of competition among
electric mine-lamp manufacturers could hardly have brought about.

The application of the principles of industrial illumination to the general
lighting of mines must be made in the face of conditions difficult to over-
come. In fact, all the conditions the illuminating engineer considers most
difficult are present: low ceilings, black walls, dust, smoke, and dampness;
but in spite of these, very satisfactory results have been obtained.

An ordinary mine, from a lighting standpoint, can be considered as com-
posed of at least six parts: the bottom, the run-around, main entry, side
entries, mule stables, and small rooms, such as offices, pump rooms, stor-
age rooms, and first-aid rooms. These are shown diagrammatically in
Fig. 1. The bottom, being the entry and exit for both men and coal, accom-
modates more traffic than any other part of the mine and should be espe-
cially considered from the standpoint of both convenience and safety.
Fig. 2 shows a portion of a well-illuminated bottom and shaft opening of a
typical mine. The lighting of the shaft in this case was accomplished by
the use of 40-watt tungsten-filament lamps equipped with angle reflectors,
placed above and across the shaft opening so as to direct the light on the
cages. The maximum intensity is at the near edge of the cage, and the eyes of the workmen on the side of the shaft toward the observer are not subjected to the glare of the lamps. For comparison, Fig. 3 shows this same portion of the mine lighted by the use of bare carbon lamps. It is readily seen that the distribution is not of the best and also that the glare of the bare lamps obscures that portion of the mine which lies beyond. These illustrations were made from actual photographs, retouched only enough to remove the halation effects of the bare lamps. The photo-
graph shown in Fig. 2 was exposed about 1 min. as against 15 min. for the one in Fig. 3.

That portion of the bottom leading into the mine, where cars are directed on to the cages, can be well lighted with 40-watt tungsten lamps in shallow dome reflectors placed above and between the tracks. These units, spaced at about 6-ft. intervals and hung about 8 ft. above the floor, will give satisfactory distribution of light. It will be noticed from Fig. 4 that the car wheels are well illuminated and that there is practically no glare. It would be well to design the lighting of this part of the mine on a basis of 4 to 5 foot-candles at the floor, not because the work demands this intensity, but because of the greater safety which results from ample illumination and because dust collecting on the lamps and reflectors decreases the amount of light delivered.

The run-around should require only sufficient light to make visible any obstructions in the path of the empties as they leave the cages. This part of the mine may be illuminated with 25-watt tungsten lamps equipped with shallow dome reflectors, spaced 15 ft. apart and suspended 8 ft. above the floor. In the main entry, the function of light is not so much to illuminate as to silhouette objects which may obstruct the passageway. With silhouette lighting, a comparatively small amount of light is needed to obtain the effect desired, which is to see objects outlined against something that is lighted. For instance, whitewashed doors or walls reflecting the light toward the observer's eye are excellent backgrounds against which objects form silhouettes when in the line of vision of the observer. The glint of the light on the rails forms another good surface from which
silhouette lighting may be obtained. With 25-watt tungsten lamps in shallow dome reflectors, spaced at intervals of about 300 ft., the height depending upon the height of the entry, the silhouette lighting is excellent. Two units, one to illuminate the switch and the junction and the other illuminating a portion of both the main and side entries, help to eliminate collisions and by the increased light warn the trip driver that his train is approaching such a junction.

The mule stables with their low roofs may be effectively lighted with 40-watt tungsten lamps equipped with angle reflectors placed along the back wall and as high as possible, one unit to each two stalls. In front of the stalls and opposite the angle units, 25-watt tungsten lamps with deep bowl reflectors may be used to illuminate the feed boxes and passageway.

The mine offices need but one 25-watt tungsten lamp equipped with a shallow dome reflector. The fireboard at the bottom should be well illuminated with one or more 25-watt lamps of this type equipped with angle reflectors, depending upon the size of the board, while the pump rooms and storage rooms may be lighted in the same manner as offices.

The first-aid rooms, in order that the best attention be given the injured, should not only be well lighted, but should have the walls well whitewashed, thereby obtaining well diffused and distributed light. Frequent whitewashing of the walls of the bottom, offices, mule stables, etc., and the walls of the entries for 20 ft. each side of the units, will greatly increase

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**Fig. 5.—Voltage Record of Mine Lighting Circuit.**
the illumination in these parts of the mine. Carbon lamps are most generally used in mines, but to keep the load on the generator as low as possible and maintain the most constant illumination in spite of voltage fluctuation, and to direct the light where wall and ceiling reflection cannot be relied upon, tungsten-filament lamps with weatherproof enameled reflectors will, in my opinion, be found most satisfactory.

It may be interesting, by reason of the high voltage usually found in mines, and its fluctuation, to show how the proper voltage for a lamp, to secure greatest life and light, is determined. A recording voltmeter is connected at the switchboard on the terminals of the switch controlling the lighting circuit, usually the trolley line. When this is in operation, a carefully calibrated portable voltmeter is connected in multiple with the recording meter and a section of the chart of the recording meter is compared with the readings of the calibrated portable meter. Fig. 5 shows a section of such a chart and the calibrated line. This chart should be taken over a period of at least 3 hr. and for 24 hr. if possible.

