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VIA FEDERAL EXPRESS

RECEIVED
JUN 2 8 1996

Catherine Garypie, Esq.
Assistant Regional Counsel
U.S. Environmental Protection Agency
Office of Regional Counsel, Region II
290 Broadway, 17th Floor
New York, NY 10007-1866

Re: Hoboken, NJ, Mercury Site

Dear Catherine:

Following up on our telephone conversation this morning, enclosed is a copy of the loose leaf "Treatise on Industrial Illumination with Mercury Vapor Lamps," which Mr. Warren Millar recently loaned to me from his personal files. In the lower right hand corner of the outside cover is embossed "General Electric Vapor Lamp Company" and inside the cover is an address label identifying the manual as "PROPERTY OF WARREN G. MILLAR, YEAR 1940." The manual obviously is at least 56 years old, and portions of it may not have copied very well. I will bring it to Mr. Millar's deposition in Cincinnati next Monday so you may review it before we return it to Mr. Millar. He also sent along a small hardcover book called Modern Glass Working and Laboratory Technique, M.C. Nokes (1937), which also came from his personal library. I have not reviewed this book, and only enclose a copy of page 123, which purports to include a schematic diagram of "an early design of diffusion pump by I. Langmuir." This design presumably is similar to at least some of the vacuum pumps used in the Hoboken lampmaking operations.

Thanks again for pulling together your files for production to us under our FOIA request. Please let me know when we can send someone by your office to review them. I know there are Section 104(e) responses from other PRPs and deposition transcripts, among other things, which we do not have and which we will want to arrange to have copied.

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I look forward to seeing you Monday morning in Cincinnati. Jane Gardner may also attend, if her travel schedule permits, but that is still up in the air. I will be there for certain to represent GE in any event.

Sincerely,

Langley R. Shook

Enclosure

›our stream and are carried along with it. ›mixed with the gas is then condensed, but the ›ream of vapour presents an impenetrable ›e gas, preventing its diffusion back into the

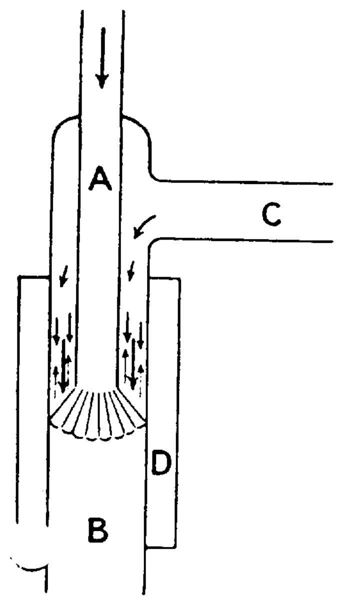

FIG. 69. Diagram illustrating the mode of working of a diffusion pump.

›apour issuing at the jet will itself tend to ›into C to some extent. This backward ›ninished by increasing the speed of the ›above a certain critical value, by efficient ›neighbourhood of the jet, and by choosing ›stance which has a low vapour pressure at

the temperature of the condensing jacket. It is probable also that the design of the jet may affect the pumping.

The lower end of the tube B is connected to a fore-pump which removes the accumulated gas from C. Diffusion pumps of somewhat complicated design can be made to work with a fore-pump pressure of 20 mm. of mercury, but a simple design can be employed for pumps which will give the highest vacua, if a fore-pump pressure of 0.1 mm. can be obtained.

JET DESIGN.

Convergent, parallel and divergent jets have all been tried, and can all be made to work, but the speed of the vapour stream seems to be more important than the

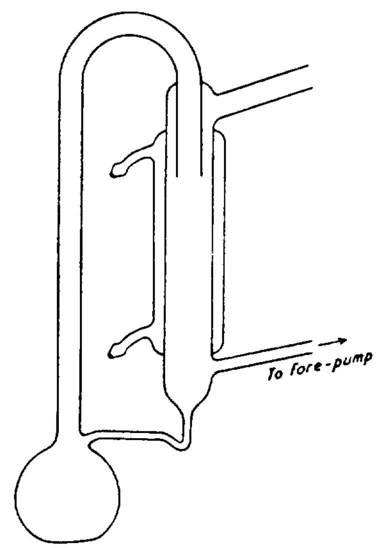

FIG. 70. An early design of diffusion pump by I. Langmuir.

A COMPLETE

TREATISE

ON

INDUSTRIAL ILLUMINATION

WITH

MERCURY VAPOR LAMPS

BY

GEORGE J. TAYLOR, B.S., S.M., E.E.
COMMERICAL ENGINEERING DEPARTMENT

GENERAL ELECTRIC
VAPOR LAMP COMPANY
HOBOKEN, NEW JERSEY, U. S. A.

1.	TORCH	1000 B.C.
2.	STONE LAMP	1000 B.C.
3.	METAL LAMP	400 A.D.
4.	CAMPHENE	1850
5.	KEROSENE	1855
6.	GAS	1870
7.	EDISON'S FIRST SUCCESSFUL LAMP	1879
8.	FIRST SUCCESSFUL COMMERCIAL LAMP	1881
9.	WELSBACH INCANDESCENT GAS MANTLE	1883
10.	CELLULOSE FILAMENT	1893
11.	METALLIZED CARBON FILAMENT	1905
12.	PRESSED TUNGSTEN FILAMENT	1907
13.	DRAWN TUNGSTEN FILAMENT	1911
14.	DAYLIGHT BULB (BLUE GLASS)	1928
15.	FLUORESCENT	

Foward

This material is written for manufacturers, salesmen, practical plant engineers, and busy executives. It is a treatise on a most pertinent subject explaining, illustrating, tabulating and sketching in as simple a way as possible the fundamental and practical application of industrial illumination.

The **COOPER HEWITT** slogan **"better than daylight"** will ring forever in the annals of industrial lighting and will continue to ring with widespread resonance as long as we depend upon **light for sight.**

Quality of mercury vapor light is not dependent upon human endeavor for perfectness—it is an inherent characteristic provided by nature and applied for the general benefit of humanity.

Aggressiveness and progressiveness are keywords for business success and go hand in hand with honesty and integrity. Only those who abide by these fundametal principles will endure the severity of present day competition. In this respect the General Electric Vapor Lamp Company have an enivable reputation.

A MESSAGE FROM THE GENERAL SALES MANAGER

As one acquires wisdom, a fuller appreciation of the element of time becomes apparent. Time must elapse, not only for the purpose of education and the moulding of opinion, but for the human mind to develop a conception and acceptance of anything that will take one out of the deep groove of an old established habit -- a difficult barrier to surmount.

The General Electric Vapor Lamp Company, formerly the Cooper Hewitt Electric Company, has for 30 years been preaching the gospel of humanitarian lighting.

It is only necessary to review the history of important inventions to understand the time required to enlighten and change opinion. The passage of thirty to forty years from invention to acceptance of a useful appliance is common.

The COOPER HEWITT lamp was invented in 1903. It has been actively promoted by our organization for 30 years and during that long period, the effort to perfect the lamp through technical research has continued unabated, with the result that the changes wrought in the lamp I knew a quarter of a century ago, are truly marvelous and a great tribute to the powers of intelligent research.

The fine quality of light generated from mercury vapor is just beginning to be appreciated after three decades and I predict it will come into general use, yes even in the educational institutions of the young people, because it is a great factor in saving the eyes. Conserving the eyes of our future generation is a task of which we may be justly proud and COOPER HEWITT mercury vapor light is a boon to mankind.

Chas. F. Otrebig

June 24th, 1935.

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INTRODUCTION

Introduction

Previous to the twentieth century there was but one kind of light in use for the regular purpose of illumination. Sunlight was the standard, and all artificial sources produced light of the same type, but varying somewhat in general effect. All the highly complex light was characterized by a continuous spectrum, the differences consisting of the comparatively slight variation in the relative amounts of the different colors contained. All artificial light was produced from glowing (incandescent) solids and contained all the colors of the sunlight, but with orange and yellow rays in larger proportion to the other primary colors.

EARLY LIGHT SOURCES

Artificial means of producing light may be said to date back as far as 5000 B.C. At this early stage no doubt the chief form of lighting was by means of the Torch. Other popular forms of flame sources are given below:

1. Stone Lamp . . . . 3000 B.C.
2. Metal Lamp . . . . 400 A.D.
3. Oil Lamp 1600
4. Candle 1800
5. Camphene Lamp. 1850
6. Kerosene Lamp. 1870
7. Gas Flame. 1880
8. Gas Mantle 1905

It must be realized that each type of light producing apparatus possessed some definite advantage over its predecessor. The most noted change in wick flame lighting units was brought about by the kerosene lamp and the gas mantle was the first real unit developed for artificial lighting with an open flame.

In 1879 the most promising of all types of lamps was introduced by Thomas A. Edison -- the Electric Lamp. The filament of this lamp was given considerable study with the following results:

1. Carbonized Bamboo (1879) . . . . 1.4 lumens per watt
2. Metalized Carbon (1905) . . . . 4.0 " " "
3. Drawn Tungsten (1911). . . . . . 10 " " "
4. Gas Filled (1913). . . . . 20 " " "

In addition to the types of lamps mentioned above the following comprises a list of light producing units commonly used:

1. Carbon Arc
   a. Open
   b. Enclosed
   c. Flame
2. Magnetite Arc
3. Nernst Lamp
4. Neon Tube
5. Mercury Vapor Lamp

The COOPER HEWITT mercury vapor lamp is the only survivor and successfully applied industrial unit of the above group of lamps.

OUTSTANDING AMERICAN PATENTS

World's Work, issue of January, 1932, contains an interesting article entitled "Patent Injustice." It discusses the intricacy and delay in the operation of the U.S. Patent System and tells how it has passed a hundred million dollar buck to American Industry. "Mercury Vapor Light" is included among the fifty-five outstanding inventions, patented between the years 1791 and 1930. The list is as follows:

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INVENTION	INVENTOR	YEAR ISSUED
Steamboat	Fitch	1791
Cotton Gin	Whitney	1794
Duplicating Lathe	Blanchard	1820
Reaper	McCormick	1834
Revolver	Colt	1836
Telegraph	Morse	1849
Vulcanized Rubber	Goodyear	1844
Sewing Machine	Howe	1846
Valve Gear	Corliss	1849
Show Sewing Machine	McKay	1862
Machine Gun	Gatling	1862
Typewriter	Sholes & Glidden	1868
Air Brake	Westinghouse	1869
Celluloid	Hyatt	1870
Shoe Welt Machine	Goodyear	1871
Automatic Train Coupler	Janney	1873
Barbed Wire	Glidden	1874
Telephone	Bell	1876
Phonograph	Edison	1878
Reenforced Concrete	Beams & Hyatt	1879
Arc Light	Brush	1879
Carbon Filament	Edison	1880
Cash Register	Ritty & Birch	1883
Expanded Metal	Golding	1884
Trolley Car	Van Depeele & Sprague	1884*
Electric Welding	Thomson	1886
Split-Phase Induction Motor	Tesla	1888
Recording Adding Machine	Burroughs	1888
Aluminum Reduction	Hall	1889
Linotype	Mergenthaler	1890
Sulphur Mining Wells	Frasch	1890*
Transmitter	Berliner	1891
Case-hardened Steel	Harvey	1891*
Dial Telephone	Strowger	1892
Kinetoscope	Edison	1893
Carborundum	Acheson	1896
Monotype	Lanston	1896
Autoplate	Wood	1898*
High-speed Steel	Taylor & White	1901
Safety Razor	Gillette	1904
Bottle-making Machine	Owens	1904
Radio Wave Production	Fessenden	1904
Radio Crystal Detector	Dunwoody	1906
Airplane	Wright Bros.	1906
Radio Grid	DeForest	1907
Electric Precipitation	Cottrell	1907*
Bakelite	Baekeland	1909
MERCURY VAPOR LIGHT	HEWITT	1912
Pressure Oil Cracking	Burton	1912*
Radio Regenerative Circuit	Armstrong	1914
Gyro Compass	Sperry	1918
Ethyl Gasoline	Midgeley	1921*
A.C. Electric Timing	Warren	1916*
Teletypesetter	Kleinschmidt & Morey	1925*
Quick Freezing	Birdseye	1930

* Year Invented

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TWO CLASSES OF LIGHTING

There are actually two classes of lighting that we use in our everyday life:

1. Social lighting

2. Industrial lighting

Industrial lighting includes all cases in which light is used in order to carry on manual labor. Social lighting includes such cases as home, decorative and general interior lighting.

With social light it is desirable to suppress or soften details, such as facial wrinkles, blemishes and defects of complexion, while with industrial light exactly the opposite is desirable; all details must be revealed as sharply and clearly as possible.

The preponderance of red, orange and yellow colors of incandescent light subdues just those points that are desired to be subdued in our occupation of leisure and social intercourse, while affording ample visual clarity for all requirements under the circumstances. On the other hand, the light of mercury vapor has a revealing power that surpasses even sunlight at its best. Fine details can be discerned only with difficulty, or not at all, under continuous spectra light, but are readily distinguished under the simple spectra light of mercury vapor. The increase in visual acuity produced by COOPER HEWITT mercury vapor light is equivalent to a very perceptible magnification.

LIGHTING SPECIALISTS

The general policy of selling illumination in industrial areas by calculating a given number of foot-candles which appear on published tables, has never been practiced by the COOPER HEWITT organization. Careful study and planning have characterized the installation and application of mercury light in every plant. Representatives very often take the place of operators to be certain that light is reaching the point where seeing is actually taking place.

Unfortunately, all manufacturing operations are not alike and consequently, lighting cannot possibly be the same. Even the same operation in different plants requires special attention. Reflection factors of machines, walls and materials all have a bearing on lighting. Theoretical calculations of intensity cannot be relied upon; only long experience by competent lighting specialists can solve illumination problems correctly.

New problems of lighting are constantly coming to the front. There are times when mercury vapor lighting is not suited to the job; without hesitation, such conditions are explained and the proper class of lighting recommended. Sometimes incandescent lighting or some special form of incandescent lighting is recommended; other times a combination of mercury vapor and incandescent lighting is recommended.

Other problems usually overlooked by illuminating engineers, but carefully considered by the entire COOPER HEWITT organization are labor turnover, scrap, seconds, rejects and other factors upon which lighting may have a bearing.

> For more than 30 years we have been successfully serving industry in the interest of Better Lighting. Our position in the trade is unique, in that we are selling illumination tailored to produce results to the purchaser. We are not just lamp salesmen or illuminating engineers, but more notably - Lighting Specialists.

In any branch of science there is usually one type of equipment best suited for its needs, and so in the important branch of industrial illumination, it is believed that the particular equipment most satisfactory is the COOPER HEWITTT mercury vapor lamp. There may be a few exceptions where mercury vapor light is undesirable, but these exceptions are so rare that they may be disregarded when considering industrial illumination in general.

MAINTAINING A HIGH STANDARD OF ILLUMINATION

The General Electric Vapor Lamp Company is proud of its reputation in the field of industrial illumination. More than 3000 prominent manufacturing plant executives verify the statement that one can see better by mercury vapor light. This large clientele of COOPER HEWITT users continue to use this light after years of experience and when new additions are added existing lamp installations are enlarged.

The character of clients served by COOPER HEWITT light in every branch of industry is one that might well be the envy of any organization of high standing.

> COOPER HEWITT light is used by more than 60 different industries.
>
> The Ford Motor Company is among the oldest and longest users of COOPER HEWITT light. Several of their plants in foreign countries also use the light.
>
> The Government Bureau of Printing have used COOPER HEWITT lighting for more than 26 years.
>
> The Stehli Silks Corporation, the premier maker of fine silks, a client for almost 30 years.
>
> The great U.S. Aluminum Company, ever watchful of the quality of their aluminum products, use well over 1000 lamps in one plant alone.
>
> The American Sheet & Tin Plate Company, makers of the finest tin plate, must pass the final critical tests under COOPER HEWITT light.
>
> The Viscose Company, the oldest, largest and most famous makers of Rayon, process and inspect their goods under COOPER HEWITT light before it reaches the market.

The Real Silk Hosiery Mills, famous in the realm of silk hosiery are large users and boosters of COOPER HEWITT light.

The Sanford Mills, with their nation-wide reputation for 'Velmo' products, spend double the sum of any competitor to light a loom. They depend upon COOPER HEWITT light to maintain high quality merchandise.

The Erwin Cotton Mills, market their blue denims all over the world. COOPER HEWITTS have lighted their looms for a quarter century.

The New Departure Mfg. Co., greatest producer of ball bearings in the world, select COOPER HEWITT light in departments requiring a high degree of accuracy.

Mr. C. E. Johannson, creator of gages for making most accurate measurements, long ago adopted COOPER HEWITTS to the exclusion of daylight for the delicate, painstaking work in his laboratory.

The Hood Rubber Company, of nation-wide repute for rubber footwear, place dependence on COOPER HEWITT light to help maintain their fine reputation.

The International Harvester Company, with their market for agricultural machinery in practically every country on the globe, use 'acres' of COOPER HEWITT lamps.

The Continental Can Company, in the foremost ranks of can manufacturers, have COOPER HEWITT lighted plants spread over the country.

The Pittsburgh Plate Glass Co., with their undisputed position in the production of plate glass, make their final tests for quality under COOPER HEWITT light.

The great Tennessee Eastman Corp., makers of the finest acetate yarn in the world, inspect their fine product under the better light of COOPER HEWITTS.

THE ART OF SEEING

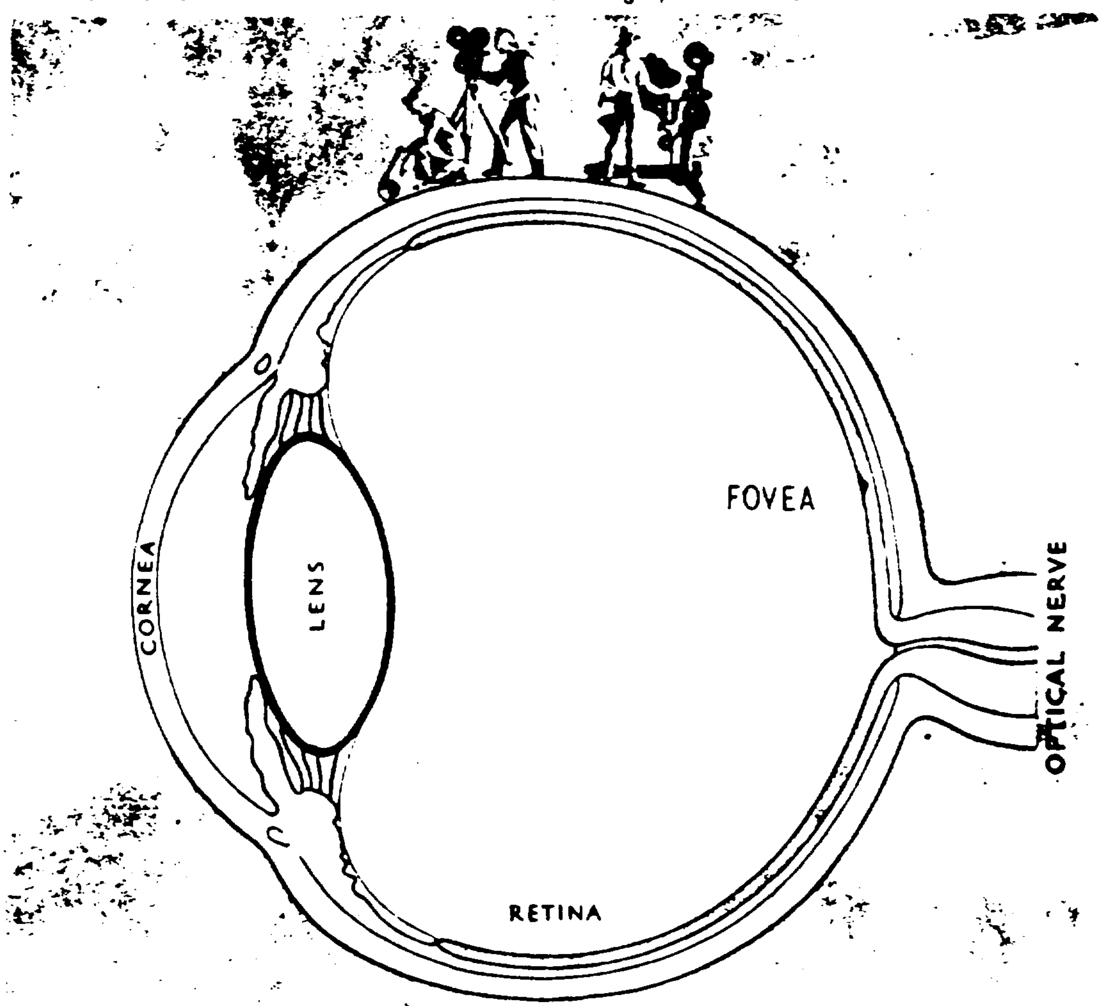
The Art of Seeing

The human eye is indeed a very complicated mechanism. In general it consists of three distinct elements:

1. Optical apparatus or eyeball.
2. Projection apparatus, which consists of a special arrangement of nerves in certain parts of the brain.
3. Cable of nerve fibres, which connect the eyeball and brain nerves.

THE PHOTOGRAPHIC FILM OF THE EYE-CAMERA

A very brief description, covering only the most essential elements of seeing will be here attempted. The eye is similar to the camera in the action of taking pictures.



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The photographic film of the eye is called the retina. It is a transparent tissue, corresponding to the gelatine of photographic emulsion, through which is distributed a great number of microscopically small nerve cells containing chemical substances that are acted upon by light. The nerve cells are of two different kinds and are named according to their general shape.

1. **Cones** - - these are distributed most thickly over the central part of the retina, occupying a small area in this region exclusively.

2. **Rods** - - these are distributed sparsely at the center, increase in numbers towards the periphera and occupy the outer part of the retina exclusively.

The retina thus comprises two different photographic films.

1. **Cone-film** - - adapted to taking pictures where sharpness of detail and full representation of all colors is required; as in color photography the cone-film is relatively **slow**, requiring a fairly high intensity of illumination to produce a visible picture.

2. **Rod-film** - - is extremely rapid, but incapable of producing sharp definition, or of showing colors. It supplies the visual picture when the light is dim.

THE FOVEA

Just off the optical axis is a slight depression in the retina where exist only cones tightly packed together and are smaller than the cones in the surrounding area. This so-called depression is known as the **fovea.**

Covering the fovea and a little surface around it is a thin, transparent, yellow tissue. This yellow color screen partially filters out the blue rays, and so reduces the chromatic aberration of the eye-lens on this part of the image.

The fovea is especially adapted to producing pictures in which the utmost sharpness of definition and discrimination of small objects is required. All of the field within our visual range which we see **distinctly** at any one instant is the part of the image which falls upon this little dent in the retina, which could be covered with the head of a pin!

THE EYE AS A MOTION PICTURE CAMERA

How is it that we seem to see a large picture clearly defined? The explanation is, that we really see a motion picture instead of a set photograph. The moving picture depends upon a physiological effect known as **persistence of vision.** The impression produced by light falling upon the retina does not cease when the image is removed, but gradually fades out. Thus, if different images fall upon the retina in rapid succession, the new image is seen before the last one has faded out, and a continuous impression is produced.

The eyeball is in constant motion through very small angles, changing slightly the direction of the line of vision **about ten times a second.** The result is on the same principle as the motion picture, but reversed; instead of seeing objects moving, we see objects in different positions blended into a single picture.

The comparatively large picture which we see plainly is produced by seeing it in very small parts in such rapid succession that we are unconscious of the process. The eye motion picture camera takes about 10 pictures a second. The eye thus remains fixed on one point about 1/10th of a second, which measures the time of exposure for that particular picture.

In dark or very dim light the rod-film becomes extremely sensitive and does the picture taking; the cone-film is insensitive. In very bright light, the cone-film does the work and the rod-film is insensitive. In average light both films act together.

The change in film sensitivity known as adaptation, takes place very slowly from light to darkness, as much as two or three hours being required to produce maximum sensitivity in the rod-film. The reverse process takes place much more quickly, from five to fifteen minutes being sufficient.

THE HUMAN TELEVISION APPARATUS

Seeing is an act of the mind; it is the conciousness of our environment produced through the agency of light.

The action of light upon the rod or cone produces a nerve-current, which passes through the trunk nerve-line to the cell in the brain, where it is transformed into the mental sensation of light. This sensation corresponds in intensity or brightness, and quality or color, to the intensity and color of the light falling upon the rod or cone. There is thus produced upon the visual screen a pattern of mental sensations exactly corresponding to the pattern of brightness and color which constitutes the light-image on the retina. The total sensation produced by this is called seeing.

There are about 5 million rods and 100 million cones on the retina, and a somewhat less number of nerve-lines in the optic tract; so that the picture actually seen is made up of some hundred millions of points of varying intensities and colors formed by the nerve-cells in the brain.

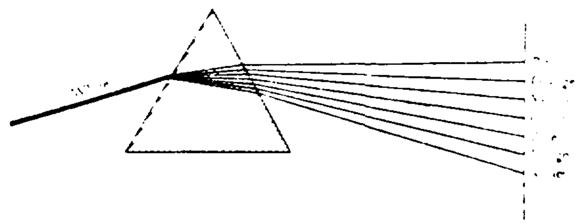
When light falls upon the retina, it thereupon ceases to be light in the physical sense of ether waves, or radiant energy. It is first transformed into heat and electro-chemical energy, then into nerve-currents, and finally into mental sensations. Of the ultimate nature of the last two forms of energy, we have no positive knowledge. The actual process of seeing is directly concerned only with the last transformation, in which physical light has no existence.

The fact to be emphasized is that the process of seeing begins where the light ceases to exist; namely, at the retina.

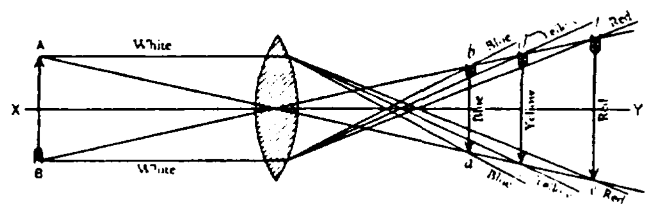
DEFECTS OF THE EYE LENS

Since all eyes are not normal the same condition of seeing does not exist. Various forms of eye defects are known - - the most common perhaps is that known as chromatic aberration. A simple demonstration of chromatic aberration may be accomplished by holding a card before the eye so as to obstruct half the aperature of the pupil. When this is done the eye will be thrown slightly out of focus and the objects which formerly had sharp clear outlines will now appear to have colored borders and look blurred.

Chromatic aberration is caused by the refractive media of the eye breaking the white light from the object into its component colors. Depending on the difference in refrangibility of the colored light, the refractive system of the eye focuses the colored images of an object at different positions in the eye. The violet image is formed closest to the lens while the red is farthest away. This may be effectively demonstrated by diagrams.



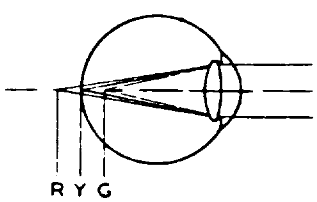
By passing white light through a prism it is divided into color bands which is explained by the theory of refraction.



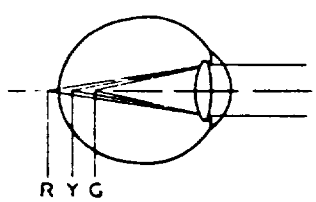
The convex lens is similar to the eye lens and again there is a separation of white light into colors.

COMMON EYE DEFECTS

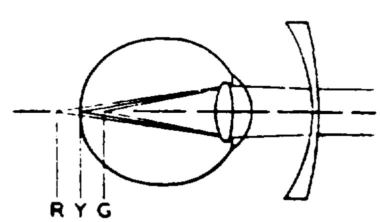
A few of the more common eye defects are capable of being illustrated by diagrams.

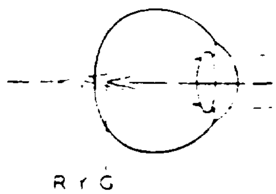


The EMMETROPIC (normal) eye focuses the yellow light sharply on the retina. The green focus falls in front of the retina and the red focus behind the retina.

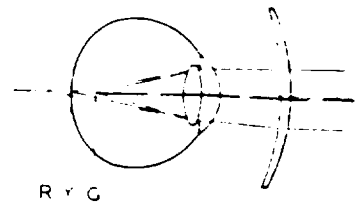


The MYOPIC eye (nearsightedness) is an elongation of the eyeball. The retina is close to the focus of the red, while the yellow and green foci fall in front of the retina. This condition may be corrected with a minus lens as shown at right.





The HYPEROPIC eye (farsightedness) with the shortened eyeball causes the retina to focus close to the green and the red and yellow fall behind the retina. Correction is accomplished with a plus lens.



Astigmatism is quite a common eye defect. The most common form is due to unequal curvature of the **cornea.** In this case the rays of light will not focus at a definite **point** on the retina.

LIGHT AND LIGHTING

Light and Lighting

In general light is thought of as a certain degree of brightness. While this is true in one sense of the word there are other factors of extreme importance that must be considered. Because of this, lighting as applied to industrial illumination requires very careful study. Existing conditions of every department of a mill or factory, as related to color of machines, materials and general surroundings, have a direct bearing on lighting.

FACTORS OF SEEING RELATED TO LIGHTING

When referring to an object in terms of seeing that object, four variables are considered:

1. Size
2. Contrast
3. Brightness
4. Exposure time

SIZE

When comparing one lighting system with another by using the same test object the size naturally remains the same. However, Dr. Louis Bell reports the following in a carefully conducted set of experiments:

> "There was a marked sense of sharper definition on the side of the mercury tube and several of the observers could only be persuaded by careful inspection that the type on this side was not actually larger than that on the other. There was also a perceptible added strain on the accommodation on the side of the tungsten lamp in making these judgments of acuity, the comparatively slight difference in focus being at once obvious."

CONTRAST

The ratio of the brightness - difference between object and background is known as contrast. A contrast of 100% is attained when a perfectly black object has a perfectly white background.

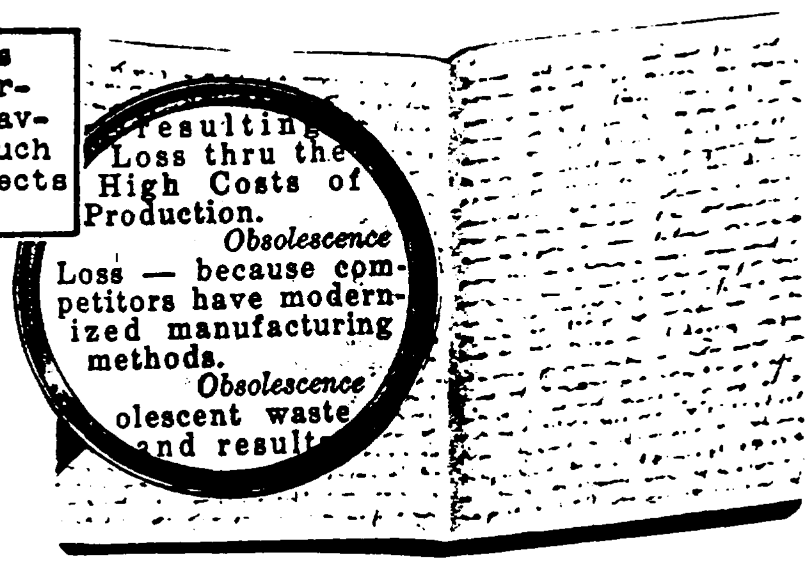
COOPER HEWITT light increases light-and-shade contrast by 50% compared with ordinary light and has the same effect upon objects in shadow as increasing the general surface brightness by 50%. Dr. Luckiesh explains contrast due to intensity of light as follows:

> "If one desires 20 foot-candles for reading black print on white paper, he should demand at least 200 foot-candles if the paper were dyed a dark gray which reflects about one-tenth as much light as the white paper. This demand is based solely upon the need for ten times more light to make the gray paper as bright as the white one. When the paper is dyed it is seen that the contrast between print and background has been greatly diminished. The effect of this lowered contrast can also be counteracted by more light. As a consequence, much more than 200 foot-candles is necessary for the same ease of seeing as in the case of 20 foot-candles on the white paper."

The above statement holds true for continuous spectra light only. COOPER HEWITT light tends to promote maximum contrast at all intensities. An example is illustrated below:

COOPER HEWITT light gives printed matter the appearance of steel plate engraving, standing out with such vividness as to make objects appear MAGNIFIED.

Ordinary light makes printed matter appear flat with a dull gray background or poor contrast



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Common type printing stands out with all the distinctness and sharpness of steel plate engraving; one almost unconciously runs a finger over the surface to feel for the relief or embossed effect which is characteristic of plate printing.

The ratio of the energy of visible radiation to the energy of the total radiation expresses a true efficiency. This ratio is comparable to the ratio of available current to wattless current produced by A.C. generators called power factor and by analogy might be called **visual power factor of radiation.** Bearing this in mind, Elliott states:

> "The visual power factor of certain species of fire-flies is 100%; of the incandescent lamp, 4%; and of the mercury tube, 40%."

From these figures it is apparent that 10 times as much radiant energy falls upon the exposed surface of the eyeball, at a given photometric intensity, with incandescent light as with mercury light. COOPER HEWITT light has the same effect on a dark gray background as incandescent light has on a white background. In industrial production areas this is a very important factor since contrast is usually very low and so is the reflection-factor of the background.

BRIGHTNESS

All visual phenomena may be traced to variations in a single mental sensation, which is familiarly known as seeing light. This sensation varies in two ways:

1. By change in vividness,
   or intensity
   (brightness)

2. By change in nature,
   or quality
   (color)

Brightness must be divided into two classifications:

1. Visual brightness
2. Physical brightness

The first refers to the intensity of the mental sensation of light or the effect as distinguished from the second which is the cause. Visual brightness does not vary with physical brightness according to any simple mathematical law. It is different for light of different wave-lengths, and for light of different mixtures of wave-lengths.

E.L. Elliott compares the respective ratios of visual to physical brightness of different light sources:

> "The greenish-yellow band may be taken as light of 100% efficiency, since it is known that light of this wave length produces the maximum visual brightness for a given physical brightness, at the common intensities of illumination. On this basis, mercury light is around 60% efficient; incandescent light, around 15% efficient; and standard white light about 45% efficient. These figures are only rough approximations representing average conditions; but the differences are sufficiently large to give them significance."

The visual efficiencies of the various light sources may be set down as follows:

COOPER HEWITT.	60%
Daylight	45%
Incandescent	15%

EXPOSURE TIME

The eye must focus a certain length of time upon an object before a definite image is apparent. Three very important things have a direct bearing upon the sharpness with which the eye perceives such an image in a given length of time:

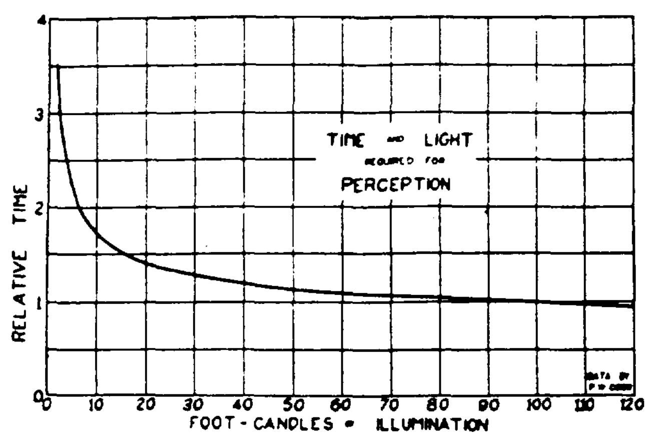
1. Quantity of light.

2. Quality of light.

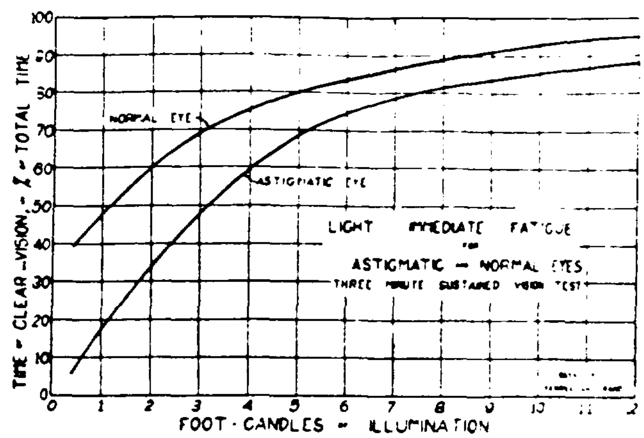
3. Retinal sensitivity.

QUANTITY OF LIGHT

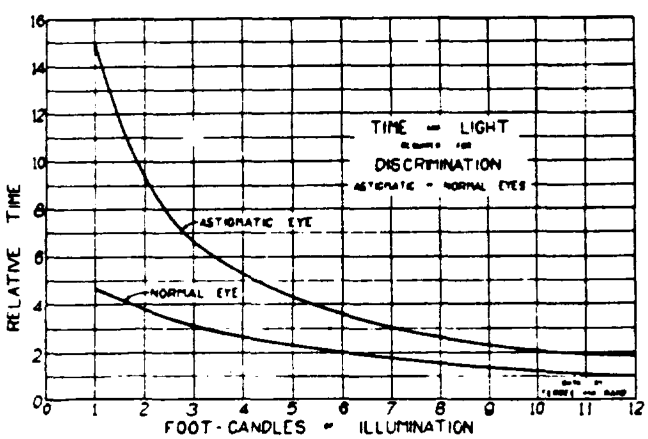
Ordinarily the more light that is available for a given task the easier it is for the eyes to perform their duty. Quality is, of course, very important in this connection, but for the purpose of this discussion let it be neglected.



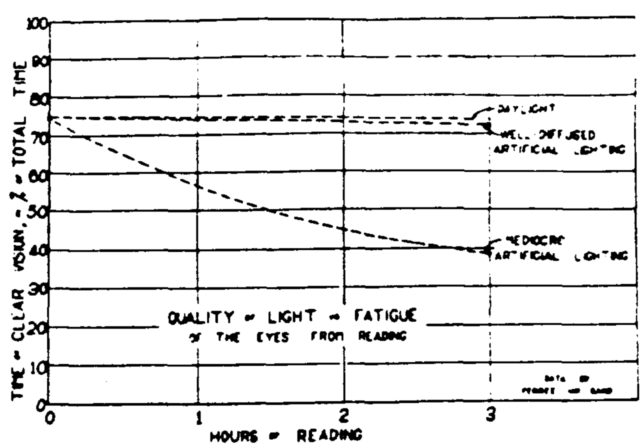
Time and Light Required for Perception



Light vs. Immediate Fatigue for Astigmatic and Normal Eyes



Time and Light Required for Discrimination Astigmatic vs. Normal Eyes

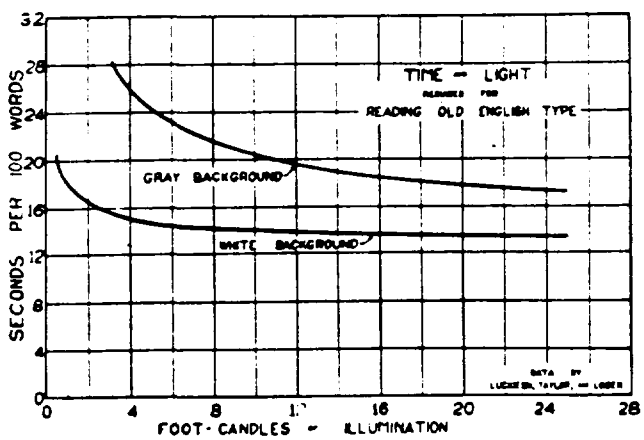


Quality of Light vs. Fatigue of the Eyes from Reading

The foregoing curves by well known authors require no detailed explanation except that in the case of the astigmatic eye more benefit is derived from higher levels of illumination, than the normal eye, while the lower levels of illumination handicap the astigmatic eye to a greater extent than the normal eye. In the case of the fatigue curves the astigmatic eye is handicapped even more than the normal eye by insufficient illumination.

When quality of light, in terms of diffusion not spectral composition, is introduced, results of visual response are somewhat improved. Later it will be shown how spectral composition will improve this condition to an even greater extent.

Luckiesh, Taylor, and Linden present the curves below indicating the time required to read Old English type, for various intensities of light, on white and gray background.



Time and Light Required for Reading Old English Type

It takes 18 seconds at 20 foot-candles to read 100 words on a gray background and the same results are attained with 1 foot-candle on a white background. In factories where scales, micrometers, machined surfaces, etc., are actually gray, COOPER HEWITT light gives better contrast at 1 foot-candle than ordinary light at 20 foot-candles.

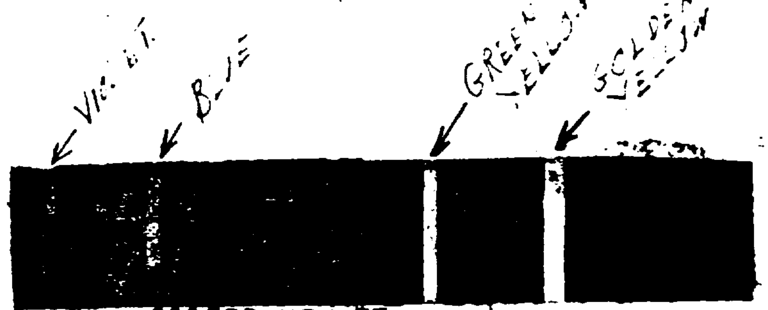
QUALITY

The quality of light depends chiefly upon its spectral or color composition. The best way to study this is by referring to the spectral analysis or spectrum of the light under consideration. On the following page the spectrum of daylight and COOPER HEWITT light are shown. The incandescent spectrum is similar to daylight except for a notable deficiency of blue rays and a predominence of orange and red rays. Neither of the latter are needed for seeing and are considered as heat or chemical rays -- the rays which Dr. Steinmetz explained as being irritating to the eyes.

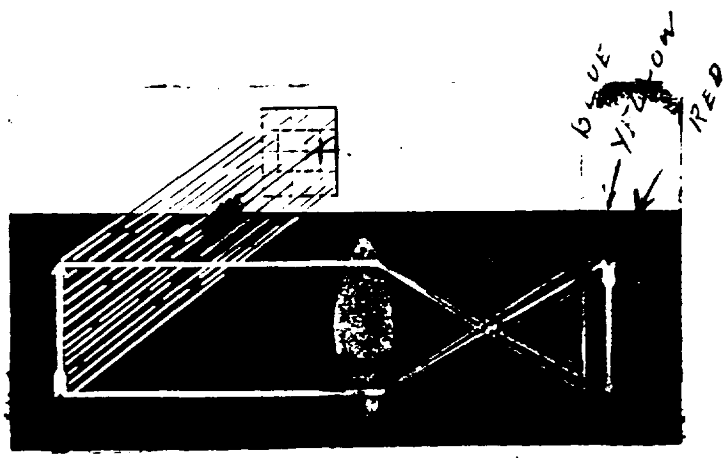
Daylight is composed of a continuous band of blending colors while COOPER HEWITT light consists of four colored lines, each in the same relative position as the colors in the solar spectrum. The colored lines predominant are yellow, green, blue and violet, which may be considered as the rays by which we see best. The dark spaces show the absence of rays which are not needed for good vision. The absence of the entire red and orange end of the full spectrum is indeed an advantage since these are the rays that contain most of the heat.

On the following page there are also shown diagrammatic illustrations of the effect produced when daylight and COOPER HEWITT light passes through a simple lens such as that in the human eye. Daylight is split into various colors only one of which can be sharply focused. The other colors being slightly out of focus tend to make images hazy. COOPER HEWITT light is practically monochromatic, producing a sharp, distinct image. The small amount of blue and violet have very low visual power compared with the high visual power of the yellow and yellow-green light. The net result is a light of high yellow content and practically that of a single color so far as the optical action of the eye is concerned. In other words, with mercury vapor light the lens of the eye forms a sharply focused image on the retina.

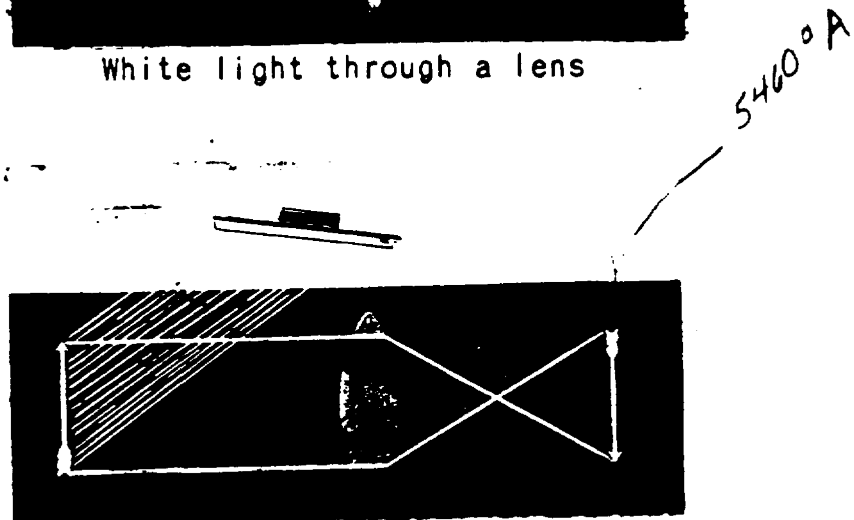
Solar spectrum



COOPER HEWITT spectrum



White light through a lens



COOPER HEWITT light through a lens

CHARTING THE MERCURY SPECTRUM

Since the mercury spectrum contains only those rays needed for test vision it will be interesting to show relative values of energy and lumen distribution of the three primary colors of the light.

Wavelength Angstroms	Group	Energy Distribution	Relative Visibility	Lumen Distribution
5790 5769	Golden Yellow	14.8%	0.890	23.1%
5460	Greenish Yellow	43.3%	0.990	75.4%
4358	Blue	41.9%	0.020	1.5%

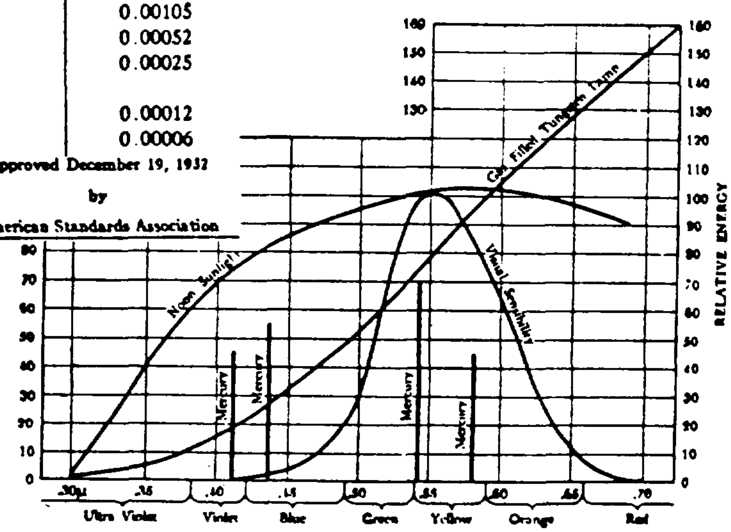
While the relative energy of the violet line is comparatively high it adds very little to the lumen output because of the low relative visibility.

