DEPRECIATION OF LIGHTING EQUIPMENT DUE TO DUST AND DIRT*

EARL A. ANDERSON** AND JAMES M. KETCH***

SYNOPSIS: A report of tests under service conditions to determine the relative depreciation or loss in efficiency of lighting equipments due to the accumulation of dust and dirt. Comparison tests were made under forced rates of dirt accumulation in an effort to determine the feasibility of obtaining quick comparisons between the depreciation rates of different equipments. Consideration of the possibilities of a simple comparison standard for predicting depreciation rates in a particular installation is included.

In order to cover a range of conditions as regards depreciation of equipment due to dirt and dust, four different locations were selected in the City of Cleveland. Samples of lighting equipment commonly used for industrial, office and store lighting practice were operated under service conditions in these four locations following the plan outlined below. Outdoor lighting unit tests were included in one location only.

Location A—Test area was in a factory warehouse adjoining a room carrying on lamp manufacturing work. Washed air is furnished to a part of the factory, which accounts for the slow depreciation of the lighting units. The dust encountered here was fairly dry and of a fine powdery nature. The space was steam heated in winter and the windows were open part of the time as is usual in a place of this character. Eighteen types of commercial, office and store lighting reflectors, including open direct, enclosing, semi-enclosing, semi-indirect and indirect types were installed for test in Location A. There were two samples of each type and the entire group was tested for two different periods of 120 days each. Thus it was possible to obtain a result for any one type of unit representing the average of four individual depreciation tests.

*A Paper presented before the Annual Convention of the Illuminating Engineering Society, Lake George, N. Y., September 24-28, 1923.

**Illuminating Engineer, National Lamp Works of G. E. Co., Cleveland, Ohio.

***Engineer, National Lamp Works of G. E. Co., Cleveland, Ohio.

Location B—The reflectors at this location were installed on the top floor of a twelve story down town building. This location is typical of the usual city office building in a down town district burning soft coal. There was more oily, sooty dust here than at Location A. Twenty types of lighting units were tested including open direct, semi-enclosing, enclosing, semi-indirect and indirect.

Location C—This was a fairly clean office building in the suburban district. Three sets of samples of open direct, enclosed and semi-indirect lighting units were run the same period of time as those tested in Location A. This run and the one at Location D were made in comparison with Location A to give an indication of the range of depreciation likely to be encountered in the same city depending upon the character of the surroundings.

Location D—This was in the furnace and blowing room of a glass factory. The room was hot, dry and dusty, and probably represents a condition which would be duplicated in only a small percentage of industrial plants. Six types of lighting units were tested including open direct, enclosing and semi-indirect.

Location E—On the roof of the building used for Location A. A railroad with fairly heavy traffic passed the corner of the building within a few hundred feet of the test location.

METHOD OF TESTING

Samples of lighting equipment used in the tests were all of standard 200-watt size. Each fixture in tests A, C and D was equipped with a seasoned and photometered 200-watt lamp selected for a voltage rating which would permit burning two two-hour periods per day throughout the test without appreciable aging. This daily burning of the lamps was considered essential as lighting of the lamps induces a circulation in many fixtures which changes the rate of dust collection. One of the two samples of each fixture design was taken down monthly during the period of the test at Location A and photometered. This sample was then rotated to a different location in the test room. The period rating was planned to determine any variation in rate of depreciation during the test run. The variations noted were not great enough to be significant and the results shown in this paper are based on total depreciation values for the test runs without reference to intermediate readings.

Extreme care was exercised in handling the equipment so that no dust and dirt would be shaken off. In fact the final figures for the equipment removed for rating during test averaged practically the same as those for the fixtures that were allowed to hang throughout the tést without handling.