**Table I.—Lamp Voltages for Various Line Voltages. Street-Railway Tungsten-Filament Lamps.**

<table>
<thead>
<tr>
<th>Average Line Voltages</th>
<th>Number of Lamps in Series</th>
<th>Voltage of Individual Lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>2</td>
<td>120</td>
</tr>
<tr>
<td>260</td>
<td>2</td>
<td>125</td>
</tr>
<tr>
<td>270</td>
<td>2</td>
<td>130</td>
</tr>
<tr>
<td>250</td>
<td>2</td>
<td>135*</td>
</tr>
<tr>
<td>290</td>
<td>2</td>
<td>140*</td>
</tr>
<tr>
<td>300</td>
<td>3</td>
<td>105</td>
</tr>
<tr>
<td>325</td>
<td>3</td>
<td>105</td>
</tr>
<tr>
<td>350</td>
<td>3</td>
<td>115</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
<td>130</td>
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<tr>
<td>425</td>
<td>4</td>
<td>105</td>
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<tr>
<td>450</td>
<td>4</td>
<td>110</td>
</tr>
<tr>
<td>475</td>
<td>4</td>
<td>115</td>
</tr>
<tr>
<td>500</td>
<td>4</td>
<td>120</td>
</tr>
</tbody>
</table>

For voltages above 500, use five lamps in series as on street-railway circuits.

* Special lamps.

Voltage readings are then taken back from the shaft along the main entry at intervals of 300 or 400 ft. by means of the portable meter, the voltage and time being recorded. A study of the chart will show the average voltage over the period taken. A comparison of the chart with the voltage readings taken back in the mine will show the average drop in the line. From the average voltage obtained from the chart should be subtracted the average line drop obtained from the readings taken in the mine, the result being the voltage on which lamps will operate to give the same life as on the fluctuating voltage in the mine.
For average voltages up to 250 volts, regular multiple lamps should be used. For average voltages from 250 up to 280 volts, there is a choice of burning lamps in multiple or in series. The best practice is to burn two lamps, carefully selected for current, in series. Such lamps can readily be obtained and are known as street-railway lamps. For voltages above 280, the proper lamps should be selected for series burning. Table I lists lamps for specific voltages.

A recording chart, used as described previously, showed a maximum voltage variation of 20 per cent. From Fig. 6 it will be seen that with a 10 per cent. reduction in voltage, the candlepower of the carbon lamps is 20 per cent. lower than that of the tungsten lamps. Fig. 6 shows that the characteristics of the tungsten lamp are such that voltage variation does not affect candlepower as much as it does that of carbon lamps.

![Candlepower Characteristics of Incandescent Lamps](image)

**Fig. 6.—Candlepower Characteristics of Incandescent Lamps.**

A few comparative cost figures in connection with the problem of more efficient illumination follow. Consider, for example, an installation, such as illustrated in Fig. 1, where twenty-six 40-watt tungsten lamps and reflectors and thirty-one 25-watt tungsten lamps and reflectors are to replace the same number of 32-cp. and 16-cp. carbon lamps, respectively. During a period of 300 days, at 10 hr. a day, the tungsten lamps would consume about 5,440 kw-hr., while the carbon lamps
would consume about 14,940 kw-hr. With the cost of current at 0.5c.
per kilowatt-hour, the saving in cost of power with the use of tung-
sten lamps would be about $50 a year. From this must be subtracted
about $17 for the difference between the cost of the carbon lamps and the
tungsten lamps. This will leave about $23 net saving. With the reflect-
ors costing $60, the installation would be paid for in three years.

These figures tend to show that if dollars and cents alone were consid-
ered, it would be more profitable to use the higher efficiency lamps. This
is even more marked when the illumination on the working plane is con-
sidered, because with the use of reflectors the illumination is more than
double that obtained with carbon lamps.

There are many other places where special applications of lighting
would tend to increase efficiency and convenience; for instance, trip-
lights—now as a rule simply oil torches on the end of the train—could be
easily replaced by small storage-battery outfits showing a red light. Locomotive headlights can be equipped with low-voltage concentrated-
filament tungsten lamps in parabolic reflectors, with a decrease in trouble,
increased light, and decreased breakage over the present carbon or reg-
ular tungsten filament. Two 30-volt, 100-watt tungsten-filament locomo-
tive-headlight lamps can be burned in series with a resistance. The loss
in current through the resistance is a small factor as compared with the
gain in steadiness and brilliancy of illumination from the parabolic head-
lights. The construction of this lamp is such that maximum strength of
filament is obtained, which is an essential feature where the service is as
severe as on a locomotive. Another possible consideration is the placing
of distinctive lights where telephones are located, or where first-aid equip-
ment may be obtained. This could be accomplished by the use of red
lights on the power circuit installed in connection with a small primary-
battery system, which would operate a miniature lamp in place of the
large lamp should the power circuit for any reason fail. This system has
been successfully worked out in theaters where the same principle is
involved.

It is hoped that, from the few figures given in this paper, it will be seen
that the application of the latest scientific knowledge to the lighting of
mines is not so expensive as it is generally thought to be, and should be
considered as a means of increasing safety, bettering working condi-
tions, increasing production, and at the same time decreasing the cost of
operation.