VALUES OF RELATIVE VISIBILITY

(UNITY AT WAVE-LENGTH OF MAXIMUM VISIBILITY)

Wave-length in millimicrons (mμ)	Relative visibility	Wave-length in millimicrons (mμ)	Relative visibility
400	0.0004	600	0.631
10	0.0012	10	0.503
20	0.0040	20	0.381
30	0.0116	30	0.265
40	0.023	40	0.175
450	0.038	650	0.107
60	0.060	60	0.061
70	0.091	70	0.032
80	0.139	80	0.017
90	0.208	90	0.0082
500	0.323	700	0.0041
10	0.503	10	0.0021
20	0.710	20	0.00105
30	0.862	30	0.00052
40	0.954	40	0.00025
550	0.995	750	0.00012
60	0.995	60	0.00006
70	0.952		
80	0.870		
90	0.757		

Approved December 19, 1932
by
American Standards Association



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The greenish-yellow band of light has a higher energy content than any of the other bands and has by far the greater lumen output. The brightness sensation of luminosity of the golden-yellow and greenish-yellow, which is more commonly expressed as yellow-green, comprises 98.5% of the total light output. The relative visibility values may be taken from the American Standard (I.E.S.) published values or from the curve which is a result of these values. Relative energy distributions of sunlight, incandescent and mercury light are included on the curve sheet.

GENERAL CHARACTERISTICS OF GASEOUS LAMPS

The table below is of particular interest since it gives the general characteristics of several well known gaseous conduction lamps. These values are up to date and many interesting comparisons in terms of wattage distribution, efficiency, brilliancy, etc., can be made.

TABLE III—GENERAL CHARACTERISTICS OF VARIOUS GASEOUS CONDUCTION LAMPS

Sources	Method of Operation	Power Factor	Watts in Aux.	Watts in Arc	Tube Diam. Inches	Arc Amps.	Arc Length Inches	Arc Voltage	Watts per Lin. Inch	Lumens per Lin. Inch	Candles per Sq. In.	Overall Lumens per Watt
H. V. Neon	React. Trans.	55	4	36	0.45	0.03	100	2050	0.24	5.8	1.30	14.5
H. V. Neon	React. Trans.	55	5	50	0.60	0.05	100	2000	0.30	7.2	1.20	13.0
H. V. Mercury	React. Trans.	55	5	45	0.45	0.03	100	2300	0.20	1.6	0.36	3.2
H. V. Mercury	React. Trans.	55	10	85	0.60	0.05	100	2100	0.55	1.9	0.32	2.0
L. V.-L. P.-Hg	110 V. D. C.	—	135	250	1.00	3.5	50	71	4.1	120.0	12.2	16.0
L. V.-L. P.-Hg	A. C. Rect. Res. Bal.	90	175	275	1.00	3.7	50	74	4.6	135.0	13.6	15.0
L. V.-L. P.-Hg	A. C. Rect. Res. Bal.	90	100	150	1.00	3.7	22	40	4.6	135.0	13.6	12.0
L. V.-L. P.-Hg	A. C. Rect. Res. Bal.	90	125	175	0.75	2.5	35	70	4.2	115.0	15.4	13.5
L. V.-H. C.-Neon	A. C. Rect. Res. Bal.	90	200	300	1.00	3.5	18	70	11.7	275.0	27.8	10.0
H. P.-Quartz-Hg	Uviarc-D. C.	—	250	650	0.70	4.0	6	160	100.0	3600.0	520.0	24.0
High Int. Hg.*	Full Wave A. C. Ind. Bal.	65	25	400	1.30	2.9	6	160	63.0	2250.0	175.0	32.0
Sodium—10,000*	Full Wave A. C. Ind. Bal.	65	25	200	3.00	6.6	9	25	15.5	1100.0	37.0	45.0
Sodium—6,000*	Full Wave A. C. Ind. Bal.	65	15	150	2.50	5.0	7	20	14.3	850.0	34.5	36.0

* Tentative data based on a depreciation of about 15 per cent, for each successive one thousand hour interval of operation, from a rated rather than actual initial output. Intrinsic brilliancy based on total emitting surface area of tube or bulb

ENERGY DISTRIBUTION AND EFFICIENCY

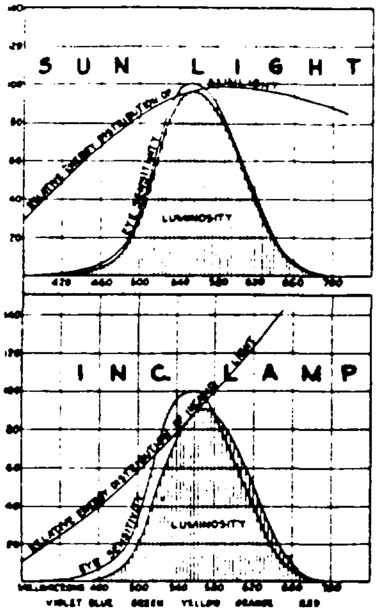
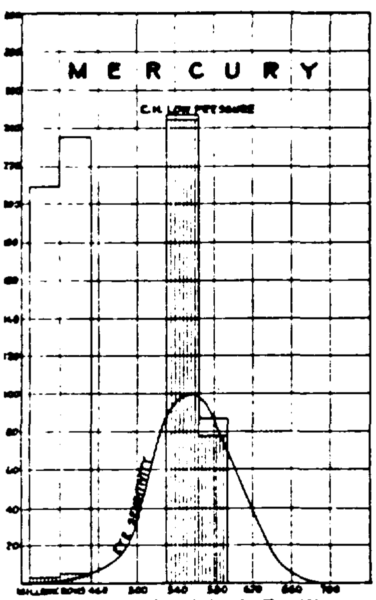


TABLE I—RELATIVE ENERGY, UTILIZATION, AND EFFICIENCY

(a) Sources	(b) Per Cent Invisible	(c) Per Cent Visible	(d) Visual Utilization	(e) Reduced Lum. Eff.	(f) Lumens Per Watt	(g) Relative White Effic.
White 380-700 only	0 0	100 0	35	35 0	220	100 0
Monochrome 555 only	0 0	100 0	100	100 0	620	280 0
Sunlight	60 0	40 0	40	16 0	100	45 0
Inc. Lamp. (500-watt)	86 0	14.0	23	3.2	20	9 0
Neon (Ind. Bal. 400-watt)	92.0	8.0	32	2 6	16	7.25
Hg. (G. E. High Intensity Ind. Bal. 400-watt)	91.0	9.0	58	5.2	32	14 5
Hg. (C. H. Low Pressure Res. Bal. 450-watt)	94.6	5.4	43	2.3	15	6 75
Sodium Arc (Ind. Bal. 225-watt)	89 0	11.0	76	7.3	45	20.0
Helium (Ind. Bal. 500-watt)	98.9	1.1	58	0.65	4	1.8



The ruled areas or luminosities of each kind of light represented, on the adjacent charts, are made equal to each other so the total areas represent graphically the theoretical visible energy. The ratio, in each case, of the luminosity area to the total energy area will then be a visual utilization factor characteristic of the light distribution and unrelated to the source.

If all the energy were concentrated at the wavelength to which the eye is most sensitive, about 555 millimicrons, its utilization might be rated as 100% (Col. d above Table) in comparison with the lower utilization factors determined graphically.

From the Table it will be observed that the visual utilization factor of COOPER HEWITT light is almost twice that of incandescent light and slightly above sunlight.

LIGHT AND VISION

707004

Light and Vision

There is little doubt that our knowledge of physiological, psychological and esthetic foundations of illuminating engineering is not as fully developed as our technical knowledge. Illuminating engineering is not be treated merely from a physical and mathematical point of view, since the eye is the receiver of visual impressions and the brain transforms these into the sensations of perceiving objects and colors. These sensations are largely dependent upon the kind or quality of light used. Light for seeing must therefore possess quality and such rays as are not needed for seeing should be eliminated in work areas. Such a light has already been termed Work-Light or COOPER HEWITT light.

PROBLEMS OF SEEING AND LIGHTING

Seeing is an act of the mind; this fact is the basis upon which all considerations of lighting problems rest. Sharpness of vision depends upon:

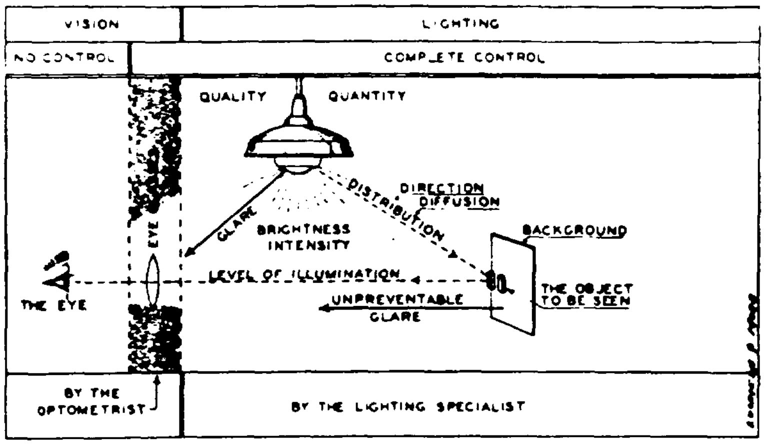
1. The eye
2. The lighting

As far as the eye itself is concerned, nothing much can be done to improve visual sharpness. Of course, if the eye has some defect it can be remedied by the application of lenses, provided the defect is not too serious.

Artificial lighting is controllable in every respect, particularly as it affects the eyes. The important factors to observe are:

1. Quality
2. Quantity
3. Distribution
4. Direction
5. Diffusion

The diagrammatic sketch below very ably illustrates the conditions of vision and lighting.



The optometrist and the lighting specialist are partners for improving seeing and conserving eyesight.

COOPER HEWITT light because of its **QUALITY** is glareless - - it is pleasing to the eye and transmits only those rays used for seeing; all other undesirable rays are absent. Consequently neither direct nor reflected glare need be considered, with the absolute assurance that the eyes will perform their visual task at maximum efficiency.

FORMULAS FOR VISION

Clear and accurate seeing depends upon two basic effects:

1. Light - brightness or intensity

2. Sight - visual perception or retinal sensitivity

The first effect as far as seeing is concerned, is an external condition and is one which can be arranged by illuminating engineers as required.

The second effect depends upon the first to some extent, but primarily upon the eye. Various formulas can be arranged for light and sight:

Better light = Better sight

No light = No sight

Normal eyesight + Darkness = Total blindness

Normal eyesight + Poor lighting = Slow seeing, Danger

Defective eyesight + Poor lighting = Accidents

Defective eyesight + Good lighting = Slow seeing, Danger

Normal eyesight + Good lighting = Quick easy vision, increased production

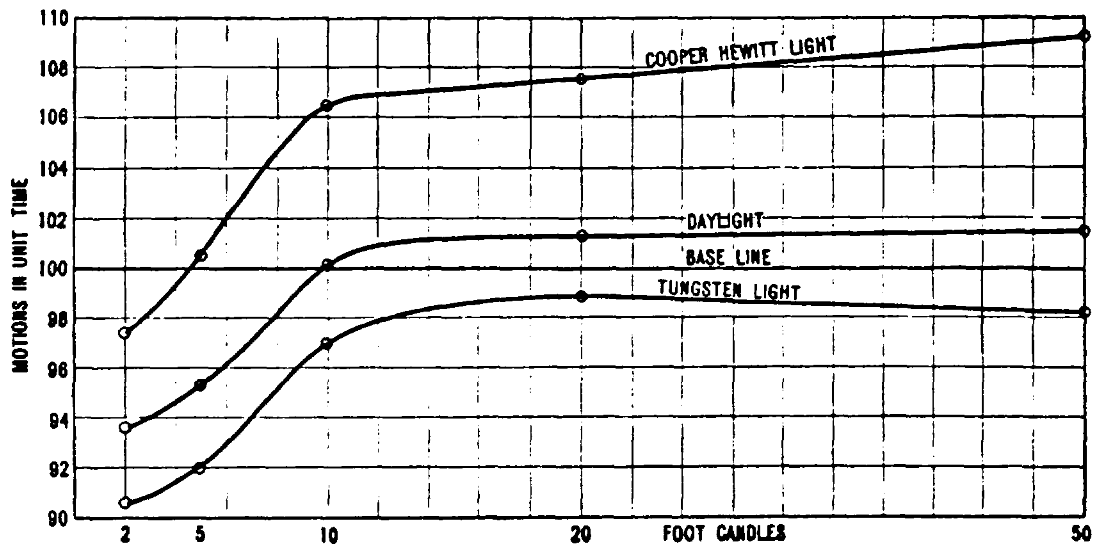
REACTION TIME

To simply **see light** is an elementary act of the brain, but to see an object and recognize it, that is, distinguish it from all other objects, requires an act of the mind which is a more or less complex process. This complex process is named **cognition**. Like all other mental processes, it requires a certain length of time for its completion. When the process of visual cognition is completed by the brain, impulses are sent out through the nerves to the proper muscles, which cause them to contract or relax, thus producing the desired motion of the member, such as reaching for an object. This motion is **muscular reaction** and the time elapsing between the formation of the image on the retina and the actual motion of the muscle is known as **reaction time.**

THE ELLIOTT TESTS

The best way to determine which light is most effective as an aid to seeing and production is by some direct means of comparison. The Elliott tests do this. The experimental set-up will not be given here - - space permits only the results of these important tests which take into account cognitive reaction-time with lights of different character and at different intensities of illumination. Three different observers were used making 26,700 observations. The average results are shown by the curves below.

CURVES SHOWING REACTIONS IN UNIT TIME UNDER DIFFERENT KINDS OF LIGHT



A close study of the curves reveal many interesting points, which have a direct and important bearing on industrial lighting. Some of these are:

1. COOPER HEWITT light at 6 ft.c. surpasses daylight at its best, i.e., 50 ft.c.

2. COOPER HEWITT light at 4.5 ft.c. equals daylight at 10 ft.c.

3. COOPER HEWITT light at 3.5 ft.c. equals tungsten light at its best, i.e., 20 ft.c.

707008

4. The curves are substantially parallel which means that the difference between the three kinds of light is the same at all the different intensities.

   a. Tungsten light shows that 50 ft.c. is not as good as 20 ft.c.

   b. COOPER HEWITT and daylight indicate that anything above 20 ft.c. is practically wasted.

   c. There is so little gain for intensities above 10 ft.c. that this may be taken as the practical minimum intensity.

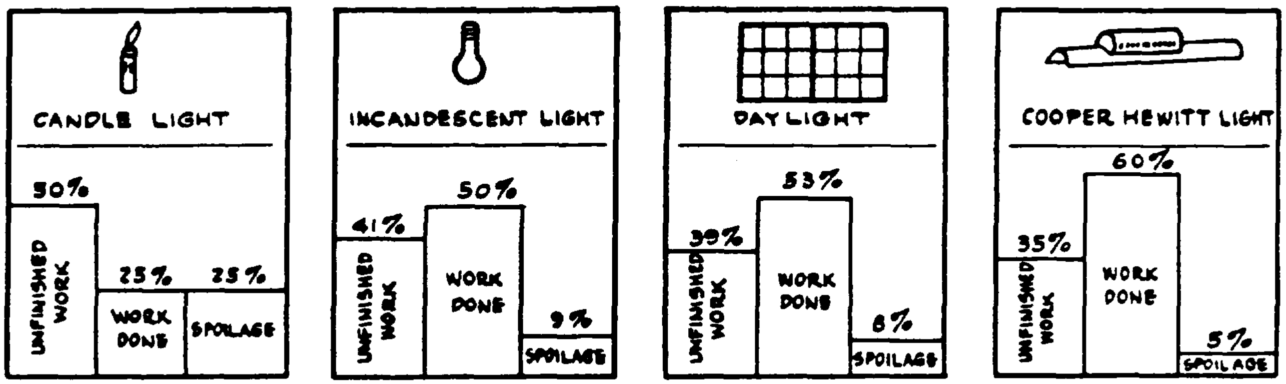
Naturally the Elliott tests are laboratory tests and the conditions for seeing were the best possible and all external hindrances to vision were eliminated. There is reason to believe, however, that practical shop tests would follow the same general conditions. The normal intensities shown on the curve sheet might be somewhat increased but the differences due to the different lights would remain the same.

THE ELLIOTT TESTS - GRAPHICALLY

A graphic representation of the effect on production due to various forms of lighting is of particular interest. The results shown were derived from the Elliott tests and relate to **the quickness of response of the hand to the eye.** The graphs show how this is affected by the quality of light at an intensity of 10 foot-candles.

At this intensity the following values of motions per unit time are read:

SOURCE	MOTIONS
Mercury	106.6
Sunlight.	100.0
Incandescent.	97.0



1. COOPER HEWITT vs Daylight

   a. 7% increase in work done

   b. 3% decrease in spoilage

2. COOPER HEWITT vs Incandescent light

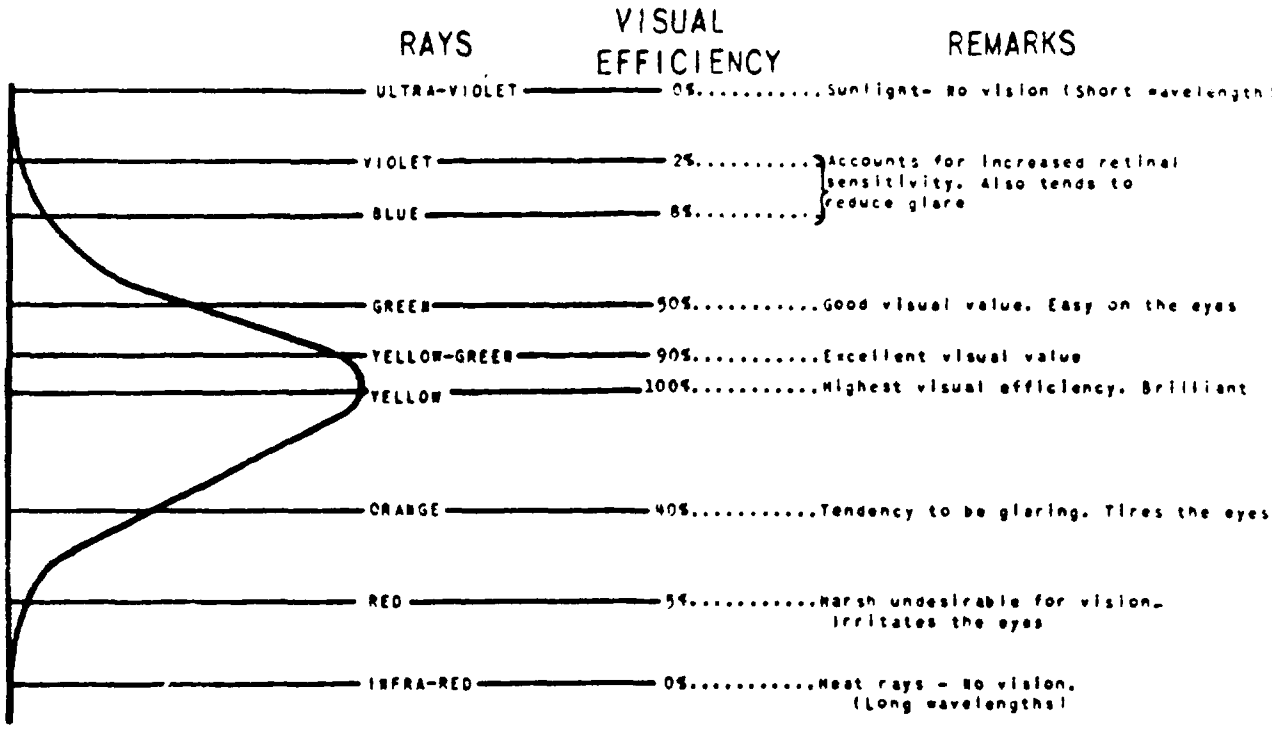
   a. 10% increase in work done

   b. 4% decrease in spoilage

Work can be carried on by candle light or dim light but the risk to man, material and machine is too great a chance in any factory. Light must serve to sharpen the visual tool, thereby protecting human life and machinery investment.

Thousands of practical comparative tests in various departments in almost every branch in industry have verified the authenticity of the above graphically represented reaction tests.

MEANING OF EYE SENSITIVITY - GRAPHICALLY



Due to the sensitizing effect of the violet and blue rays on the retina and the visual results of yellow and yellow-green rays and the soothing effect on the eyes by the green rays, it is reasonable to expect that COOPER HEWITT light promotes eye sensitivity far in excess of any other form of light source, not excluding daylight.

It may be of interest to know that navy surgeons have found that the acuity of night vision of naval officers is improved by giving the comparatively rested eye small doses of light in the blue and violet region of the spectrum; the eye becomes sensitized and sharpness of vision is greatly improved in perceiving distant and dimly lighted objects.

COOPER HEWITT contains 90% visual rays in the yellow and yellow-green portion of the spectrum and 10% sensitizing rays in the blue and violet portion.

This broader understanding of visual efficiency explains why mere foot-candle readings must be replaced by some measure of light in terms of actual seeing.

Many executives who have lighted their factories with foot-candles are now changing the lighting systems so that the workers can SEE. Their experience is responsible for the expression:

> "Don't light your mill with
>
> foot-candles;
>
> Light it so your workers can
>
> SEE!"

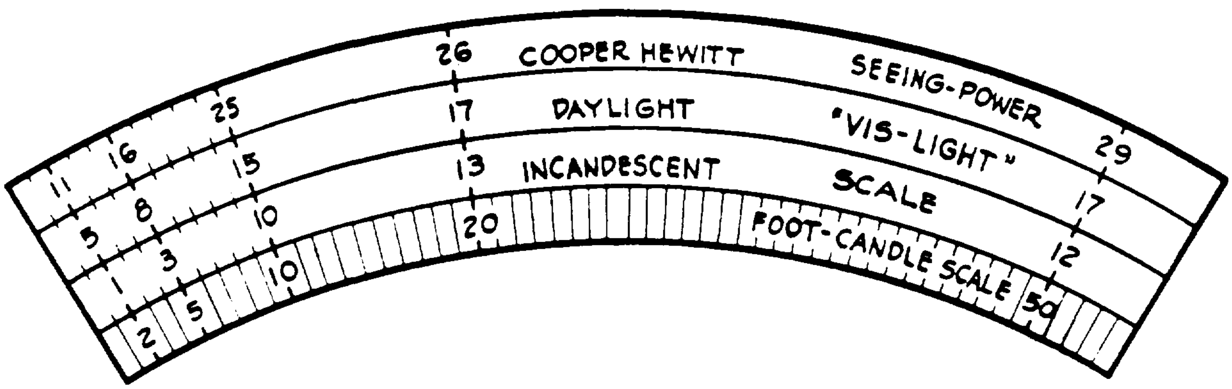
The era of average foot-candle lighting is being replaced by specific lighting at the point of vision. In lighting a factory or shop the first job is to determine the point of work and then get as much VISION - - NOT LIGHT - - as possible at that point.

Here are a few things of which vision is not a measure:

1. Checkerboard lamp layouts
2. Hanging height of lamps
3. Watts
4. Candlepower
5. Lumens
6. Foot-candles
7. Lumens per watt
8. Watts per square foot
9. Foot-candles per watt per square foot
10. Uniform intensity on a working plane
11. Hot spot light at the working point
12. Reflectors

THE SEEING-METER

Scientists believe it will be difficult to devise a meter that will measure **seeing-power** because of the many factors envolved, such as quality, quantity and distribution of light, glare, contrast, speed and comfort. Since there is no such meter available, a suggestion showing a scale with comparative seeing-power values is reproduced below.



Accomplished work is the result of seeing at the point of work. Seeing cannot be measured in terms of candlepower or foot-candles, but must be measured as **seeing power**. The **illuminometer** scale is not a direct reading scale of seeing power, but must be transformed by means of a visual function curve. The above scale has been prepared from the Elliott tests, which clearly illustrates seeing power against foot-candles.

The word **"vis-light"** is arbitrarily assigned as a unit of measure for seeing power. A **vis-light** meter would, of course, have but one scale - - the four scales are drawn merely to show what values of vis-light are obtained for COOPER HEWITT, Daylight, and Incandescent light at various foot-candle readings. A few definitions may make it more clear as to what vis-light really means by comparison with candlepower:

CANDLEPOWER is the intensity of a beam of light.
→ **Foot-candle** is the illumination produced by a light of one candlepower at a distance of one foot.

SEEING-POWER is a function of the mind.
→ **Vis-light** is the clear vision produced by mind due to a quality of light.

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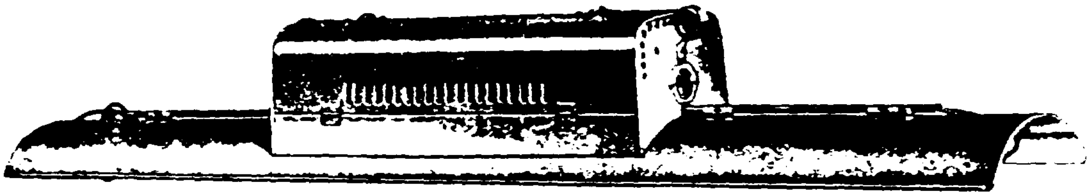
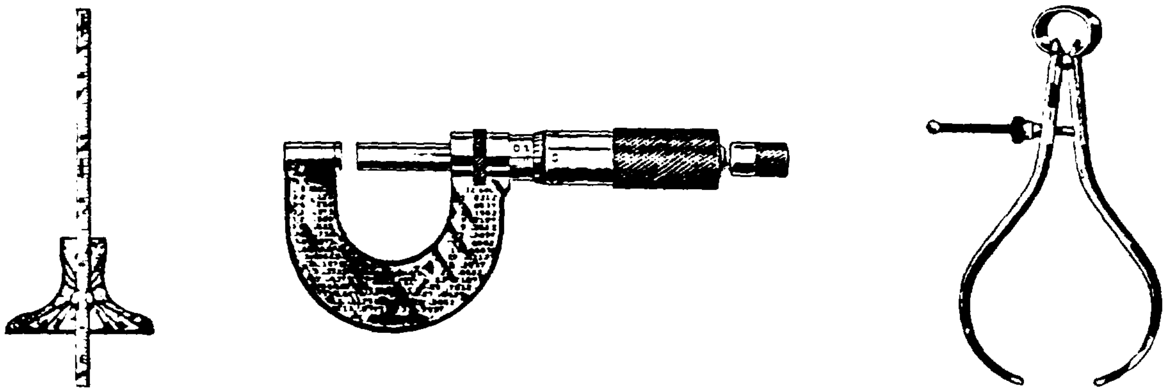
TOOLS OF INDUSTRY



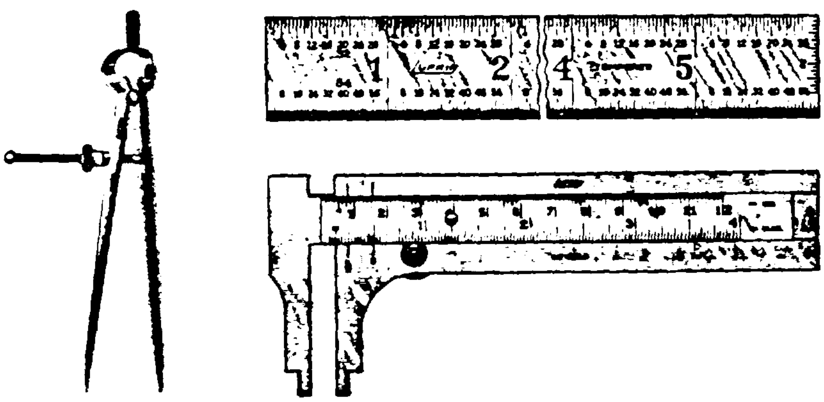
Master Tool

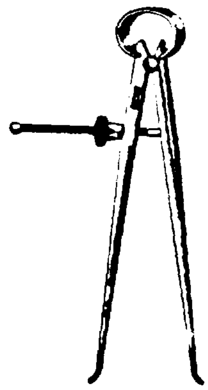
LIGHT PAYS FOR ITSELF THROUGH EYES

Visual Tool



Mechanical Tools





COOPER-HEWITT light is a precision light of extreme accuracy. It gives the eye a micrometer setting for seeing.

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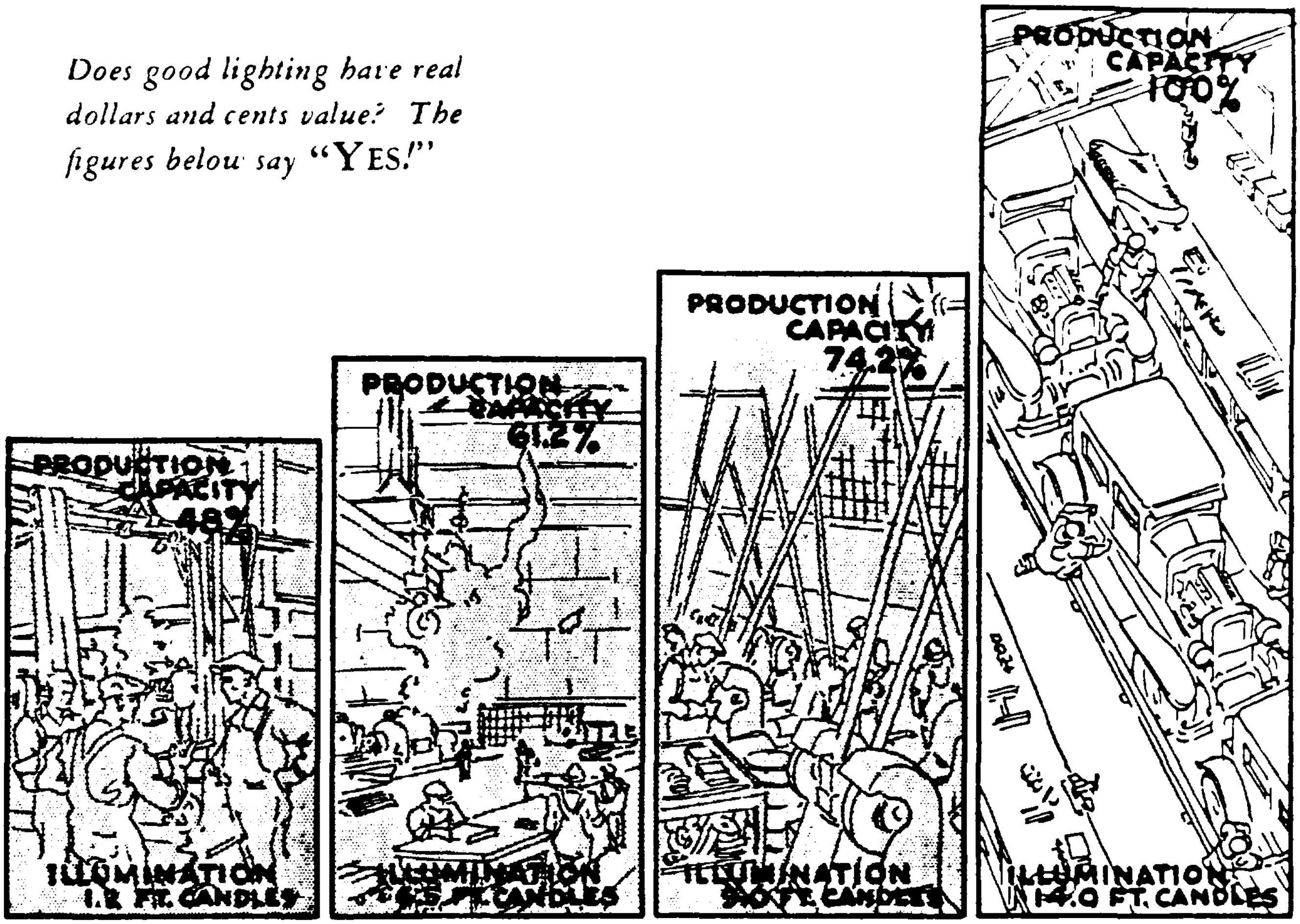
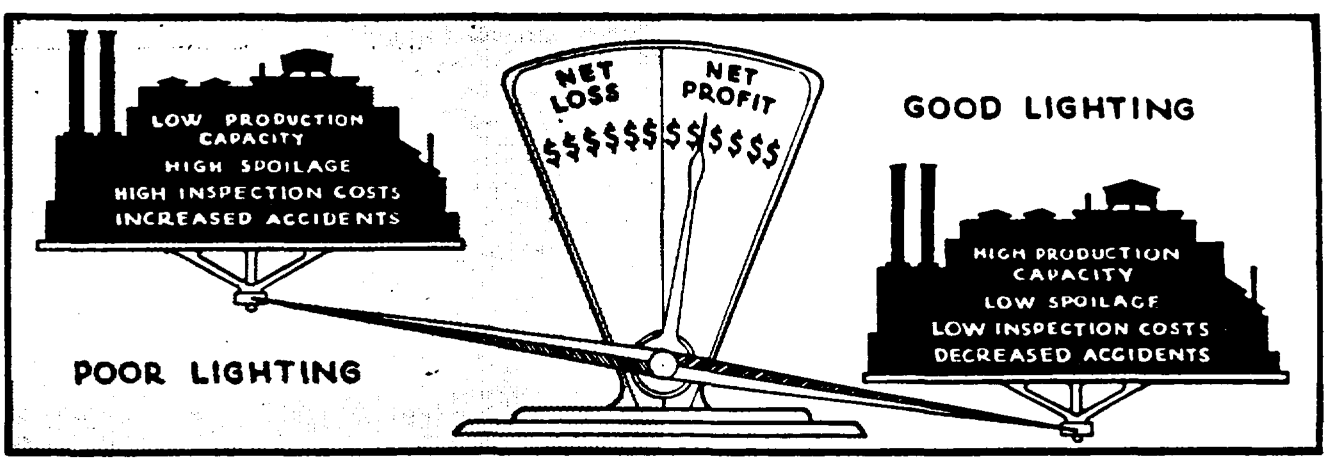
Does good lighting have real dollars and cents value? The figures below say "YES!"



(The percentages refer only to this test and are for purposes of comparison only.) These figures are from the results of a 15-month investigation conducted in a metal-working plant. The original lighting system produced an average illumination intensity of 1.2 foot-candles and made possible a production capacity equal to only 48 per cent of that attained with illumination intensity raised to 14 foot-candles. As indicated, four levels of illumination were tried out with the results as shown. The maximum increase in cost of electricity was 48 per cent—equivalent to only 2 per cent of the payroll. Savings in decreased spoilage and accidents easily paid for the extra current. (From "Light and Work"—Luckiesh.)



Good lighting often effects savings equal to the difference between *net loss* and *net profit*. Buying the benefits of good lighting for your plant is equivalent to buying additional net profit—and increasing your competitive ability for years to come.

707015

VISUAL ACUITY

Visual Acuity

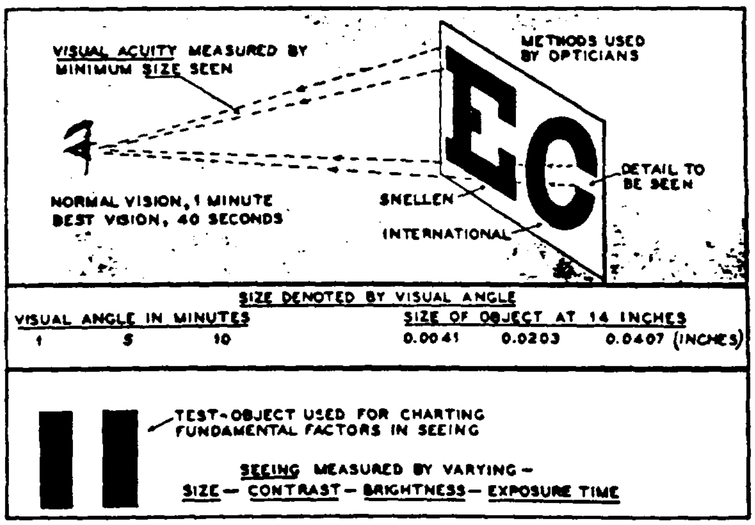
The term visual acuity is too broad to define in a few words with any degree of accuracy. Since the word visual refers to seeing and acuity means sharpness the most simple definition: 'Sharpness of seeing' is the most effective as far as general comprehension is concerned.

RESOLVING POWER

Technical literature has referred to visual acuity as the equivalent of resolving power. This is indeed a limited meaning of resolving power but is being used because of the fact that it is susceptible of physical measurement. The true interpretation, however, is complicated by certain psychophysical factors relating particularly to visual contrast or the effects of sharpness of delineation. Thus, visual acuity is a measure of the optical sharpness of an image, and the degree of visual contrast. The often overlooked fact is that both of these factors are affected by the spectral composition of light.

SEEING MEASUREMENTS

The ordinary method of visual acuity measurement is illustrated below. The size of the angle is all important in such measurements; normal vision is given at 1 minute (one sixtieth of a degree) and best vision at 40 seconds (one ninetieth of a degree).



Ordinarily only four variables of an object are considered - size, contrast, brightness and exposure time. One other very important factor must be included, namely, the sensitivity of the eye. These conditions are analogous to photography in which size, contrast, and brightness has a direct bearing upon time of exposure. The remaining factor in getting a good picture is sensitivity of the film. The analogy is closer if motion picture photography is taken, in which the time of exposure is invariable. The sensitivity of the film (retina) then determines the success of the results with any given lighting condition.

CHROMATIC ABERRATION

The lens of the eye is a simple convex lens having several inherent defects or limitations - - one in particular is its inability to bring different colored rays to a focus on the same surface. If red rays are focused, the blue will be out of focus, and other rays to a less extent. If blue rays are focused then red rays will be decidedly out of focus. When the eye must handle light containing all the colors of the visible spectrum it makes a compromise by focusing on the yellow, which is a mean between red and blue.

The eye has always used this compromise in focusing with natural light; therefore it has become much more sensitive to the middle range of colors - - yellow and yellow-green - - than to the other portions. It takes less energy in the form of yellow light to produce a given visual effect than it does for any other color. The inability of the eye to focus all colors at once is called chromatic aberration.

So in considering the choice of an illuminant for industrial lighting it is without doubt, that one possessing a monochromatic yellow-green ray is to be preferred. Naturally, with such a characteristic light the eye is properly focused making it unnecessary for a compromise as explained above. COOPER HEWITT light is composed almost entirely of yellow-green rays of light; it therefore sharpens vision with the same effect as that of providing glasses for defective eyesight.

SHARPNESS OF VISION

Sharpness of vision depends upon retinal brightness and kind (quality) of light. Since the structure of the eye cannot be changed the light must be of such a quality as to produce this sharpness. By using a light containing only one color the lens of the eye can produce a perfectly sharp image on the retina. This is represented pictorially by the two photographic cuts. If the eye were unable to compromise for a single color a blurred image would result with an effect even worse than shown by the picture since it shows an out-of-focus condition in one dimension; whereas the actual image would actually be in every direction, horizontally as well as vertically and through the various intermediate angles.

Sharp Image

Blurred Image

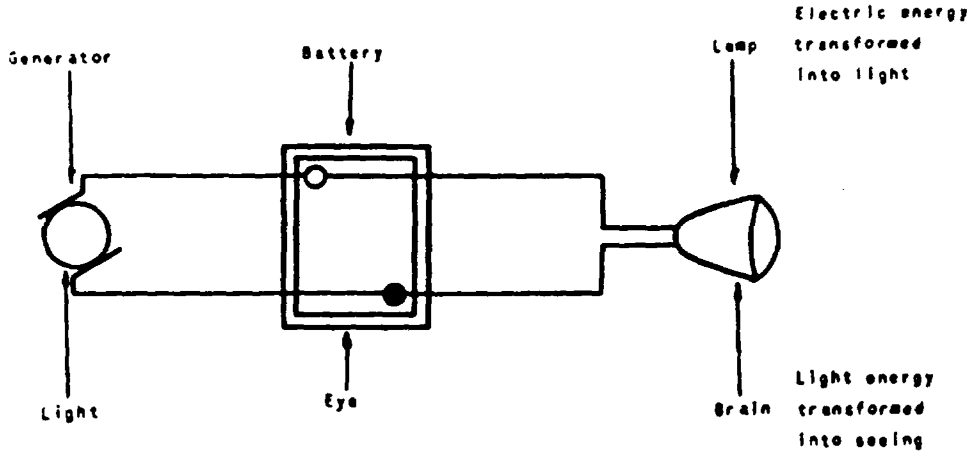
COOPER HEWITT light has only four color bands and almost 99% of the light is in the yellow and yellow-green region - - the rays which are responsible for ease and sharpness of vision.

RETINAL SENSITIVITY

If the eye were subjected to the task of seeing it could best do this with a light of monochromatic yellow, as indicated by the eye sensitivity curve. However, the structure of the retina is such that if exposed to pure yellow light for long periods of time it becomes fatigued.

The basis of continued superior seeing power of COOPER HEWITT light is its enhancement of retinal sensitivity and this is due primarily to the violet and blue action on the retina. This is technically known as reflex retinal action.

The analogy between the eye and an electric battery is the best possible means of explaining the part that reflex retinal action plays in seeing. Each retina contains something more than a hundred million electric batteries, each one connected with the seeing projector in the brain.



If the generator terminals were disconnected from the battery the lamp would naturally burn, but if continued to burn the battery would slowly lose energy and eventually the light from the lamp would be very dim.

In the case of the eye, yellow light has a tendency to run down the many million batteries of the eye. Under continued use, the eye becomes fatigued and vision is somewhat dimmed or indistinct. Just as the generator is used in the above circuit, so are the blue and violet rays used in COOPER HEWITT light to keep the retinal batteries at full charge preventing fatigue.

Although the luminosity of the blue and violet amounts to only 1½% and add little to the apparent brightness of illumination, these rays have considerable energy and have a powerful action in maintaining a high level of retinal sensitivity, restoring the exhaustion caused by yellow and other visually effective rays.

This explains the higher seeing-power of COOPER HEWITT light and accounts for the increase in contrast perception as shown experimentally:

1. 60% increase over daylight
2. 100% increase over incandescent light

MERCURY LIGHT ENHANCES VISION

The superiority of COOPER HEWITT light for industrial use consists in its greater power to:

1. Light up dark spots

2. Increase visual discrimination

The low spots in illumination are the spots where light is more or less cut off by obstructions, that is, where shadows fall. The same proportion of light will be cut off whatever the kind or position of light sources. But the portion of light that reaches the spot from the COOPER HEWITT lamp, by increasing retinal sensitivity 100%, increases the seeing-power of the light by just that much, and so has the same visual effect as increasing the intensity of incandescent light by the same amount. This is another reason for the shadowless effect of mercury light.

Some time ago Dr. Luckiesh said:

> "It has long been known that visual acuity under monochromatic light of certain wavelength is superior to light of extended or heterogeneous spectral character. Furthermore, this advantage is generally greater at low brightness levels than at higher ones."

Contrast sensitivity produced on the retina of the eye together with brightness of the image is the measure of visual acuity. Contrast does not vary alone with photometric brightness, but depends also upon the spectral composition of light.

Contrary to the general concensus of opinion, mercury light and ordinary light cannot be measured or compared in terms of seeing-power by ordinary photometric means.

> . . . . mercury vapor light appears to magnify details and produces visual results considerably greater than its photometric intensity would indicate."
>
> DR. LOUIS BELL, PH. D.
> *Author of "Art of Illumination"*

Three independent sources have proven this experimentally.

1. Elliott shows the results in percentages, using daylight as the standard:

   a. Daylight 100%

   b. Incandescent 82%

   c. COOPER HEWITT. 132%

2. Bell in his report on Visual Acuity shows the ratio of mercury to incandescent light of:

   $$\frac{1}{1.5} \text{ to } \frac{1}{1.75} \text{ or 1 to 1.6}$$

3. The average hue sensitivity of daylight and mercury light as derived from the areas:

   a. Daylight 4.3

   b. COOPER HEWITT. 5.9

   This gives a ratio of 1 to 1.4

Bell comparing the visual discrimination of light states:

> "- - - the seeing-power of mercury light is equal to that of incandescent light of twice the photometric intensity."

Never has anyone disputed the value of COOPER HEWITT light as the best and most desirable for industrial areas. Many large concerns in this country when confronted with a lighting problem turn toward COOPER HEWITT LIGHTING as a solution - - they have standardized on one type of lighting.

THE PRACTICAL SEEING TEST

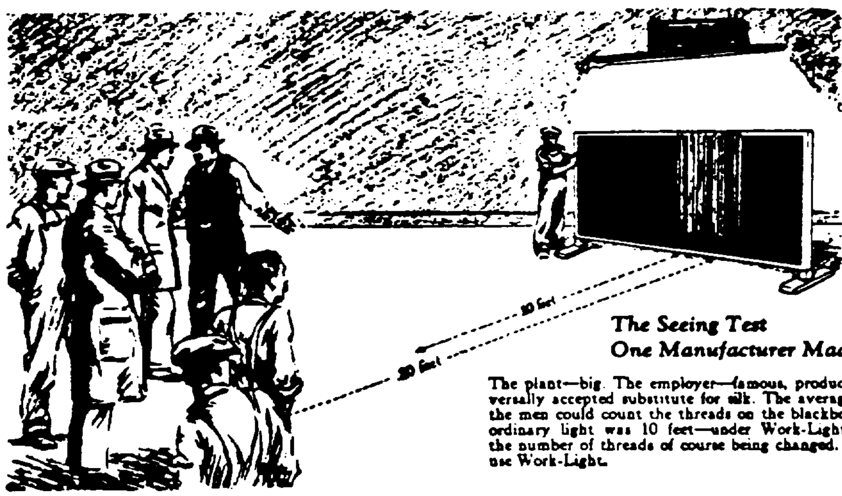
While the laboratory test must be relied upon for accurate results in any branch of science, the practical test is more often important. Several tests of various natures have been conducted in the field and proved conclusively that:

COOPER HEWITT

light is

BETTER THAN DAYLIGHT

One of these field tests is reproduced below in the form of a picture story.



The Seeing Test
One Manufacturer Made

The plant—big. The employer—famous, producing a universally accepted substitute for silk. The average distance the men could count the threads on the blackboard under ordinary light was 10 feet—under Work-Light, 20 feet, the number of threads of course being changed. They now use Work-Light.