TABLE I

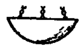
ACTUAL DEPRECIATION OF LIGHTING EQUIPMENT AS AFFECTED BY LOCATION AND EQUIPMENT DESIGN

DIRECT LIGHTING UNITS

			Actual Depreciation	
No.	Luminaire	Description	Location A 120 Days Dry Fine Dust	Location B 49 Days Oily, Sooty Dust
1.		Light density opal glass—clear lamp	—	10.9
2.		Light density opal glass—bowl-enameled lamp	—	25.5
3.		Dense opal glass—clear lamp	11.2	—
4.		Prismatic glass—clear lamp	12.4	17.3
5.		Prismatic glass—bowl-enameled lamp	—	30.4
6.		Deep enameled steel bowl—clear lamp	11.5	—
7.		RLM Dome—clear lamp	12.8	—
8.		RLM Dome—bowl-enameled lamp	16.3	—
9.		Diffusing globe and enameled steel reflector	22.9	—
10.		Diffusing globe—no vent	13.4	15.3
11.		Diffusing globe—bottom vent	22.7	27.9
12.		Diffusing globe—top and bottom vent	22.1	—
13.		Frosted ball—top and bottom open	15.0	—
14.		Semi-enclosing opal bowl with diffusing plate	27.2	33.4

TABLE II

INDIRECT AND SEMI-INDIRECT LIGHTING UNITS—OPEN TYPE

No.	Luminaire	Description	Actual Depreciation: Location A, 120 Days, Dry Fine Dust	Actual Depreciation: Location B, 49 Days, Oily, Sooty Dust
15.		Dense opal bowl	22.5	50.8
16.		Light density opal bowl	—	36.3
17.		Enameled metal reflector with opal glass bottom	26.0	25.9
18.		Mirrored Glass bowl	26.2	40.7
		CLOSED TYPE		
19.		Clear top with bottom opening	35.6	24.0
20.		Clear top without bottom opening	15.0	—
21.		Prismatic, without bottom opening	10.1	—

The photometric ratings of equipments at Locations A, C and D were made using a 6 foot modified cube as an integrating sphere.

At Location B the lamps were burned for short periods only and it was not practical to take down the units for photometry; instead the comparative measurements were made on a basis of foot-candles.

Tables I and II above give the number, cut of lighting unit, description, and the final depreciation of the equipments tested in Location A and B.

COMPARISON OF DEPRECIATION IN DIFFERENT LOCATIONS

Table III shows the relative depreciation at the four locations used in the test series, compared with the depreciation found in Location A for each of three types of lighting units.

TABLE III

No.	Luminaire	Relative Depreciation: Location A	Location B	Location C	Location D
6	Deep steel bowl—open reflector—clear lamp	100	—	31	138
10	Diffusing globe—no vent in bottom	100	114	28	200
15	Dense semi-indirect opal bowl—open	100	226	70	218
	Average	100	170	43	185

The average person might assume that these locations were nearly alike as regards dirt, for in none of the buildings was there any unusual source of dust collection such as machinery or belting, yet equipments fell off in light output four times as fast in the down town location as in the suburban office building. In other words where a cleaning once in two months would be adequate for one location the same equipment requires cleaning every two weeks to hold the same efficiency in another building with less clean surroundings. The results demonstrate the value of a check on each lighting installation in working out an economical cleaning schedule.

TABLE IV

RELATIVE DEPRECIATION IN DIFFERENT LOCATIONS AS AFFECTED BY EQUIPMENT DESIGN

No.	Luminaire	Test Standing: Location A	Test Standing: Location B
4	Direct open prismatic—clear lamp	1	2
10	Direct enclosing—diffusing globe—no bottom vent	2	1
15	Semi-indirect—open type—dense opal bowl	3	8
11	Direct enclosing—diffusing globe—bottom vent	4	4
17	Semi-indirect open type—enameled metal reflector with opal glass bottom	5	6
18	Totally indirect mirrored glass bowl	6	7
14	Semi-enclosing—open type—opal bowl with ceiling reflector	7	5
19	Semi-enclosing—closed type—clear top—bottom opening	8	3

Table IV shows comparisons of depreciation for the eight types of lighting units tested both in Location A and in Location B. It is apparent from this table that a proper ranking of equipments according to rate of depreciation is likely to depend very considerably upon the nature of dust and dirt and its circulation in different surroundings. Thus, the same semi-indirect, enclosed clear top unit with bottom opening ranked 8 in one location and rated 3 in another.