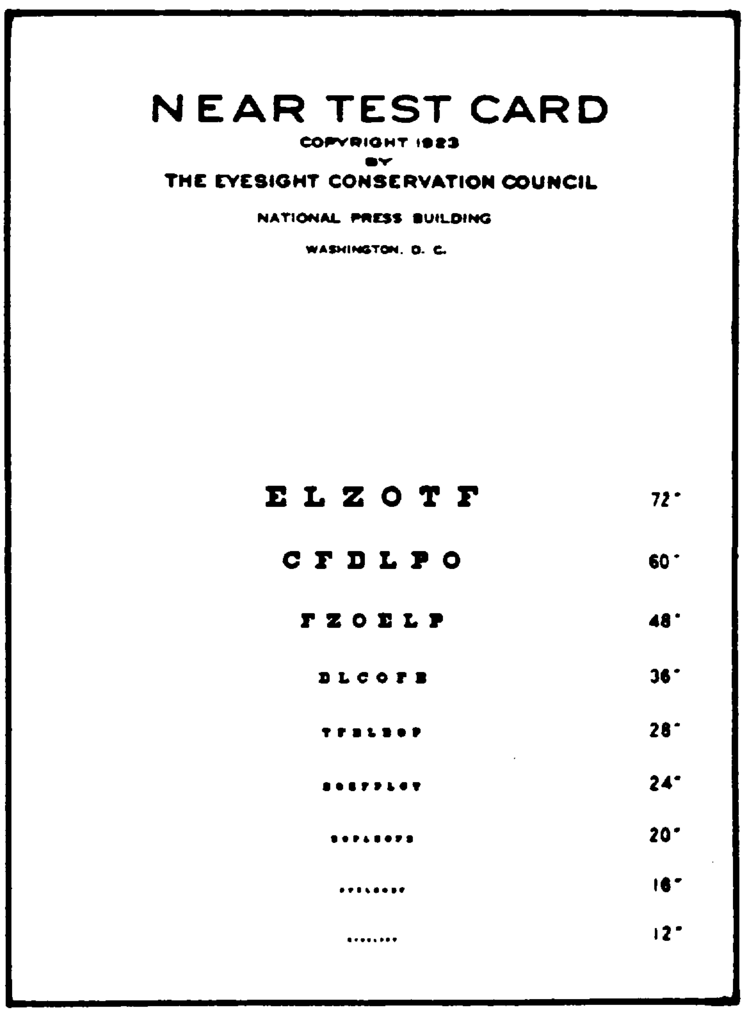
Another field test quite as interesting as the above was conducted at a well known Cotton Mill in the cotton spinner room. Twenty operators stood at one end of the spinner, and a careful record was made of the distance they could observe and count the threads on the spinning frame. The average results were tabulated as follows:

DAYLIGHT:	
Average Intensity	10.5 ft.c.
Distance at which threads were distinguishable.	17.4 feet
COOPER HEWITT:	
Average Intensity	3.5 ft.c.
Distance at which threads were distinguishable.	24.8 feet

There is almost a 43% increase in the distance of vision with a 70% decrease in the intensity of light. Manufacturers are invited to make similar tests to satisfy themselves that all the claims made for COOPER HEWITTS are quite conservative rather than over-emphasized.

These tests indicate the practical conception of visual acuity. When the opportunity arises try the following as a simple experiment under different kinds of light.

Read the smallest line discernible under COOPER HEWITT light - then repeat under any other kind of light. Allow 10 to 15 minutes between readings.

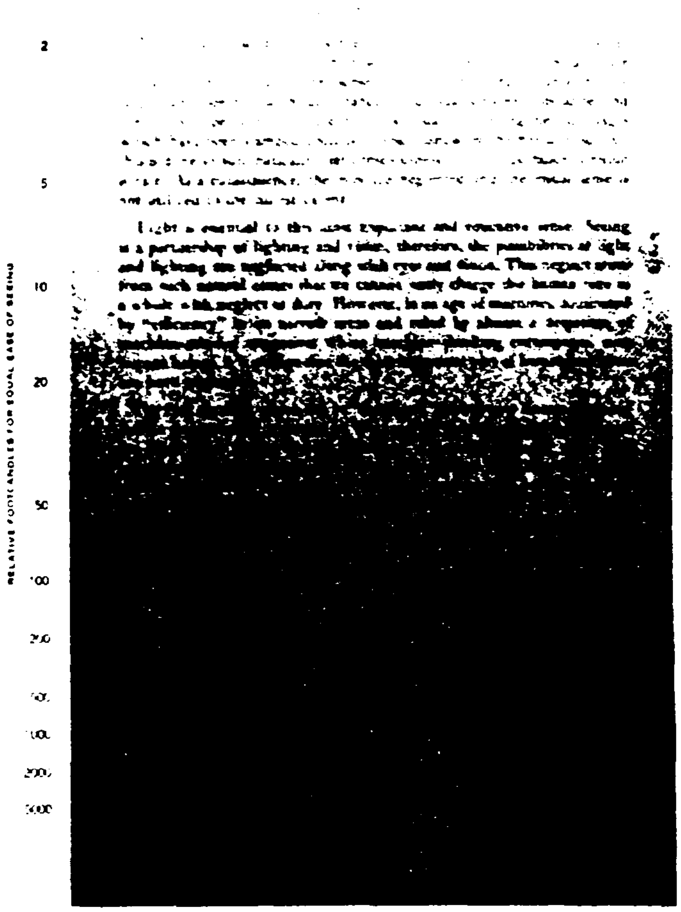


A VISIBILITY INDICATOR

The indicator below presents a series of visual tasks which increase uniformly in difficulty. By means of these visual tasts it is possible to demonstrate the influences of light, lighting, eyesight, eye-glasses and other factors upon seeing.

Visibility and Ease of Seeing are closely related

Visibility increases as the intensity of illumination increases. So does ease of seeing. Read the printed matter below under different intensities of illumination and note the point at which reading becomes difficult or impossible.



VISIBILITY INDICATOR

LIGHTING RESEARCH LABORATORY
NELA PARK ENGINEERING DEPARTMENT
GENERAL ELECTRIC COMPANY
CLEVELAND OHIO

A WARNING

In the "April 1935" issue of the I.E.S. Transactions, Mr. Ward Harrison has voiced the hazard in relying upon the foot-candle meter as a measure of good lighting. Mr. Harrison says in part:

> "I have just one misgiving in connection with a great deal of what is being done under the head of Better Light - Better Sight. It avoids so much hard work just to depend entirely on the sight meter for your illuminating engineering judgments, and to say to a customer - 'you are all right because you have 25 foot-candles' - or 'you are all wrong because you have only 5'. If we are not careful we will be in danger of an epidemic of bad lighting simply because it is so easy to concentrate on quantity and forget all about quality."

A foot-candle has no more significance in measuring the important factor of seeing-power than pounds have in expressing a kind of steel or yards have in revealing the quality of a material.

VISUAL FATIGUE

Visual Fatigue

The ability of the eye to detect small objects and fine details distinctly, without effort, is known as visual acuity. Anything of serious consequence in interfering with ease, comfort, certainty and satisfaction of vision is known as visual fatigue. There are an unlimited amount of things which cause visual fatigue and the conditions of these causes are quite variable. The eye itself is perhaps the most variable, since it depends wholly upon the individual.

RESULT OF USING THE EYES

The age of a person has a great deal to do with the process of seeing. Examinations have revealed that the eyes of an infant are naturally far sighted (hyperopic); that is, the eyes have evolved to function best for distant vision. As the child grows older, the eyes are used more and more for close work tending to cause near sightedness (myopia).

The progressive character of myopia with age as given by M. Luckiesh is as follows:

	Number Examined	Emmetropic (Normal)	Myopic (Nearsighted)
Infants	1,534	6.2	2.5
Pre-school children	356	10.4	7.9
Elementary school children. .	13,929	63.6	11.4
Intermediate school children.	42,283	37.4	27.5
College students.	4,207	37.9	52.5

The figures are given as a percentage of the eyes tested. The data indicates that myopia increases steadily with advancing age and use of the eyes.

EFFECT OF AGE ON EYES

In connection with increasing age Luckiesh has also shown that "as the eyes grow older the pupils gradually undergo a reduction in size and consequently the brightness of the retinal images decrease, although the level of illumination upon the objects to be seen remains the same.* The variation in pupil diameter was shown to be in daylight as follows:

Age.	Pupil dia. in mm.	Relative Brightnesses of Retinal Images.	Foot-candles for equal effectiveness.
20	4.7	100	20
30	4.3	84	24
40	3.9	69	29
50	3.5	55	36
60	3.1	43	46
70	2.7	33	60
80	2.3	24	83

The figures indicate that the older eyes require a higher level of illumination if the same brightness of retinal image is to be maintained. For factory lighting then it is difficult to say just how much light is actually required. If the level of illumination is to be ideal for all involved, the intensity should be such that it satisfied the poorest seeing condition of any one man's eyes. An average intensity of light would normally result in average rate of production, or specifically, increased illumination gives increased production. From the standpoint of the individual, increased illumination improves visibility, permitting the eye muscles to function with less strain or contraction, thereby reducing ocular fatigue.

RESULT OF INTENSITY

Luckiesh has shown in his experiments that if the intensity of light is increased the distance at which an object can be seen is greater. The result of such an experiment is as follows:

Foot-candles	Distance for equal visibility (inches)
1	14.0
2	15.3
5	17.5
10	19.1
20	20.8
50	23.2
100	25.4

FACTORS OF GLARE

Since the eye differs in many respects due to the individual let us proceed to explain how various factors produce eye fatigue. Here again it must be remembered that such factors are also variable, such that the normal eye may withstand a greater strain than the eye suffering from myopia or the like.

Visual fatigue was explained as anything interfering with the ease or comfort of the eye in its ability to see. Any such interference causes the eye to make certain adjustments which tax or strain the eye. This straining of the eye, or eye strain, if continued for any length of time tires the muscles of the eye, just as over exercise tires the muscles of the body, causing the eye to become fatigued. A tired or fatigued eye hinders vision and when such is the case both physical and mental conditions of the body suffer the effects. Visual fatigue is therefore detrimental to mind and body and may result in physical injury to a worker.

The most common factors causing visual fatigue from industrial lighting systems are:

1. Objectionable shadows
2. Dangerous glare
3. Insufficient light

MINIMIZING OBJECTIONABLE SHADOWS

Objectionable shadows are shadows that obscure vision. Shadows, of course, are necessary to clear vision but when a shadow is improperly placed and too dense or dark the eye has difficulty in functioning properly. In other words, the eye views an object until it is perfectly clear or defined, so when a shadow interferes with this clear vision the eye readjusts itself until clear vision is again attained. However, this readjustment is in the form of muscular reaction which results in eye strain.

Realizing that shadows actually cause eye strain we may summarize the points essential to minimizing objectionable shadows and eye strain.

1. Shadow must be correctly placed.
2. Must be of proper density.
3. Heavy and dark shadows are reduced when the lighting unit is large in proportion to the area lighted.
4. High visual acuity essential (in shadows) at low intensities.

HARM PRODUCED BY GLARE

The problem of devising general rules for the avoidance of glare is greatly complicated by the personal equation. Not only is the condition and age of the eye to be considered but also the color of the eye. People with gray or blue eyes are particularly annoyed by exposure to glare. The muscles of the light colored eye has difficulty in controlling the pupil aperature since there is less protection against the heat and infra-red rays, which may therefore have a tiring effect. Dark colored eyes, of course, are also affected by the presence of light units emitting red rays, but with less tiring effect. Below an excerpt from Dr. Steinmetz.

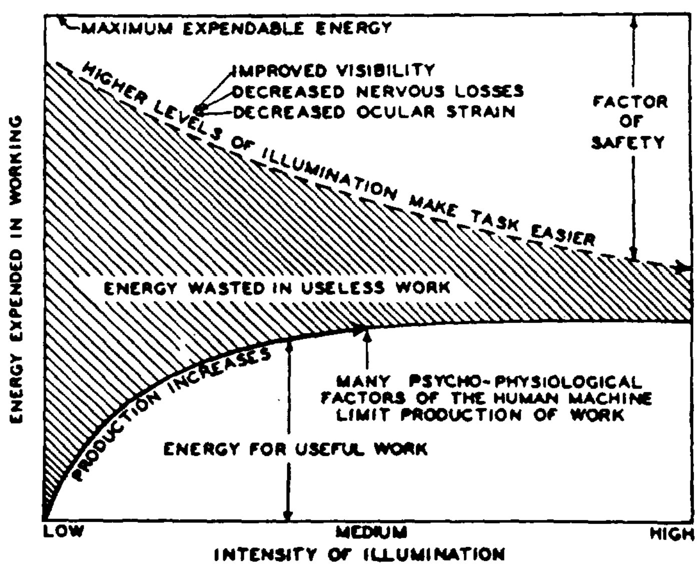
"Radiation is a form of energy, and when intercepted and absorbed, disappears as radiation by conversion into another form of energy, usually heat. Thus, the light which enters the eye is converted into heat, and if its power is considerable is may be harmful or even destructive, causing inflammation or burns. This harmful effect of excessive radiation is not incident to any particular frequency, but inherent in radiation as a form of energy. It is, therefore, greatest for the physiological effect, that is, the same amount of visibility, for those frequencies of light which have the lowest visibility or highest power equivalent, that is, for the red and the violet and least for green and the yellow, which for the same amount of vision represent least power. Hence, green and greenish yellow light are the most harmless, the least irritating to the eye, as they represent the least power. We feel this effect and express it by speaking of the green light as 'cold light' and of the red and orange light as 'hot' or 'warm.' The harmful effect of working very much under artificial illumination is largely due to this energy effect, incident to the large amount of orange, red, and especially ultra-red in the radiation of the incandescent bodies used for illuminants and thus does not exist with 'cold light,' as the light of the mercury lamp."

From Steinmetz' remarks it is apparent that the hot rays of red light are irritating to the eye, causing unpleasantness and eye strain. This fact together with the reasons given under the section of "Glare", gives evidence that glare is a very undesirable factor in an industrial lighting system.

NECESSITY OF PROPER LIGHTING

Recently there has been a great deal of discussion about sufficient quantities of light. Scientific considerations of seeing are being more thoroughly studied now than ever before and more attention is given to the behavior and welfare of human beings as human seeing machines. A few years ago M. Luckiesh and Frank K. Moss developed a very interesting diagram of the human seeing-machine at work. The results are not entirely supported by quantitative data, but they are based on many years of research. The diagram has plotted along the horizontal axis intensity of illumination. As the intensity of illumination is increased the rate of production naturally increases.

The shape of this curve depends upon the class of work to be performed. If rough tasks are involved low intensities of illumination suffice for vision and the production curve tends to reach a maximum. If the work is complicated the visual task is more difficult, thus, for maximum production higher intensities are required.



HUMAN WELFARE

Although the production curve spoken of is valuable, inasmuch as production efficiency is concerned, it does not take into account the welfare of the worker. The upper part of the diagram is designed to account for human energy expanded, and from the curves shown the measure of efficiency of a human being as a seeing machine might be derived as far as the ratio of the useful work done to the total useful and useless work done. Luckiesh states: 'from pure reasoning and meager data a broken-line curve is drawn so as to represent pictorially the decrease in useless internal work done by the human seeing-machine as the intensity of illumination is improved far beyond the point where production ceased to increase appreciably owing to other limitations of the worker.' The clear area or extreme upper part of the diagram is given as the reserve energy capacity of a human being, it being different for different individuals. The intensity of illumination has much to do with this reserve energy in every case. Foot-candle intensities far greater than the so-called productive intensities create a continuous partial rest period which is operative even while workers are working. This partial rest period thus aids the worker and adds to his reserve energy.

Insufficient light is, therefore, very much involved and the part it plays in industrial lighting is of great importance. If a job is properly lighted the expenditure of energy is greatly reduced; the nervous muscular tension, which is a combination of tense nerves and muscles, or body fatigue, is reduced by means of improved visibility. Improved visibility is attained only with improved illumination; high intensities of illumination improves the productivity curve, as well as the behavior and welfare of human beings.

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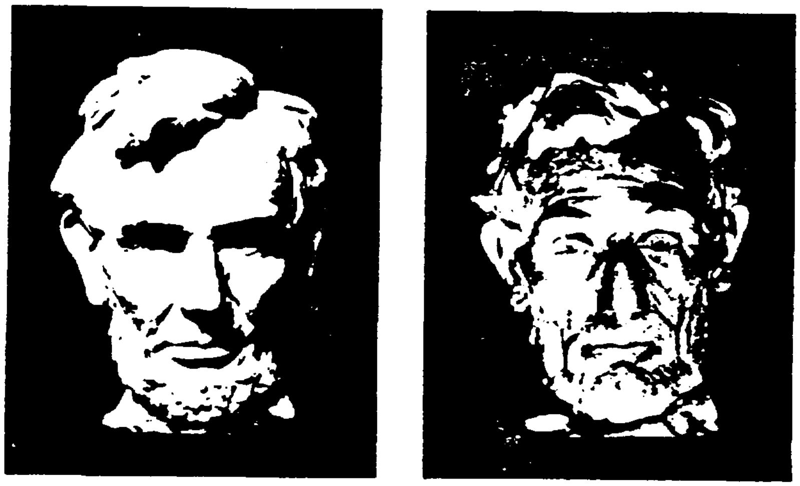
GLARE

Glare

There are many available technical definitions of glare. Whatever the phraseology may be it is an established fact that glare is objectionable in industrial lighting systems. Even the expression of a lifeless stone statue is changed as shown below, due to the glare of floodlighting.



Change of expression due to different conditions of floodlighting

GLARE IS OBJECTIONABLE

Actually glare is objectionable because of a great many reasons. A few of the more important ones may be listed as:

1. Sensation of discomfort
2. May result in permanent eye injury
3. Fatigues the eye and body
4. Reduces speed of vision
5. Reduces effective illumination intensity
6. Prevents discrimination of detail

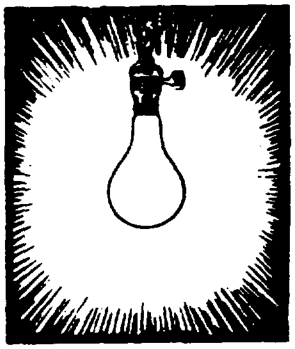
TWO KINDS OF GLARE

Glare is produced in two ways, both of which are a hindrance to a worker's efficiency.

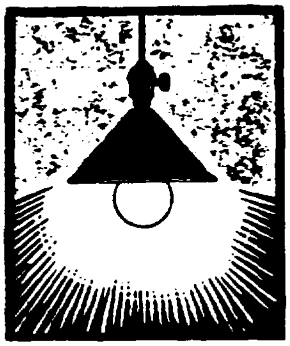
Direct Glare is the most frequent and serious cause of bad lighting. It results among other things from unshaded or inadequately shaded light sources located within the field of vision, or from too great contrast between the bright light source and a dark background or adjacent surfaces. Glare should be avoided by the use of proper reflecting and diffusing equipment.

Reflected Glare from polished working surfaces is particularly annoying because of the necessity of directing the eyes toward those surfaces, and further because the eyes are by nature especially sensitive to light rays from below. The harmful effects of this specular reflection can be minimized by properly shielding from below or diffusing the source.

A few typical instances of direct glare are sketched below.



Bare Lamps



Tin Shades

Light Sources in Line of Vision

Spotty Light

These are also apparent as reflected or specular glare from shiny surfaces. Even with properly designed reflectors specular glare is still unavoidable if the source itself is inclined to be glaring, as noted by the high spots on the machines below.

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FACTORS OF GLARE

In industrial lighting the degree to which glare is experienced depends upon five principal factors:

1. Intrinsic brilliancy of the source
2. Contrast between source and background
3. Total volume of light entering eye
4. Location in field of view
5. Time of exposure

INTRINSIC BRILLIANCY OF SOURCE

The intrinsic brilliancy or brightness of the filament of an incandescent tungsten lamp is extremely high, being above 1000 candlepower per square inch. In terms of brilliancy Table I reveals that a COOPER HEWITT lamp is only about 15 candlepower or less than a 25-watt inside frosted Mazda B lamp.

TABLE I-- BRIGHTNESS OF LIGHT SOURCES

SOURCE	Candlepower Per Sq. In.
Sun as observed at earth's surface	1,064,600
Crater, carbon arc	84,000
1000-watt Mazda C lamp (clear bulb)	7,900
Nerst glower	3,010
Tungsten (1.25 watts per candle)	1,060
Carbon (3.5 watts per candle)	400
50-watt Mazda C lamp (inside frosted)	29
25-watt Mazda B lamp (" ")	16
COOPER HEWITT	15
Kerosene flame	9
Candle	3

LOCATION IN FIELD OF VISION

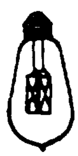
Mr. Henry Schroeder (Edison Lamp Works) states:

> "In the case of clear Mazda lamps the brightness is very high, especially that of Mazda C lamps. If such lamps are in the direct line of vision, they should be used with diffusing media to increase the surface from which the light comes in order to reduce the brightness."

EVOLUTION OF INCANDESCENT LAMPS

The evolution of incandescent lamps would require quite a lengthy discussion. A few of the marked improvements relating to efficiency are interesting.

1. 
50-watt carbon filament lamp .... 3 watts/cp .... 250 cp per sq. in.

2. 
Vacuum tungsten filament lamp .... 1½ watts/cp .... 900 cp per sq. in.

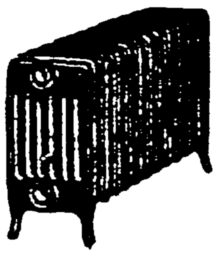
3. 
Nitrogen gas-filled lamp .... ¾ watts/cp ....3000 cp per sq. in.

4. 
Latest (Argon) gas-filled lamp .... ½ watt/cp ....4000 cp per sq. in.

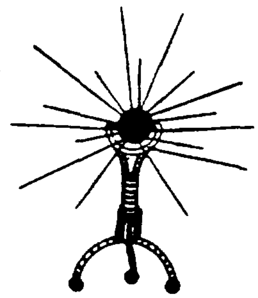
Thus the development of the incandescent lamp brought with it a constant increase in glare. This made necessary the development and use of diffusing media in order to combat the glare that seriously impaired vision. **COOPER HEWITT** light requires no difusing media, consequently no light is absorbed at the source -- less kilowatt energy is required to provide the same illumination at the point of seeing.

VOLUME OF LIGHT ENTERING EYE

The volume of light does not hurt or affect the eye if the light is of proper quality. Concentrating a given amount of light to a small source lends itself to high brilliancy. Radiators, registers and other heating equipment are designed with large surfaces to reduce the heat given off per square inch. If this equipment were required to give off an equal quantity of heat from a very small source, such a source might become red hot and it would be difficult to withstand heat at distances of several feet.

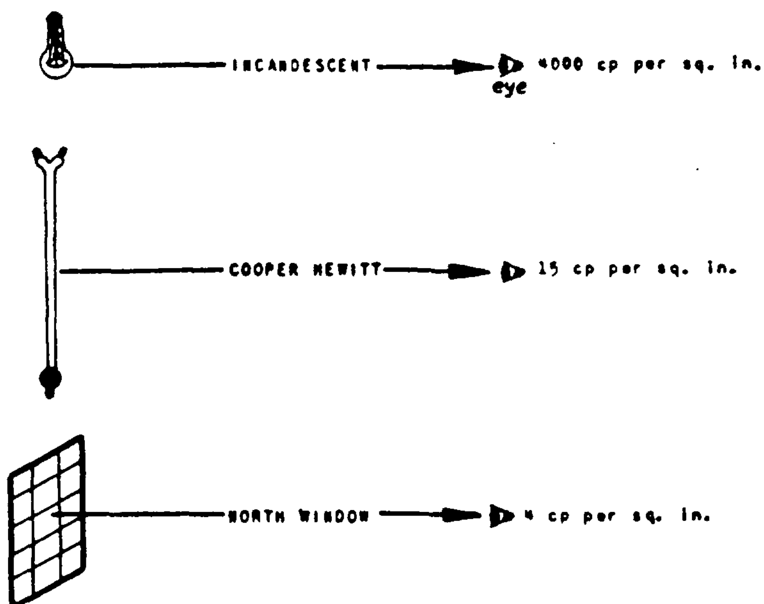


Large radiating surfaces permit comfort at close range and also distribute heat more efficiently.



Concentrating heat to a small source would result in discomfort at a distance of several feet.

The above analogy applies to illumination in a somewhat similar manner. Comparing three of the most widely used sources for industrial illumination clearly shows this to be a fact.



North daylight from side windows is quite unsatisfactory since intensity falls off rapidly - 20 feet away light is inadequate for fine work.

VOLUME OF LIGHT FROM BLUE SKY

That the volume of proper quality of light does not hurt the eyes is illustrated on the golf course. It is quite possible to clearly see a fast moving golf ball without eyestrain.

Clear vision against a blue sky.

The condition of illumination may be as high as 10,000 foot-candles. However, the brilliancy against a blue sky is only about 4 candlepower per square inch. COOPER HEWITT lamps are only four times this value. Thus, in a uniformly or well lighted shop COOPER HEWITT light is **glareless.**

PIN TEST

Looking directly at mercury vapor light for several minutes, one might turn directly away without an after image and clearly see to pick up ordinary pins scattered about the floor. This in itself is positive proof of the glareless feature of COOPER HEWITT light.

QUALITY OF LIGHT

Quality of light has a direct bearing on glare insofar as the rate at which the eye becomes fatigued or irritated. It is evident that best vision results from a source with predominance of energy in the yellow-green wave band and entirely lacking in red and infra-red. These rays are heat rays and do not aid vision, as a matter of fact they are a great hindrance because they irritate the eye.

". . . . green and greenish-yellow light are the most harmless, the least irritating to the eye . . . the harmful effect of working very much under artificial illumination . . does not exist with cold light such as the light of the mercury lamp."

DR. CHARLES P. STEINMETZ
Author of "Radiation, Light and Illumination"

E.L. Elliott has this to say about quality of light:

> Ordinary electric light is strongest in yellow and red; and as these rays contain more energy, they are the most effective in producing glare. The first impression on encountering light of this quality is, that it is "bright." Cooper Hewitt light consists of yellow, mixed with green and blue; these rays are practically *pure light*, being free from the heat accompanying the orange and red rays. Cooper Hewitt light is therefore glare-less under all conditions found in actual practice. The first impression of illumination by such light is, that it is "mild"—not "bright."

DIFFUSE REFLECTION FOR VISION

Scientific investigations have found that diffuse reflection alone is serviceable to vision. The eye sees objects only by light that is diffusely reflected, not by the light that is specularly reflected. Due to the absence of glare from COOPER HEWITT lamps 100% vision is obtained.

Because of this glareless feature no intensity is too great for eye comfort with mercury vapor light. Intensities up to 1600 foot-candles or more are used for various classes of inspection.

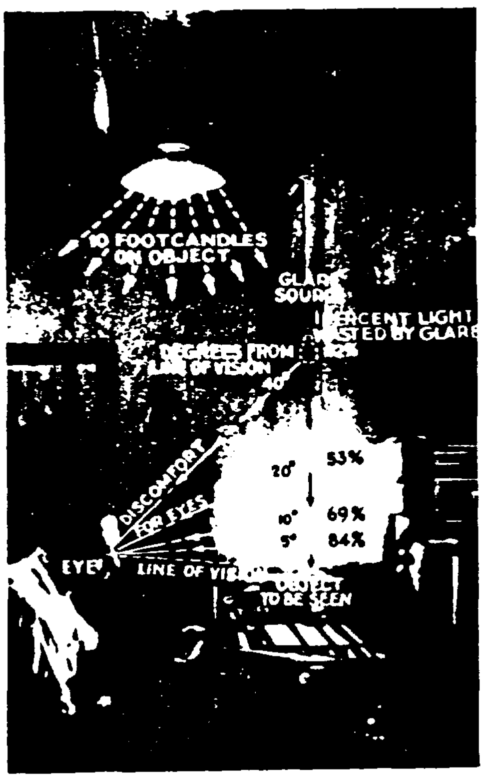
Photograph shows how Plate Glass for rear view mirrors is inspected under Work-Light at the Dayton Plant of the Chrysler Corporation.

SCIENTIFIC ANALYSIS OF REFLEX ACTION

After many years of investigation Prof. Frank Allen, (University of Manitoba) concluded that:

> When light of one color (wave-length) falls upon the retina of one eye, both eyes being light adapted, the sensitivity of the retina of that eye for that color is reduced, while the sensitivity of the other eye for all colors, but predominantly for the complementary color, is increased. The same action also takes place with respect to the two lateral halves of the retina of each eye. Action of one set of nerves induced by the action of another set is called *reflex action*.
>
> The amount of reflex retinal action is different for each different wave-length, or spectral color, of light, but is the least with yellow, and the greatest with violet, the reflex sensitizing effect of violet being 700 times as great as that of yellow.

Simply stated the addition of blue and violet have a balancing effect which reacts upon the retinal organisms in such a way as to sensitize or adjust the eye for highest visual efficiency obtainable from the yellow rays of light and in such a manner as to subdue the normal glaring condition of these yellow rays. This increased sensitivity means a higher degree of contrast perception, which in turn means increased visual acuity or seeing power.



Loss of light due to glare

EFFECT OF GLARE

The effect of glare is readily appreciated by referring to the adjoining picture. Assuming the intensity of illumination to be 100% when the glare-source is absent, the effective intensity of illumination decreases to 58% when the glare-source is 40 degrees above the horizontal line of vision. The effective foot-candles continue to decrease as this angle decreases. In other words, the wasted light, when the glare-source is at an angle of 40 degrees, is 42%. (Luckiesh and Moss).

EVALUATION OF GLARE

An evaluation of glare in terms of Mazda lamps was presented at the 22nd Annual Convention (I.E.S.) in 1928, (Report of Committee on Lighting Legislation - Mr. Ward Harrison, Chairman). Grading was determined by comparative measures, viewing two light sources against the same background. A classification of Grade A can be placed almost anywhere in the field of vision without causing discomfort. The results are tabulated in Tables 2, 3 and 4.

Table 4 may be condensed in a comparative manner:

1. A bare COOPER HEWITT tube is equivalent to:
   - a. Bright southern sky
   - b. 32 cp carbon filament lamp
   - c. 40 W tungsten filament lamp
   - d. 200 W tungsten lamp in a 12" diffusing opal globe
2. A standard COOPER HEWITT lamp is:
   - a. Four grades less than 300 W dome reflectors
   - b. Six grades less than 500 W dome reflectors
   - c. Five grades less than a 500 W Glassteel

Table 3 shows that at normal mounting heights, 9 to 11 feet and above, COOPER HEWITT lamps satisfy all conditions of glare, even with bare tubes exposed to the eyes at the working plane.

TABLE 2

GRADE	WATTS	STANDARD
A	10	Tungsten Filament lamp in 6" frosted ball globe
B	15	" " " " " " " "
C	25	" " " " " " " "
D	40	" " " " " " " "
E	50	" " " " " " " "
F	60	" " " " " " " "
G	100	" " " " " " " "
H	150	" " " " " " " "
I	300	frosted lamp
J	500	" "
K	1000	" "

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TABLE 3

LIMITING GRADES OF LIGHT SOURCES PERMISSIBLE FOR VARIOUS CONDITIONS

Height of light source above floor in feet	Ordinary mfg. operations		Offices, Drafting & fine mfg. operations	
	Short rooms	Long rooms	Short rooms	Long rooms
6.5 or less	D	D	C	C
6.5 - 7.5	F	F	E	E
7.5 - 9	H	G	G	F
9 - 11	I	H	H	G
11 - 13	J	I	I	H
13 - 16	J	I	I	H
16 - 20	K	J	J	I
20 and up	K	K	K	J

TABLE 4

SPECIFIC CLASSIFICATION OF COMMON LIGHT SOURCES FROM THE STANDPOINT OF GLARE AS DERIVED FROM TABLE 2

Natural Light Sources (as seen through windows)		COOPER HEWITT		Carbon Incandescent Lamps	
Sun	K	Tube -- (visible from working position)	G	16 candle power	F
Bright Southern Sky	G				
Northern Sky	C	With reflector (tube not visible)	A	32 candle power	G

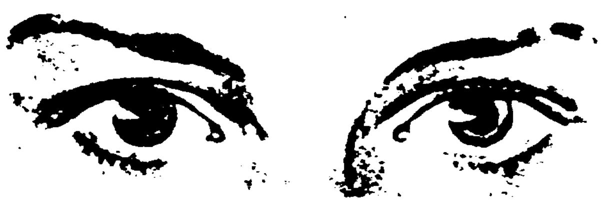
Tungsten Filament Lamps

Watts		40	60	100	150-200	300	500-1000
Bare Lamps		G	H	I	J	J	K
Dome Reflectors	Filament Visible	G	H	I	J	J	K
	Filament Not Visible	B	B	D	D	E	G
Diffuse Opal Globes	8"	C	E	F	-	-	-
	12"	-	-	E	G	H	I
	16"	-	-	-	F	G	H

LIGHTING AND THE PUPIL OF THE EYE

The pupil of the eye has a greater effect upon the efficiency of the worker than is generally realized. It has been found that the pupil varies in diameter from 2 to 8 mm., depending upon the brightness to which the eye is adapted or exposed. It has also been found that the ability to see fine detail is approximately constant from a range of pupillary diameter from 2.5 mm. to 5.5 mm. The pupil contracts very much when it is exposed to glaring light sources, but the practical effect of this contraction is too generally overlooked.

Eyes with contracted pupils are slow-seeing eyes — slow to grasp details or catch rapid motion. Images of moving objects are blurred.



Pupils wide open are fast-seeing eyes — as sharp to register quick action as the motion picture camera.

The contraction of the pupil of the eye to protect the sensitive retina from blinding glare takes place in one second -- but it takes 60 times longer to expand again for normal seeing.

Let it be assumed that a workman has 5 foot-candles upon his work, but that the lighting is so glaring that his pupils are contracted to a diameter of 3 mm. For the sake of comparison let it be further assumed that the second workman also has 5 foot-candles upon his work, but that the lighting units are of the proper design and the light of proper quality. In this case the absence of glare, it will be assumed, causes his pupils to expand to 4¼ mm. The brightness of the retinal image being proportional to the square of the diameter of the pupil, the retinal images of the second workman will be twice as bright as those of the first workman.

Even though the intensity of illumination is exactly the same in both cases, the second workman is really enjoying the advantage of twice as much light. His visual doorway is open one hundred percent (100%) more than that of the first workman exposed to glare.

With the present knowledge of increase in production resulting from an increase in illumination intensity, this aspect of glare is of much interest. There are other beneficial results arising from elimination of glare, such as greater comfort and safety, but the one just stated is directly measurable in terms of foot-candles or effectiveness of illumination.

Strictly speaking, glare is very much misunderstood when referred to the human eye. It is difficult to accurately discuss glare in practical terms since the physiological explanation must be included and not only the physical as is usually the case. In other words, three things must be considered:

1. Intensity
2. Diffraction
3. Spherical aberration

All three are controlled by the automatic adjustment of the eye until a definite balance is obtained.

COOPER HEWITT light aids the eye in this balancing effect because:

1. No intensity is too great for general eye comfort.
2. Shorter wave lengths reduce diffraction.
3. Spherical aberration, chromatic aberration and other forms of aberration are practically absent.

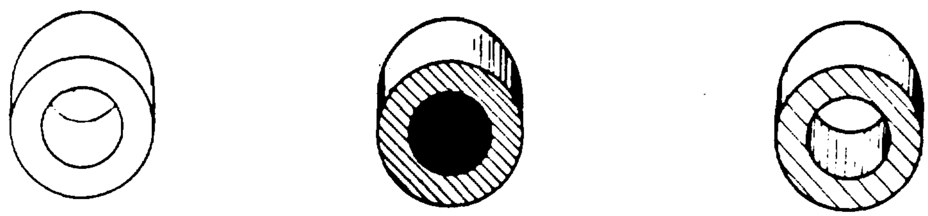
SHADOWS

Shadows

The most important consideration when dealing with shadows is the fact that they are necessary for proper vision. Shadows produce the effects in perspective which are commonly called roundness and depth. Thus, we distinguish the forms of objects by their outlines, and by differences in light and shade.

DIFFUSION OF SHADOWS

Diffuse light is desirable since it tends to cut down the harshness of shadows. Diffusion is indicated by the blending off of the edges of shadow. Where diffusion is 100% there are no shadows.



No Shadow (Flat) — Harsh Shadow (Obscure) — Proper Shadow (Clear details)

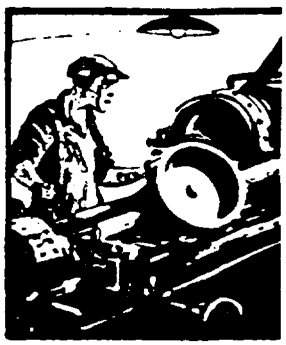
Where shadows are missing, objects appear flat and indistinct. If they are intense the line of demarkation between the object and the shadow is hidden. Deep or harsh shadows may appear to be part of the object, which is very undesirable. An object is most clearly seen when the shadow is sufficient to fully bring out the relief without being so dark or sharp as to obscure the details of the subject in any place. Diffusion is the result of proper distribution of lighting units provided such units are not over glaring. COOPER HEWITT light has the distinct advantage of being practically glareless due to low intrinsic brilliancy and possesses a characteristic quality of light that is ideal from the standpoint of diffusion.

OBJECTIONABLE SHADOWS

Shadows are formed in many ways and if the quality of light is not proper they usually are sources of annoyances to workers.

Shadows, that is, differences in brightness of surfaces, are essential in observing objects in their three dimensions, but are of little or no value in the observation of flat surfaces. Where shadows are desirable, they should be soft and luminous, not so sharp and dense as to confuse the object with its shadow.

A few typical examples of objectionable shadows are sketched below:



Shadows on work

Working in own light

To windows for seeing

Dark corners

Heavy shadows cast on the work are dangerous shadows - - they slow down production, are the cause of spoiling materials and endanger limb and life of man.

Where insufficient light prevails due to shadows, it is possible for a workman to go to windows or raise instruments to light sources; but the work being machined cannot be so moved,- - eliminating shadows from the production means removing seconds from the product.

The luminous source of a COOPER HEWITT lamp being four feet long it can be hung near enough to the operator to shine around his head and so cast no shadows on his work. Placing two incandescent lamps four feet apart will avoid the obstructive shadow of the workman, but will form double shadows, both formative and obstructive, which are highly objectionable - - with COOPER HEWITTS a workman cannot stand in his own light.

FORMATION OF SHADOWS

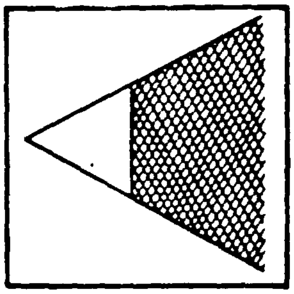
The formation of a shadow is caused when an object is in the path of light rays produced by a light source. In general practice there are three classes of shadow formation:

1. When the light is smaller than the obstruction.

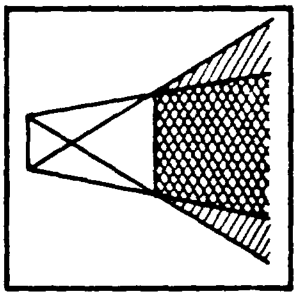
2. When the luminous surface is the same size as the obstruction.

3. When the luminous surface is larger than the obstruction.

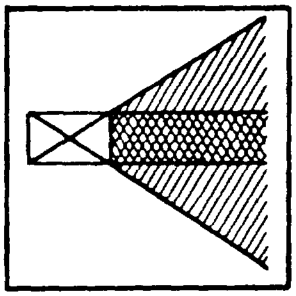
The formation of shadows due to various sizes of sources may be graphically represented.



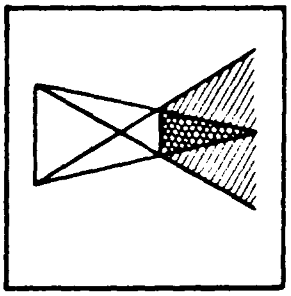
Point Source



Source smaller than obstruction

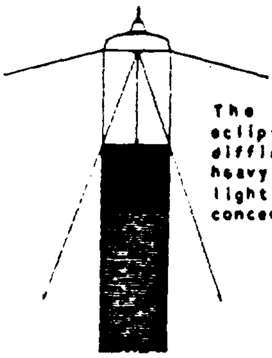


Source and obstruction same size

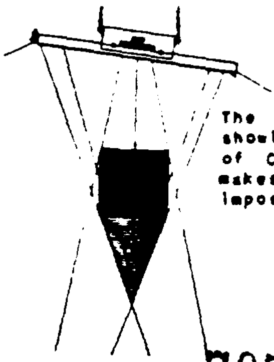


Source larger than obstruction

In the case of a point source the obstruction will cause the formation of a **total shadow**. This is a theoretical condition and rarely, if ever, exists in practice since **reflectors** are used for transmission or distribution of light and the total surface is considered as the luminous source, as noted below. Therefore, the usual condition will give rise to a region of partial shadow which is known as **penumbra** and total shadow which is known as the **umbra**.



The "shadow of an eclipse"-depicting the difficulty of avoiding heavy shadows with a light coming from a concentrated source.



The "eclipse of a shadow"-showing how extended source of COOPER HEWITT light makes objectionable shadows impossible.

ELIMINATION OF HARSH SHADOWS

Modern industrial illumination demands the elimination of deep, heavy shadows which are present in some types of general lighting systems. In order to properly serve its purpose as an essential element of vision, the shadow must conform to two specifications: it must be (a) rightly placed and (b) of proper density.

The position of a lighting unit governs the position of a shadow, while the quality of light and the size of source determines the density of a shadow.

1. The position of a lighting unit is easily controlled.
2. The size of the unit depends upon the type of illuminant and is restricted to some form of gaseous discharge.
3. The quality depends upon the spectral value of the light which must be of such a characteristic as to promote ease of vision with least effort.

COOPER HEWITT lamps fit the specifications in every detail -- no other factory illuminant can boast of all these remarkable features. Even daylight falls short of accomplishing the ideal as voiced by E.L. Elliott:

> "In order to eliminate heavy shadows, the size of the light source must be large in proportion to its distance from the working plane. This may be seen readily by observing the shadows cast by direct sunlight and by diffuse daylight coming through window openings which are comparatively small in proportion to the area which they light. Either of these sources, while large in themselves, are too far away from the working plane to eliminate deep shadows."

THE EFFECT OF QUALITY LIGHT

The light from a COOPER HEWITT lamp is of superior quality for visual purposes. With such a lighting system it is possible to obtain an even intensity of light on all working surfaces. The few shadows which may be present are luminous and permit accurate vision because of the high visual acuity even at low intensities.

Another peculiar effect of COOPER HEWITT light that adds to the ability of the eye to see in shadows is the fact that the light increases contrast by at least 50% above that of ordinary light.

Objects become indistinguishable when the difference between light and shade disappears. Conversely, the greater the difference between light and shade the more boldly the objects stand out. Shadows reduce this contrast, which entirely disappears when all light is shut off and proportionately when a part is cut off.

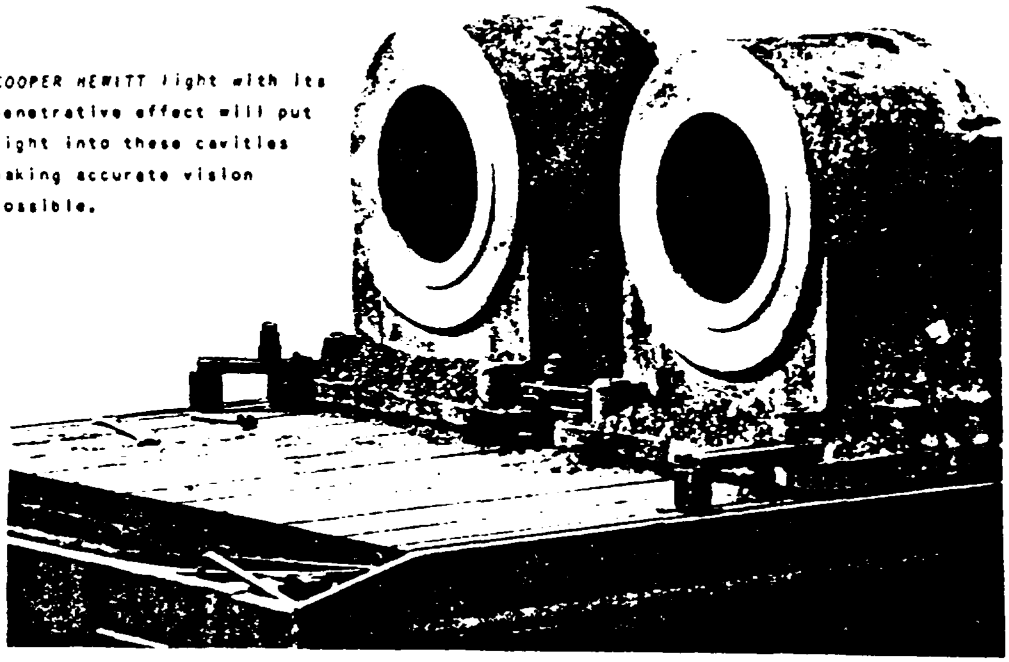
COOPER HEWITT light by increasing the light and shade contrast 50% has the same visual effect upon objects in shadow as increasing the general surface brightness by 50% with ordinary light.

THE TWILIGHT EYE

Due to the structure of the eye the resultant composite picture projected on the retina is more perfect in all the details that lie in the regions of lower intensity, which includes all shadows. Vision under lower intensities is sometimes termed as vision with the **twilight eye**. High intensities activate the **daylight eye**.

There are many instances when it is necessary to look into cavities and covered spaces, to see under as well as over, within as well as without.

The fact that the eye can see in low intensities of COOPER HEWITT light where ordinary light fails is a valuable asset to the conditions stated in the foregoing statement.



COOPER HEWITT light with its penetrative effect will put light into these cavities making accurate vision possible.

The high visual yellow-green rays literally wrap themselves around an object and penetrate into cavities and covered spaces.

Ordinary light throws darkness into spaces where light is needed. COOPER HEWITT by actual test gave a reading of 2.25 foot-candles in a cylinder, as against .75 foot-candles under incandescent lighting. These readings were taken in a shop where Mercury and RLM lamps were on trial; the result - - COOPER HEWITTS installed throughout the shop.

DOWN AMONG THE GEARS

There is no doubt that no matter what type of lighting is used, the light down among the gears, on the cutting edges between the dies, or in the depths of any machine, is lower than the surface intensity. These are vital points where work actually is done. Unless there is seeing power there, light is not serving its purpose. Failure to light these close work spaces properly, explains why so many lighting installations that look good do not provide the workman with the kind of help he needs.

DEEP, DARK, HARSH SHADOWS

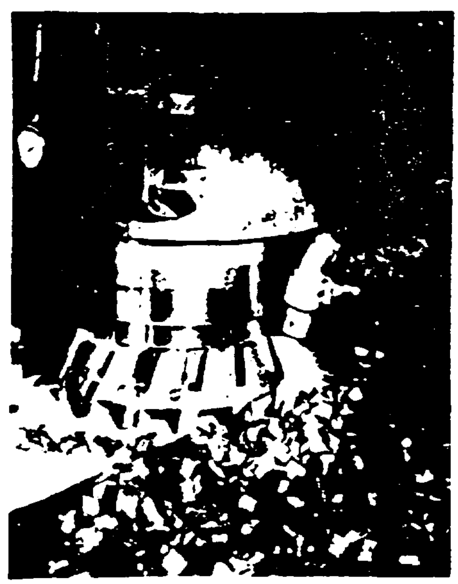
OBSTRUCTIVE, OBJECTIONABLE SHADOWS

SOFT, LUMINOUS SHADOWS - DETAIL WELL DEFINED

COOPER HEWITT light with its soft luminous shadows and high visual acuity at low intensities will give operators sufficient light where light is needed. Drop lights will not be necessary which give high lights or hot-spots as indicated below.

Gear Cutting

Note harsh shadows

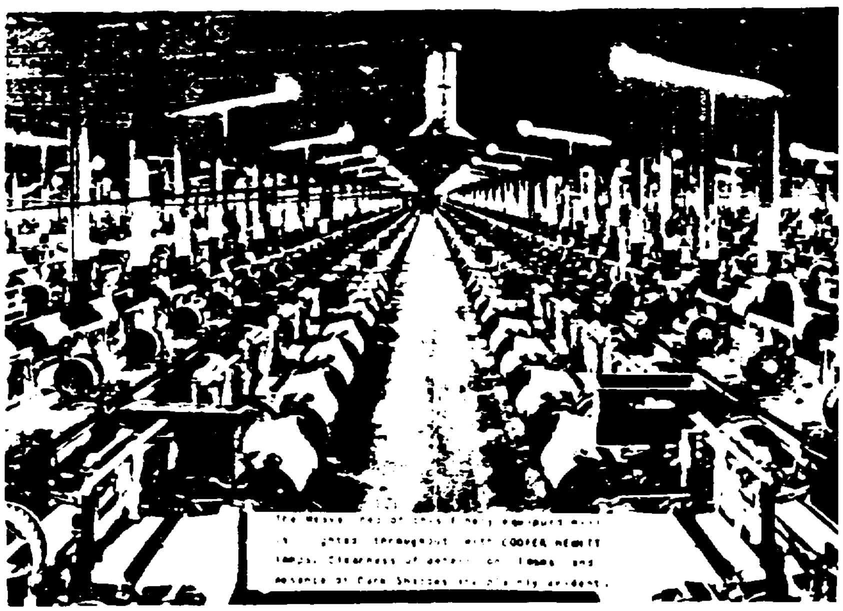


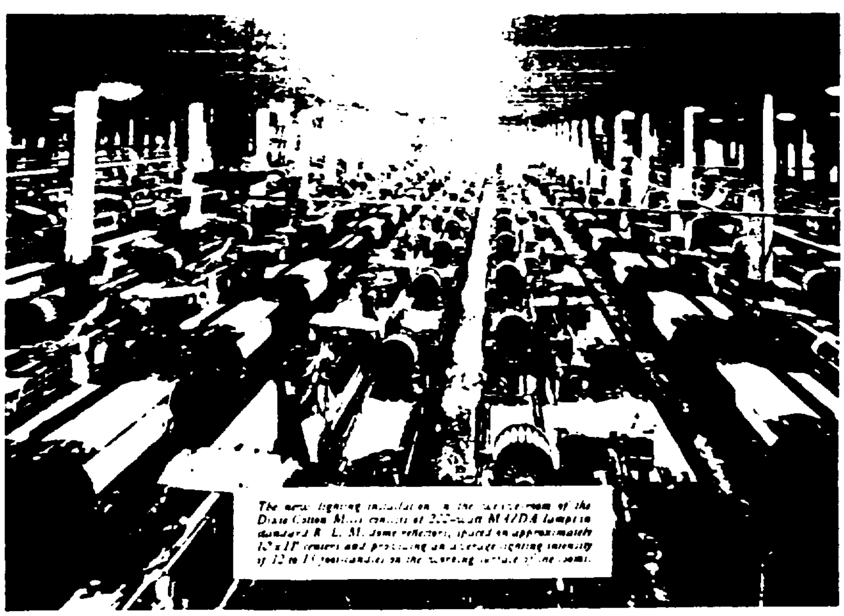
Heavy Duty Milling Cutter

Note absence of detail

COMPARATIVE LIGHTING

Below are two lighting installations, one using incandescent lamps and the other COOPER HEWITTS. Note particularly the shadows, clearness of detail and tendency to glare in both photographs - - both are printed reproductions. After careful or casual study, choose the one which is known to pay profits by increasing production and reducing seconds. Remember, also, there is more light from COOPER HEWITTS for the same wattage.





SAFETY

Safety

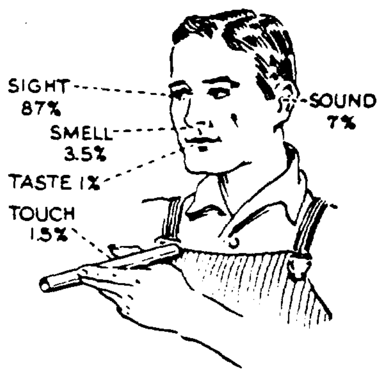
It has been pointed out by a prominent engineer that we use our eyes twenty times as much for close reading as did our ancestors. This does not merely imply reading books and literature but also includes the reading of instruments and fine details of workmanship in manufacturing areas. The use of our eyes in industrial circles becomes very important from the standpoint of safety or accident prevention.

WARNING OF APPROACHING DANGER

An accident, is an unexpected event which may happen regardless of the care or precaution exercised by human beings. When danger threatens the body from an external source a system of elaborate controls are caused to function. These controls are partly automatic and partly operated by the conscious action of willpower. Warning of approaching danger is usually received through one or more of the several common senses. These senses are known as taste, smell, sight, hearing, and touch. We are warned of the presence of gas by smell; poison and impalatable food is readily detected by taste. High temperatures are realized by the sense of touch, while various approaching dangers are denoted by hearing.

CONTROL OF ACCIDENTS THROUGH HUMAN SENSES

The combined action of the four senses given above is responsible for only 13 percent of our muscular activities. The remaining 87 percent of our muscular movements are governed by sight. It would appear that 87 percent of industrial accidents could be charged up to sight, but this cannot be so simply classified since an accident is usually the result of a combination of causes.



In the first place, the mental faculties must be seriously considered. Vision cannot be charged with casualties resulting from the failure of the mind to act upon the warning given. The same may be said of the other senses mentioned. Protective action by the body, in response to danger signals given by the senses, depends upon the acuteness of the senses, and the efficiency with which the body responds to the signals. The efficiency of the control system of a human being depends upon general health and mental attitude. Therefore, the percentage of the senses given merely furnish an incentive for providing all the facilities necessary to cause the body to respond to certain signals.

The conditions of maximum safety or minimum liability to accidental injury has been given by E.L. Elliott as follows:

1. When the immediate source of danger is surrounded to the utmost with physical means of protection.
2. When the operative has full knowledge of all sources of danger.
3. When all his senses function normally.
4. When he is habitually careful.
5. When his body and mind are in a condition to act with maximum efficiency.

In industry, many accidents that occur are avoidable, but the reason they are not avoided is simply because none of the sense organs warn the victim of the impending danger quickly enough to allow him to take precautionary measures to get away from the zone of danger. The sense of sight is the agent by which 87 percent of these warnings are transmitted to the brain and a delay of even a fraction of a second is often the margin between safety and danger. To secure the highest degree of efficiency in the prevention of accidents, the visibility of human beings must be as nearly perfect as possible. The perfectness of vision depends first upon the eye; the defective eye is the result of defective vision. Proper illumination is the other dependable factor for perfect vision. Illumination is, of course, merely an aid to the eye as a seeing mechanism, but the better the illumination the more accurately does the eye function.

SURVEY OF LIGHTING CONDITIONS IN THIS COUNTRY

The value of good illumination has been recognized for some time. Many factories have adopted satisfactory lighting installations in the past ten years. Many are operating with old, obsolete installations which may be considered as definite sources of accidents. The Eyesight Conservation Council in cooperation with the Federated Engineering Societies investigated 446 plants with reference to lighting conditions, and give the following results:

Excellent	8.7%
Good	32.0%
Fair	29.1%
Poor	18.8%
Very poor	3.5%
Partly good, partly poor	7.8%

The above results show that only about 40 percent of the investigated plants are suitably lighted. This is indeed a very poor showing when considering the development of the lighting art. Perhaps the managers of the remaining 60 percent of these plants are not actually aware of the importance of lighting as a safety measure and of the fact that proper lighting removes a very definite and now well recognized hazard of industry. It certainly must be clear to most everyone that employees should be able to see clearly and distinctly, in performing their duties and moving about the plant, if the hazards of accidents are to be removed. Mr. Luckiesh in his book entitled 'Light and Work' states that by properly improving illumination in our industrial plants, a 10 percent increase in production could be obtained, and this would have a net value to the country as a whole, of over two and one-half billion dollars per year, exclusive of the cost of spoilage, labor turnover, and accidents. This is a stupendous sum but relates only a value in dollars. Life and limb are of prime consideration when expressing the real value of lighting. If this could be expressed in dollars we would find that the economic saving through the accident prevention influence of proper illumination, would represent an even greater sum than the first one cited.

At an I.E.S. Convention in Baltimore, Ward Harrison declared:

> "A survey of industrial plants showed 90% of them to be under-wired as well as under-lighted. For such plants the recent development of new, high-efficiency mercury and sodium lamps will prove a boon by making possible double the illumination without any increase in wiring."

VALUE OF GOOD LIGHTING

Mr. Guy A. Henry, director-general of the Eye Sight Conservation Council, recently estimated that a yearly saving of four hundred and sixty million dollars could be made by this country if only the eyes were given the proper help by correction of defect and proper illumination. Of this total sum, accidents resulting from poor lighting annually amount to $300,000,000 and $30,000,000 of industrial waste is charged directly to poor lighting. These figures alone tend to show that good lighting should be of prime importance in industry regardless of cost. Yet the cost for providing adequate illumination for the entire industry of the country would only amount to one-half to one per cent of the wages.

The total cost of an accident, to manufacturers, is usually underestimated. That this is true, has been brought out by W.D. Keefer, (Director Industrial Division, National Safety Council).

> "It is generally agreed that more than 1½ million (1,567,000) workers were killed or seriously injured in the United States in 1931. On the other hand, comparatively few people realize that, on an average, each of these disabilities cost the employer $200.00 in cold hard cash. This represents the sum paid for compensation, for doctor bills and for hospital fees.
>
> Nor is that all. That is simply the out-of-pocket expense that is accounted for by company book keepers and auditors. For in addition to that sum recent studies made by the Travelers Insurance Company indicate that there is an indirect and indefinite cost that never appears on the books, but which, nevertheless, must be paid by the company. This indirect cost includes the value of lost production, of labor turnover, of damaged machinery and materials and other items which after careful study are calculated to amount to at least four times the direct cost. In other words, on the average, the company loses about $1000.00 every time a worker suffers disabling injury. Thus, the total cost of accidents in American industry each year amounts to more than 1½ billion dollars ($1,567,000,000). If it could be said that 15% of this amount would be saved by good lighting the saving would amount to approximately a quarter of a billion dollars ($235,050,000). On a 5% basis the saving would be $78,350,000."

There are numerous other data available which clearly indicate that improved lighting decreases accidents considerably, in manufacturing areas. Savings of thousands of dollars to manufacturers, who invest only a few hundred dollars for improved lighting, is covered by many substantial reports.

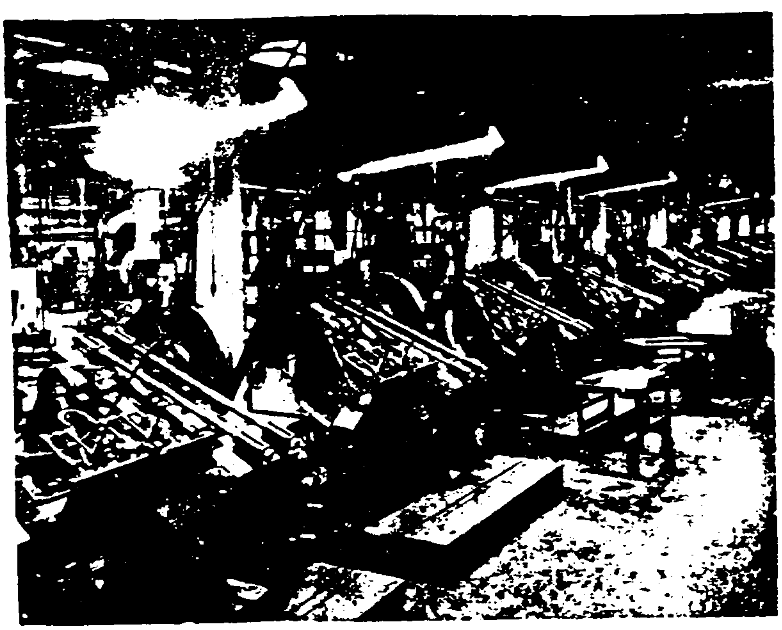
Artificial lighting for factories is, therefore, important not only because it decreases accidents but because it is profitably to the manufacturer. The hazards of accidents are materially decreased if the artificial lighting system has the following qualities:

1. Shadowless - avoiding the possibility of confusing objects with shadows.

2. Glareless - preventing temporary blindness which would incapacitate the eyes in rendering warning of danger.

3. Sufficient light - enabling the worker to see his work clearly.

The combination of these three important qualities naturally tend to prevent eyestrain or fatigue, thus keeping the body physically and mentally fit.



The accompanying photograph gives significant indication of the effect of COOPER HEWITT illumination in reducing accident hazards. The shadows and glare which traditionally complicate punch press operation are not to be seen, a condition which contributes measurably to quantity and quality of production.

LIGHT ON THE TRAFFIC ACCIDENT PROBLEM

While industrial lighting and road lighting are two different problems they bear a close relationship as far as accidents are concerned. Recently H.S. Beagle presented a complete report on traffic accidents which is given in outline form as follows:

1. 3100 people killed, 1,000,000 injured, on New York highways in 1933.
2. Economic loss in wages, medical expense and associated property damage - $2,500,000,000.
3. If all night traffic accidents could be eliminated, the economic saving each year would pay the salaries of all teachers, supervisors and principals of all elementary and secondary public schools in this country.
4. Night accidents increasing at faster rate than day accidents.
5. Chas. A. Harnett, Commissioner of Motor Vehicles for New York State:
    a. 83,344 accidents, 2,709 deaths, in N.Y. -1933
    b. 88,443 accidents, 2,785 deaths, - 1932
    c. Of the 2,709 fatal accidents, 117 occurred during dusk; 1,308 during dark hours.
    d. Of the 2,785 fatal accidents, 141 during dusk, 1,270 during dark hours.
6. More than 1/2 the fatal accidents on New York State roads occur during dusk and darkness.
7. Unusual large proportion of accidents since less than 1/5 highway traffic occurs during hours of darkness.
8. Chas. A. Harnett:
    a. 6 year test - 3 years poor road lighting - 3 years improved lighting. (6 miles of the Schenectady-Troy and Schenectady-Albany highway).
    b. Day accidents increased 21.4%
    c. Night accidents decreased 32.6%

ACCIDENT RATE LOWERED BY BETTER LIGHTING

Modern machinery and shop conditions are designed for utmost safety. To warrant the added expenditure for such conditions, lighting must be adequate as far as intensity is concerned and of proper quality if considered as an accident prevention measure.

Extensive studies by casualty insurance companies show conclusively that good lighting is an aid in the prevention of accidents. COOPER HEWITT light aids materially in reducing industrial accidents because of its power to create fast and accurate vision. Workers are far less likely to be injured by contact with moving parts on machines or by accidental falling, if they can see clearly and distinctly.

The following report is convincing evidence that poor lighting in industrial sections is hazardous.

THE RELATIONSHIP OF ILLUMINATION TO INDUSTRIAL SAFETY

A lecture given by ARTHUR C. CARRUTHERS, *Editor Safety Engineering*

Herewith are what eleven leading casualty insurance companies writing workmen's compensation insurance have to say on the subject of defective illumination, as a cause of industrial accidents.

1. "We have made a very careful analysis of the data entering into our statistics, resulting from inadequate and poor lighting in industrial establishments. We estimate that from 13 to 20% of all industrial accidents are caused directly or indirectly by poor lighting."

2. "I feel safe and conservative in estimating that at least 15 per cent of all accidents occurring in industrial plants and construction work which are covered by this company for compensation insurance are due either directly or indirectly to poor illumination."

3. "Some industrial concerns have definitely shown a reduction in accident frequency over preceding years and increased efficiency after adequate lighting units have been installed."

4. "In our inspection work we find that it is quite necessary many times to request proper lighting for employes knowing that it is going to decrease the number of accidents and also increase production. We are entirely in sympathy with proper lighting and often find it necessary to discuss this very item with plant managers and superintendents."

5. "I think you will find safety engineers agree that poor lighting is a prolific cause of accidents in industrial plants."

6. "We are firmly convinced that inadequate lighting and defective vision constitute an important factor in our industrial accident record."

7. "We know that a large percentage of accidents in the industries are directly and indirectly caused by poor lighting. This is, no doubt, also true in reference to a great many accidents that occur under our Public Liability coverage due to falling and tripping on floors and stairs."

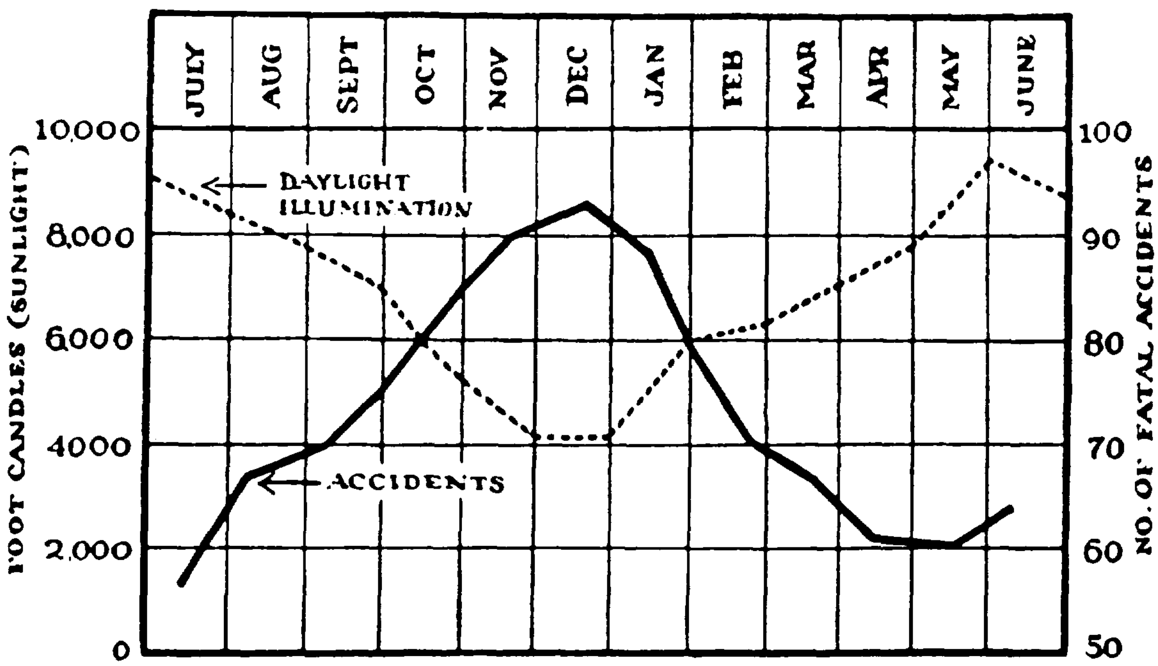
8. "In the past twenty-five years I have been called upon in a great many instances to inspect plants which were having a high accident frequency and in the majority of cases I found that the accidents were caused by poor lighting. In one special plant in Buffalo, we recommended the changing of the lighting equipment, with the result that the machine accidents were reduced to a minimum."

9. "Good lighting is an accident prevention aid."

10. "Our impression of good lighting as a Safety Factor is beyond question and that poor lighting is unquestionably a hazard which should be safely guarded against in all industrial plants."

11. "We have a very definite impression that poor lighting is an important industrial hazard."

To further prove that the accident rate increases as lighting fails is shown graphically below.



Not only are accidents the result of insufficient lighting alone, but quality of light as well. Glaring light sources and harsh shadows on the work are contributary factors in causing accidents. A. Paulas (Westinghouse Lamp Co.) states:

> "Every time a person glances from a brightly lighted area to a dark area, the muscles of the eye must act to change the size of the pupils. This continued change results in eyestrain, fatigue, headaches and finally accidents."

COOPER HEWITT light is composed of rays which promote maximum visual acuity with the greatest of ease, thereby reducing eyestrain, fatigue and accidents.

Obviously, the primary purpose of industrial lighting is to enable workers to see. Yet simply increasing the quantity of light does not necessarily result in a corresponding increase in seeing power. Improperly applied increased intensity of light may actually be more of a hindrance than a help. Nor can best results be obtained without careful attention to the *quality* of illumination.

PREVENTION OF ACCIDENTS

In general, accidents are preventable to a large extent if the following conditions prevail.

1. Proper lighting.
2. Good eyesight.
3. Good health.

The first condition is simply a combination of the qualities listed on page 5, namely: Shadowless - Glareless - Sufficient light. The second depends upon the individual. If a worker has defective eyes he should be required to visit an eye specialist in order to remedy the defect present. Many concerns are rendering services to the employees for the care and correction of their eyes. Such practice is indeed to be encouraged. Sanford DeHart (Director of Hospital - R.K. LeBlond Machine Tool Co.) writes:

> INDUSTRIAL eye injuries are costing industry a prodigious sum each year. Eye injuries cost New York State in one year $1,000,000 for compensation, and Pennsylvania has not fared much better, as this state paid out $800,000 for the loss of eyesight due to industrial injuries in one year, and more than $8,000,000 since the enactment of the State Workmen's Compensation Act. Pennsylvania, and of course this means the employers of the state, has paid out more money as compensation for loss of eyes than for all other accidents combined. Three hundred and five eye losses cost the state of Pennsylvania in compensation as much as it would cost to compensate for 133 lives. The National Committee for the Prevention of Blindness found as a result of its recent survey, covering practically every industry and state in the Union, that the annual loss to industry through eye accidents exceeds $23,000,000.

He also conveys the following important information in regard to light as an aid to seeing:

> "Psychologists tell us that blue lights are best for close work; red is preferred for distant objects, and ordinary white for all-around work. Our own experience has been that many obstinate inflammatory eye conditions among our employees actually improve while working under COOPER HEWITT lights. There is reason for this in that a green or blue light relaxes the eye, rather than straining it."

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The last condition is, of course, very important. The healthy person is stronger and can endure the hardships of life more successfully than an unhealthy person. Healthy people are content and happy, which has a direct bearing upon industrial efficiency.

The Traveler's Insurance Company issued the following statement:

> "Adequate illumination decreases the frequency as well as the cost of industrial accidents. It helps to conserve the health and promote the comfort of industrial workers."

HYGIENIC LIGHTING

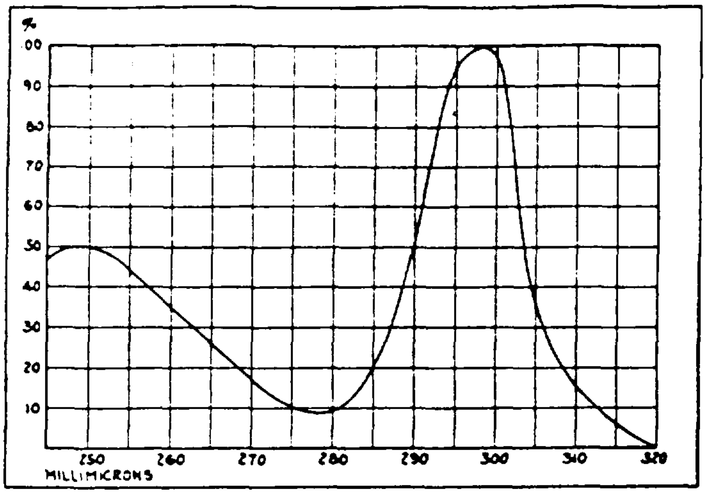
Hygienic Lighting

The rapid progress of modern industrial lighting considers not only illumination but also certain health rays beneficial to human beings. These health rays are identified as sun rays or ultra-violet rays. The medical profession warns the public to avoid the use of ultra-violet light treatment for certain diseases. The advice of a physician is absolutely necessary in the case of the treatment of diseases, since the manner of application must be thoroughly understood. These are extreme cases only. The value of ultra-violet light received in moderate dosage, as in the case of sunlight, is of a health-protecting and health-building nature.

DUAL PURPOSE LIGHT

Sunlight, of course, is composed of various wavelengths as given by its spectrum. The lower wavelengths in the region of the violet part of the spectrum are known as ultra-violet rays of light. The wavelengths in the region of the yellow and green bands are the visible rays of light. Since the ultra-violet are health rays and the yellow-green are visible rays, both are important considerations of an industrial lighting system. The term generally applied to this consideration is known as dual purpose light.

It is definitely known that the ultra-violet rays of sunlight are health giving rays. As a matter of fact, these rays have been shown to be tied in with the production of that food constituent, known as vitamin D, so valuable to the building up of the human body. The present generation seems to have changed its diet, mode of living, and general habits to such an extent that a sufficient supply of vitamin D is lacking. Perhaps this is a broad statement, yet we have been admonished to live more outdoors, thriving on fresh air and sunshine. Consider the amount of sickness, such as acute coryza, bronchitis, la grippe, rhinitis, influenza, incipient tonsilitis, in the winter as compared with the summer. The reason illness is more pronounced in the winter is due to the fact that most people are not exposed to the sun's rays in sufficient amounts, thereby lacking the required supply of vitamin D necessary to the body.



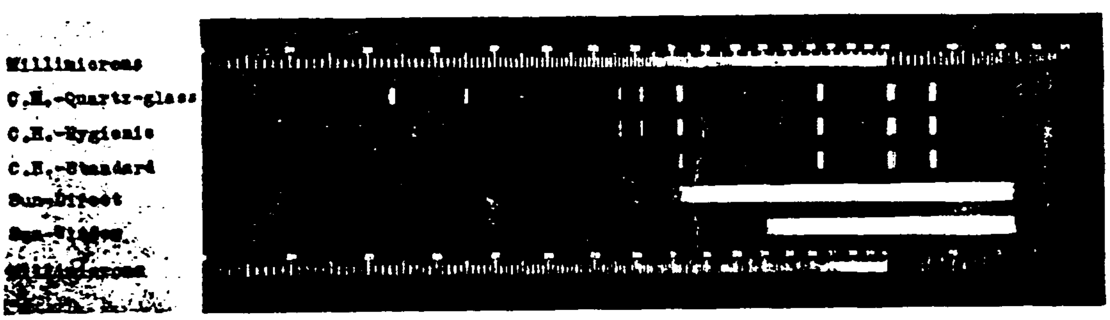
Erythematic Effect—Hausser & Vahle.

The beneficial rays of ultra-violet light are to be found within the wavelength range of 2000 and 3200 Angstrom units. The hygienic effect of ultra-violet radiation is measured by the degree of skin-reddening known as "erythema". Various wavelengths in the range of ultra-violet radiation produce different degrees of erythematic effect as shown by Hausser and Vahle.

PRODUCTION OF ULTRA-VIOLET RAYS

The most common sources of producing ultra-violet rays artificially are with the carbon arc and the mercury arc. The carbon arc will not be discussed since it is not a dual purpose lighting source. The mercury arc, in producing ultra-violet rays, gives wavelengths far lower than those of direct sunlight.

The mercury arc spectrum differs somewhat from that of the sun as shown by the chart below. The spectrum of the mercury arc is non-continuous or a line spectrum, while the sun forms a continuous spectrum, from deepest red to deepest violet.



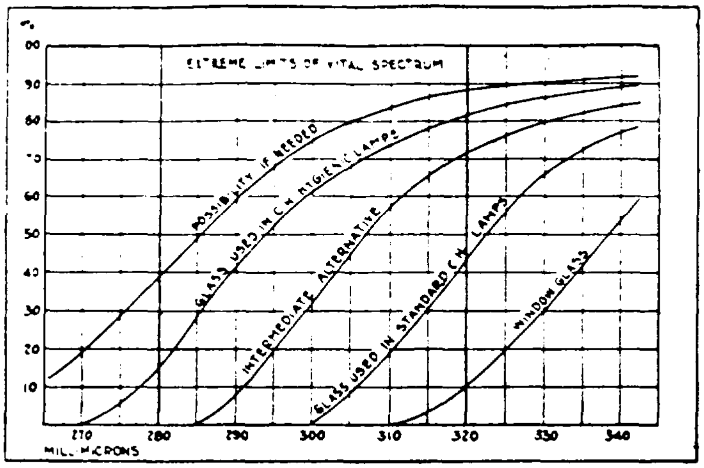
Spectra of Sun and of Cooper Hewitt Lamp

Ultra-violet rays are not transmitted through all kinds of glass. As a matter of fact, ordinary window glass transmits ultra-violet down to the wavelength of only 315 millimicrons. Hausser and Vahle show that the erythematic effect at this wavelength is of no practical value. The ultra-violet given by direct sun is about 290 millimicrons at the lower limit. The erythematic effect is a maximum between the limits of 290 and 300 millimicrons.

Special glasses are made to transmit ultra-violet to the extreme limits of the so-called vital spectrum, down to wavelengths shorter than 200 millimicrons. Referring to the spectrum chart, bright lines indicate spectral value (quality not quantity) of ultra-violet. To utilize the mercury arc radiation to the fullest extent a glass known as quartz is used. The various lines of importance may be read as follows: 253, 265, 289, 296, 302 and 313 millimicrons. There are actually many more arc lines than shown but they are appreciably weaker than the six here listed. These lines lie entirely outside the range of human visibility. The other lines shown by the mercury arc spectrum are, of course, within the range of human visibility. When working with the mercury arc in a quartz tube, such as are used in the COOPER HEWITT UVIARC lamps, extreme care must be taken to protect the eyes from the invisible but injurious ultra-violet radiation. Goggles using ordinary window glass would serve to filter out these injurious rays.

ULTRA-VIOLET TRANSMISSION THROUGH GLASS

It would naturally be dangerous to use quartz glass for ordinary industrial areas. It is possible, however, to vary the amount of ultra-violet transmitted, by using special materials in the manufacture of glass. The special hygienic glass tube now used in COOPER HEWITT lamps transmits ultra-violet in an amount and an intensity of about one-twentieth of that transmitted by quartz glass of considerably smaller size, such as used in sun-bath lamps. The appreciable lines on the spectrum chart are 289, 296, 303 and 313 millimicrons, for this hygienic glass tube.

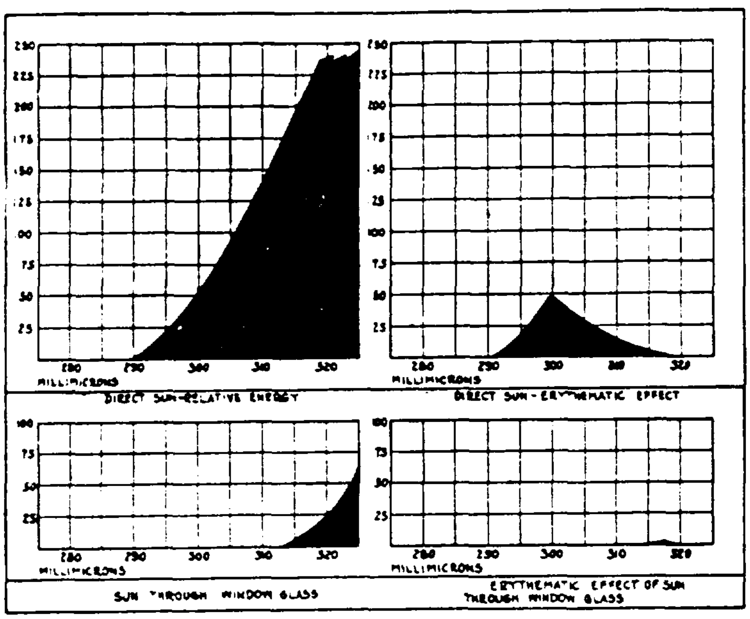


Transmission of Lamp Tube Glasses.

The standard glass tube filters out the important lines leaving only one (313 millimicrons) which has only a small erythematic effect.

The transmission of vital rays of three lamp tube glasses and ordinary window glass is given by the accompanying curves.

RELATIVE ENERGY - COOPER HEWITT AND DAYLIGHT



The relative energy of direct sunlight, under ideal conditions is given in graphical form, and shows that there is no radiation shorter than 290 millimicrons. When passing through window glass the ultra-violet energy is considerably reduced as shown by the graph. The erythematic effect of direct sunlight and when passing through window glass is also represented in the graphs. So small is the erythematic effect when sunlight passes through ordinary glass windows that it may be considered of absolutely no value as far as health rays are concerned.

The glass used in a standard COOPER HEWITT lamp produces only slight erythema. Some benefit might result in cases of exceptionally long exposure. During the past 5 or 6 years, many experiments with the standard COOPER HEWITT lamp have been conducted, using animals as subjects to determine the health giving effect.

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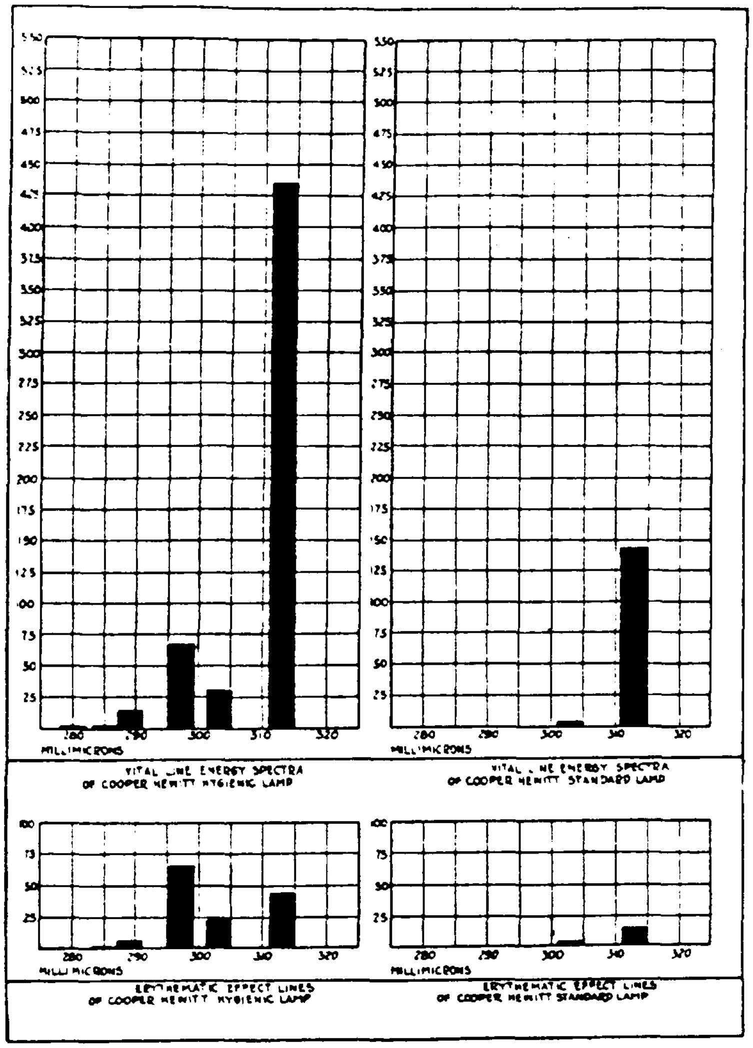


In one case it was found that 50 day old chicks exposed daily to these rays for 6 hours grew to be normally strong chickens, while a similar lot receiving sunlight through glass windows developed typical avian rickets (leg weakness).

However, best results for transmission of beneficial health rays as well as visible light, is obtained by using the hygienic glass tube, the cost of which is only slightly higher than the standard glass tube. The ultra-violet transmitted compares with that of average outdoor June sunlight and will not harm the eyes.

Wavelength alone does not determine the value of vital rays of a light source. The intensity or energy of a wave is very important when considering hygienic effect. The intensity or energy of a wave is greater when the brightness of line is greater, as shown by the spectrum chart. For instance, the amount of energy in the 310 line spectral region, of the COOPER HEWITT lamp, is greater than that in the 295 to 300 region. This is shown by the fact that the 310 line is brighter than those represented by the 295 to 300 lines. The graphs above give a quantity comparison of the energy in different wavelengths and show the hygienic effect of each. The waves of 310 millimicrons possess much more energy than those between 295 and 300 millimicrons, but the hygienic effect resulting is considerably less.

It is, therefore, interesting to note that the waves in the 310 line spectral region have a large amount of energy to make up for its weaker erythematic effect. The waves within the region 295 to 300 millimicrons, while comparatively weak in intensity are very strong in erythematic effect. This is also true of the same wavelengths in sunlight.

To provide for a health-promoting system of illumination, the illuminant must possess the characteristic of producing ultra-violet rays and a glass to transmit a given quantity and quality of these rays. The COOPER HEWITT HYGIENIC lamp produces an effect like that of average mid-summer sunlight with the same exposure time.

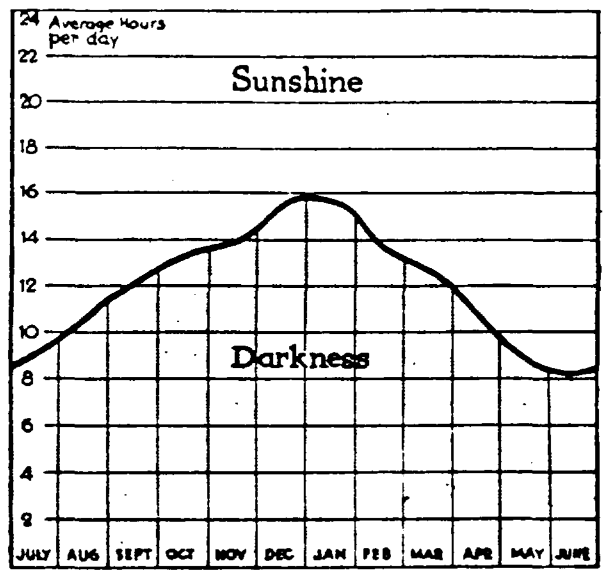
NATURAL AND ARTIFICIAL ULTRA-VIOLET SOURCES

Intensities of illumination necessary to deliver equal total amounts of erythema-producing radiation throughout four different periods of exposure, have been determined by Dr. Luckiesh, and is presented in tabular form as follows:

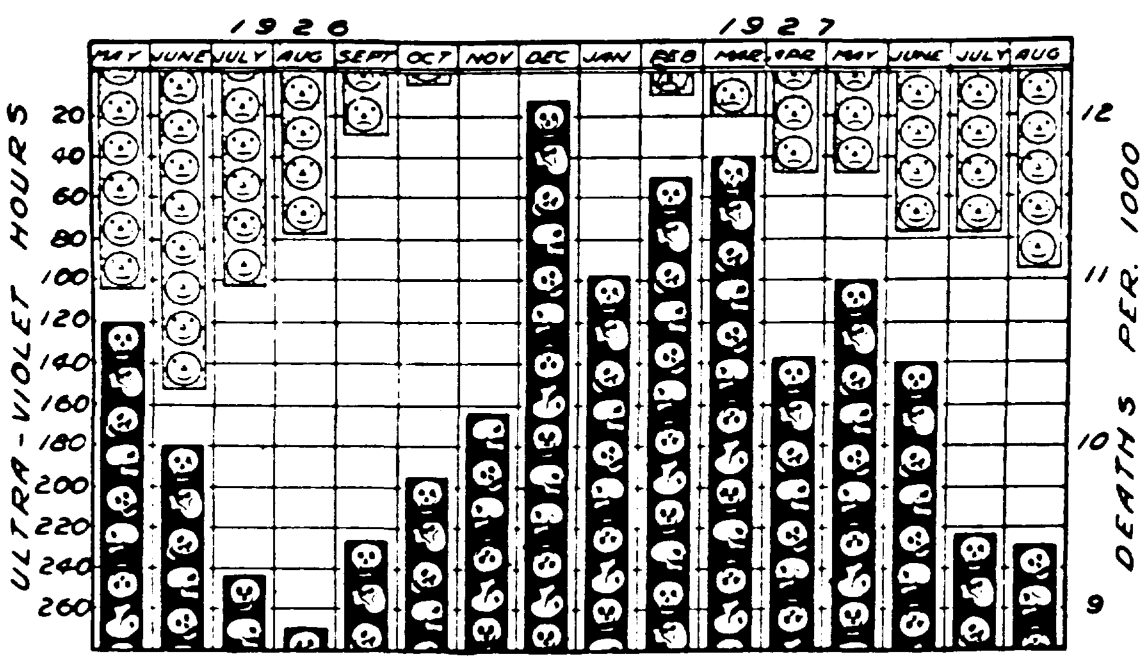
SOURCE	FOOT-CANDLES			
	One Hour	Two Hours	Four Hours	Eight Hours
Sunlight plus Skylight				
1. Midday midsummer	3000	1500	750	375
2. Midday equinox	7000	3500	1750	875
High-pressure mercury arcs				
3. Quartz mercury arc (new)	6	3	2	1
4. Quartz mercury arc (2000 hours)	12	6	3	2
Corex D filter, 0.8 mm	21	11	6	3
With 888 filter, 0.6 mm	23	12	6	3
With 690 filter, 0.9 mm	55	28	14	7
Low pressure mercury arcs				
5. Tube of 888 glass	96	48	24	12
With porcelain reflector	185	93	46	23
6. Tube of 690 glass	150	75	38	19
With porcelain reflector	293	146	73	37
Sunlight (Type S-1) lamps, oxidized aluminum reflector.				
7. Average Corex D bulbs	67	33	17	9
8. Average 690 bulbs	106	53	27	13
Tungsten-filament lamps, 310 deg. K.				
9. Bulb of 888 glass	2400	1200	600	300
10. Corex D bulb	1680	840	420	210

VARIATION IN SUNSHINE THROUGHOUT THE YEAR

The average variation in hours of sunshine and darkness during the 24 hour period throughout the year is shown by the following graph.



Mr. F. Paul Anderson prepared an interesting chart entitled Suns and Skulls. Note the variation in rate of mortality as sunshine diminishes. It almost follows the darkness curve on the above chart.



SUNS AND SKULLS

VITAL RAYS A HEALTH MEASURE

Since modern mode of living has changed somewhat, as compared to times prior to our machine age, most people are robbed of ultra-violet radiations required to sustain good health, because they live in smoky and dusty cities and factory towns. Smoke and dust filter out the vital rays of the sun to a great extent. Even those who live away from these conditions are usually no better off since they work in offices and buildings. Here again the vital rays of the sun are lacking even though many windows may be at hand. Thus, a great proportion of people, particularly factory workers, have reached a point where a continued lack of exposure to ultra-violet radiation may affect their health.

Many factories have installed dual purpose lighting in the past few years and report astonishing results. Sanford DeHart, director of the hospital department for a large machine tool company, pointed out several interesting facts recently in regard to electrical therapeutics in industrial plants. He tells of an economic study of colds made in Boston, Massachusetts, where it was estimated that colds cost more than $20.00 per person. Another survey made by competent authorities showed that ordinary colds cause a direct money loss to wage earners in this country amounting to $70,000,000 a year. The United States Public Health Service made a recent survey and found that colds caused a time loss equivalent to 1.4 days per year for every man on the payroll and 2.1 days for every female employee. Colds were responsible for 39 per cent of all absences among men and 31 per cent among women.

PROVING THE VALUE OF VITAL RAYS

The efficiency of ultra-violet treatment in the prevention of colds is illustrated by the work carried on at the Cornell University, where, many experiments have been conducted by Dr. Dean F. Smiley and Dr. George H. Maughan, for more than three years. The test was conducted by segregating the entire male student body into various groups, dependent upon their susceptibility to colds. Twenty-five per cent of each group were exposed to ultra-violet rays at definite intervals of time during a week. Of each group treated, a reduction in colds of 42½ per cent was noted as compared with similar susceptible groups not treated. Other research work of importance has been done by the Basic Science Research Laboratories of the University of Cincinnati, under the direction of Prof. George Sperti; and by Dean F. Paul Anderson at the University of Kentucky.

Many other experiments of a similar nature to those stated above have been carried out and are at present being conducted to show the actual value of ultra-violet as an aid to health. Sanford DeHart covers the entire situation of dual purpose lighting in a single paragraph as follows:

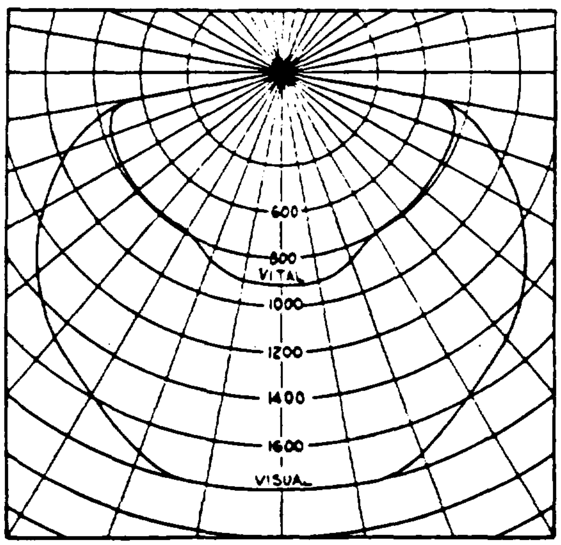
> "For the past two years we have been experimenting in the shop with a new COOPER HEWITT light tube which has a glass tube transmitting 2650 Angstroms (265 millimicrons) or the same registration as June sunlight. Tests made in our shop over a period of several months show that the ultra-violet emanated from these lamps has caused an appreciable decrease in the number of absences due to minor illnesses, in addition to furnishing excellent illumination. Because the industrial worker is confined at his work during the entire period when he might otherwise receive the sun's rays, we consider this an ideal combination, in which the vital health quality is added to industrial lighting."

This health-promoting system of illumination can be easily and economically installed in any industrial plant. In plants already illuminated by standard COOPER HEWITT lamps the change to this modern system of hygienic lighting can be made overnight. The COOPER HEWITT system is, indeed, the only illumination system that can be changed on short order to provide hygienic lighting.

THE COOPER HEWITT HYGIENIC LAMP

In factories, mills and workshops all over the country and abroad, COOPER HEWITT light has long been recognized as BETTER THAN DAYLIGHT as a light to see by. There are two reasons for this; one because of its superior quality and the other because of its steady light output 24 hours a day.

COOPER HEWITT is now becoming recognized as BETTER THAN SUNLIGHT because of its health giving rays through the use of special glass tubes. It is better than sunlight because of its ease of installation in factories, and greater vital ray effect than sunlight passing through windows. It is available whenever needed during the 24 hours of the day.



Distribution—Visual and Vital Ultraviolet.

The COOPER HEWITT HYGIENIC lamp is not an experiment. Several thousand lamps have been installed both industrially and commercially with gratifying results. Even schools and educational institutions have set up solariums as an aid to students.

BETTER THAN DAYLIGHT

Better Than Daylight

The expression BETTER THAN DAYLIGHT has long been used as a slogan for COOPER HEWITT lighting. Actually any artificial lighting system is better than daylight when considering the fact that daylight as a source of illumination is restricted to a certain number of hours in a 24 hour day. However, the expression refers to quality of light rather than the time or number of hours available.

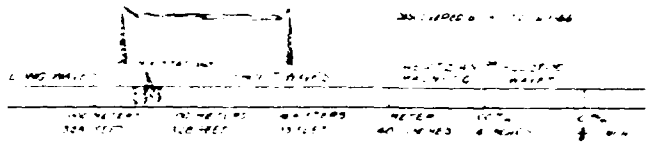
WAVELENGTH - A UNIT OF MEASURE

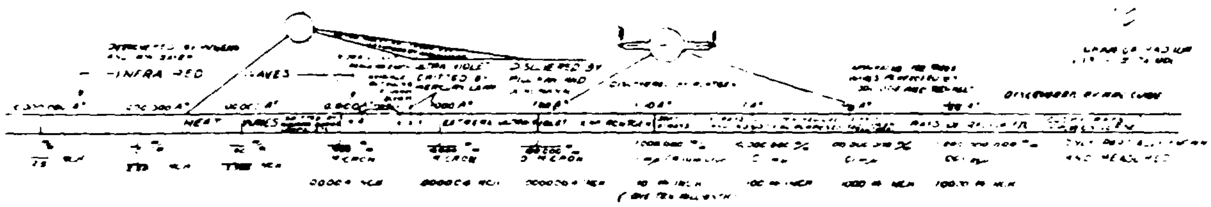
The measure of efficiency of any light for seeing depends upon its wavelength. Daylight is considered as light contained within a range of wavelengths by which the eye can see. This is sometimes referred to as the visible spectrum and has a range of wavelengths between 400 and 700 angstrom units or .40 to .70 microns. The micron is a scientific unit of length equal to one one-thousandth (.001) of a millimeter. The angstrom unit is, therefore, one ten-millionth (.0000001) of a millimeter.