COMPARISON OF EQUIPMENTS UNDER THE SAME CONDITIONS

The following data were obtained from the tests conducted in Location A.

TABLE V

EFFECT OF BOTTOM VENT HOLE IN ENCLOSING GLOBE

	Luminaire	Depreciation
Direct		
No. 11	Diffusing globe with bottom vent	22.7
10	Diffusing globe without bottom vent	13.4
Semi-indirect		
19	Semi-indirect closed type clear top—bottom opening	35.6
20	Semi-indirect closed type clear top—no bottom opening	15.c

These comparisons bear out the generally accepted conclusions that bottom ventilating holes greatly increase the rate of depreciation of enclosing globes. The rate of loss was as 6 to 10 or nearly double for the diffusing globes with drilled bottom holes and as 4 to 10 or roughly three times as much for the semi-indirect fixtures with bottom openings.

As a check on the comparison test of Table V, one of the indirect fixtures with hole in bottom was photometered after having been thoroughly washed outside only, and it was found that approximately one half of the total depreciation was due to dirt on the interior. In other words by eliminating the infiltration of dirt into the interior most of which entered via the bottom vent hole, the total depreciation would have been reduced approximately one half.

A comparative test run was also made on two similar diffusing globes with drilled bottoms using on one a standard solid brass fitter and on the other a fitter with a number of ¼″ holes drilled in the vertical sides of the fitter. The addition of these holes did not appreciably affect the depreciation rate. This would be expected since a clearance of even 1/16″ between the 6-inch fitter and the globe was itself equivalent to 1.2 square inches, or a hole 1¼ inches in diameter; the additional small holes at the top added but little to the circulation rate of air through the globe.

It is the bottom hole in the globe which so greatly increases the rate of depreciation.

TABLE VI

RELATIVE DEPRECIATION OF ENCLOSING GLOBES OF DIFFERENT DENSITIES DUE TO INSIDE DIRT

	Luminaire	Depreciation
Direct Enclosing		
No. 11	Diffusing globe—bottom vent	22.7
13	Frosted globe—open top—bottom vent	15.0
10	Diffusing globe—no bottom vent	13.4

The results in the above table illustrate clearly how much more important it is to keep dirt from the inside of highly diffusing glass globes, such as are enjoying a deservedly great popularity in lighting practice, as compared with less diffusing equipment. It will be noted from the table that in the extreme case of the glass globe frosted both inside and outside and with top and bottom vent the depreciation was only two thirds as great as for the diffusing globe of smooth glass with bottom vent.

The cause of the greater loss with dust on the inside of the diffusing glass globe is, of course, that there is much more cross reflection of light in the globe, rendering a given dirt film more destructive to efficiency than where light flux makes one passage, as in clear or frosted globes.

It should be noted however that when the bottom vent was closed on the diffusing globe, avoiding the circulation of dirt into the globe, it depreciated less than the frosted globe with hole.

TABLE VII

COMPARISON OF BOWL-ENAMELED LAMPS AND OTHER DIFFUSING MEDIA AND CLEAR LAMPS IN DOME REFLECTORS

	Luminaire	Depreciation
No. 9	Diffusing globe and enameled steel reflector	22.9
8	RLM Dome Reflector—bowl-enameled lamp	16.3
7	RLM Dome Reflector—clear lamp	12.8

A more frequent cleaning is indicated from Table VII as desirable for the diffusing globe and enameled reflector and also RLM reflectors with bowl-enameled lamps than for clear lamps. This is to be expected, considering that a much larger proportion of the light in these units is directed against the reflector whence it is diffused to the plane of work. This lessening of the brightness of the lamp and increase in the amount of light from the large reflector source represent the advantages of the diffusing globe and enameled steel reflector and the bowl-enameled lamp combination in minimizing direct and reflected glare and in softening shadows. These advantages, of course, far more than offset the differences in maintenance in locations where a diffuse quality of light is of importance. On the other hand in extremely dirty locations where this quality of light is not essential the clear lamp unit represents economy.