Daylight, with its range of wavelengths between .40 and .70 microns, consists of seven primary colors, making up the solar spectrum:

COLOR	WAVELENGTH
Violet	0.39 to 0.43
Blue	0.43 to 0.47
Green	0.47 to 0.53
Yellow	0.53 to 0.59
Orange	0.59 to 0.62
Red	0.62 to 0.77

Some conception of the wide range of wavelengths used in present day activities is given by the sketch below:





VISIBILITY OF LIGHT WAVES

As previously expressed the eye is sensitive to certain rays in the visible spectrum. Mr. Henry Schroeder (Incandescent Lamp Department) very clearly explains this as follows:

> "The amount of energy within the visible spectrum is not necessarily indicative of the candlepower of the light, as the eye is not equally sensitive to the various wavelengths within the range 0.4 to 0.76 microns. A given amount of energy at the wavelength 0.556 microns (a yellow-green color) affects the eye more than the same amount of energy at either the wavelength 0.510 microns (a blue-green color) or 0.610 microns (an orange color). Thus the candlepower of two light sources, having relatively different distributions of energy at various wavelengths, will not necessarily be in proportion to their total energy within the visible spectrum. A light source emitting a preponderance of GREEN AND YELLOW light gives much more candlepower than light sources of the same amount of radiant energy within the visible spectrum which emits a preponderance of blue or red light."

COOPER HEWITT light has a preponderance of green and yellow light, almost 99% by candlepower measurement. A sufficient amount of blue is present to keep the eye well balanced or sensitized for keen vision.

COOPER HEWITT light is the ideal light because of this perfect balance. It permits workers to focus on detail with greater ease, thereby increasing sharpness of vision with the desired outcome of improved quality of merchandise and increased production. No other light, not even daylight, will illuminate vertical surfaces and penetrate into niches and cavities with the detail revealing effect as will mercury light. Nor will any other light produce maximum visual acuity and conserve the energy of workers with the same degree of efficiency as COOPER HEWITT light.

WHITENESS OF MERCURY LIGHT

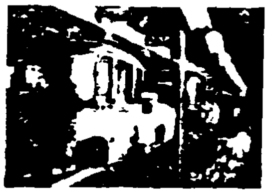
The fact that the color of mercury light is distinctly bluish affords an impressive demonstration of the difference between the brightness effect of monochromatic light and its coloring power. The 1½ percent of blue and violet is sufficient to over-balance the 98½ percent of yellow-green in coloring power. The colors of the four bands constitute two pairs of complementaries; blue and yellow, violet and greenish-yellow. So nearly are these matched that the color of the light is very nearly visual white. The general effect by mercury light is therefore one of cool whiteness.

This mental sensation of visual white is, likewise, important because of the excellent way in which mercury light blends with daylight. When COOPER HEWITT light is used with daylight one scarcely realizes the waning of daylight - workers keep pace with production requirements day or night.

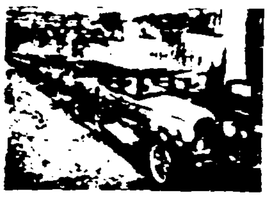
CONTINUOUS PRODUCTION RESTS ON UNIFORM LIGHTING

COOPER HEWITT light is the only industrial illuminant that can furnish an unvarying intensity every hour of the twenty-four. Here are a few reasons why this is true and several prominent users who have found it to be true.

PACKARD
B[illegible]



LINCOLN
Body [illegible] deck



CHRYSLER
[illegible]

AC SPARK PLUG
Speedometer assembly

Because — *it blends perfectly with daylight*

Sundown never means slowdown in a Cooper Hewitt lighted plant. The strongly visual yellow-green rays serve to strengthen daylight at all times. When the sun goes down and the lights come on, workmen do not notice the transition. Their seeing power is in no way diminished. And at night, when Cooper Hewitts have the field all to themselves, both quality and quantity of production are as good as, or better than, the daylight production.

Because — *it throws an even light over, around and inside the machine*

Men working under Cooper Hewitts do not know what it is to have "too much" light in one place and "not enough" in another. The illumination from the long tubes bathes every machine and gets down inside complex working mechanisms just as evenly. Eyes are able to hold their focus; pupils do not have to expand and contract constantly. This one advantage alone effectively reduces eyestrain.

Because — *its detail-revealing quality permits uniform inspection — day and night*

This is the feature which usually has the strongest appeal to manufacturers making their first acquaintance with Cooper Hewitt. They quickly find that Cooper Hewitts automatically "tighten up" their inspection, and notice that this holds good on night as well as day shifts. The peculiar ability of Cooper Hewitt light to magnify small detail makes defects which are usually invisible stand out sharp and clear.

Because — *it eliminates all eye-strain and removes the chief cause of defective workmanship*

Everybody knows that "green is good for the eyes," but Cooper Hewitt has more than color in its favor. The complete freedom of strain that Cooper Hewitt provides is the combined product of several other distinctive features—such as perfect diffusion, absolute glarelessness and total absence of the hot, fatiguing red rays found in all other light.

DODGE BROTHERS
[illegible]

FORD
Body assembly

HUDSON
Parts inspection

FISHER BODY
Sewing tables

Thousands of COOPER HEWITTS are used in every department of the great automobile industry. In no other manufacturing branch is competition so keen and production tolerances so important.

Because of this, leading automobile concerns must use the best of everything, be it machinery or light. They must have a light of sure seeing-power, one that enables their workmen to put the trim along the inside tops of closed car bodies with no auxiliary light.

707083

DAYLIGHT VARIATIONS

Daylight intensities are somewhat variable throughout the day as shown graphically on the next page. These graphs were taken at the Georgia School of Technology and are the results of daylight intensities from 5 A.M. to 6 P.M. on three different days with conditions as follows:

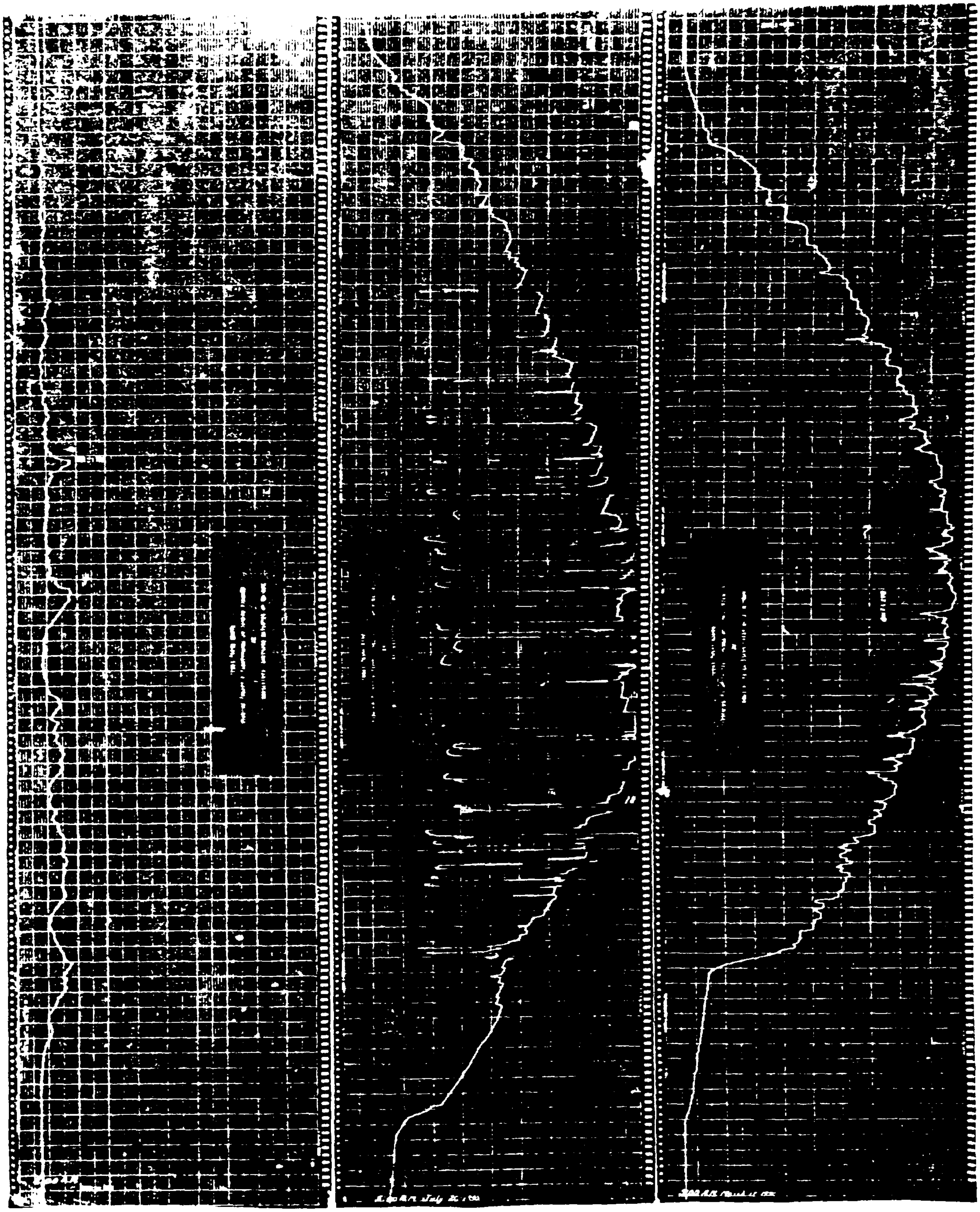
1. Normal clear day
2. Cloudy day
3. Dull day

On clear days with a proper arrangement of windows, intensities within a plant may be suitable to carry on work. When the day is cloudy and the clouds frequently pass by the sun, intensities are so variable in such short spaces of time that it is quite difficult for workmen to see clearly. On very dull days artificial lighting is necessary.

Many of the larger cities in the United States have accumulated and compiled data in tabular form showing the number of clear, cloudy, and dull days in each month of the year. The average number of clear sunshiny days is in the neighborhood of 50%. The remaining days are cloudy and dull, making intensities on the working plane either objectionable or insufficient.

Since COOPER HEWITT light blends so perfectly with daylight it can be used to straighten out the sudden dips of daylight intensities on cloudy days and provide sufficient well balanced light on dull days. Herbert Chase remarks:

> "It is characteristic of the Ford organization, as of many other progressive concerns, that it does not allow such variables as weather or time of day to interfere with the steady march of production. Daylight, for example, though employed when available and where its use fits in with the production program, is not a primary consideration. There is no cramping of the program to make it conform to the vagaries of weather. Ford buildings are designed to conform to production requirements, and provision then is made to assure adequate and good-seeing light without regard to weather, season, or time of day. The perfection of modern lighting systems has made this policy possible and highly successful.



THE DAYLIGHT BUILDING

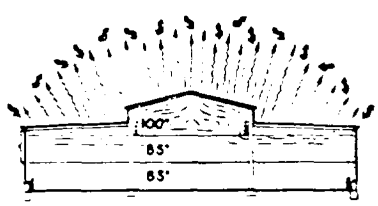
The daylight building or one having windows to furnish light in working areas requires special attention. Best daylight is obtained with overhead windows which add considerably to the expense of a building and are either restricted to top floors or single-story construction.

When planning on daylight for production, many important factors must be considered and its reliability and economy thoroughly checked. These factors are:

1. Geographic location.
2. Atmospheric conditions.
3. Cost of skylights and side windows.
4. Skylight and window maintenance.
5. Heat loss through glass and sash.

Such a check will reveal that daylight is not free but has its operating costs just as any other lighting system.

The maintenance cost of washing windows varies in amounts from ½ to 1½ cents per square foot of window area. A superintendent of a large motor truck company reports that the average window bill in his plant, being cleaned on a year's contract basis of 5/8 cents per square foot, amounts to an average of $2200.00 a month.

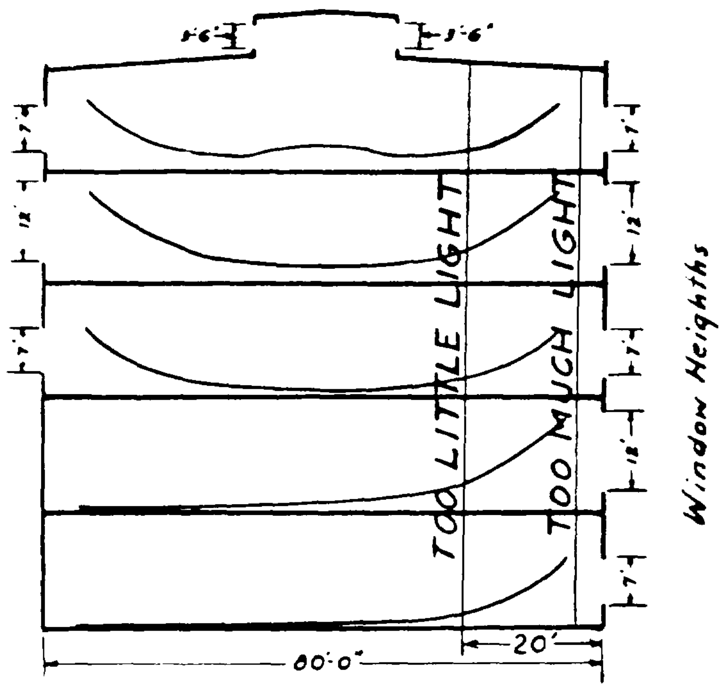


Heat loss through windows

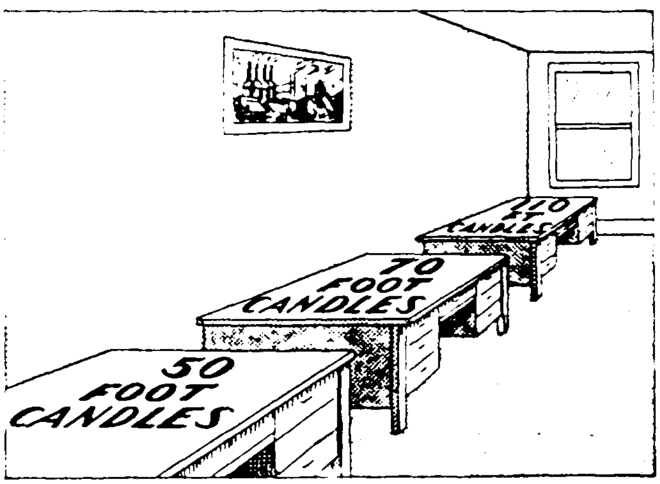
L.L. Holladay (National Lamp Works) made a very careful study of the cost of lighting industrial buildings and finds that a monitor top building costs $5.42 per 100 square feet of floor area to heat. Thus a building 200 feet square would cost a total of $2168.00 for heat losses due to windows.

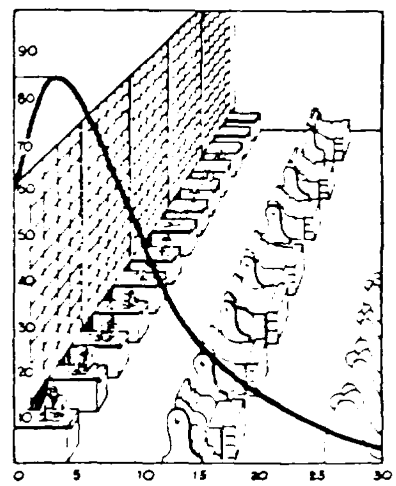
DAYLIGHT VALUES IN BUILDINGS

Some time ago the I.E.S. Transactions published data showing the typical falling off of daylight values in buildings with various heights and with a monitor top.



During daylight hours ample light may be provided near windows, but the intensity rapidly falls off toward the center of the building.





A well known architect made a test on the intensity of daylight in a modern multiple story building and found that sufficient daylight for good work was available only 14 feet from the windows on each side of the building. He stated that:

A BUILDING MORE THAN 30 FEET

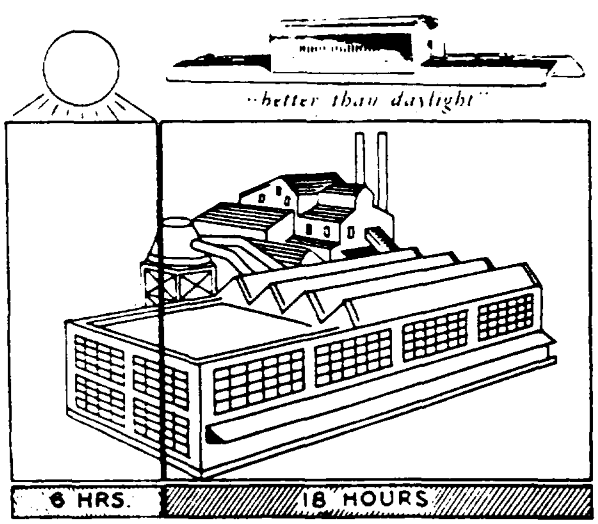
WIDE WAS NOT WELL DAYLIGHTED

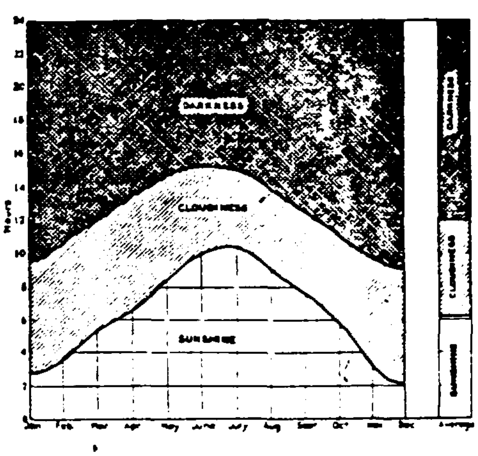
Unless good lighting is used in the center of the building it it only good for storage space - - the rental value is only worth one-half to one-fourth that of well lighted sections.

H.S. Jacoby (H.K. Ferguson Co.) remarks:

"Too much dependence should not be placed upon side wall windows for lighting wide buildings. The glare from a large area of glass causes eyestrain and fatigue. Additional light through saw-tooth or monitor windows must supplement sidewall illumination so that the ratio between maximum illumination at the side of the building and minimum illumination in the interior shall not exceed 3 to 1."

Whatever may be said about daylight, as far as lighting departments of manufacturing plants, it is only available about 25% of a 24 hour day. The charts below show how little daylight is available over a period of a year.





FIVE-FOOT SKYLIGHTS

Many attempts have been made to reach the ideal of daylight illumination within buildings by installing glass in the roof. This method of illumination, however, presents many handicaps and limitations. In the first place, it is adaptable only to top floors and single-story buildings. It is wholly dependent upon weather conditions and of course limited to daylight hours. Skylights result in higher fuel costs due to tremendous heat loss. The maintenance of such a lighting system also presents a problem, due to the great amount of dust and dirt which collects on both sides of the glass. Thus, the skylight is not an ideal form of lighting.

Through long experience and practice it has been found that one COOPER HEWITT lamp will provide illumination equal to the best results obtained from a FIVE-FOOT SKYLIGHT. There are many advantages in favor of COOPER HEWITT illumination in comparison with skylight illumination.

Several large manufacturers after discovering the advantages of COOPER HEWITT light, have changed construction plans of new buildings. These changes eliminated contemplated skylights and specified COOPER HEWITT light 24 hours a day. These executives state that savings in heating costs by eliminating skylights more than pay for 24 hours of artificial light and that the artificial light was eminently satisfactory.

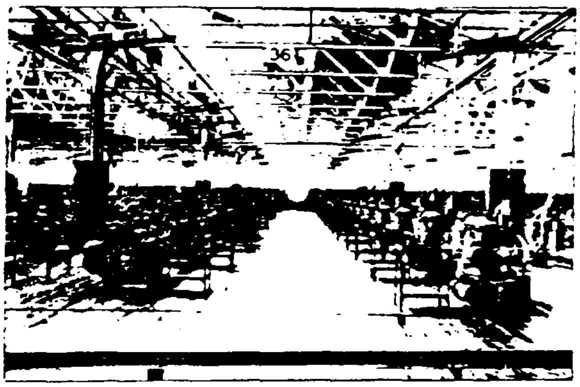
Daylight is variable. You can't count on it. Daylight suffers also by comparison on items of last cost and upkeep. Windows and skylights cost money. They are practical only where conditions are favorable. They are fixed, not movable. With them, there is no escape from excessive heat loss; and you must pay to keep them spotless or suffer the far greater expense of depreciation in seeing power.

Cooper Hewitt light is better than daylight not only because it is of constant intensity at any hour but because it is composed almost entirely of yellow-green (the best-seeing) rays of light. It has none of the glare producing qualities which are hard on the eyes.

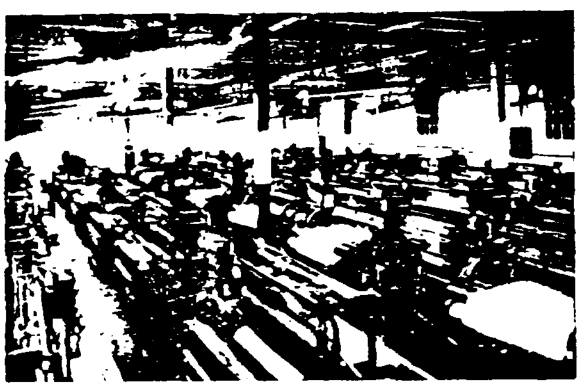
As a result, every detail becomes sharp and clear as if magnified, vision is more acute and the response of brain and hand is more rapid.

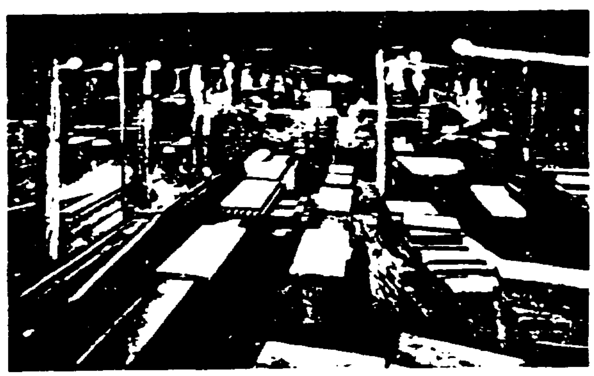
COOPER HEWITT SKYLIGHTING

Comparing the two photographs below shows how COOPER HEWITT light provides skylight illumination at its best. The daylight conditions are obtained from strictly modern saw-tooth skylights in a single-story building while the artificial lighting is obtained from a modern installation of COOPER HEWITT lamps.



Two other photographs show how ideal skylight illumination has been provided to supplant daylight. The wood-working shop is in a basement - - the lighting has been put where it is needed and the workers are not dependent upon the weather for lighting. The silk weave room has uniform illumination throughout - - the lack of harsh shadows on the looms and the ability to see each thread clearly make greater production and better quality possible.





ADVANTAGES OVER DAYLIGHT

A few of the more important advantages of COOPER HEWITT light over daylight may be listed as follows:

1. No heat loss.
2. Much easier to clean.
3. Uniform light 24 hours a day.
4. Dust and dirt accumulation much slower.
5. Can be installed when and where needed.
6. Better visual value at low intensities.
7. EVERY LAMP EQUAL TO A FIVE-FOOT SKYLIGHT.
8. Revealing power surpasses daylight at its best.
9. Can be installed anywhere in any kind of a plant.
10. Can be moved to different locations if occasion demands.
11. Always of constant value, evenly and uniformly diffused.
12. Direction of light always under control and very flexible.
13. Uniform production regardless of fog, cloudy days or twilight.
14. Detail revealing quality permits uniform inspection day or night.
15. At an intensity of 6 foot-candles surpasses daylight at its best.
16. At 4.5 foot-candles equals daylight at 10 foot-candles.

ADVANTAGES OF COOPER HEWITT LIGHT WHEN USED WITH DAYLIGHT

1. Reinforces daylight.
2. Increases eye sensitivity.
3. Blends with standard daylight.
4. Adds considerably to the seeing-power.
5. Provides higher visibility at point of seeing.
6. Blends perfectly with daylight at twilight.
7. Helps appreciably to increase visual discrimination.
8. Makes scribe marks on scales and machines more distinct.
9. Permits clear vision in recesses and shielded places.
10. Blends so perfectly with daylight that there is no contrast either in intensity or quality.

ARTIFICIAL DAYLIGHT

There are few instances when true daylight or north daylight is required for accurate color matching purposes. When such is the case special lighting equipment is required. There are some instances also, when colors must show up with approximate true values. In this case, lighting may be such that it is approximately the same or as near daylight as possible.

Two methods of approximating the color value of daylight are known:

1. Subtractive method

2. Additive method

The **subtractive** method is accomplished with incandescent lamps using a blue glass bulb. When glare is objectionable by this method the clear incandescent bulb may be used with a blue glass diffuser. In both cases the blue colored glass absorbs a greater amount of light toward the red than toward the violet end of the spectrum, so as to balance more equally the amount of radiant energy at all wavelengths within the spectrum. The blue bulb or diffuser absorbs one-third or more of the total light emitted by the filament of the lamp.

The **additive** method uses a combination of mercury vapor and incandescent light. The mercury vapor being deficient in the red and the incandescent in the blue end of the spectrum balance to give a white light. Various degrees of color effect can be obtained depending upon the amount of mercury vapor and incandescent light used. Various fixtures of this nature are available for both industrial and commercial application.

It is quite apparent that the additive method is to be preferred from the efficiency standpoint since both light sources operate under normal conditions while the subtractive method requires a filter which absorbs light.

COST OF LIGHTING INDUSTRIAL BUILDINGS

The report given by L.L. Holladay contains so much valuable information that a table containing all the important features has been prepared for ready reference. This table is set up in simple form but should nevertheless be carefully studied so that it is thoroughly understood.

An example of the method of determining the annual cost per 100 square feet of floor area for artificial lighting, (Building A), is given as follows:

Uniform intensity on working plane.	13 ft.c.
RLM reflectors - 200 watt W.B.lamps- total of . . .	108
Cost of wiring at $8.65 per outlet.	$934.00
Cost of lighting units installed at $4.05 each. . .	437.00
Total investment cost for artificial lighting . . .	1,371.00
Total cost per 100 sq. ft. of floor area.	12.70

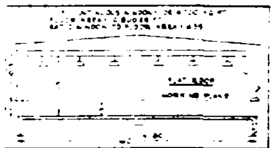
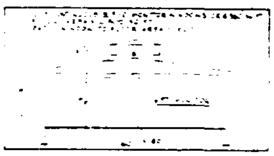
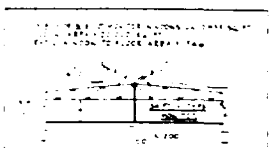
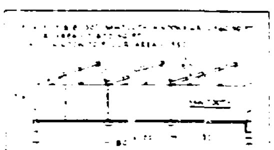
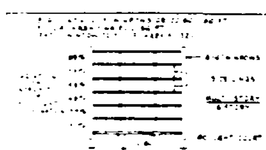
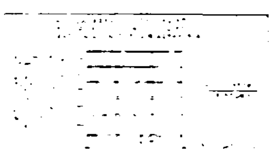
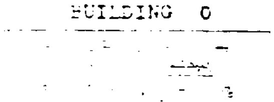
Based on the above figures, the items of annual cost of artificial lighting used to supplement natural lighting in maintaining the prescribed minimum of 13 foot-candles upon the working plane are:

Interest, depreciation, repairs, taxes, etc. on wiring, $934.00 x 12%	$112.00
Interest, depreciation, repairs, taxes, etc. on lighting units, $437.00 x 21%	91.80
Cleaning lighting units six times 108 x 6 x .07 . .	45.36
Lamp renewals, 108 x 651 x $.67/1000.	47.10
Electric energy at two cents per kw-hr., 108 x 651 x 200/1000 x $.02	281.24
Total	$577.50

Therefore, the total annual cost of artificial lighting is $577.50 or an annual cost of $5.35 per 100 square feet of floor area.

"THE COST OF LIGHTING INDUSTRIAL BUILDINGS" - L. L. HOLLADAY
Journal of The Franklin Institute-Vol.207,#2,Feb.1929.

Annual Cost of Lighting per 100 Sq. Ft. of Floor Area of Various Types of Industrial Buildings. Windows are washed twice a year at 1 1/2¢ per Sq. Ft. for washing. Results include heat losses incident to the windows, repairs, taxes, maintenance, interest, depreciation, etc., on equipment. Electric energy at 2¢ per KW hour. Working hours per year 2240.

	Min. Foot-Candles Watts per lamp.	5.5 100	9.4 150	13 200	21 300	[illegible] 500	HEAT LOSS THRU WIN-DOWS
BUILDING A	BRICK & STEEL - TOTAL BLDG. COST - $21,600. - TOTAL COST OF NATURAL LIGHTING-$6,086. or $28.56 per 100 Sq. Ft.						
	Av.no.of hrs. lamps oper.per yr.	267	448	651	1140	[illegible]	
	Annual cost of natural lighting	$5.83	$5.83	$5.83	$5.83	$5.8[illegible]	
	" " " electric "	2.43	3.57	5.35	10.77	21.81	$3.06
	" cost of nat. & elec. "	8.26	9.40	11.18	16.60	27.64	
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area	.0670¢	.0447¢	.0354¢	.0353¢	.0[illegible]¢	
BUILDING B	BRICK & STEEL - TOTAL BLDG.COST - $22,[illegible]. - TOTAL COST OF NATURAL LIGHTING-$5,332. or $49.31 per 100 Sq. Ft.						
	Av.no.of hrs. lamps oper.per yr.	195	298	379	[illegible]	[illegible]	
	Annual cost of natural lighting	$10.18	$10.18	$10.18	$10.18	$[illegible]	
	" " " electric "	2.26	3.04	4.08	7.40	[illegible]	6.42
	" cost of nat. & elec. "	12.44	13.22	14.26	17.58	[illegible]	
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area	.1010¢	.0628¢	.0489¢	.0374¢	.0[illegible]¢	
BUILDING C	BRICK & STEEL - TOTAL BLDG. COST - $41,000. - TOTAL COST OF NATURAL LIGHTING-$12,290. or $61.50 per 100 Sq. Ft.						
	Av.no.of hrs.lamps oper.per yr.	141	205	255	385	746	
	Annual cost of natural lighting	$12.16	$12.16	$12.16	$12.16	$12.16	
	" " " electric "	2.14	2.72	3.50	5.43	11.78	6.71
	" cost of nat. & elec. "	14.30	14.88	15.66	17.59	[illegible]	
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area	.1160¢	.0706¢	.0537¢	.0379¢	[illegible]	
BUILDING D	BRICK & STEEL - TOTAL BLDG. COST - $49,650. - TOTAL COST OF NATURAL LIGHTING-$17,270. or $79.90 per 100 Sq. Ft.						
	Av.no.of hrs. lamps oper.per yr.	142	203	253	390	[illegible]	
	Annual cost of natural lighting	$14.13	$14.13	$14.13	$14.13	[illegible]	
	" " " electric "	2.14	2.71	3.49	5.47	[illegible]	[illegible]
	" cost of nat. & elec. "	16.27	16.84	17.62	19.60	[illegible]	
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area	.1320¢	.0600¢	.0605¢	.0417¢	.0[illegible]¢	
BUILDING E	LIGHT COURTS-80 FEET BETWEEN BUILDINGS-REINFORCED CONCRETE-TOTAL BLDG. COST-$194,400.-TOTAL COST OF NATURAL LIGHTING-$14,470. or $22.30 per 100 Sq. Ft.						
	Av.no.of hrs. lamps oper.per yr.			1167	1564		
	Annual cost of natural lighting			$6.73	$6.73		
	" " " electric "			7.86	13.76		2.28
	" cost of nat. & elec. "			14.59	20.49		
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area			.0501¢	.04[illegible]¢		
BUILDING F	LIGHT COURTS - 80 FEET BETWEEN BLDGS. - REINFORCED CONCRETE-TOTAL BLDG. COST-$183,600.-TOTAL COST OF NATURAL LIGHTING - $41,840. or $77.[illegible] per 100 Sq. Ft.						
	Av.no.of hrs. lamps oper.per yr.		455	704	1219		
	Annual cost of natural lighting		$14.91	$14.91	$14.91		
	" " " electric "		3.60	5.59	11.33		[illegible]
	" cost of nat. & elec. "		18.51	20.50	26.24		
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area		.0879¢	.0704¢	.0[illegible]6¢		
BUILDING G	BRICK & STEEL - TOTAL BLDG. COST $21,600.						
	Av.no.of hrs. lamps oper. per yr.	2240	2240	2240	2240	[illegible]	
	Annual cost of electric lighting	6.93	9.86	11.77	[illegible]	[illegible]	
	Cents per min. f.c. per hour per 100 Sq. Ft. of floor area	.1[illegible]3¢	.0468¢	.0[illegible]¢	[illegible]	[illegible]	

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The following is a list of most important features contained in the Summary of the report:

1. "When the minimum intensity of illumination desired upon the work-plane is less than about 10 ft.c. or more than 75, artificial illumination is the more economical one. Between these limits, usually at about 38 ft.c. the combined cost of natural and artificial illumination per ft.c. per hour attains a minimum."

2. "The investment cost of heating equipment to supply heat losses incident to windows varies from $.32 to $.45 per sq. ft. of window surface for buildings having side windows only, and from $.41 to $.59 for buildings having windows in the roof also."

3. "The annual cost of maintaining and operating the heating system to supply heat losses incident to windows varies from a minimum of 7 cents per sq.ft. of window surface in Building A, to a maximum of 12.3 cents in Building C."

4. "Under average conditions the ratio of the initial costs of natural lighting to electric lighting equipment varies from 2.25 for a single-story flat roof building to 6.3 for a sawtooth building."

5. "Under the same conditions the ratio of the annual cost of natural lighting to the annual cost of electric lighting varies from 1.09 for a single-story, flat roof building, to 4.03 for a sawtooth building."

6. "It appears that a practice of washing windows less frequently than twice a year is uneconomical excepting when the minimum intensity of illumination upon the work-plane is maintained at less than 10 ft.c."

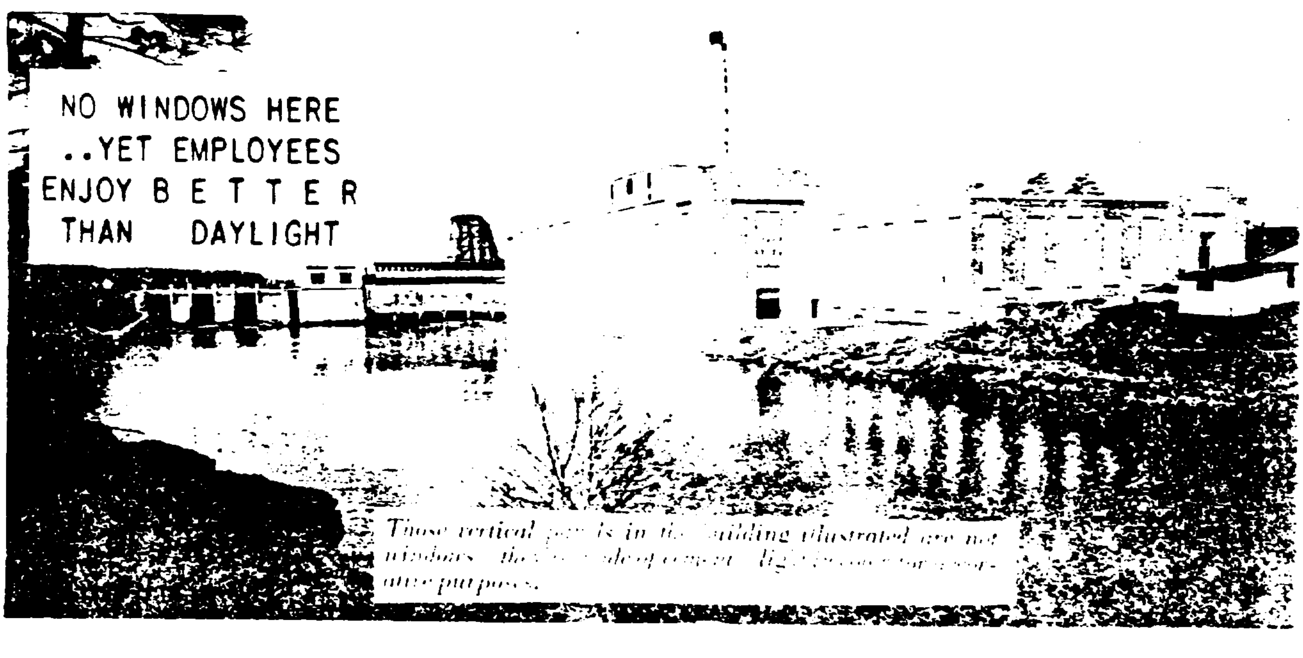
7. "When determined merely by the cost of lighting, it appears from these results that for any type of standard building investigated and operating under average conditions that no appreciable expenditure for natural lighting equipment is justifiable when electric energy can be purchased as low as 1.4 cents per kw.-hr."

WINDOWLESS FACTORY

In many cases windows are a menace to both employees and employer. The employee does not benefit materially from the fact that windows are present. Neither light, heat, nor ventilation are properly obtained from them; moreover, sunlight is absolutely of no benefit to workers coming through the glass windows.

The windowless factory is by no means a dream. The photograph below of the Blandin Paper Company's mill, (Grand Rapids, Minn.) is only one of many windowless buildings now in existence. Heating, ventilating, and **lighting** systems are scientifically engineered and controlled. In addition to this, COOPER HEWITT lamps are equipped with special glass tubes which emit health-promoting ultra-violet rays equivalent to the ultra-violet radiation of average June sunlight. All this may be considered as **improvements** on Nature and further, proves that:

Cooper Hewitt
is
"better than daylight"

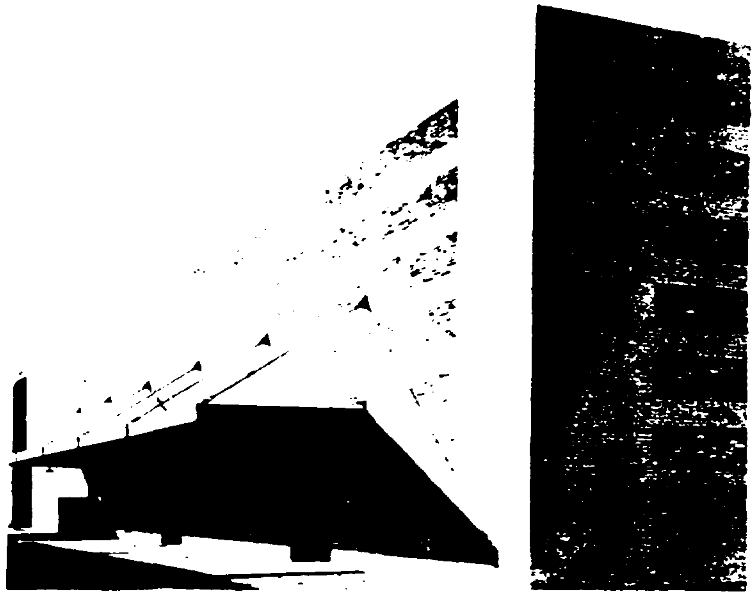


At Fitchburg, Mass., stands the mighty windowless factory of the Simonds Saw and Steel Company. Its austere beauty has attracted many thousand people and all proclaim that the light within the enclosing brick walls, matches that of sunlight. There are 720 fixtures in which mercury vapor tubes are combined with incandescent lamps. Mr. Gifford Simonds desired lighting units that would give the nearest approach to daylight in order to remove from the minds of the workers the consciousness that they were working without the benefit of daylight. Here then, is a 'controlled-conditions' plant which relies not upon Nature in any way -- not even daylight.

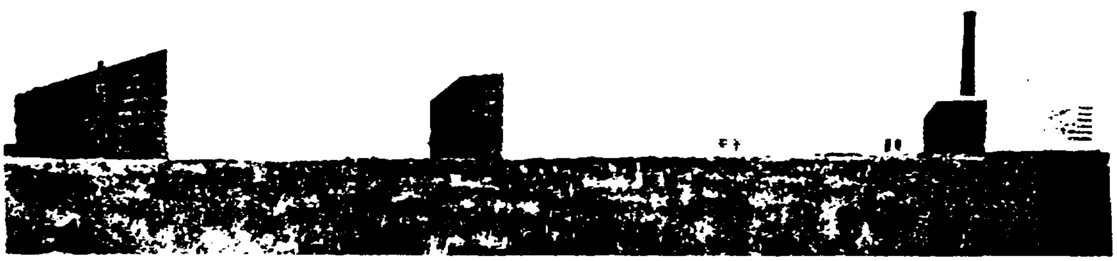
The Wallingford Steel Company, to avoid the suspended dirt and gas that filters into office space through windows, have moved into their new office building where glass plays no part in the side wall or overhead construction. Not only is the interior immaculately clean and temperature under better control, but the partitions are thoroughly insulated against external noises. Again the system of artificial lighting that would simulate daylight in effect was demanded, namely, a combination of Mercury-Mazda.

The famous Hershey Chocolate Company have built a windowless structure for their new office building. Standard COOPER HEWITT tubes again are combined with Mazda to produce daylight illumination. A total of 150 fixtures provide office workers with light that eliminates eye-strain and fatigue.

The trend toward windowless buildings will gain impetus as the pioneers like Blandin, Simonds Saw, Wallingford, Hershey and others, prove their value. The above examples are strictly modern conceptions of lighting and the 'plant of the future'. Within this 'plant' is assured a definite quantity of fresh humid air, the temperature always constant, health rays in just sufficient quantities and light that will never vary throughout the day. These are truly humanitarian aspects in which the mercury vapor lamp will be a most essential element to the health and well-being of future generations.



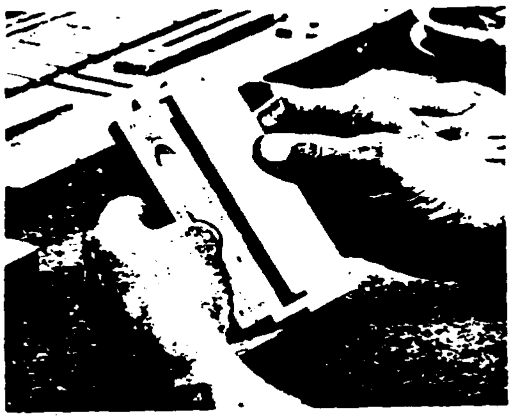
CLOSE-UP OF WINDOWLESS FACTORY



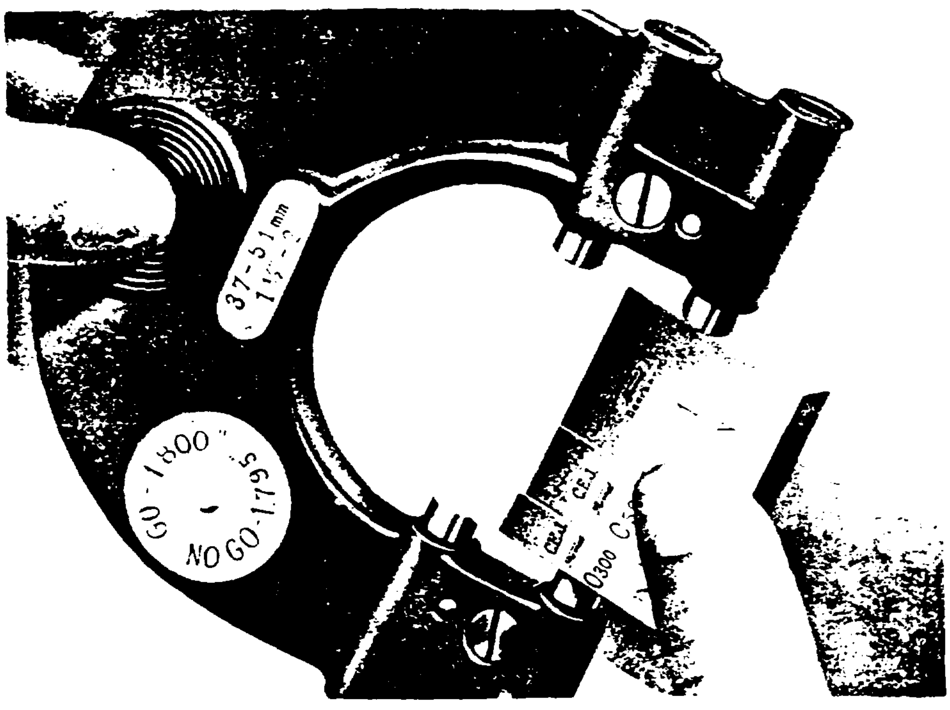
EXTERIOR VIEW OF AUSTERE BEAUTY- SIMONDS SAW AND STEEL CO.

INTERIOR DURING CONSTRUCTION-SHOWING LIGHTING UNITS

COOPER HEWITTS are used exclusively in the laboratory where the world's most accurate gages are made. So accurate are these gages that they measure one one-millionth of an inch. For many years **COOPER HEWITT** lamps have been used exclusively by C.E.Johansson, Inc., in the Gage Department in Ford's Laboratory Building (Dearborn). This laboratory is in an isolated section where daylight is not available and where temperature is held constant throughout the day.



The Johansson Gage Department is just another typical example of the **'better than daylight'** quality of **COOPER HEWITTS.** The very qualities that make mercury vapor light so satisfactory for this exacting 'gage' work, make it ideal for all types of manufacturing operations -- even where windows are excluded and daylight is not available or desired.



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COMPETITIVE

707100

Competitive

There are only two types of industrial lighting available at present, which can be considered competitive ---

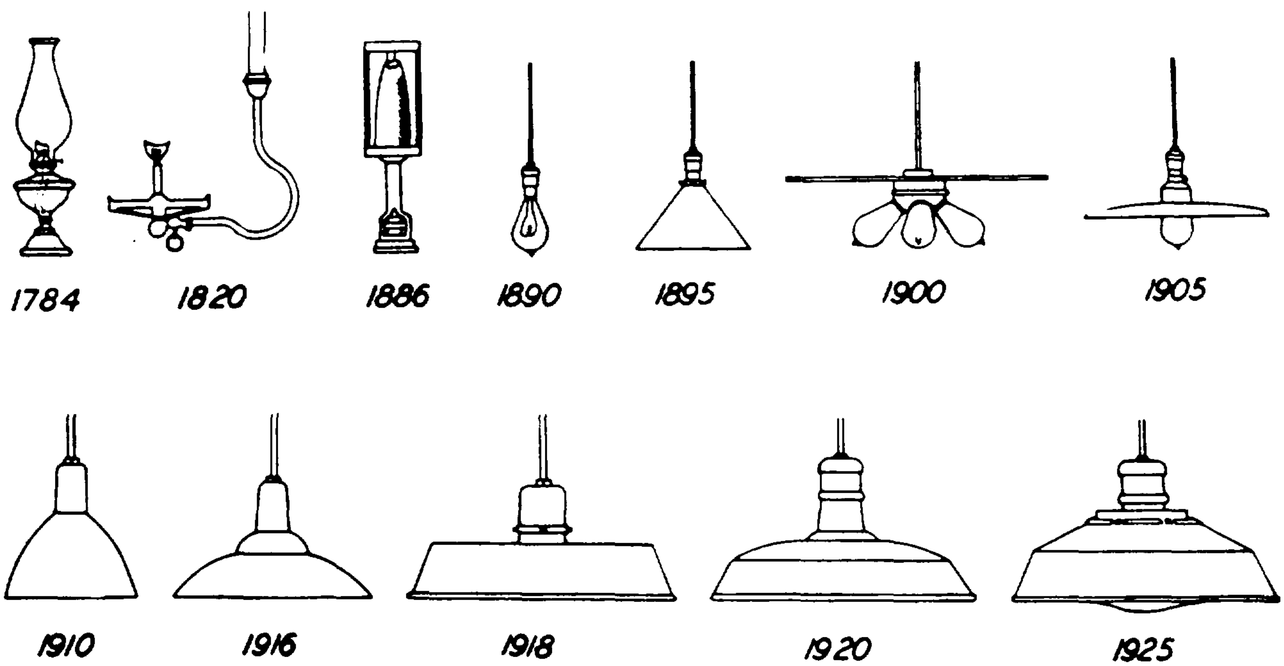
1. Mercury

2. Incandescent

Not many years ago there were other forms of light popularly used, such as carbon arcs, glow lamps, carbon incandescent lamps, and many others. COOPER HEWITT lamps have competed with all these light sources which are now practically forgotten. As a matter of fact, vacuum, gas and nitrogen filled tungsten lamps may be included with this list; even daylight is less thought of, by virtue of the fact that fewer windows, as well as windowless factories are becoming more common.

THE PASSING OF LIGHT SOURCES

A few of the most popular lighting units employed in American industry are shown below.



All but the last two have passed into oblivion. Prior to 1920, both incandescent lamps and reflectors were relatively inefficient. In order to control the design and efficiency of reflector equipment the "Reflector and Lamp Manufacturers" drew up a set of specifications recommending a specific shape for enameled steel reflectors for low bay mounting. These units have since been known as RLM reflectors.

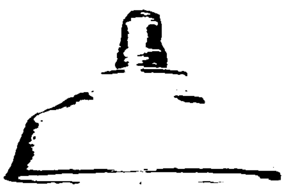
The demand for higher intensities of illumination in the next few years found the RLM reflector to be too brilliant for comfort and objectionable shadows were cast on vital points where seeing was required.

In 1925 the RLM Dome was modified to include a diffusing glass globe around the incandescent lamp, in an attempt to reduce the intrinsic brilliancy and soften shadows.

MODERN INCANDESCENT REFLECTORS

RLM Standard Dome

12	inch	diameter	- - - -	60-100	watt	lamp.
14	"	"	- - - -	150	"	"
16	"	"	- - - -	200	"	"
18	"	"	- - - -	300-500	"	"
20	"	"	- - - -	750-1500	"	"

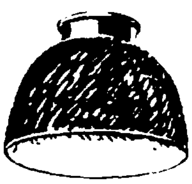


Standard Glassteel Diffuser

18	inch	diameter	- - - -	150-200	watt	lamp
20	"	"	- - - -	300-500	"	"
24	"	"	- - - -	750-1500	"	"

Prismatic Glass Reflectors

Furnished in various sizes and styles depending upon area to be lighted.



Silvered Glass Reflectors

Furnished in various sizes and styles depending upon area to be lighted.

Manufacturers of reflectors have made changes in design of equipment frequently, to keep up with the change in general construction of the incandescent lamp. Radical changes took place about every 5 years since 1895.

COOPER HEWITT lamps in the past 30 years have undergone slight changes in reflector design and refinement of auxiliary parts. The principle of light emission, however, has never changed. It has maintained its high efficiency throughout the many years and still remains unchallenged as the most desirable light from the standpoint of:

1. Being glareless
2. Being shadowless
3. Promoting maximum contrast
4. Providing greater seeing-power
5. Highest visibility at point of seeing
6. Reducing fatigue
7. Increasing eye sensitivity
8. Being easy on the eyes

110 V AND 220 V INCANDESCENT LAMPS

The 110 volt incandescent lamp is considered as standard for lighting circuits. Very often 220 volts is preferred with a substantial saving in wiring costs. Recently R.L. Zahour, (Westinghouse) stated in an article published in the Electrical Record, the advantages of the 110 volt lamp over the 220 volt lamp. These are briefly outlined as follows:

1. Decreased lamp cost (20% less for same wattage).
2. Higher light output (23% higher for same wattage).
3. Better performance (filament approximately twice diameter of 220 volt lamp).
4. Filament more rugged (less likely to be broken).
5. Ease of obtaining replacements.

While the incandescent lamp is a comparatively simple device, there are many precautions that must be observed in using them industrially. Some of these have been listed as follows:

Don'ts for Mazda Lamps

1. Don't use lamps in reflectors designed for smaller lamps.
2. Don't expose ordinary lamps to severe vibration or heavy shocks.
3. Don't use lamps rated at a higher voltage than the circuit.
4. Don't use unprotected lamps where breakage may cause an explosion.
5. Don't use gas-filled lamps (60 watts upward) exposed to rain or snow.
6. Don't use ordinary lamps for color matching without an auxiliary filter.
7. Don't use 220-volt service for extension cords.
8. Don't use 220-volt service for lighting when 120 volts can be used.
9. Don't use the special mill-type lamp for vibration service in other than the base-up position.
10. Don't use any white-bowl lamp base-down.
11. Don't expect a regular PS-bulb lamp to give as good service base-down as base-up.
12. Don't unscrew a large-wattage lamp from its socket while burning.
13. Don't immerse a lamp bulb in water when washing it.
14. Don't keep a blackened lamp in service.

COOPER HEWITT lamps operate on 110 volt or 220 volt circuits with the same characteristic of high efficiency and operating performance in either case. There is no filament to burn out or become broken and the replacement tubes are the same on either 110 or 220 volt service, since an auto-transformer supplies same voltage values to the tube terminals. Point 14 is the only serious "don't" to observe with COOPER HEWITTS.

PROGRESS OF LIGHT

The operating cost of various lighting units based on the same candlepower rating is indicated below.

130 **Tallow candles** giving
130 c.p. for 1000 hours
would cost. $1500.00

8 **Original Edison Lamps** would give
130 c.p. for 1000 hours
at a cost of. 68.75

1 **Modern** 100 w **Mazda Lamp** giving*
130 c.p. for 1000 hours
would cost. 2.20

1 **Modern** COOPER **HEWITT** producing **
130 c.p. on the basis of 1000 hours
would cost. 1.50

* 100 watts x 1000 hours = 100 kw. @ 2¢ = $2.00
plus 20¢ renewal = $2.20

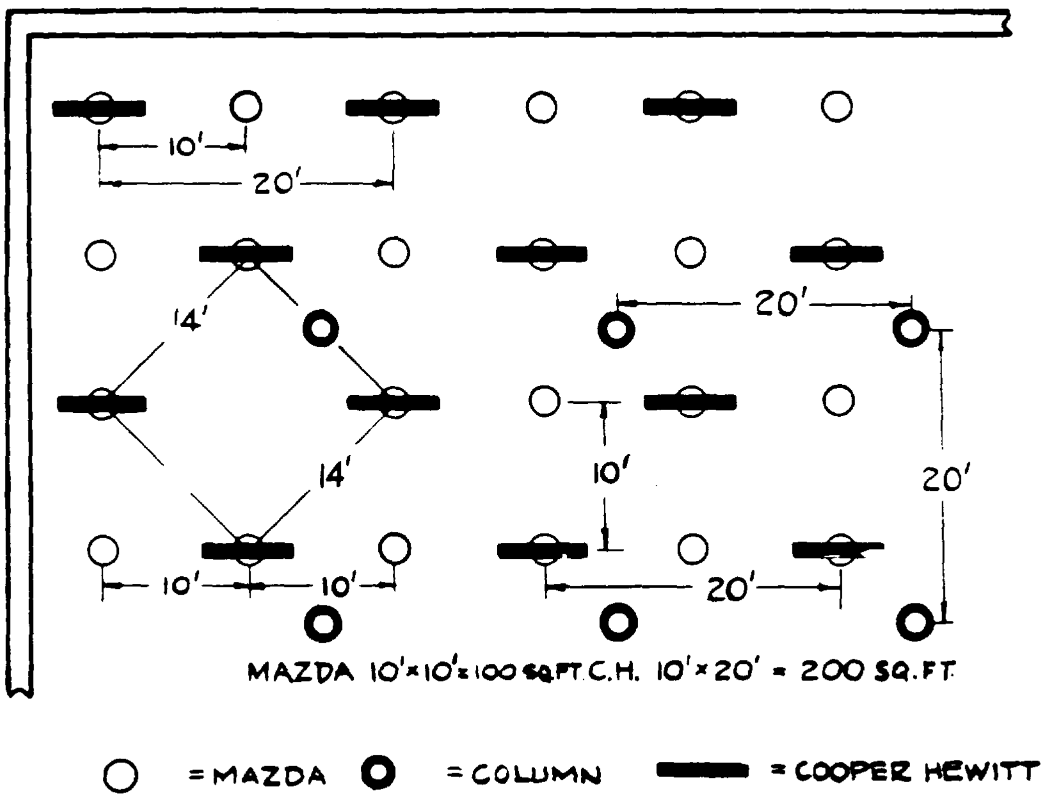
** Standard 450 watt COOPER HEWITT produces 893 c.p.; approximately 1/7 of a lamp, then would give the 130 c.p. in the above calculation.

1/7 x 450 watts x 1000 hours = 64.3 kw. @ 2¢ = $1.30

Renewal, 1/7 of one tube for 1000 hours = $0.20

COOPER HEWITT VS INCANDESCENT LAMPS

Data has been made available in tabular form showing average foot-candle intensities for various spacings and mounting heights for both COOPER HEWITT and incandescent lamps. From these Tables reliable comparisons of efficiency can readily be made. Below is a section of a room showing incandescent lighting units on 10' x 10' spacings with COOPER HEWITTS superimposed on alternate spacings that will give the same or higher average intensities.



Typical section of shop- - - - - - - - - - 1200 sq.ft.

INCANDESCENT

16 - 300 watt Glassteel lamps.
10' x 10' centers - - - 100 sq.ft.
3 watts per sq.ft.
13 - 18 ft.c. (Franklin Specifications)
15.5 ft.c. average.

16 - 300 watt White Bowl RLM lamps.
10' x 10' centers - - - 100 sq.ft.
3 watts per sq.ft.
16 - 21 ft.c. (Franklin Specifications).
18.5 ft.c. average.

COOPER HEWITT

8 - 450 watt standard 50" lamps
14 x 14 ft. centers (staggered 20' x 10' centers)- 200 sq.ft.
2.3 watts per sq.ft.
21 ft.c. average (G.E. tables).

One half the number of outlets.
One half the initial wiring cost.
Better distribution, diffusion and quality of light.
15% to 35% more light.
30% less wattage.

PRACTICAL COMPARATIVE TESTS

Thousands of practical tests in almost every branch of industry have been conducted during the past 30 years, proving that COOPER HEWITT lamps are not only the most suitable and ideal industrial lighting units, but also the most efficient. Many examples could be cited but space does not permit more than two. Both tests prove conclusively the validity of the comparative figures given above.

EXAMPLE NO. 1

International Harvester Co. (McCormick Works).

Section of Shop - - - - - - - - - - - 1280 sq.ft.
16 - 300 watt Glassteel lamps
12 - 450 watt COOPER HEWITT lamps

COOPER HEWITT	INCANDESCENT
5400 watts	4800 watts
4.2 watts/sq.ft.	3.8 watts/sq.ft.
47 foot-candles	31 foot-candles

EXAMPLE NO. 2

Tennessee Eastman Corporation

One of the most extensive tests of a most practical nature was conducted at the above concern in the presence of the Executive-Director, Chief Engineer, Electrical Engineer, Superintendent and heads of all rayon departments; as a matter of fact, these men conducted the tests themselves on recommended installations consisting of Holophane, Benjamin (Glassteel Diffusers with daylight lamps), Abolite (Glassteel Diffusers with clear lamps), and COOPER HEWITT lamps.

All lamps were installed side by side on 10' x 10' centers.

Every conceivable phase of each type of lighting was carefully studied until after midnight.

Results of the tests were approved with the following average intensities:

1. COOPER HEWITT - - - - - - - - - - - - -450 watts - - 30 ft.c.
2. Holophane (special) - - - - - - - - -750 " - - 18 ft.c.
3. Abolite (Glassteel Diffuser)- - - -500 " - - 16 ft.c.
4. Benjamin (Daylight Diffuser)- - - -500 " - - 10 ft.c.

The COOPER HEWITT watts per square foot were lower than any of the other systems, yet the intensity in foot-candles was practically twice that of the best competing system and three times that of the lowest system.

Everyone unanimously agreed that the **seeing qualities** of **COOPER HEWITTS** were by far superior to that produced by the other fixtures.

Orders for more than 1000 lamps resulted from these tests. Other manufacturers will save time and expense if they accept the findings of the Tennessee Eastman Corporation.

DOWNWARD LUMEN COMPARISON

A very interesting comparison between COOPER HEWITT lamps and RLM and Glassteel lamps may be made by referring to downward lumen output curves of the various lamps.

Luminaire	Lamp Size Watts	Curve	Downward Lumens	Number of units required to deliver as much illumination as one C.H.		Wattage required on the basis of number of units required	
Cooper Hewitt 160-9WLI	450	SK-610-R	5625				
Cooper Hewitt 110-9WLI	385	S-157	5167	160-9WLI	110-9WLI	160-9WLI	110-9WLI
RLM	200	S-120	2240	2.50	2.30	500	460
Glassteel Standard	200	S-120	1955	2.87	2.65	574	530
Glassteel Daylight	200	None	1285	4.36	4.00	872	800
RLM	300	S-121	3970	1.42	1.30	426	360
Glassteel Standard	300	S-121	3110	1.81	1.66	543	498
Glassteel Daylight	300	None	2120	2.65	2.44	795	732

The COOPER HEWITT lamp by this comparison gives more light with fewer outlets and less wattage in every case. There is a slight gain in wattage with the 300 watt RLM Dome lamp, but the glare from this lamp would be objectionable for ordinary mounting heights in production departments. The results computed in this Table are of a theoretical nature, since they are not indicativc of the distribution of the lamp fixtures.

FOOT-CANDLE INTENSITY COMPARISON

Practical engineers and plant men prefer using the foot-candle in making intensity comparisons. The COOPER HEWITT lamp in this respect is far superior to incandescent lighting as shown by the following Table of foot-candle intensities.

COMPETITIVE

TABLE
FOOT-CANDLE INTENSITIES AND WATTS PER SQ.FT. BASED ON PUBLISHED DATA OF THE G.E.VAPOR LAMP CO. BENJAMIN ELECTRIC CO. FRANKLIN SPECIFICATIONS

		INCANDESCENT LAMPS								COOPER HEWITT			
		RLM DOME				GLASSTEEL DIFFUSER				STANDARD 450 WATT LAMPS			
		200 WATTS		300 WATTS		300 WATTS		500 WATTS					
SPACING IN FEET	HEIGHT IN FEET	WATTS PER SQ. FT.	FT.C.	WATTS PER SQ. FT.	FT.C.	WATTS PER SQ. FT.	FT.C.	WATTS PER SQ. FT.	FT.C.	SPACING IN FEET	HEIGHT IN FEET	WATTS PER SQ. FT	FT.C.
7¾ x 7¾	7.5	3.3	18.5	5	29.5	5	26	8.0	47	8 x 8	7.5	7	62.1
8½ x 8½	8.0	2.8	15.5	4	25.0	4	21	6.6	38				
9 x 9	8.5	2.5	13.5	3.7	21.5	3.7	19	6.1	34	9 x 9	8.6	5.5	58.6
9½ x 9½	9.0	2.2	12.5	3.3	20.0	3.3	17	5.5	30				
10 x 10	9.5	2	11.0	3	18.5	3	16	5.0	28	10 x 10	9.6	4.5	44.3
11 x 11	10.0	1.6	9.0	2.5	16.0	2.5	13	4.1	24	11 x 11	10.6	3.7	34.2
11½ x 11½	10.5	1.5	8.0	2.3	13.5	2.3	12	3.7	21	12 x 12	11.6	3.1	29.2
13 x 13	11.5	1.3	6.5	1.9	11.5	1.9	11	3.2	19	13 x 13	11.6	2.5	28.0
13½ x 13½	12.0	1.1	5.5	1.6	9.5	1.6	9	2.7	16	14 x 14	12.6	2.3	22.8
14¾ x 14¾	12.5	.9	5.0	1.4	8.5	1.4	7	2.3	13	15 x 15	12.6	2.0	19.1
15½ x 15½	13.0	.8	4.25	1.2	7.0	1.2	6.5	2.1	12	16 x 16	13.6	1.7	16.6
16¾ x 16¾	13.5	.7	3.75	1.1	6.5	1.1	5.5	1.7	11				
18 x 18	14.5	.6	3.25	.9	5.5	.9	4.5	1.5	9	18 x 18	14.6	1.4	13.7
19 x 19	15.5	.5	2.75	.8	4.5	.8	4.0	1.4	8	20 x 20	15.6	1.1	11.3
20½ x 20½	16.5	.4	2.25	.7	3.75	.7	3.5	1.2	7	20 x 20	16.6	1.1	11.4
21¾ x 21¾	17.0	--	----	.6	3.25	.6	3.0	1.0	5.5	24 x 24	16.6	.78	6.6

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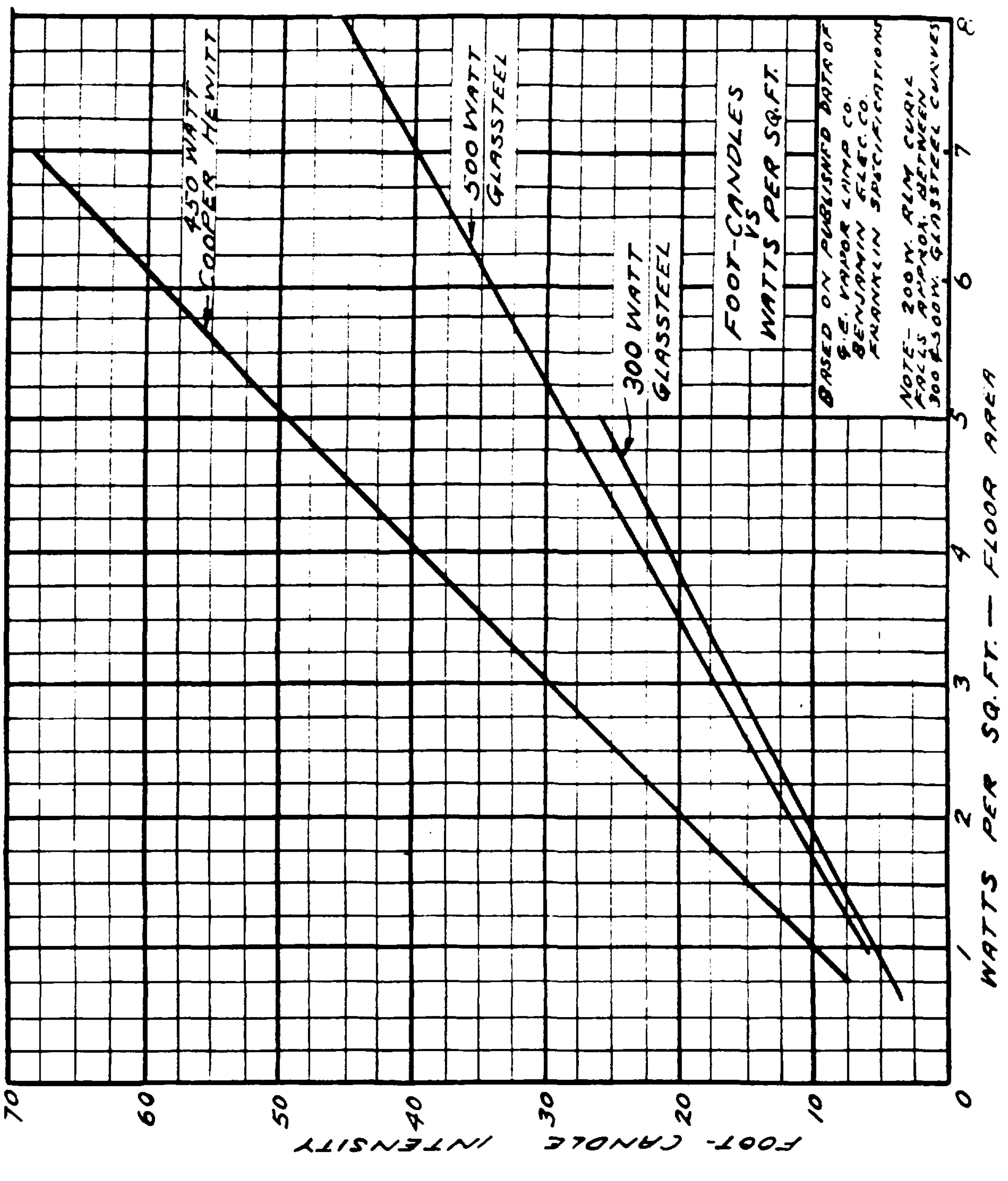
COMPETITIVE



NOTE: CURVES REPRESENT AVERAGE OF PLOTTED VALUES — VARY WITH COMPARABLE HEIGHTS & SPACINGS OF LAMPS

COMPARATIVE CURVES
FOOT-CANDLES
VS
WATTS PER SQ. FT.

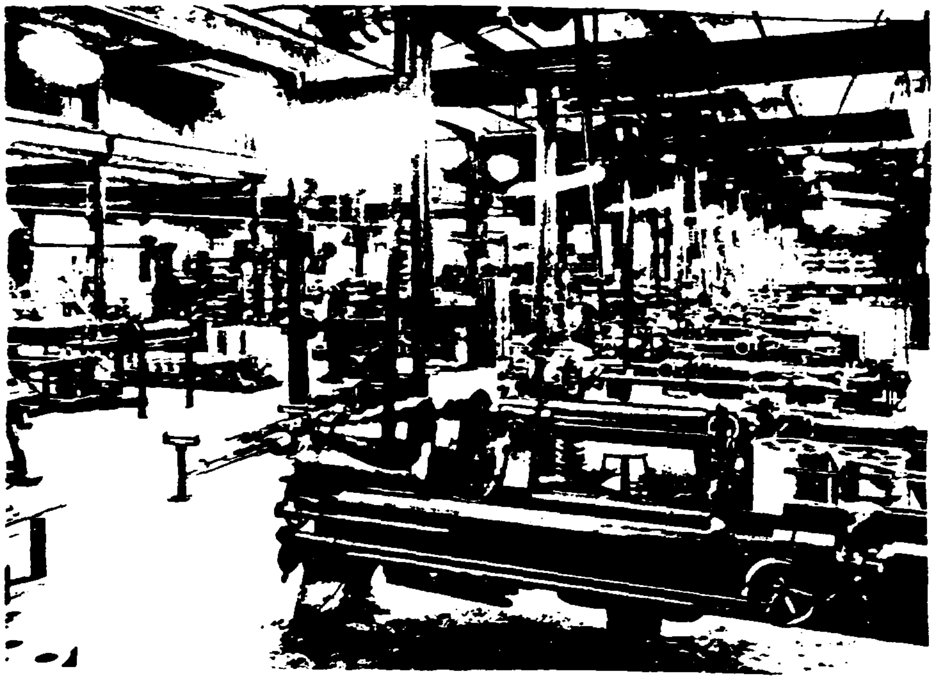
GENERAL ELECTRIC
VAPOR LAMP COMPANY
ILLUMINATING ENGINEERING DEPARTMENT
HOBOKEN, N. J.

DATE:-	DWN BY	CK BY	
5-31-34	G-J-F		S-181

707111

COMPARING QUALITY OF LIGHT PHOTOGRAPHICALLY

As far as actual value of lighting by comparison is concerned photographs tell the story with perfect accuracy. The lens of the camera projects the picture on the film, just as the lens of the eye projects the picture on the retina. Thus, in actual practice it is just as easy to pick out the best lighted shop as it is in the photographs here presented. There are no high spots of light reflected from bright metal parts of machines; neither are there shadows to obstruct vision when COOPER HEWITTS are on the job.

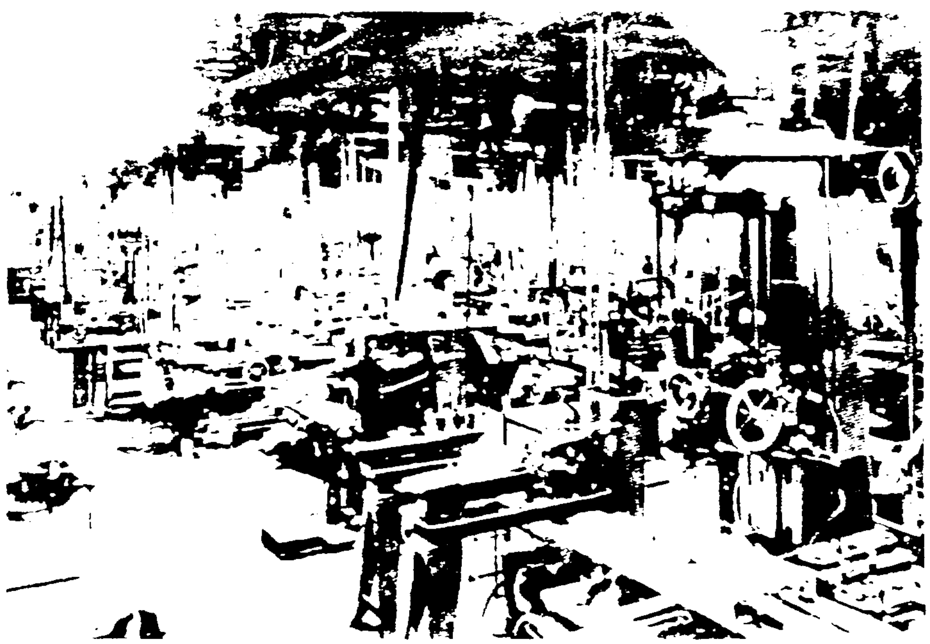


Modern COOPER HEWITT Installation

Modern installation — [illegible] watt Glassteel diffusers

707112

Modern installation - 200 watt RLM lamps

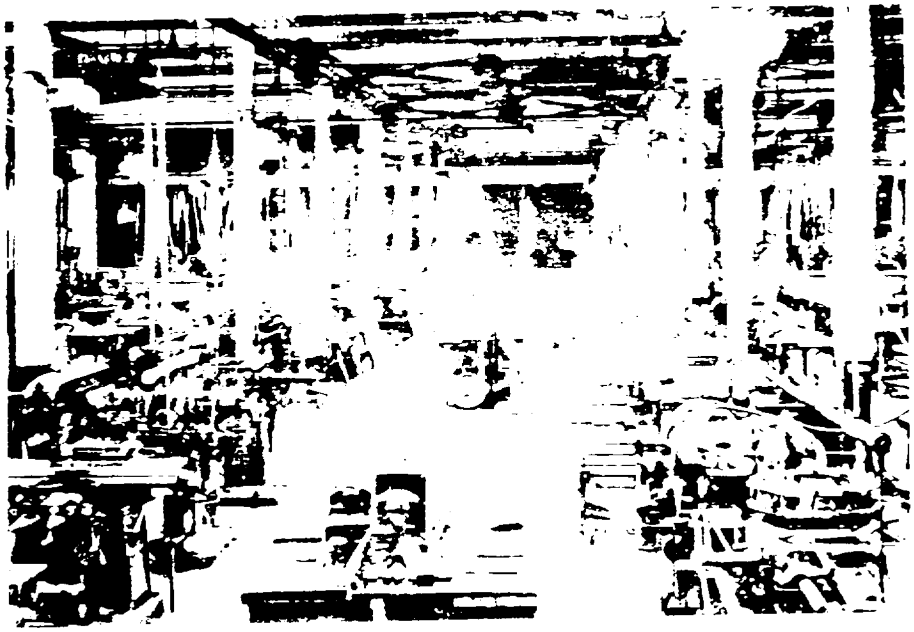


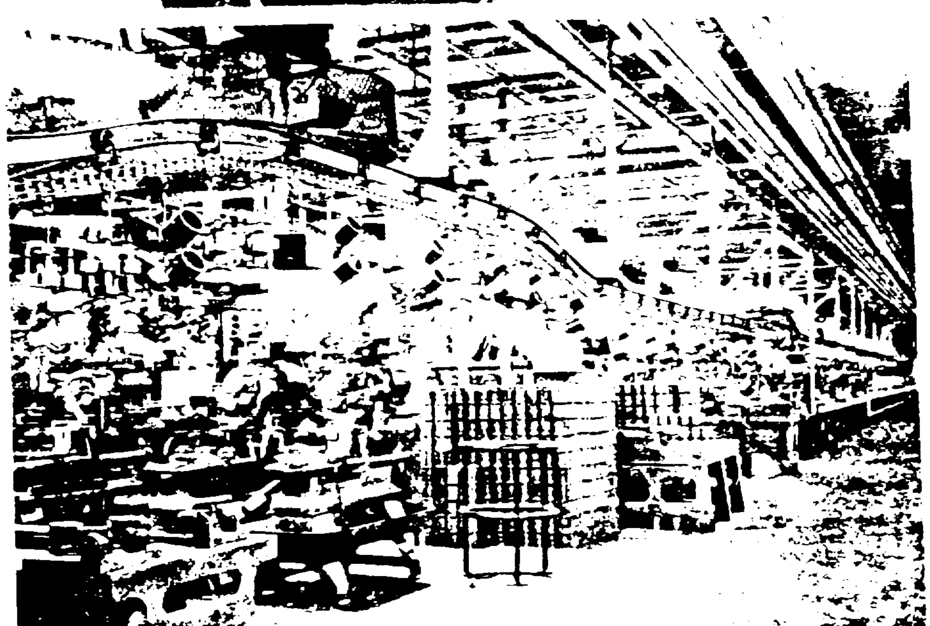
COOPER HEWITTS in a Machine Shop

Machine shop lighting is not only important, but difficult. Soft even diffusion with plenty of seeing power is required. The light must penetrate to the very minute point of seeing -- where the tool touches the metal. In the above COOPER HEWITT photograph, mercury vapor light reaches the working points making every smallest detail stand out as sharply and clearly as if magnified. Despite the forest-like appearance of this machine-filled room, no dark shadows interfere with the quick, accurate vision of operatives.

COMPETITIVE

MODERN COOPER HEW[illegible]





Carefully planned production lines deserve carefully planned lighting. C[illegible] [illegible] equal to the most exacting requirements for speed [illegible] assemblies. Its high visual value, reduction of shadow and lack of glare make quick and accurate seeing possible at every point in the operation.

707114

STANDARD PRICE SCHEDULE

MAZDA C LAMPS

Watts	Bulb	Screw Base	*Rated Initial Lumens	Rated Initial Lumens Per Watt	Std. Pkg.	List Price			Daylight Lamps Blue Bulbs		
									List Price		Rated Initial Lumens
						Clear	Inside Frosted	White Bowl	Clear	Inside Frosted	
40	A-19	Med.	432	10.8	120	—	$0.15	—	--	--	—
60	A-19	Med.	750	12.5	120	--	0.15	—	--	$0.30	490
75	A-19	Med.	1035	13.8	60	--	0.20	--	--	--	--
100	A-23	Med.	1520	15.2	60	—	0.20	--	--	0.35	988
150	PS-25	Med.	2505	16.7	60	$0.40	0.35	$0.45	$0.65	0.70	15[illegible]
200	PS-30	Med.	3400	17.0	24	0.55	0.60	0.60	0.90	0.95	2210
300	PS-35	Mogul	5520	18.4	24	0.90	0.95	0.95	1.35	1.45	3590
500	PS-40	Mogul	9800	19.6	12	1.55	1.65	1.65	2.30	2.45	6370
750	PS-52	Mogul	14550	19.4	6	3.75	—	3.95	--	--	--
1000	PS-52	Mogul	20500	20.5	6	4.00	—	4.20	—	--	--
1500	PS-52	Mogul	33000	22.0	6	5.75	—	5.95	--	—	--

230 VOLT - 1000 HOUR LIFE

Watts	Bulb	Screw Base	*Rated Initial Lumens	Rated Initial Lumens Per Watt	Std. Pkg.	Clear	Inside Frosted	White Bowl
100	A-23	Med.	1100	11.0	60	—	$0.38	--
200	PS-30	Med.	2720	13.6	24	$0.85	0.90	$0.90
300	PS-35	Mogul	4320	14.4	24	1.25	1.35	1.35
500	PS-40	Mogul	8000	16.0	12	2.15	2.30	—
750	PS-52	Mogul	12600	16.8	6	4.25	--	--
[illegible]	PS-52	Mogul	18300	18.3	6	4.75	—	--

April 1, 1935

*Lumens shown are approximate for clear and inside frosted lamps. For white bowl lamps lumens are approximately 3% less

DISCOUNT SCHEDULE

Net Value (Exclusive of Transportation Charges)	Discounts		Minimum Net Purchases Under Each Basis to Reach Next Higher Basis
	Standard Package Quantities	Broken Package Quantities	
TO PURCHASERS UNDER FORMS E AND CE CONTRACT			
Primary (Less than $150)	15%	10%	$ 159.38
$150	20%	10%	311.69
$300	23%	13%	616.00
$600	25%	15%	1,232.87
$1,200	27%	17%	2,570.42
$2,500	29%	19%	5,144.93
$5,000	31%	21%	10,298.51
$10,000	33%	23%	20,303.03
$20,000	34%	24%	30,461.54
$30,000	35%	25%	50,781.25
$50,000	36%	26%	101,587.30
$100,000	37%	27%	152,419.35
$150,000	38%	28%	228,688.53
$225,000	39%	29%	305,000.00
$300,000	40%	30%	....
TO PURCHASERS WITHOUT CONTRACT			
Any quantity in Standard Packages	15%		

Efficiency of Lamps Increases With Size

Lamp Size*	List Price	Lumens Output	Lumens per Watt	Lumens per Dollar of Lamp Cost†
25 Watt	$0.20	250	10.0	1,250
40 Watt	0.20	428	10.7	2,140
60 Watt	0.20	738	12.3	3,690
75 Watt	0.20	1,028	13.7	3,855
100 Watt	0.25	1,490	14.9	4,470
150 Watt	0.65	2,355	15.7	3,620
200 Watt	0.85	3,360	16.8	3,950
300 Watt	1.35	5,430	18.1	4,020
500 Watt	2.15	9,700	19.1	4,510
750 Watt	3.75	14,400	19.2	3,840
1,000 Watt	4.00	20,400	20.4	5,100
1,500 Watt	5.75	32,100	21.4	5,580

*25-watt to 500-watt rating, inside frosted; 750- to 1,500-watt rating, clear.

†On basis of equal length of life.

707115

16

COMPETITIVE

COMPARATIVE CHARACTERISTICS, ESTIMATE OF INSTALLATION AND OPERATING COST OF COOPER HEWITTS VS INCANDESCENTS, BASED ON LUMEN OUTPUT.

		C. H.	R. L. M.	R. L. M.	Glassteel
	1. Type of unit	C. H.	R. L. M.	R. L. M.	Glassteel
	2. Watts per unit	450	150 B.E.	200 B.E.	300 Cl.
	3. Avg. life in hours	5000	1000	1000	1000
*	4. Unit downward lumens	5625	1600	2380	3310
	5. Avg. of unit through life	85%	90%	90%	90%
	6. Avg. downward lumens through life	4780	1440	2140	2980
	7. Investment				
	A. Unit	$15.40	$ 2.32	$ 2.68	$ 7.60
	B. C. H. Tube (Std.Pkg.)	9.60			
**	C. Mazda Lamps (@ 23% Disc.)		.35	.46	.69
	D. Wiring and Installing per unit - estimated to include panels, fuses, switches, etc.	12.00	7.00	7.00	7.50
		$37.00	$9.68	$10.14	$15.79
	8. Non-operating overhead per unit				
	A. Ins. Int. & Taxes (10%)	3.70	.97	1.01	1.57
	B. Depreciation (15%)	5.55	1.45	1.51	2.36
		9.25	2.42	2.52	3.93
	9. Operating Cost per Unit				
	A. Hours burning per year	1000	1000	1000	1000
	B. Renewals-costs per year	$2.16	.36	.46	.69
	C. Cleaning	2.00	2.00	2.00	3.00
	D. Current @ 1.5¢ per KWH	6.75	2.25	3.00	4.50
		$10.67	$4.61	$5.46	$8.19
	10. No. of units to produce 320,000 downward lumens throughout life	67	222	150	107
	11. Cost of producing 320,000 downward lumens Based on #7	$2480.00	$2150.00	$1520.00	$1690.00
	12. Non-operating overhead on 320,000 downward lumens Based on #8	$ 620.00	$ 537.00	$ 378.00	$ 420.00
	13. Operating costs per year on 320,000 lumens Based on #9	$ 715.00	$1023.00	$ 820.00	$ 875.00
	14. Investment in percent of Cooper Hewitts (#11)	100.	86.7	61.30	68.2
	15. Operating cost in percent of Cooper Hewitts (#13)	100.	143	114.	122.

* RLM = 66% of lamp lumens in 0°-90° zone. Glassteel = 60% of lamp lumens 0° - 90° zone.

** 1935 Price List.

GEVLCO (060135)

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COMPARATIVE COSTS OF FACTORY LIGHTING

1000 MAZDA 300 WATT GLASSTEEL - VS - 500 COOPER HEWITT 450 WATT UNITS

LIGHTING 100,000 Sq. FT. OF FLOOR AREA

Service 3000 Hours Per Year - Current @ 1½¢ per KWH.

Type of Unit	Glassteel Mazda	Cooper Hewitt	
Average foot candles	20	20	
Spacing	10' x 10'	10' x 20' (or 14'x14')	
Square feet per lamp	100	200	
Lamp units required	1000	500	
FIRST COST			
Lamps, reflectors, hangers	$7.50	$15.40	
Bulbs or tubes	(1000 hrs.) .62	(6000 hrs.) 9.60	(1000 hrs.1.60)
Feeders, cabinets, wiring and labor	$15.00	$15.00	
Extra 75 KW trans. @ $10.00/KW	$750.00		
Cost - Lamps, bulbs or tubes & wiring complete	$23,870.00	$20,000.00	
A-Saving in first cost			$3,870.00
CURRENT COST			
Watts per sq. ft.	3	2¼	
Watts per lamp	300	450	
Total kilowatts	300	225	
Cost - 3000 hrs. @ 1½¢ per KWH	$13,500.00	$10,125.00	
B-Saving in Current Cost			$3,375.00
MAINTENANCE COST			
Average hours life	1000	6000	
Renewals per 3000 hrs.	3000	250	
Cost of renewals - each	62¢	$9.60	
Total renewal cost	$1,860.00	$2,400.00	
C-Savings in renewals	$540.00		
Cost of Current & Renewals	$15,360.00	$12,525.00	
Savings in Current & Renewals - B & C			$2,835.00
Total Savings (3000 hrs.) A - B - C			$6,705.00
Savings per 1000 sq. ft. per 1000 hrs. - Current & Renewals			$ 9.45
First Cost Per Sq. Ft. - Floor Area	$2.34	$2.00	

MAINTENANCE

Maintenance

Lighting equipment should be treated with the same degree of care as shop machinery. In order to get the most useful work out of machinery a periodic cleaning schedule is essential. This is no less true with a lighting system. Dust and dirt are bound to accumulate on tubes and reflectors causing them to absorb almost as much light as they transmit. No one would permit an automobile to run without oil; the reason being obvious. Dirty lighting equipment is actually the same as an automobile without a sufficient quantity of oil, but for psychological reasons it is not as apparent. Simply expressed: "Soap and water is to a lighting system what oil is to an engine."

LOSS OF LIGHT

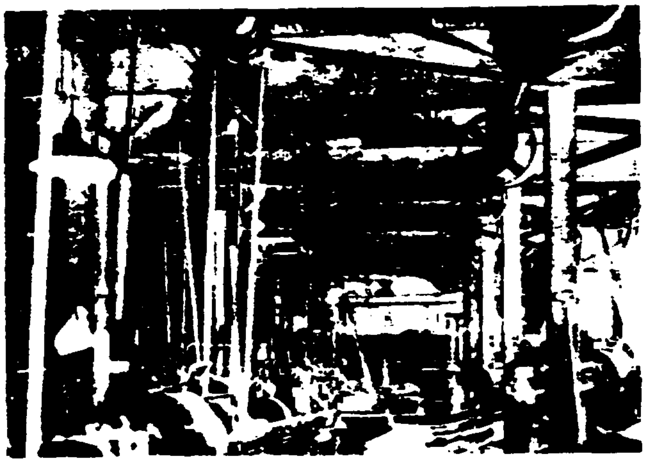
There are many causes for the loss of light to a given working area. The principal causes, for a COOPER HEWITT installation, may be given as follows:

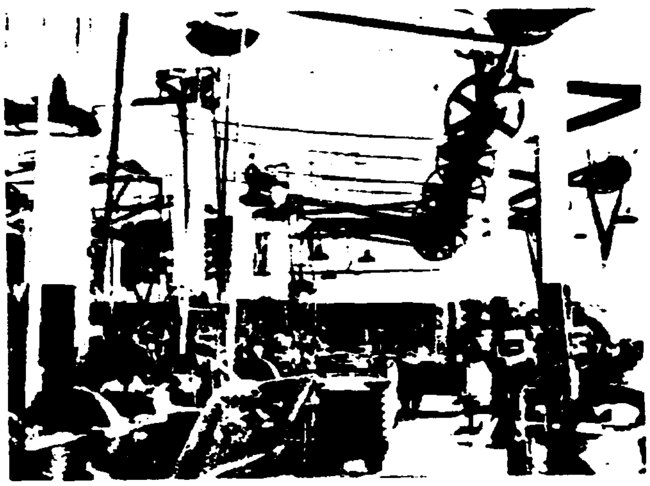
1. Dirty reflector and tubes.
2. Tube depreciation.
3. Inoperative lamps.
4. Under-voltage burning of lamps.
5. Darkened walls and ceilings.

The first and last items listed above are obviously a case of cleanliness. Light colored paint, with good reflecting power, is becoming very popular where good lighting is appreciated. Even the painting of machinery is recognized by many as good practice, especially where close work is being done. Of course, the color of the paint must not be overlooked.

VALUE OF PAINT IN INDUSTRY

Lighting is greatly assisted by the proper painting of ceilings and sidewalls. Various specifications have been set down by paint manufacturers recommending certain paint combinations that will give best results, both as to reflection factor and durability of the paint on certain surfaces.





By way of contrast. Dark, gloomy work places are inefficient and depressing. Application of light paint heightens visibility and improves the morale of workers

The adjoining pictures, before and after painting, require no explanation. Note that in the unpainted picture the lamps are burning while in the painted picture they are not.

Below is an interesting table prepared by Dr. Henry A. Gardner, (Director, Paint and Varnish Industry's Research Laboratories, Washington, D.C.)

LIGHT REFLECTING VALUE OF COLORED PAINTS

Color	*Per Cent of Light Reflected*
White, new	82–89
Cream	73–78
Ivory	62–80
Buff	61–75
Aluminum	65
Light green	49–66
Yellow	48–75
Gray	36–61
Light blue	34–61
Pink	30–46
Dark tan	17–63
Dark red	13–30
Dark green	11–25
Light wood varnish	42–49
Natural wood, brown stain	17–29

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Many manufacturers have found it profitable to paint machinery. Again the accompanying photograph illustrates the real worth of paint in industry. No longer is paint merely considered a supplement to industrial architecture -- it is becoming more and more popular by being recognized as part of the fundamental design of factory illumination.

Sisters under the skin—but one was painted with an oil-proof white. The result was so striking that the entire department received similar treatment

It ties in with illumination because in any lighting system there is always a certain amount of 'spill' light that reaches the walls and ceilings; this light will be entirely wasted unless the surface is capable of reflecting it down on the working areas. Painting of machinery materially aids in intercepting light and reflecting it to working points. Good painting also reflects cleanliness and good housekeeping.

EFFECT OF DUST AND DIRT

A good lighting system is installed for many reasons. From the investment standpoint alone, production is expected to increase. The effect of dust and dirt may materially reduce this rate of increased production. The accumulation of dirt on tubes and reflectors varies according to location of lamps.

The loss of light due to dust and dirt accumulation also depends to a large extent upon the lighting unit. Sometime ago the I.E.S. Transactions published results of incandescent luminaires.

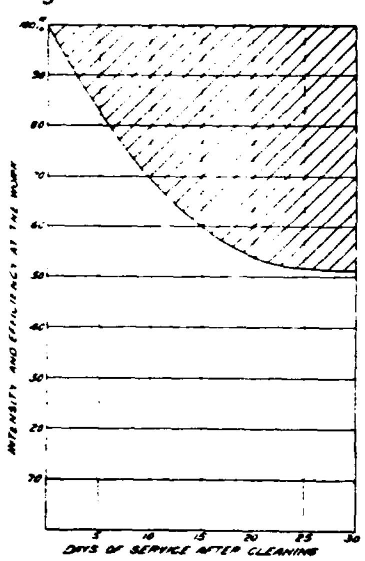
The results of the tests, given below, showed in general, that the rate of depreciation was lowest with direct open shades, somewhat higher with direct enclosing globes, and highest with semi-indirect and totally indirect units.

ACTUAL DEPRECIATION OF LIGHTING EQUIPMENT AS AFFECTED BY EQUIPMENT DESIGN*

Luminaire	Description	Actual Depreciation 120 Days Dry Fine Dust In Per Cent	Luminaire	Description	Actual Depreciation 120 Days Dry Fine Dust In Per Cent
1	Dense opal glass—clear lamp	11.2	9	Frosted ball—top and bottom open	15.0
2	Prismatic glass—clear lamp	12.4	10	Semi-enclosing opal bowl with diffusing plate	27.2
3	Deep enameled steel bowl—clear lamp	11.5	11	Dense opal bowl	22.5
4	RLM Dome—clear lamp	12.8	12	Enameled metal reflector with opal glass bottom	26.0
5	RLM Dome — bowl-enameled lamp	16.3	13	Mirrored glass bowl	26.2
6	Diffusing globe and enameled steel reflector	22.9	14	Clear top with bottom opening	35.6
7	Diffusing globe—no vent	13.4	15	Clear top without bottom opening	15.0
8	Diffusing globe—bottom vent	22.7	16	Prismatic, without bottom opening	10.1

* Transactions of Illuminating Engineering Society, Anderson and Ketch, Vol. XIX. No. 1. 1924.

In locations where grease frequently lodges on the reflectors more light is lost than where mere dust is prominent. Some idea of the effect of dirt on lighting equipment is given by the accompanying curve. In extreme cases the amount of light consumed by dirt approximates 50 percent in 30 days.



When selecting a particular lighting system, some thought should be given to the surrounding conditions with respect to the depreciation of light from a luminaire.