COMPARISON OF THE DEPRECIATION OF INDIRECT AND SEMI-INDIRECT REFLECTORS AT TWO DIFFERENT LOCATIONS

A wide variation was found in the depreciation of semi- and totally indirect lighting units, as seen from Table II. Since a large portion of the light from these types of units pass through the upper surfaces, on which the dirt collects faster, it is natural that the depreciation would be higher than for direct lighting types.

However, in certain of the designs tested the equipment has been so developed as to show a depreciation no worse than that for well made direct lighting units. The results emphasize the difficulty and error in generalizing on different classes of lighting units. The slope of the surface, relative dust tightness, proportion of direct component of light distribution, smoothness of material and other factors have a bearing on the depreciation rate of a particular equipment which needs to be closely studied before drawing a conclusion.

Attention is called to the fact that the depreciation of the direct lighting units did not vary much whether the dirt encountered was dry or damp and sooty, but the indirect and semi-indirect units showed relatively higher depreciation in the sooty location. This is accounted for by the fact that the sooty dirt adhered to the inverted reflecting and transmitting surfaces of the indirect and semi-indirect units thus causing a higher depreciation.

RESULTS OF FORCED DUST CONDITION EXPERIMENT

Forced tests were conducted on different equipments by suspending the units in a closed room and circulating dust by means of electric fans.

However, it was observed that in spite of precaution taken to reproduce natural circulation of air an undue preponderance of dust settled on top surfaces and the same infiltration to internal surfaces did not take place as in usual service conditions.

A forced test which would correctly approximate service results would be of usefulness in studying changes in design with a view to improvement in depreciation performance. However, the simple experiments tried indicate that such checking of such a test arrangement would be necessary before placing full reliance on the results.

DEPRECIATION OF OUTDOOR LIGHTING EQUIPMENT

Seven outdoor lighting units were operated on the roof of the building used in Location A. The lamps were lighted two two-hour periods each day as in the case of indoor tests. The test extended over a period of 120 days, readings being taken on the same schedule as for the indoor equipment tested at Location A.

The following table gives a description of the equipment included and the relative depreciation measured at the end of the test period.

TABLE VIII

	Luminaire	Depreciation Relative	Depreciation Actual
A	Nested parabolic enameled steel reflectors	100	41.2
B	Flat enameled steel reflector—bowl refractor—closed bottom	85	34.9
C	Ventilated fixture dome refractor—clear rippled globe—hole in bottom	83	34.2
D	Dome refractor without globe	69	28.3
E	Light opal 8 paneled hinged top lantern—dome refractor	68	27.9
F	Dust tight fixture one piece cast top, felt globe gasket, dome refractor and light rippled globe—no hole in the bottom	58	23.8
G	Radial fluted enameled steel reflector	37	15.3

The test results on units C and F demonstrate the usefulness of closed dust tight fixtures in reducing the depreciation due to the collection of dust, as compared with units having globes with holes in the bottom. Incidentally, the hole represents an extra cost as it must be ground after the globe is blown, adding an extra operation in production. The hole also weakens the globe, increasing the breakage in handling and service.

Holes were necessary when globes were used on old arc lighting equipment, to supply air circulation and ventilation to carry off the fumes. Incandescent lamps require no such circulation of air and many thousands of units in street lighting installations equipped with globes having bottom holes, would be more efficient if a change was made to globes without holes.