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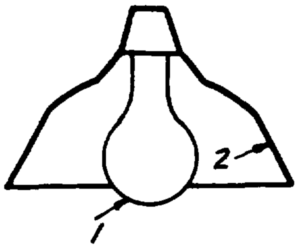
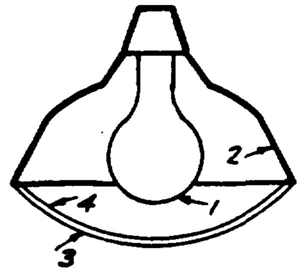
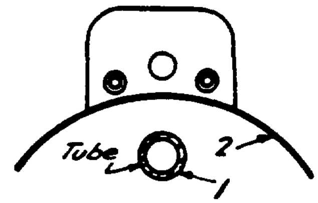
Units that are simple to clean must also be considered, in order that maintenance costs may be reduced to a minimum. The three most widely used lamps are represented below. The numbers indicate the surfaces upon which dust and dirt will accumulate.



RLM DOME



GLASSTEEL



COOPER HEWITT

The RLM Dome will suffer a loss of light due to a dirty bulb (1) and a dirty reflector (2). The dirt around the bulb actually absorbs some of the light passing through it, while the dirt on the reflector absorbs light coming to it and also being reflected from it. In any event, there are two surfaces which absorb light in this lamp and the same conditions prevail in the case of the COOPER HEWITT lamp.

The Glassteel lamp is used to diffuse light and thus reduce glare. However, the addition of this globe naturally absorbs light and to obtain the same candlepower reading as the RLM lamp the wattage rating of the electric light bulb must be increased. Another handicap is the two additional surfaces (3) and (4) upon which dust and dirt will accumulate. The light must pass through these two dirty surfaces losing power in addition to that from the surfaces (1) and (2).

Suggested Cleaning Schedules For Direct Lighting Systems

Characteristic of Location	Interval in Days if Units are Wiped out*	Interval in Days if Units are Thoroughly Washed
Very Dirty	3	5
Dirty	7	10
Average	15	20
Clean	30	40

*Washing every third or fourth interval assumed.

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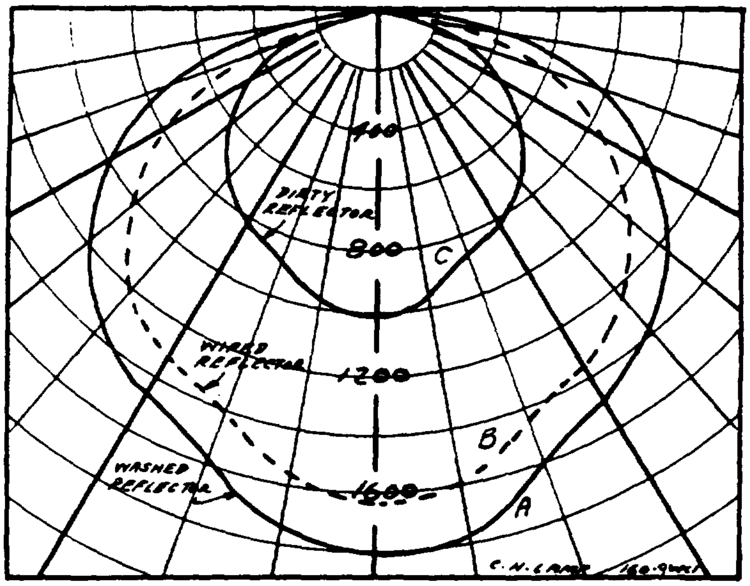
PHOTOMETRIC ANALYSIS OF DIRT ACCUMULATION

The approximate variation of photometric rating of a dirty lamp is illustrated by the curves below.



It is difficult to attempt to set down a method of cleaning or a schedule of cleaning lighting equipment. In places where dry dust settles on the lamp it may be sufficient to merely wipe off this dust with a clean dry cloth on the average of not more than every two weeks. A wiped reflector does not return the light giving value of a lamp back to its original efficiency as denoted by the dotted curve B. Each successive wiping will diminish the extent of this curve B, so it is naturally advisable to wash a lamp at definite intervals. A simple and effective schedule would be to interchange dry wiping and washing as required.

The lamp with a photometric rating as represented by curve A, pays dividends to the manufacturer. Even curve B is acceptable, as a profit sharing item, but curve C is unreasonably low in candle-power intensity.

From the characteristic shape of these curves it is readily apparent that there is truth in the familiar saying -- "Water is cheaper than Watts."

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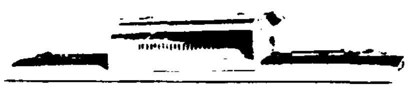
COST OF MAINTENANCE

Referring again to the photometric sketch, curve C indicates that the lamp can be rated as only half a lamp, or two dirty lamps give only as much light as one clean lamp. Furthermore, one lamp costs only one-half as much to maintain as two dirty lamps.



1.	One clean lamp- - - - EQUALS - - - -	Two dirty lamps
2.	Light output (5625 lumens)	Light output (5625 lumens)
3.	Current - 450 watts	Current - 900 watts
4.	Power cost per month - 25¢	Power cost per month - 50¢
5.	Maintenance per month- 25¢	Maintenance per month- 50¢
6.	Total operating cost - 50¢	Total operating cost - $1.00

Cost of cleaning - 5 cents per lamp

or

Only 5% of total operating cost

at

An increase in illumination of 50%

ONE DIRTY LAMP- - - - EQUALS - - - -  HALF A LAMP

The loss of light by deposits of dust and dirt on reflectors is costly in another respect. Unfortunately as the light intensity decreases the power consumption remains at a constant value. If it takes two dirty lamps to produce the same amount of light as one clean lamp, then the power consumed will be twice as much for equal intensities of illumination. Reliable collective data has shown that the cost of cleaning a **COOPER HEWITT** lamp is in the neighborhood of five cents, while the cost of renewals and maintenance is about twenty-five cents per lamp per month. The power consumed by an alternating current lamp on an average will amount to about 25¢.

Thus, the cost of cleaning is only 5 percent of the total operating cost of a lighting installation and the increase in illumination is 25 to 50 percent or more.

TYPICAL EXAMPLES OF LIGHT LOSS

Many articles in popular periodicals have emphasized the importance of cleaning lamps, but failed to convince manufacturing executives that they should proceed with regularly adopted maintenance schedules. A few typical examples of the loss of light due to dirt accumulation has been taken in prominent industrial concerns and will be reproduced here to prove that dirty lamps absorb 50% or more of the light output.

1. Spalding Knitting Mills.

   Dirty lamp -- 31 ft.c. on top of yarn carrier
   -- 20 ft.c. at cylinder

   Lamp cleaned -- 50 ft.c. on top of yarn carrier
   -- 30 ft.c. at cylinder

   60% increase in lighting on top of carrier
   50% increase at cylinder

2. Dodge Motor Company - Tests in Lathe Production Dept.

   Dirty lamps averaged - - - - 3.6 ft.c.
   Clean lamps averaged - - - - 8.6 ft.c.

   140% increase in lighting

3. International Harvester Co. (Rock Island).

   Area of 100 lamps

   Dirty lamps averaged - - - - 11 ft.c.
   Clean lamps averaged - - - - 16 ft.c.

   45% increase in lighting

4. International Harvester Co. (McCormick Works).

   Dirty lamp - - - - - - - 16 ft.c.
   Clean lamp - - - - - - - 40 ft.c.

   150% increase in lighting

5. The Trio Laundry (Atlanta, Ga.)

   Test on one lamp with meter at two heights above the floor.

Height	Dirty lamp	Clean lamp	Light increase
2.5 ft.	5.7 ft.c.	20 ft.c.	250%
5.5 ft.	10.2 ft.c.	42 ft.c.	310%

6. Cincinnati Office tests:

Test No. 1

Dirty tube and dirty reflector - - - - - 21 ft.c.
Clean tube and " " - - - - - - 22½ ft.c.
Clean tube and clean reflector - - - - - 26½ ft.c.

Test No. 2

Distance from tube	Dirty Reflector	Clean Reflector	Light Increase
4 ft.	72 ft.c.	105 ft.c.	50%
6.5 ft.	32 ft.c.	42 ft.c.	31%

In this test a new clean tube was used; consequently the reflector alone is responsible for the light loss.

Not only does a dirty lamp reduce the light output but there is a 'shrinking of the initial form of the distribution curve. A lighting system that originally gave high uniform average intensity of illumination, will eventually become unsatisfactory because of uneven distribution and low intensity of light, if it is not properly cleaned at frequent intervals. This means that lighting is only accomplishing part of its job. It may also mean that only one-half of the workmen are receiving fair light, while the remaining half are working with very poor light.

During the past 5 or 6 years there has been a decided improvement in the methods of wiring and installing COOPER HEWITT lamps with a result of marked improvement in the operation and maintenance cost. Present day problems of lighting are not ---

The high cost of lamp maintenance

but

The high cost of neglect

There are a multitude of instances where attention on the part of the customer's maintenance crew has made a drastic cut in the cost of maintaining lamps.

HIGH COST OF DAYLIGHT

In the American Machinist (May 1927) Luckiesh has this to say about daylight in regard to depreciation:

> "Dirt accumulation on windows is very great and in six months time may reduce the daylight value 50 percent. Investigation has shown that three-fourths of this dirt is on the inside of factory windows. Thus, it is seen that this particular feature can be largely overcome by merely cleaning the inside of the windows, which is usually easier than cleaning the outside. Samples of window glass taken from factories and skylights have been found after cleaning to increase their light transmission from 5 to 250 times."

An automobile concern reported that the cost of cleaning windows twice a year amounted to as much as the cost of renewals for COOPER HEWITT lamps for one year. This is evidence that the cost of maintaining daylight 4 to 6 hours a day is equal to the cost of maintaining artificial light 8 to 16 hours a day. Ordinary daylight and skylight illumination is usually thought to be inexpensive. On the contrary, it has been pointed out, daylight is of high initial cost, expensive to change, gives rise to loss of heat in cold weather and is frequently costly to maintain. Except in very rare cases artificial illumination is the most preferable.

TUBE DEPRECIATION

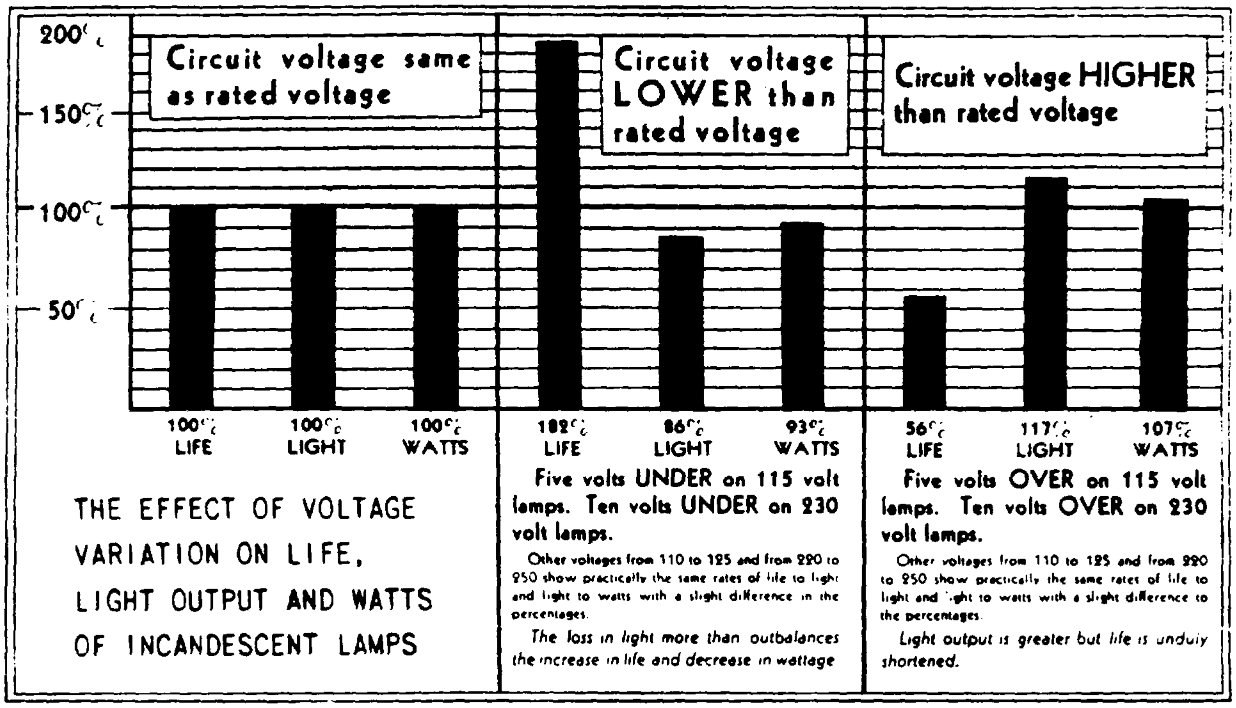
An unavoidable circumstance which contributes to the loss of light from illuminants is "tube depreciation". Such a depreciation will cause a "shrinking" effect of the distribution curve. With COOPER HEWITT lamps this effect is slow, since at the end of 6000 hours of operation the alternating current lamp gives 78 percent of its initial light output, and 86 percent for the direct current lamp at the end of 6000 hours of operation. A tube with 25 percent depreciation should be considered as past its prime of usefulness and replaced by a new tube. On the basis of burning a lamp on the average of four hours a day, the life or usefulness of a tube is over four years. This, of course, is excellent service when compared with the average 1000 hour life of an incandescent lamp.

WIRING REQUIREMENTS

The central station is responsible only for delivering voltage to the meter. The consumer must determine the size of wire to the lamps in order to maintain the necessary voltage supply. City ordinances and fire underwriters' rules specify minimum sizes of wire for safety but not necessarily adequate for economic operation.

Since incandescent lamps are designed to operate on a particular voltage the variation should not be very great above or below the rated voltage. Over-voltage burning reduces the life of a lamp. While over-voltage increases the light output of a lamp, this gain is outweighed by the item of lamp replacement costs. Under-voltage burning shows less consumed electricity and longer lamp life, but with a distinct disadvantage of smaller light output. Unfortunately the last factor of light loss far overbalances the other two mentioned.

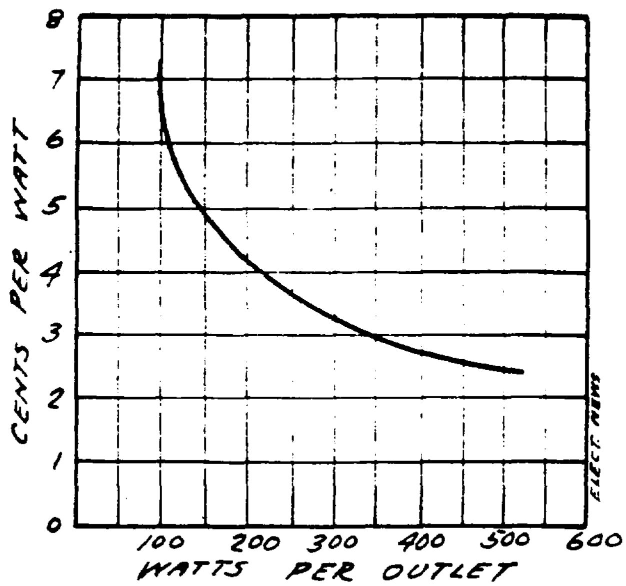
It has been shown that for every one percent drop in voltage, the wattage is reduced one and one-half percent and the amount of light over three percent. In spite of the fact that lamp life is increased and wattage consumption decreased, it has also been shown that on the same light basis there is a substantial increase in the unit cost of light.



THE EFFECT OF VOLTAGE VARIATION ON LIFE, LIGHT OUTPUT AND WATTS OF INCANDESCENT LAMPS

COOPER HEWITT lamps are subject to approximately the same conditions of over-voltage and under-voltage characteristics as the incandescent lamps, but due to the auxiliary apparatus certain corrections for prevailing voltages may be readily made. In the case of an alternating current lamp, connections can be made by means of the transformer taps to voltage limits from 100 to 120 volts. In addition to these transformer connections, ten percent variations in line voltage is readily absorbed by the auxiliary protective features without serious damage to the lamps. No other lighting system is so well guarded from the bad effects of supply line variations.

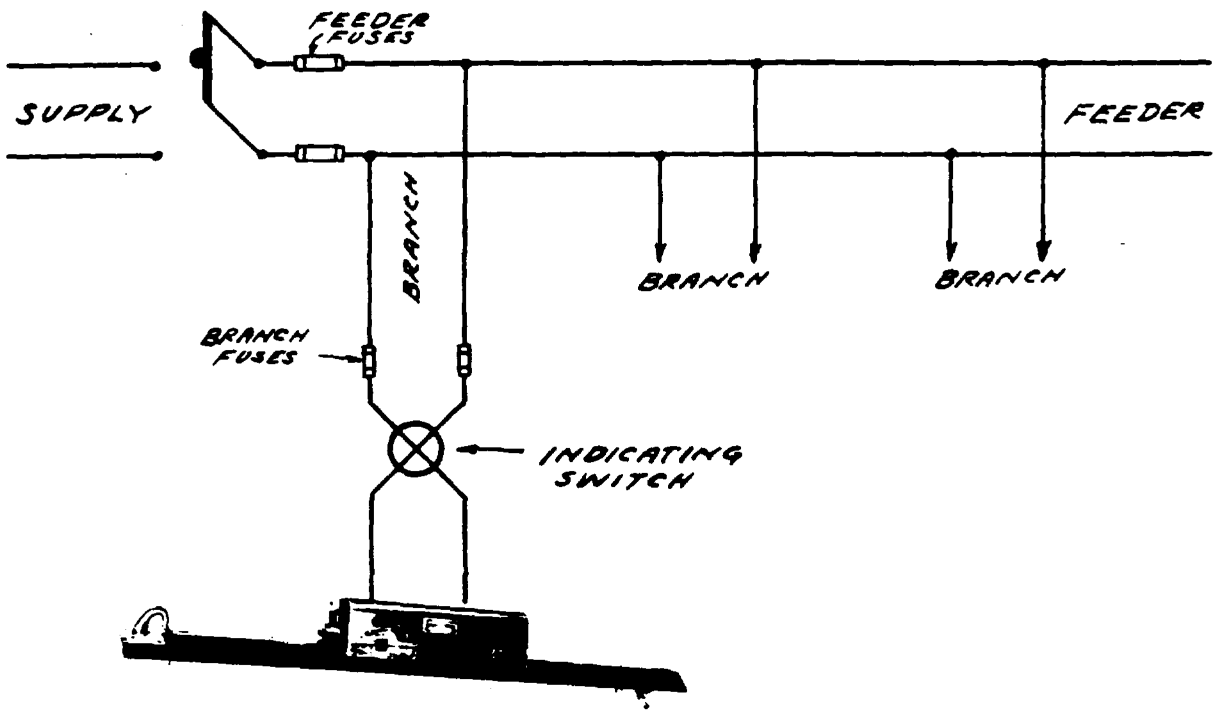
Some time ago the Electrical News published an article which included a curve giving the cost per watt of wiring installation. The results, responsible for the curve, were obtained and averaged from eleven estimates. It is cheaper to install wiring for 200 watt requirements than for 400 watts. However, the cost is materially increased when two 200 watt units are wired as compared with one 400 watt unit.



Wiring of any installation is important, since good wiring aids good lighting. With COOPER HEWITT lamps the wire size is given. The supply voltage should be carefully checked and recorded. After all wiring to outlets is completed a recording voltmeter should be installed at various outlets for not less than 24 hours. This will give accurate voltage conditions as they exist and proper connections can then be made. Voltage fluctuations are bound to occur during different times of the day due to no load or light load on the system. During darker hours of the day and at night time, when artificial lighting should be at its best, it may be at its worst because of heavy lighting loads. With COOPER HEWITT lamps this may be almost entirely eliminated by checking the voltage at the lamps.

COOPER HEWITT WIRING RECOMMENDATIONS

A. C. Lamp 110 volts		A. C. Lamp 220 volts		D. C. Lamp 110 and 220 v.	
Size of wire	Capacity of fuse (amps)	Size of wire	Capacity of fuse (amps)	Size of wire	Capacity of fuse (amps)
No. 12	15	No. 14	10	No. 12	10
Length of run not to exceed 100 feet					



Wiring diagram of Cooper Hewitt lamp circuit

707132

COOPER HEWITT INDUSTRIAL MAINTENANCE

TYPICAL FOR A YEAR - 1933

PRODUCT	NO. INSTAL-LATIONS	NO. LAMPS	TOTAL MAIN-TENANCE	COST PER LAMP PER YEAR
Aluminum	16	3,759	6,998	$1.84
Asbestos	3	228	565	2.47
Automobile	52	71,327	149,913	2.10
Brass	7	145	593	4.08
Cotton	89	7,565	27,010	3.57
Die & Tool	44	3,103	1,552	0.50
Enamel	7	314	51	0.16
Glass	41	1,651	9,464	5.73
Hosiery	130	11,912	23,154	1.94
Laundry	20	496	341	0.68
Leather	4	41	94	2.29
Machine	246	28,523	38,688	1.35
Metal	8	225	73	0.32
Paper	24	1,234	2,228	1.80
Printing	87	3,563	8,504	2.38
Radio	1	93	---	---
Rubber	27	2,124	3,750	1.76
Shoes	7	343	759	2.21
Silk	113	10,360	17,465	1.68
Silver	1	86	51	.59
Steel	35	2,577	6,083	2.36
Tin	23	3,034	8,203	2.70
Underwear	17	1,172	2,392	2.04
Wire	15	378	407	1.07
Woodworking	17	1,851	1,198	0.64
Wool	32	704	1,613	2.29
Zinc	6	315	1,011	3.20
Miscellaneous	407	17,889	23,869	1.33
TOTAL	1,509	175,641	335,719	$ 1.91

In addition, the following figures are typical of the general performance of COOPER HEWITT Lamps throughout the country.

No. Installations Reported On		Cost Per Lamp Per Year	Cost Per Lamp Per Month
1928	1214	$5.93	$0.50
1929	1477	4.11	0.35
1930	1580	2.50	0.21
1931	1565	2.06	0.17
1932	1497	1.65	0.14
1933	1509	1.91	0.16
6 YEAR AVERAGE		$3.03	$0.25

707133

MAINTENANCE

OPERATING COST DATA
COOPER HEWITT A. C. LAMP
450 WATTS - 115 or 230 VOLTS

Complete operating cost per lamp per hour including:

1. Interest on investment at 6%
2. Depreciation at 10%
3. Current at indicated rates
4. Tube maintenance (Standard package discount - 20%)

Burning Hours Per Yr.	With average current rate per KW. Hr.				
	1¢	1½¢	2¢	2½¢	3¢
1000	$0.0101	$0.0123	$0.0146	$0.0168	$0.0191
1500	$0.0090	$0.0109	$0.0133	$0.0155	$0.0177
2000	$0.0081	$0.0104	$0.0126	$0.0149	$0.0171
2500	$0.0077	$0.0099	$0.0122	$0.0144	$0.0171
3000	$0.0072	$0.0097	$0.0119	$0.0141	$0.0164
3500	$0.0072	$0.0095	$0.0117	$0.0140	$0.0163
4000	$0.0071	$0.0094	$0.0116	$0.0138	$0.0161

Sample calculation

Burning hours per year------------------------------------2000 hours
Current---1½¢ per KW Hr.
Average life of tube--------------------------------------6000 hours
Current consumption per lamp------------------------------450 watts
First cost of lamp--$25.00
Renewal tube--$9.60
Depreciation--10%
Interest--6%

Interest and depreciation .16 x 25.00 = $ 4.00
Current 2000 x .450 x .015 = $13.50
Tube maintenance 2000/6000 x 9.60 = $ 3.20

Total cost per 2000 hours burning-------------------------$20.70
Total operating cost per lamp per hour--------------------$ 0.01035

GEVLCO (060135)

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EFFICIENCY OF A LIGHTING SYSTEM

It is evident that industrial illumination is a specialized art. Much experience and thought is necessary in the planning and engineering of a factory lighting system. The lighting expert must understand the machinery that is to be lighted. Certain types of work require light to be directed from a definite angle. Each lamp must be considered as a definite piece of equipment and placed at a certain height and distance from a machine or work bench.

The efficiency of a good lighting system also depends upon the manner in which outlets are spaced for existing lamps as well as future lamps that might be needed. Wiring must always be of such size as to deliver maximum voltage to the lamps. With COOPER HEWITT lamps the choice of wire size is not complicated by means of calculation.

Once the lighting system is approved and installed a schedule of maintenance should immediately be authorized. Regular inspection of lighting equipment with a foot-candle meter will indicate whether or not the illumination efficiency is being maintained. Ammeter and voltmeter tests at certain intervals will relate the efficiency of lamp operation. Periodic cleaning of lamps and reflectors is essential. The time between cleanings and the kind (washed or wiped) of cleaning depend on the conditions in various departments.

LAMP DATA

Lamp Data

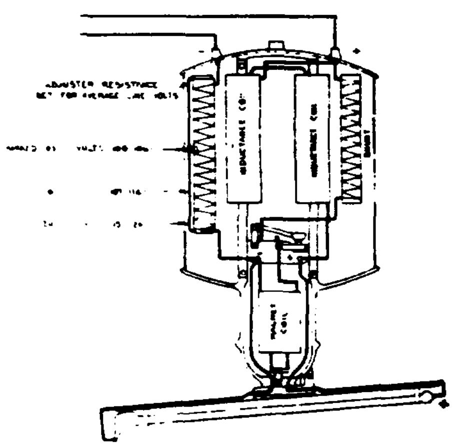
The construction of COOPER HEWITT lamps from their inception has varied somewhat in outward appearance, but the theory of operation has been practically unaltered. The first really practical lamp for industrial use was one using a quartz tube, surrounded by a large glass reflecting unit. Many of these units were installed but because of the quartz tube they were rather expensive and soon replaced by lamps using ordinary 'lead glass'. These lamps were of the linear type and operated with their glass tubes exposed, rather than surrounded by a glass bulb as in the case of the quartz lamps.

EARLY TYPE LAMPS

The very early form of regular COOPER HEWITT lamps that became popular in industry contained the auxiliary equipment in a barrel-shaped housing to which the reflector was attached. Two methods of starting or lighting the lamps were used:

1. Non-automatic tilting
2. Automatic tilting

In either case starting was accomplished by causing the mercury in the tube to momentarily form an uninterrupted stream between the negative and positive electrodes. When this stream was broken the lamp or tube lighted. In the non-automatic lamps tilting was done manually while the automatic lamp tilted by means of a magnet. These units were referred to as Type H lamps - the automatic type is shown by the accompanying diagrammatic sketch. Originally two lamps operated in series (110 volt supply) and later two tubes were mounted under a single reflector. The light giving length of each tube was 20¼ inches.

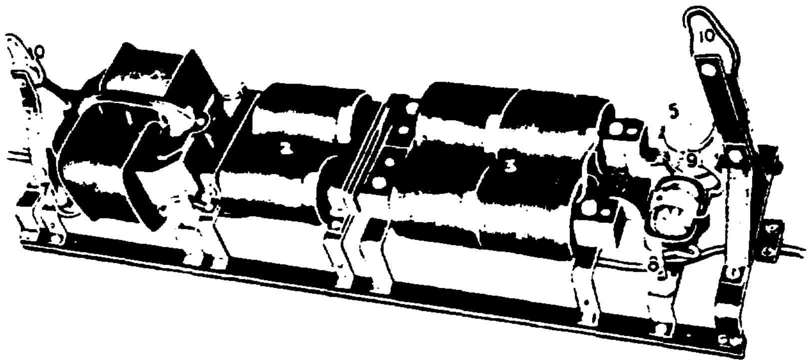


TYPE H LAMP

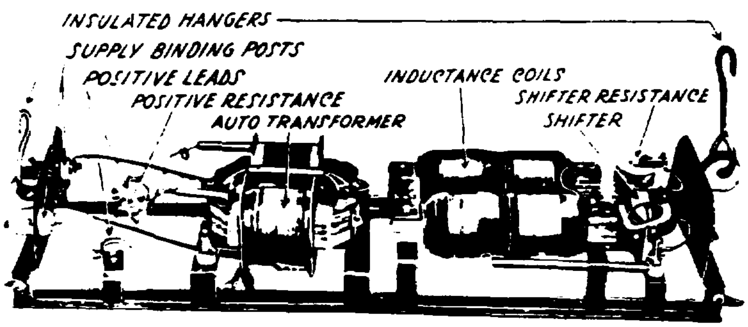
Next followed the Type K lamp using one tube 45 nches long.

ELECTRICALLY STARTING LAMPS

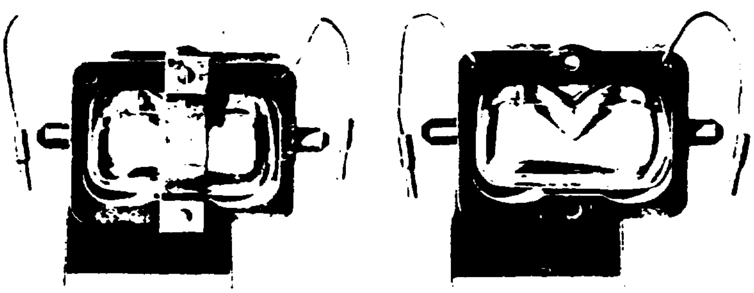
Although lighting was accomplished by means of the magnet coil, it was not really practical nor satisfactory due to the fact that a mechanical operation was necessary. After much experimentation an electrical method of starting was accomplished; the old moving or tilting lamp was doomed. The earlier electrically starting lamps were known as Type P (Direct Current) and Type F (Alternating Current). Two of the earlier alternating current models are shown below.



TYPE F LAMP - EA AUXILIARY



TYPE F LAMP - EC AUXILIARY



Shifter Complete, and with Band Removed to Show Mercury Bridge.

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The tube in the EA lamp was 50 inches long. A choke coil was used to regulate the lamp tube current. Starting was automatic, using a shifter. The power factor was 52 percent. Along with this unit was developed the Type E lamp with a 35 inch tube and 68% power factor.

Objection was raised to EA lamps because of low power factor. The EC lamp with 50 inch tube was developed and operated at 85% power factor.

These lamps grew up with the electrical industry. As new discoveries were developed in regard to copper wire, insulation, resistance wire, etc., COOPER HEWITT lamps kept pace with the times. Inductance coils, auto-transformers and series resistance coils used materials and design to give high efficiency and continued service.

All improvements possible were added to the Type F (EAC auxiliary) lamp which eventually developed into lamps known as 160-6WLI and 160-7WLI using 50 inch tubes.

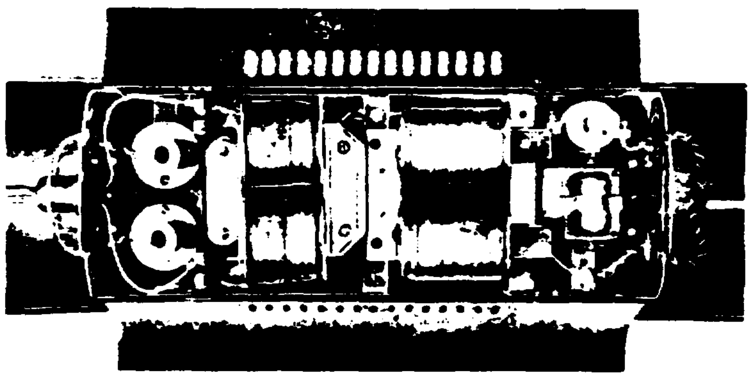
A very important improvement in these lamps was in the positive resistance coils which regulate the current of the lamp. These units are in series with the lamp tube; any increase in temperature rapidly increases the resistance of the resistor. If an increase in line voltage produces an increase in current and hence an elevation of the temperature of the resistor, the resistance of the resistor is thereby increased to such an extent that it absorbs nearly all the line voltage increase with only a slight increase in current. As a result, the operating characteristics of the lamp tube are but slightly affected.

[illegible]

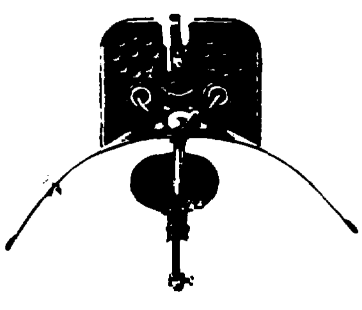
It is obvious that any given percentage change in line voltage has relatively less effect on the current in a lamp equipped with COOPER HEWITT regulating resistance units than in one equipped with ordinary resistance.

COOPER HEWITT LAMP - NO. 160-7WL1

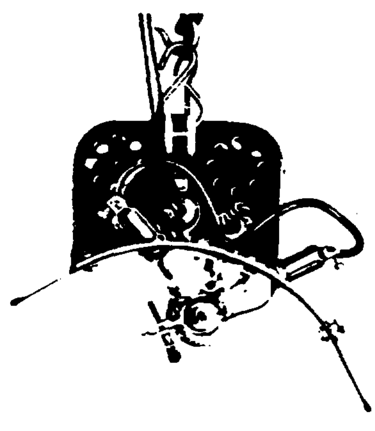
Complete Unit



Auxiliary Completely Wired.



Cathode (Negative) Connections.



Anode (Positive) Connections.

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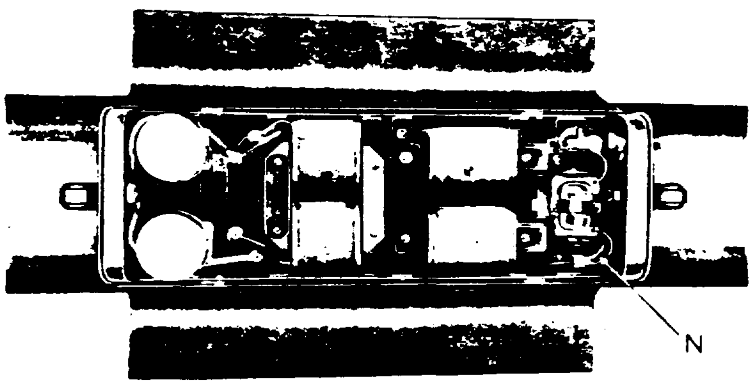
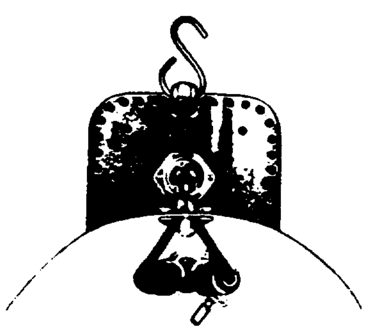
COOPER HEWITT LAMP - NO. 160-9WL1

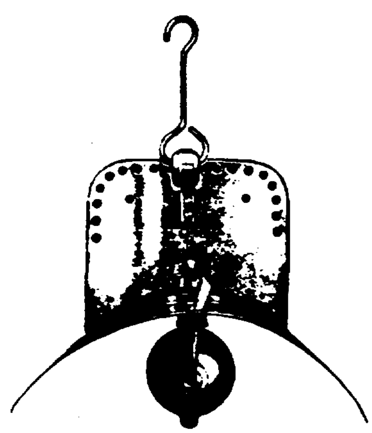
Complete Unit



Auxiliary Completely Wired.



Anode (Positive) Connections.



Cathode (Negative) Connections.

THE NEW AND IMPROVED LAMP

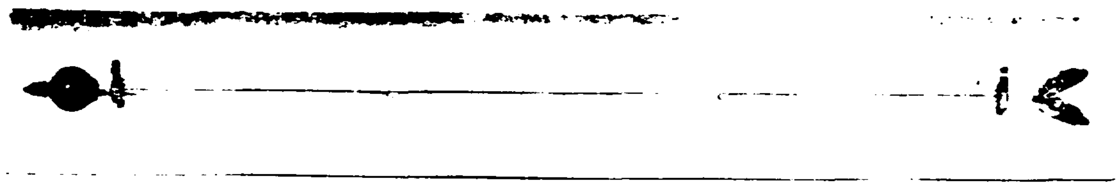
A new trend in design has come about - automobiles, machinery, buildings and the like, lean toward simplicity and smooth, even lines, more often referred to as 'stream line'. COOPER HEWITT lamps continue to keep pace with the times by introducing the so-called **new and improved lamp** - 160-9WL1.

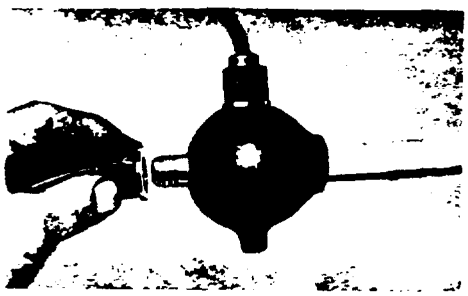
The auxiliary, reflector and tube, have all been changed to give added distinctiveness and efficiency. The changes and improvements incorporated in this design were the result of extensive research and development work. The following improvements are noteworthy:

1. Straight-line tube
2. Concealed wiring
3. Greater reflection surface
4. Reentrant seals
5. Insulated screw base terminals
6. Binding posts for transformer connections
7. Metal shield ballast coils
8. Rectifier starting

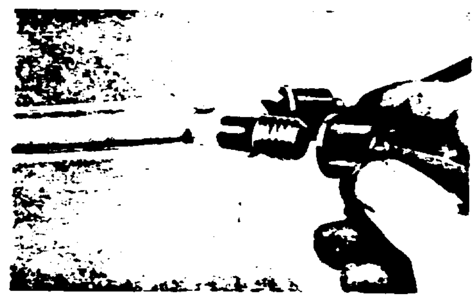
Externally the auxiliary is slightly longer than previous models and is equipped with draw pressed end plates with rounded ends, flush mounted attachment plug and stronger cover latches. The greatest improvements, however, are within the auxiliary; greater spacings are provided which permit easier access to resistance units, transformer taps, attachment plug, etc. The new model is equipped with a three point attachment plug instead of the conventional two point style. The third point is grounded within the auxiliary frame of the lamp and may be used when desired as a grounding point for the lighting unit.

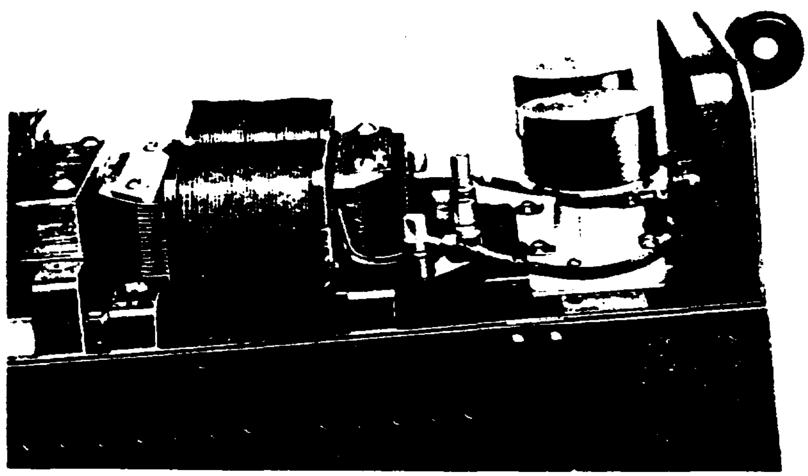
SALIENT DESIGN FEATURES OF THE 160-9WL1 LAMP

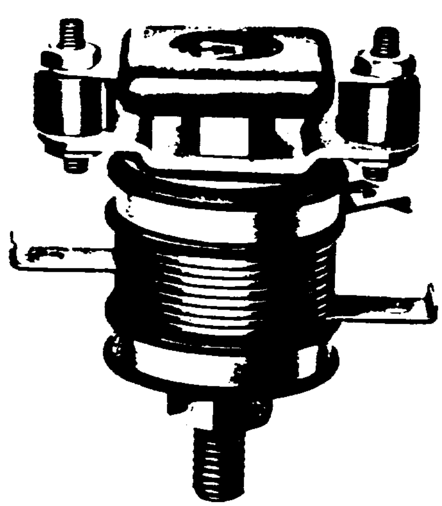


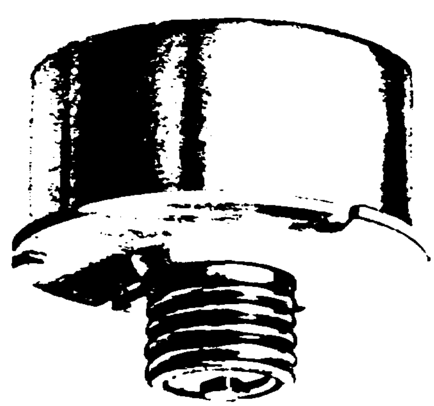


Pictures show ease of attaching new insulated screw base terminals.



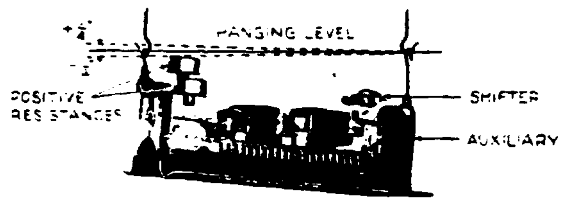






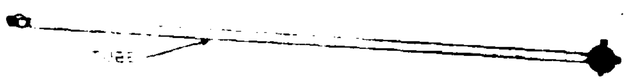
DESCRIPTION OF THE COOPER HEWITT LAMP

THE Cooper Hewitt industrial unit is made up of three essential parts; the tube, reflector and auxiliary.



The AUXILIARY contains the coils and mercury switch which serve to start the lamp and stabilize it during operation. It also has the suspension hooks and attachment plug attached to it and serves as a support for the reflector and tube.

The REFLECTOR is of metal, coated on the underside with white enamel. It extends the full length of the tube and down the sides to a point eighteen degrees below the center of the light source. The reflector throws practically all of the light into the lower hemisphere.



The TUBE, which is the light giving portion, is a fifty-inch glass tube, exhausted to a practically perfect vacuum and containing a small amount of mercury. Under the action of electricity a small portion of this mercury vaporizes and becomes luminous, developing a soft evenly diffused light free of red rays, practically monochromatic and of high visual acuity.

The unit is easy to wire as it is only necessary to attach the line leads to the attachment plug at the front of the auxiliary.

Automatic Lighting:

35—The automatic starting of the Cooper Hewitt lamp is of interest to many. An examination of Fig. 15 will show that the shifter is connected to the transformer through a copper oxide rectifier. When the line switch is closed, about one ampere at four volts *direct* current flows through the shifter circuit and energizes the inductance coils. The shifter is rotated thereby, the current through it is interrupted and a momentary high induced E.M.F. is produced on the mercury within the lamp. By the aid of the condenser action of the starting band a "cathode spot" is formed on the mercury pool, the mercury vapor in the tube is ionized and the current flows through the tube. The shifter is magnetically held in the open position by the arc current flowing through the inductance, thus keeping the rectifier circuit open while the lamp is lighted. If the lamp does not light on the first operation of the shifter, the cycle is repeated. If the temperature of the room is low there may be a delay in the automatic starting of the lamp. This is due to the reduced vapor pressure.

The Lamp as a Rectifier:

50—The mercury pool of the lamp is connected through inductance to the middle point of a transformer while the two anodes are connected through resistance units to its outer terminals, Fig. 15. Once the lamp is started the two halves of the transformer work alternately, the current shifting from one anode to the other with every alternation of the voltage but continuing to flow as a pulsating direct current through the negative of the lamp to the midpoint of the transformer. The inductance in series with the lamp maintains the current during the time of zero voltage and smoothes out the pulsations in the rectified direct current. A careful study of the oscillograms of Fig. 18 will show the relationships between the lamp voltages and currents.

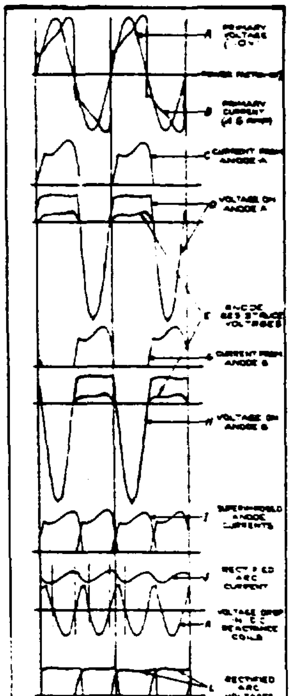


Fig. 18

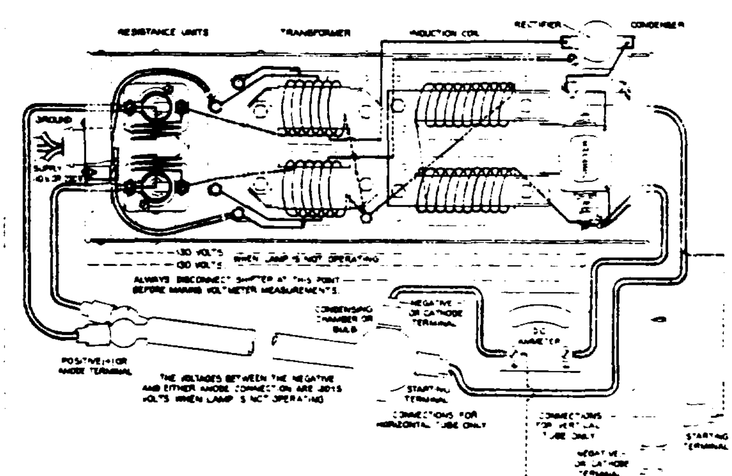


Fig. 15—Wiring Diagram.

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GENERAL CHARACTERISTICS AND SPECIFICATIONS

SPECIFICATIONS—COOPER HEWITT INDUSTRIAL LIGHTING UNITS	Alternating Current		Direct Current
Code No.—Standard Unit*	160-H9WL1	260-H9WL1	110-H9WL1
Voltage range	Connections for 95-**100**-111 103-**110**-121 112-**120**-130	 190-**200**-222 206-**220**-242 224-**240**-260	Automatic Regulation 100-**110**-125
Total Average Watts per Lamp	450	450	385
Average Line Amperes	4.65	2.3	3.5
Power Factor	88%	88%	—
Candle Power—Mean Hemispherical with curved reflector	900	900	800
Rated Total Lumens—Lower Hemisphere	5600	5600	5200
Lumens Per Watt—Lower Hemisphere	12.5	12.5	13.4
Light source—diameter 1 inch	50 in. long	50 in. long	50 in. long
Frequency	60-50 cycle	60-50 cycle	—
Special units available for	25-40 cycle	25-40 cycle	—
WEIGHTS			
Each unit complete	49 lbs. net	49 lbs. net	36 lbs. net
Packed for domestic shipment—one	85 lbs.	85 lbs.	72 lbs.
Packed for domestic shipment—five	330 lbs.	330 lbs.	265 lbs.
Packed for domestic shipment—ten	620 lbs.	620 lbs.	485 lbs.
Prices on application to nearest office.			

* If deep reflector for rotation is desired, specify "with AC-H1OR1F1 reflector."