VARIATION OF LIGHT ABSORPTION LOSS FOR GLASS AT DIFFERENT ANGULAR POSITIONS

In order to obtain data on the relative dust collection according to the angular position with the horizontal, the following investigation was made.

Two sets of plates—one of clear glass and the other of frosted glass—were arranged in positions at different angles 10 degrees apart and floor dust was circulated about them by means of fans for a period of two hours. Care was exercised to provide as even a circulation of dust as possible by using baffles and by rotating the direction of the air streams. Two such tests were conducted, the results of which are shown in Table IX.

TABLE IX

Plate Angle from Horizontal	Per Cent Depreciation Clear	Blasted	Cosine of Angle
0	100.0	100.0	1.0
15	93.1	92.2	.97
30	90.2	86.7	.87
45	78.9	75.9	.71
55	64.0	64.0	.57
60	58.0	47.7	.50
65	44.8	—	.42
75	23.6	22.3	.26
90	8.1	5.9	.0

As might be anticipated in a test of this kind where the dust tended to settle downward the light absorption loss varied almost directly with the projected area in a horizontal plane, i.e. the cosine of the angle made by the plate with the horizontal. It is significant also that between the angles of 60° and 70° slippage of the dry dust occurred in both the frosted and clear glass samples. The results of this experiment therefore show the usefulness of fairly steeply sloping sides in shedding dry dirt. Had the experiment been reproduced in a damp atmosphere it is possible that the results would have varied somewhat.

COMPARISON STANDARD PLATE TEST EXPERIMENT

Glass test plates as described below were installed along with the lighting equipment in Location A. Thirty plates were used, ten each of which were held in horizontal, 45°, and vertical positions throughout the 120-day service test already described.

Acid etched, sand blasted and vaseline coated plates were included. The measurements of depreciation for these plates are listed in the table following:

TABLE X

	Actual Depreciation —% Horizontal Plane	45° Plane	Vertical Plane
	One Side Coated		
Acid etched	30.5	22.5	3.2
Sand blasted	32.8	25.7	2.5
	Both Sides Coated		
Acid etched	32.2	25.0	6.2
Sand blasted	35.5	30.5	7.0
Clear glass vaseline coated (hardened during test)	20.8	14.2	11.5

More work would need to be done to establish the relative behavior of glass plates such as those tested in comparison with standard lighting equipments. However, if such a comparison could be developed using, say, a 45° frosted or coated plate which would somewhat take into account dust circulation against vertical surfaces as well as falling dust, a useful means for predicting approximate depreciation rates and necessary cleaning schedules for lighting equipment would be at hand. It would only be necessary to place one or more of these plates in the space under consideration and after a stated interval to observe the transmission before and after cleaning the plate using a foot-candle meter or other simple illuminometer.

CLEANING OF REFLECTING EQUIPMENT

The experiments reported have had to do only with the rate of depreciation of lighting units without reference to the relative amount of labor involved in restoring the initial efficiency. It must always be recognized of course that the time and care required to restore efficiency varies a great deal depending upon the accessibility of the design and the character of the surfaces. For example if one unit required a wiping with a damp cloth on the outside it might easily in some installations be less costly to clean such a unit twice than to clean but once another type if the latter had much dirt on the interior surfaces, was difficult of access, or required disassembly for satisfactory cleaning.

Comparative measurements confirmed results previously reported indicating that wiping with a dry cloth removes only one-half to two-thirds of the dust and dirt that is easily taken off by a damp cloth. Thus there is a distinct advantage and very little extra trouble in using water while cleaning instead of depending upon dry methods only.

DISCUSSION

F. L. Farmer: There is just one point I want to make that does not appear in Mr. Stair's paper, in which I am very much interested—one reason for getting to the architect before the building is fully planned, and that is the appropriation that the architect makes.

One of the greatest difficulties we have in making a selection of suitable lighting equipment for the building is on account of the