PHOTOMETRIC RATING

ALTERNATING CURRENT COOPER HEWITT LAMP

INITIAL OUTPUT

WATTS (RATED)---------------------------450

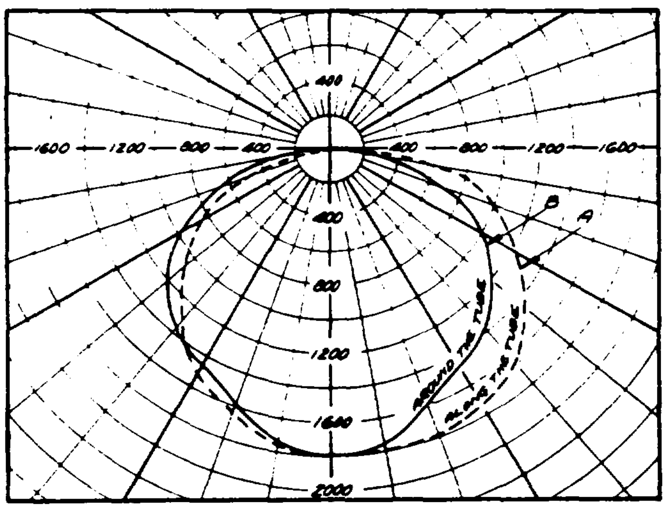
MEAN LOWER HEMISPHERICAL CANDLE---------900

WATTS PER MEAN HEMISPHERICAL CANDLE------0.50

DOWNWARD LUMENS-------------------------5625

DOWNWARD LUMENS PER WATT----------------12.5

TEST AT 25 FT RADIUS



A - VERTICAL PLANE OF TUBE

B - VERTICAL PLANE PERPENDICULAR TO A
UNIVERSAL CURVED REFLECTOR
TUBE 1" DIAMETER x 50" LONG

DATA CALCULATED FROM TEST
NO H-131799 DATED FEB 10, 1927 BY
ILLUMINATING ENGINEERING LABORATORY
GENERAL ELECTRIC COMPANY
SCHENECTADY, N.Y.

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TABLES OF FOOT-CANDLE INTENSITIES

TABLE I. INTENSITIES PRODUCED BY ONE 450 WATT COOPER HEWITT LAMP AT VARIOUS HEIGHTS AND DISTANCES

HORIZONTAL DISTANCE IN FEET

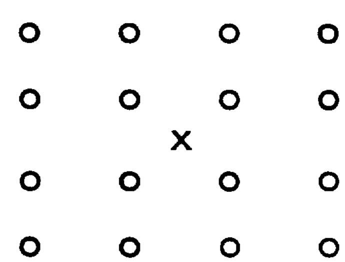
Height	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25
4	[illegible]	[illegible]	55.5	39.2	25.0	15.8	10.5	7.1	5.0	3.5	2.5	1.9	1.5	1.4	1.1	.9	.8	.65	55	45	37	.28
5	59.7	53.4	43.3	32.2	25.2	15.9	11.2	8.1	5.9	4.2	3.2	2.3	1.8	1.7	1.4	1.1	.9	.75	.65	55	46	.28
6	41.6	35.5	32.7	26.1	20.0	14.8	11.0	8.8	6.2	4.7	3.6	2.9	2.2	2.0	1.6	1.3	1.1	.85	.75	65	55	.28
7	30.7	28.5	25.3	21.2	17.3	13.5	10.5	8.1	6.3	5.0	4.0	3.1	2.4	2.2	1.7	1.5	1.2	1.1	.90	75	65	.28
8	23.3	22.1	20.1	17.4	14.6	12.0	9.7	7.9	5.9	5.1	4.1	3.2	2.7	2.3	1.9	1.5	1.4	1.2	1.0	90	75	37
9	18.5	17.6	16.4	14.5	12.6	10.8	8.9	7.4	6.1	5.0	4.0	3.2	2.8	2.4	2.0	1.6	1.5	1.2	1.1	90	.75	45
10	14.9	14.4	13.4	12.2	10.9	9.5	8.0	6.8	5.7	4.8	3.9	3.4	2.9	2.4	2.0	1.8	1.6	1.3	1.2	1.0	.85	55
12	10.3	10.1	9.7	8.8	8.1	7.3	6.5	5.8	5.0	4.4	3.8	3.2	2.8	2.3	2.0	1.8	1.6	1.4	1.3	1.1	.90	55
14	7.6	7.4	7.2	6.8	6.3	5.9	5.4	4.9	4.2	3.8	3.4	3.0	2.6	2.1	2.0	1.7	1.6	1.5	1.3	1.1	1.0	55
16	5.8	5.7	5.5	5.3	5.1	4.7	4.3	4.0	3.7	3.4	3.0	2.8	2.5	2.1	1.9	1.6	1.5	1.4	1.2	1.1	1.0	65
18	4.6	4.6	4.4	4.3	4.1	3.9	3.6	3.4	3.1	2.9	2.8	2.6	2.3	1.9	1.8	1.5	1.5	1.3	1.2	1.1	1.0	65
20	3.7	3.7	3.7	3.5	3.4	3.2	3.0	2.8	2.7	2.6	2.2	2.2	2.0	1.6	1.4	1.3	1.3	1.3	1.1	1.1	90	.65
25	2.4	2.4	2.3	2.2	2.1	2.1	2.1	1.9	1.9	1.9	1.8	1.7	1.6	1.2	1.1	1.0	1.0	.9	.9	.75	65	55

TABLE II: INTENSITIES PRODUCED BY SIXTEEN 450 WATT COOPER HEWITT LAMPS SYMMETRICALLY SPACED

HORIZONTAL DISTANCE BETWEEN LAMPS

Height	8	9	10	11	12	13	14	15	16	18	20	24
4	55.0	40.4	24.5	23.0	17.9	15.7	11.8	9.7	7.0	5.7	3.9	1.4
5	62.1	55.4	39.6	27.6	21.6	19.7	15.4	12.2	9.2	7.4	5.4	2.3
6	65.2	58.6	42.5	30.7	24.5	22.6	17.8	14.3	10.9	7.8	6.6	3.2
7	65.2	58.4	44.3	33.0	26.5	25.0	19.3	15.9	12.5	9.9	7.7	4.0
8	64.2	57.4	45.0	34.2	28.2	27.2	20.9	17.3	13.9	11.0	9.1	4.7
9	62.1	55.2	43.7	34.8	29.2	28.0	22.0	18.3	15.1	11.9	9.6	5.3
10	59.7	53.0	42.3	34.3	29.6	27.6	22.8	19.1	16.0	12.7	10.1	5.8
11	57.0	50.6	40.8	33.3	29.5	27.0	23.0	19.4	16.6	13.3	10.8	6.2
12	54.1	46.0	39.2	32.3	29.0	26.2	22.5	19.5	16.7	13.7	11.2	6.3
13	51.2	45.6	37.7	31.3	28.3	25.5	22.0	19.4	16.6	14.0	11.3	6.5
14	48.0	42.8	36.2	30.2	27.4	23.8	21.3	19.2	16.4	14.2	11.4	6.6
15	44.5	38.6	34.7	29.1	26.7	23.7	20.7	18.7	16.1	14.1	11.4	6.7
16	40.6	34.6	33.1	28.0	25.7	22.9	19.3	18.2	15.7	13.8	11.2	6.7
18	36.6	33.1	30.0	25.5	23.5	20.9	17.7	16.9	14.9	13.0	10.7	6.7
20	32.6	29.7	26.7	23.0	21.1	18.4	15.2	15.3	13.9	11.2	10.3	6.6
Approximate Watts per Square Foot of Horizontal Surface												
	7.0	5.5	4.5	3.7	3.1	2.5	2.3	2.0	1.7	1.4	1.1	.78

Table II gives the average intensity produced by sixteen 450 Watt Cooper Hewitt Lamps sym-



metrically spaced, as shown in the diagram; the intensity being calculated for the point indicated by X.

NORMAL LAMP OPERATION

It occasionally is necessary to check lamps to determine whether they are operating normally. The most accurage method is to take an ammeter reading in the negative circuit of the tube. Voltage readings across the tube are not only difficult to take accurately, but are not absolute in their indications.

Tube current is more sensitive to lamp operating conditions such as line voltage, temperature regulation, etc., and is, therefore, our best indicator. The tables on the following page give normal values for our standard sizes of tubes. Lamp operation which does not conform with these values within plus or minus 5% cannot be considered as normal.

The wiring diagrams are not complete necessarily, but only show how readings should be taken.

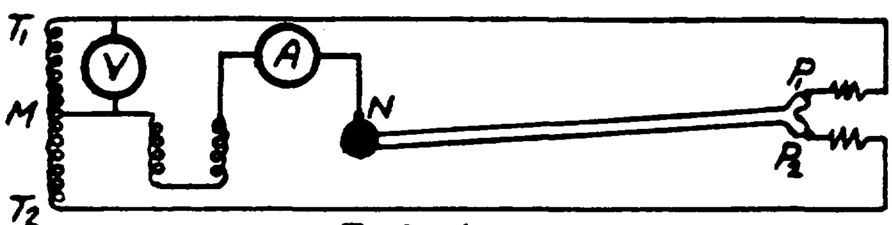


FIG. 1

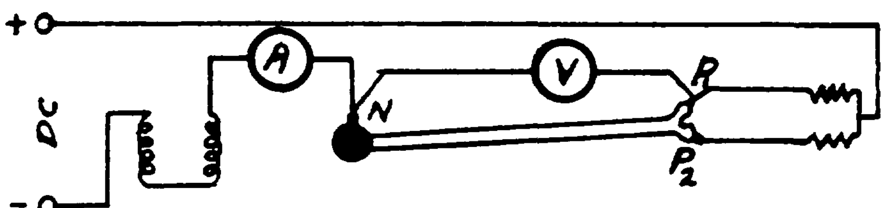


FIG. 2

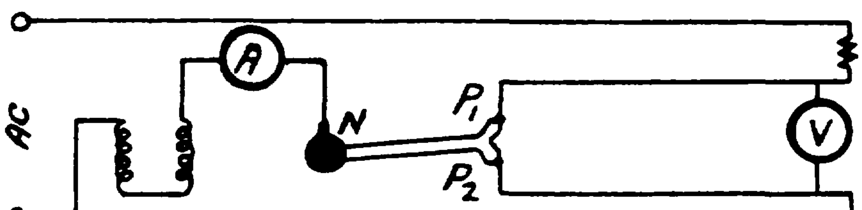


FIG. 3

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TUBE	SERVICE	SEE	*NORMAL DC AMPS	**NORMAL VOLTS AS INDICATED
50"x1"	AC	Fig. 1	3.65	'130V M to T
50"x1"	DC	Fig. 2	3.50	''70-75V N to P
22"x1"	AC	Fig. 1	3.65	'76V M to T
35"x¾"	AC	Fig. 1	2.50	'125V M to T
35"x¾"	DC	Fig. 2	2.50	''68-73V N to P
14"x1"	AC	Fig. 3	#3.40 (3.10 with inc. in same unit)	
10"x1"	AC	Fig. 3	#2.8-3.4(Depending on inc. wattage)	

* Use DC ammeter and take readings after 30 minutes operation on proper tap for line voltage.

** Use AC voltmeter.

' Take readings with shifter open, lamp out and current on.

'' Take readings with lamp running stable. If operating unstable voltmeter may be ruined.

These values at 120 volts at attachment plug. Current goes down as heat from Incandescent lamps goes up.

ELECTRICAL MEASUREMENTS OF COOPER HEWITT LAMPS

When attempting to take electrical measurements of COOPER HEWITT lamps many precautions must be exercised. In 1925 several alternating current lamps were carefully tested; the results of which will be briefly given.

TABLE SHOWING RESULTS OF WATTAGE TESTS

	Initial	1 Min	5 Min	10 Min	25 Min	45 Min
HIGH	1000	680	530	500	470	455
LOW	940	600	470	460	435	445
AVERAGE	961	628	493	463	451	445

These values were obtained from several EAC-160B auxiliaries run on the normal 110 volt loop of the transformer. The voltage was maintained at a value varying not more than 3 volts either way. Curves plotted from average readings showed that at the instant a lamp is turned on the wattage is 960 watts and the line current starts at 11 amperes with a tube current of 8.6 amperes.

Measurements of the starting current taken on an oscillograph show the true instantaneous current on starting to be 12 to 13 amperes, which would bring the wattage up to about 1225. The initial surge, however, is instantaneous as it drops within the first 30 seconds to 650 watts, 6.5 amperes line current and 5.5 amperes tube current. From this point the drop was more gradual so that at the end of ten minutes run, the lamp was operating at almost specified wattage and current. During the next 20 minutes the lamp became more stable, the wattage and current fluctuating slightly below and above normal.

All the lamps tested were run for 45 minutes at the end of which time the average curve showed them to be operating at 445 watts, 4.6 amperes line current and 3.8 amperes tube current.

From the foregoing it is obvious that the true rating of the lamps cannot be obtained at the time a lamp is turned on nor even within the first 10 minutes. The true operating performance of a lamp seems to require a length of time approaching 45 minutes. These facts are not at all alarming since most electrical equipment, especially motors, require a certain duration of time before stable conditions are reached.

Tests were also conducted to determine the effect of varying voltages and transformer taps. Results obtained at the end of 45 minutes or more are tabulated below.

VOLTAGE	WATTS	LINE CURRENT	TUBE CURRENT	TRANSFORMER CONNECTION
110	445	4.60	3.80	Normal
105	415	4.40	2.08	Normal
115	480	5.00	3.30	Normal
110	440	4.30	3.80	Highest
110	560	5.80	4.10	Lowest

TECHNICAL DATA

Technical Data

The Tables and Curves on the following pages are technical data pertaining to industrial lighting units, both for the COOPER HEWITT lamp and incandescent lamps. Various comparisons can readily be made to show the efficiency of both systems of lighting when applied to industrial illumination on average conditions of intensities.

Only Curves, Tables, and Drawings that were known to be authentic are included in this section.

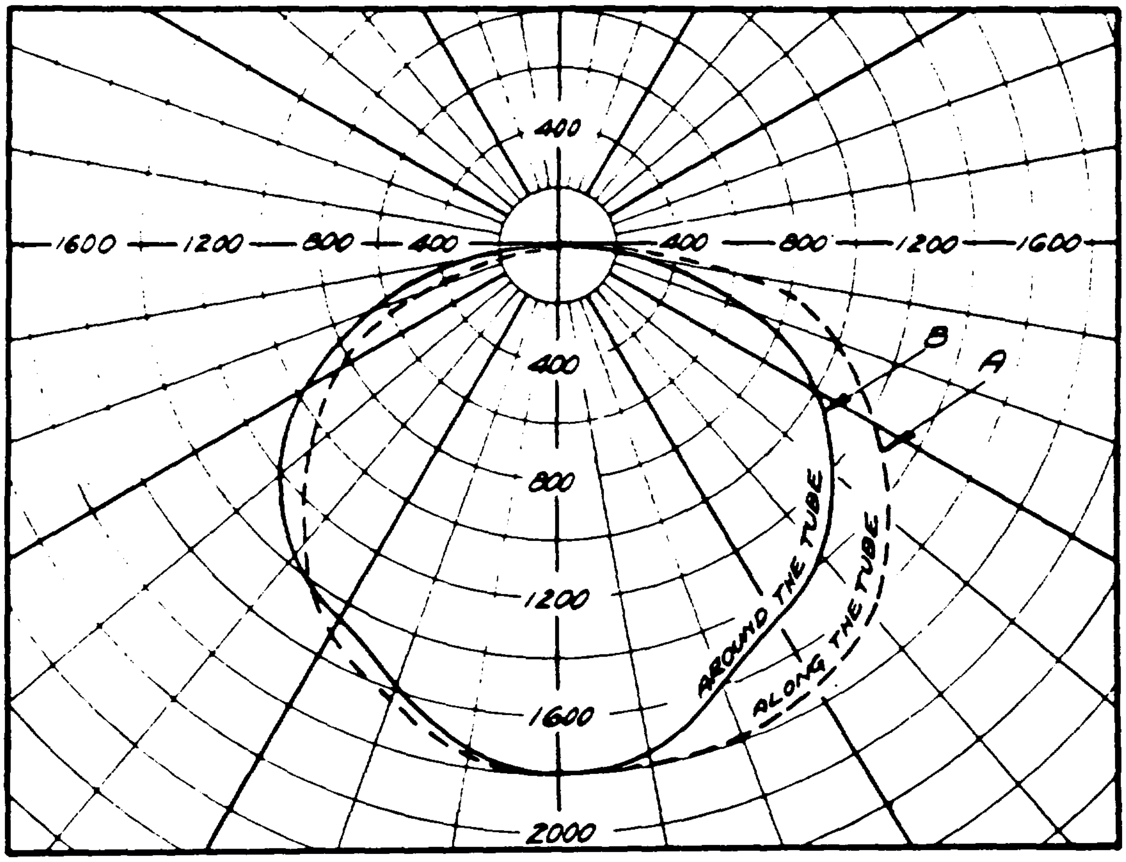
PHOTOMETRIC RATING

ALTERNATING CURRENT COOPER HEWITT LAMP

CODE NO. 1609WLI

INITIAL OUTPUT

WATTS (RATED) - 450
MEAN LOWER HEMISPHERICAL CANDLE - - - - - - - - - 900
WATTS PER MEAN HEMISPHERICAL CANDLE - - - - - - 0.50
DOWNWARD LUMENS - 5625
DOWNWARD LUMENS PER WATT - - - - - - - - - - - - 12.5
TEST AT 25 FT RADIUS

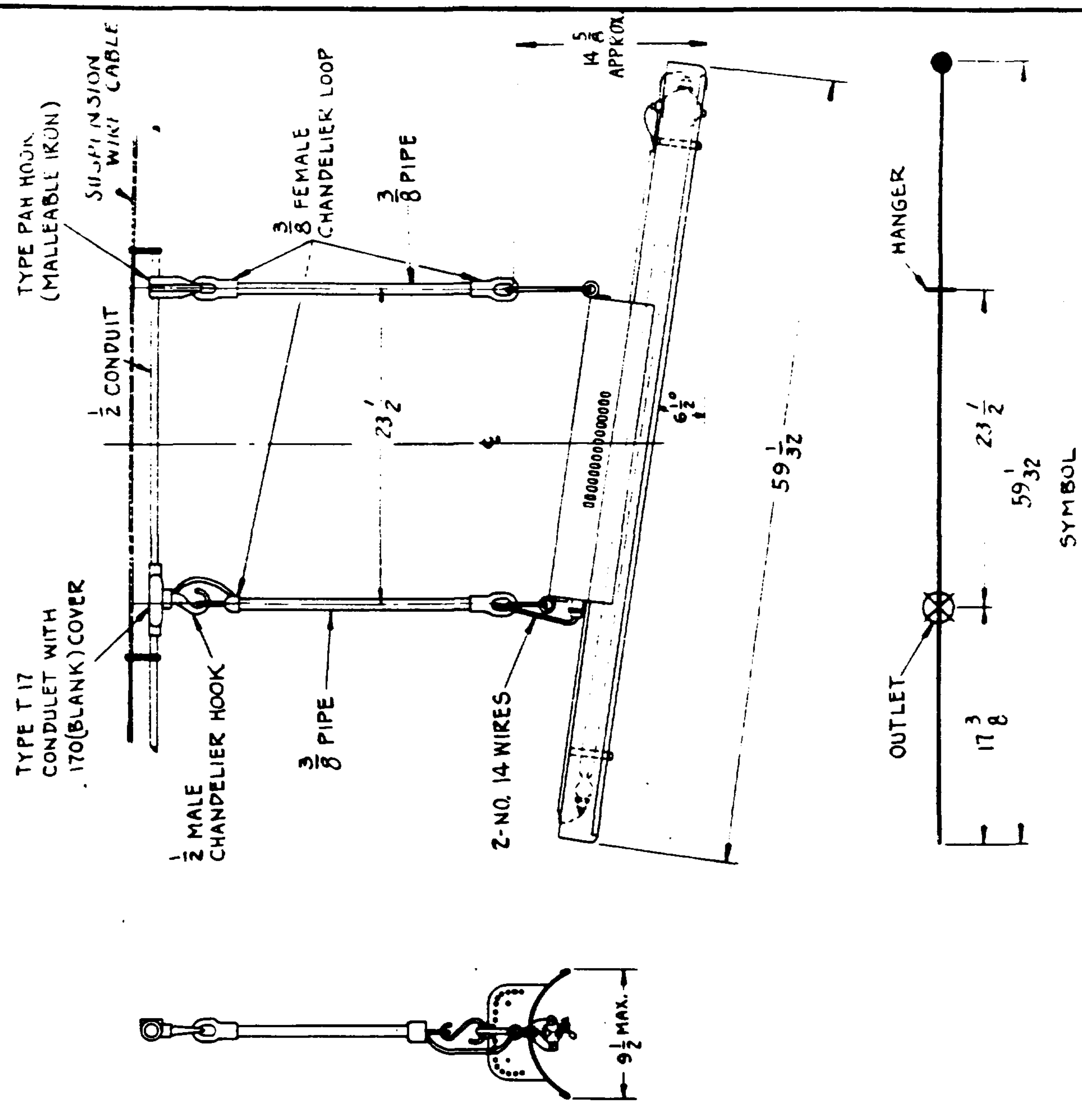


A - VERTICAL PLANE OF TUBE

B - VERTICAL PLANE PERPENDICULAR TO A UNIVERSAL CURVED REFLECTOR TUBE 1" DIAMETER x 50" LONG

DATA CALCULATED FROM TEST NO H-131799 DATED FEB. 10, 1927 BY
ILLUMINATING ENGINEERING LABORATORY
GENERAL ELECTRIC COMPANY
SCHENECTADY, N Y

SK-610-R



METHOD OF SUSPENDING LAMP
(SHALLOW REFLECTOR)

GENERAL ELECTRIC VAPOR LAMP COMPANY
ILLUMINATING ENGINEERING DEPARTMENT
HOBOKEN, N. J.

DATE:-	DWN BY	CK'D BY	
6-2-32	A.W.	[illegible]	S-172

TECHNICAL DATA

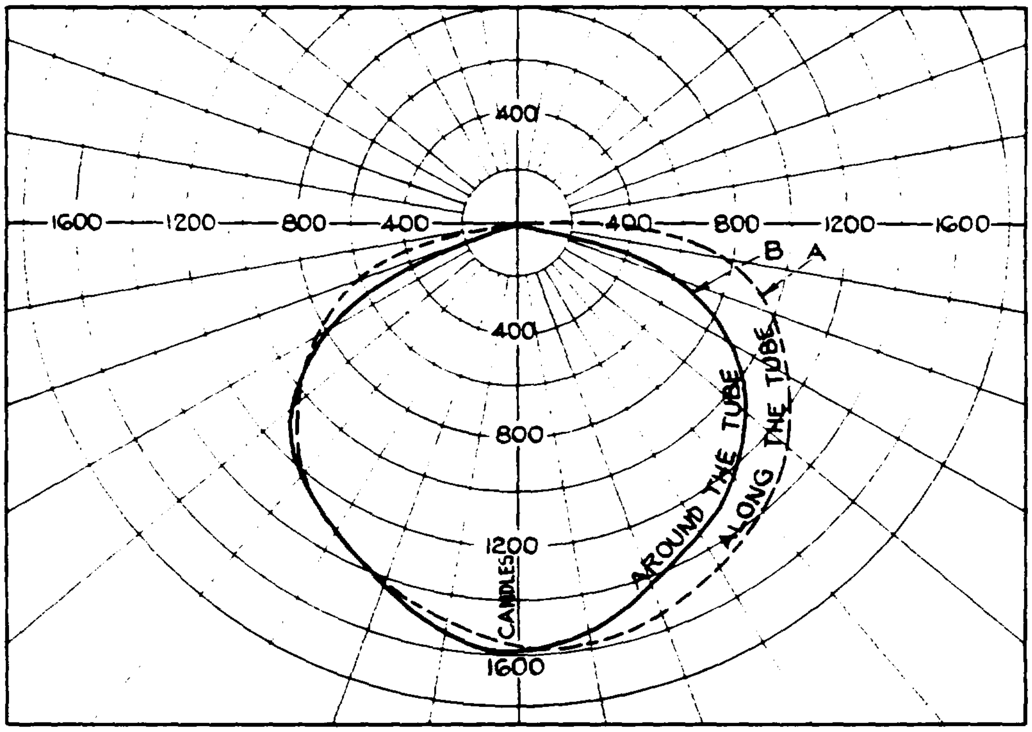
PHOTOMETRIC RATING
ALTERNATING CURRENT COOPER HEWITT LAMP
CODE NO. 160H9WL1

USE ACHIORIFI REFLECTOR IN NORMAL POSITION

INITIAL OUTPUT

WATTS (RATED)	450
MEAN LOWER HEMISPHERICAL CANDLE POWER	840
WATTS PER MEAN HEMISPHERICAL CANDLE	0.53
DOWNWARD LUMENS	5233
DOWNWARD LUMENS PER WATT	11.6

TEST AT 20 FT. RADIUS



A — VERTICAL PLANE OF TUBE
B — VERTICAL PLANE PERPENDICULAR TO "A"
UNIVERSAL DEEP REFLECTOR ACHIORIFI MAY BE ROTATED TO THROW LIGHT 30° TO RIGHT OR LEFT OF ABOVE NORMAL POSITION
TUBE 1" DIA. × 50" LONG

DATA FROM TEST REPORT DATED AUG. 18, 1932

CANDLE POWER DISTRIBUTION
ALTERNATING CURRENT LAMP
WITH DEEP REFLECTOR

GENERAL ELECTRIC
VAPOR LAMP COMPANY
ILLUMINATING ENGINEERING DEPARTMENT
HOBOKEN, N. J.

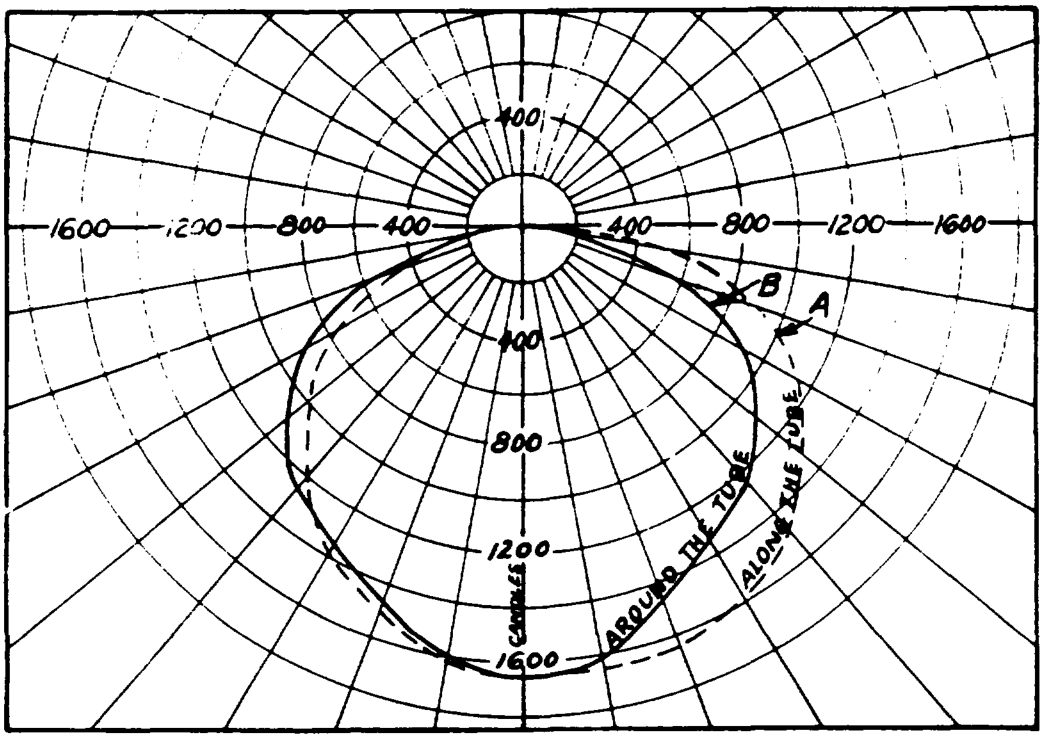
DATE	DWN. BY	CK'D BY	
8-29-32	W.L.	[illegible]	S-174

707156

PHOTOMETRIC RATING
Direct Current Cooper Hewitt Lamp
Code No. 110-9WL1

WATTS (Rated)	365
MEAN LOWER HEMISPHERICAL CANDLE POWER	816
WATTS PER MEAN HEMISPHERICAL CANDLE	0.47
DOWNWARD LUMENS	5167
DOWNWARD LUMEN PER WATT	13.4

Test at 25 Ft. Radius.



A - Vertical plane of tube
B - Vertical plane perpendicular to A

Universal curved reflector
Tube 1" Diameter by 50" long.

Data calculated from test H-131798
By Illuminating Engineering Laboratory
General Electric Company, Schenectady, N.Y.

CANDLEPOWER DISTRIBUTION
DIRECT CURRENT LAMPS

COOPER HEWITT ELECTRIC CO.
ILLUMINATING ENGINEERING DEPT.
HOBOKEN, N. J.

DATE:	DWN BY	CKD BY	
8-5-29	DHS		S-157

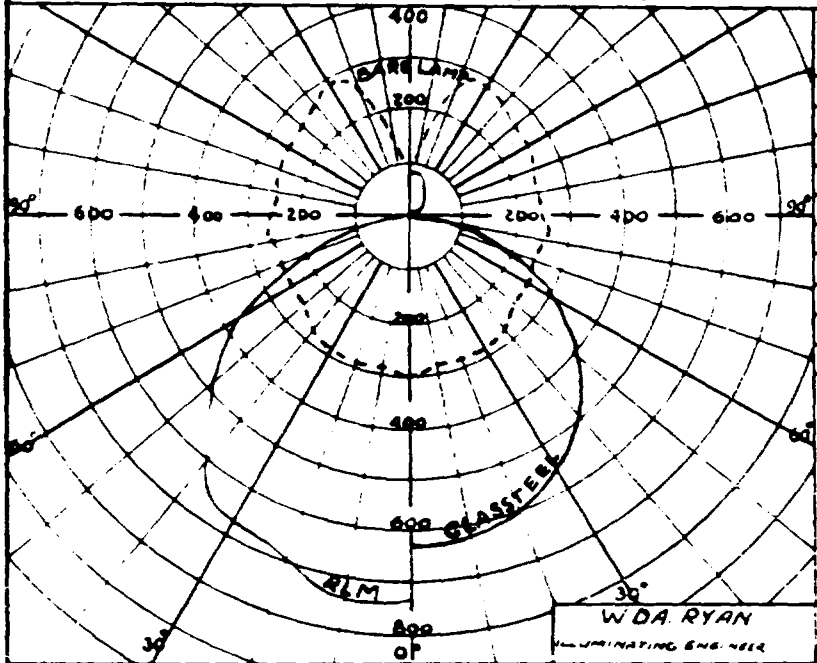
TECHNICAL DATA

DISTRIBUTION CURVES - 200 WATT MAZDA LAMPS

REFLECTOR	NONE	RLM	GLASSTEEL
LAMP	CLEAR	WH. BOWL	CLEAR
VOLTS	115	115	115
AMPERES	1.74	74	1.74
WATTS (RATED)	200	200	200
MEAN HEMISPHERICAL C.P.	261	357	311
WATTS PER MEAN HEMISPHERICAL C.P.	0.77	56	0.65
DOWNWARD LUMENS	1635	2240	1955
DOWNWARD LUMENS PER WATT	8.7	20	9.78
MEAN SPHERICAL C.P.	255	78	171
WATTS PER MEAN SPHERICAL C.P.	0.79	12	117
TOTAL LUMENS	3200	2240	2155
TOTAL LUMENS PER WATT	16.00	20	10.75
PERCENT TOTAL LUMENS OF BARE LAMP		70 0	67.4

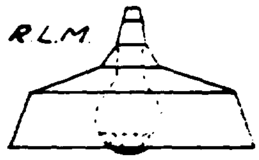
PHOTOMETRIC TESTS

DISTRIBUTION OF INITIAL CANDLE POWER IN A VERTICAL PLANE

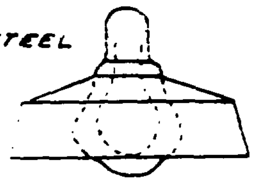


ZONE 0 TO	LUMENS		
	BARE	R.L.M.	GLASSTEEL
10	28	71	58
20	109	277	283
30	243	593	505
40	420	1018	841
50	625	1430	1200
60	850	1805	1535
70	1095	2085	1780
80	1355	[illegible]	1920
90	1635	2240	1955
180			

R.L.M.



GLASSTEEL



READINGS TAKEN AT 10 FT. RADIUS
CLEAR LAMPS OPERATED AT 3200 TOTAL LUMENS

DATA ON BARE LAMP CALCULATED FROM GE LAB TEST NO. 5152
" " R.L.M. UNIT " " " " " NO. 4056
" " GLASSTEEL UNIT " " " " " NO. 4759

SCHEDULE

DISTRIBUTION CURVES - 200 W. LAMPS
CORRECTED TO MANUFACTURERS
EFFICIENCIES PUBLISHED FEB 1. 1926

COOPER HEWITT ELECTRIC CO.
ILLUMINATING ENGINEERING DEPT.
HOBOKEN, N. J.

DATE	DR. BY	CKD. BY	
JUNE 1. 1926			S 120

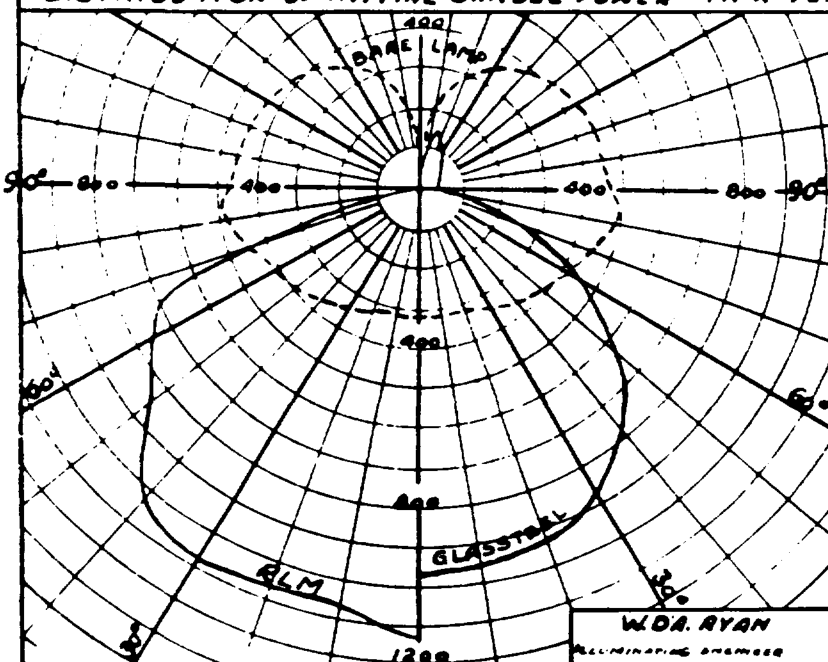
707158

DISTRIBUTION CURVES - 300 WATT MAZDA LAMPS

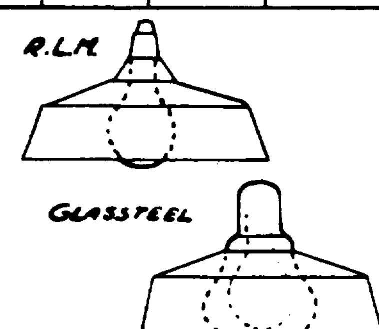
REFLECTOR	NONE	RLM	GLASSTEEL
LAMP	CLEAR	CLEAR	CLEAR
VOLTS	115	115	115
AMPERES	2.61	2.61	2.61
WATTS (RATED)	300	300	300
MEAN HEMISPHERICAL C.P.	417	632	495
WATTS PER MEAN HEMISPHERICAL C.P.	0.72	0.47	0.61
DOWNWARD LUMENS	2630	3970	3110
DOWNWARD LUMENS PER WATT	8.76	13.20	10.35
MEAN SPHERICAL C.P.	413	315	276
WATTS PER MEAN SPHERICAL C.P.	0.73	0.95	1.09
TOTAL LUMENS	5200	3970	3470
TOTAL LUMENS PER WATT	17.3	13.20	11.55
PERCENT TOTAL LUMENS OF BARE LAMP		76.2	66.8

PHOTOMETRIC TESTS

DISTRIBUTION OF INITIAL CANDLE POWER IN A VERTICAL PLANE



ZONE 0 TO	LUMENS BARE	R.L.M.	GLASSTEEL
10	30	106	92
20	118	409	360
30	272	909	788
40	493	1587	1320
50	787	2310	1870
60	1148	3045	2380
70	1580	3730	2780
80	2090	3930	3000
90	2630	3970	3110
S.F.D.			



READINGS TAKEN AT 25 FT. RADIUS
CLEAR LAMPS OPERATED AT 5200 TOTAL LUMENS

DATA ON BARE LAMP CALCULATED FROM GE LAB TEST No. 4196
" " R.L.M. UNIT " " " " " No. 4249
" " GLASSTEEL UNIT " " " " " No. 4628

SCHEDULE	

DISTRIBUTION CURVES - 300 W. LAMPS
CORRECTED TO MANUFACTURERS EFFICIENCIES PUBLISHED FEB 1. 1926

COOPER HEWITT ELECTRIC CO.
ILLUMINATING ENGINEERING DEPT.
HOBOKEN, N. J.

DATE:	DWN BY	CKD BY	
JUNE 1. 1926	D.H.		S 121

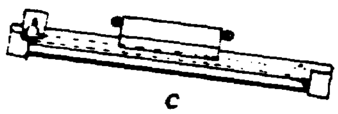
707159

A

RLM Std Dome Reflector - White Bowl Lamp
Lumens in Lower Hemisphere - 0° to 90° - 66%

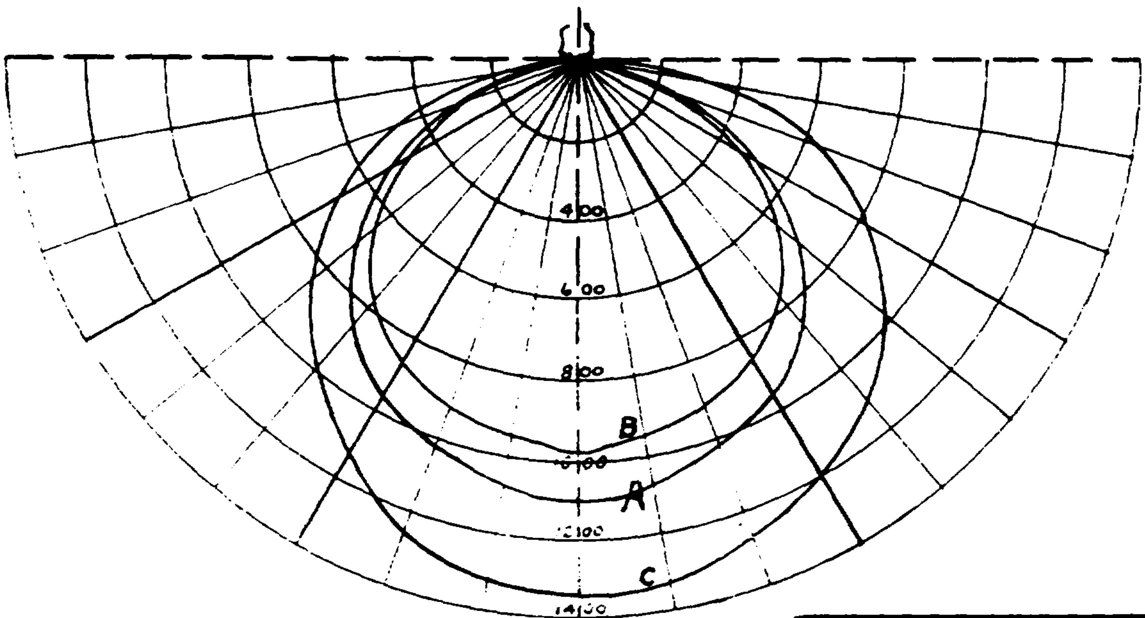
B

Glassteel Diffuser - Clear Lamp
Lumens in Lower Hemisphere - 0° to 90° - 60%



C

Cooper Hewitt Lamp
Lumens in Lower Hemisphere - 0° to 90° - 83.5%

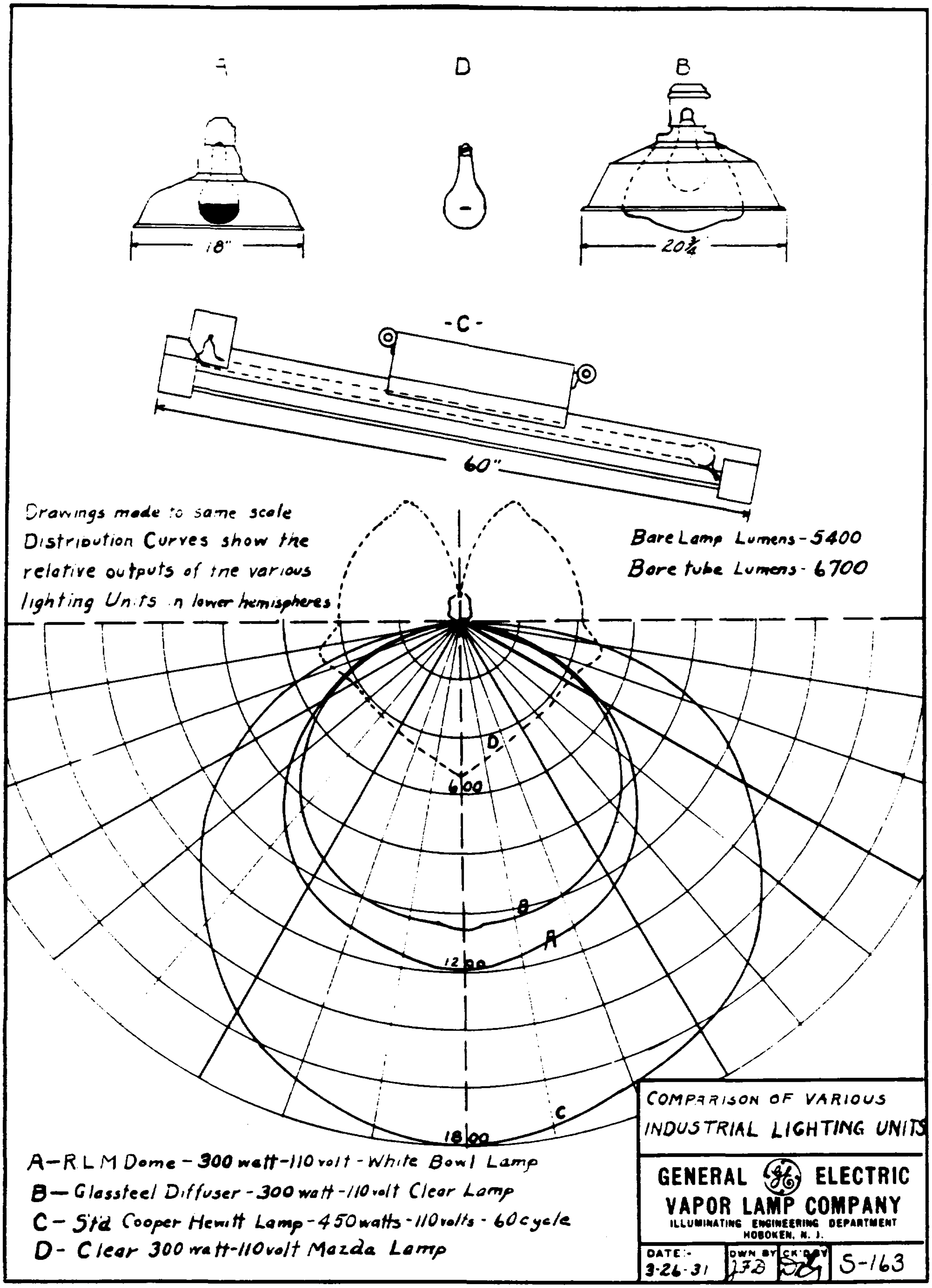


DISTRIBUTION CURVES OF INDUSTRIAL UNITS USING AS A BASIS HYPOTHETICAL BARE LAMP SOURCES WITH OUTPUTS OF 5000 LUMENS IN EACH CASE

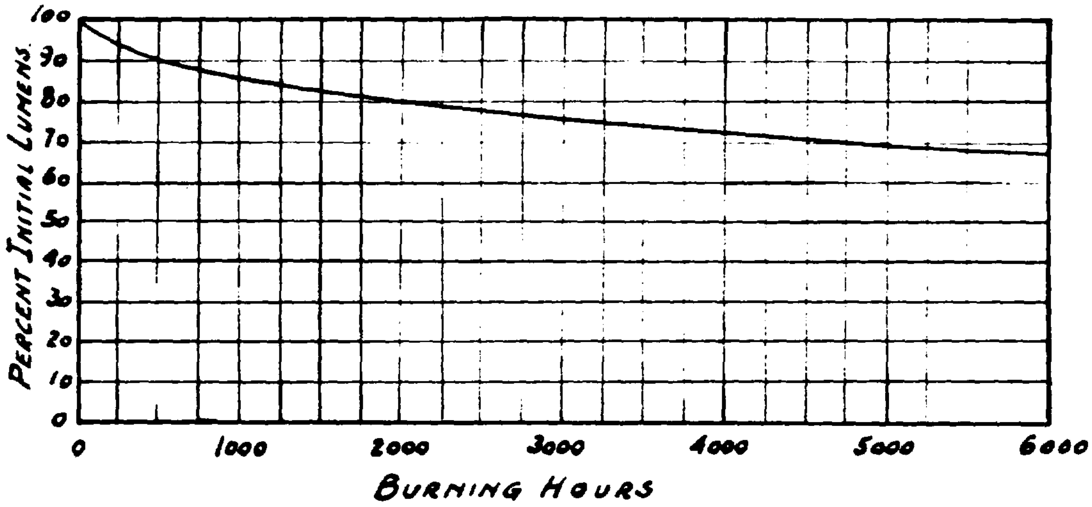
REFERENCES — Lamp Works Bulletins-123B + L.D.6
G.E. Illuminating Lab. Report

COMPARISON OF VARIOUS INDUSTRIAL LIGHTING UNITS	
GENERAL ELECTRIC VAPOR LAMP COMPANY ILLUMINATING ENGINEERING DEPARTMENT HOBOKEN, N. J.	
DATE - 3-26-3[illegible]	DWN BY [illegible] CK BY [illegible] S-16[illegible]

707160


A
D
B
18"
20¾"
-C-
60"
Drawings made to same scale
Distribution Curves show the relative outputs of the various lighting Units in lower hemispheres
Bare Lamp Lumens - 5400
Bare tube Lumens - 6700
D
600
B
A
1200
C
1800
A—RLM Dome - 300 watt - 110 volt - White Bowl Lamp
B—Glassteel Diffuser - 300 watt - 110 volt Clear Lamp
C—Std Cooper Hewitt Lamp - 450 watts - 110 volts - 60 cycle
D- Clear 300 watt - 110 volt Mazda Lamp
COMPARISON OF VARIOUS INDUSTRIAL LIGHTING UNITS
GENERAL ELECTRIC VAPOR LAMP COMPANY
ILLUMINATING ENGINEERING DEPARTMENT
HOBOKEN, N. J.
DATE:- 3-26-31
DWN BY
CK'D BY
S-163

CHARACTERISTIC DEPRECIATION OF LIGHT OUTPUT
DATA IN PERCENT OF INITIAL LUMENS
ALTERNATING CURRENT COOPER HEWITT LAMPS
DATA SHOWN FOR LAMP COMPLETE WITH REFLECTOR.



Data based on extensive tests made at
Ill. Eng. Lab. Cooper Hewitt Electric Co. and
Ill. Eng. Lab. General Electric Co. Schenectady, N.Y.

SCHEDULE	
Rated Initial Lumens	5625
Rated Watts per Unit	450
Avg. Output thru 6000 hours in percent of initial.	78%

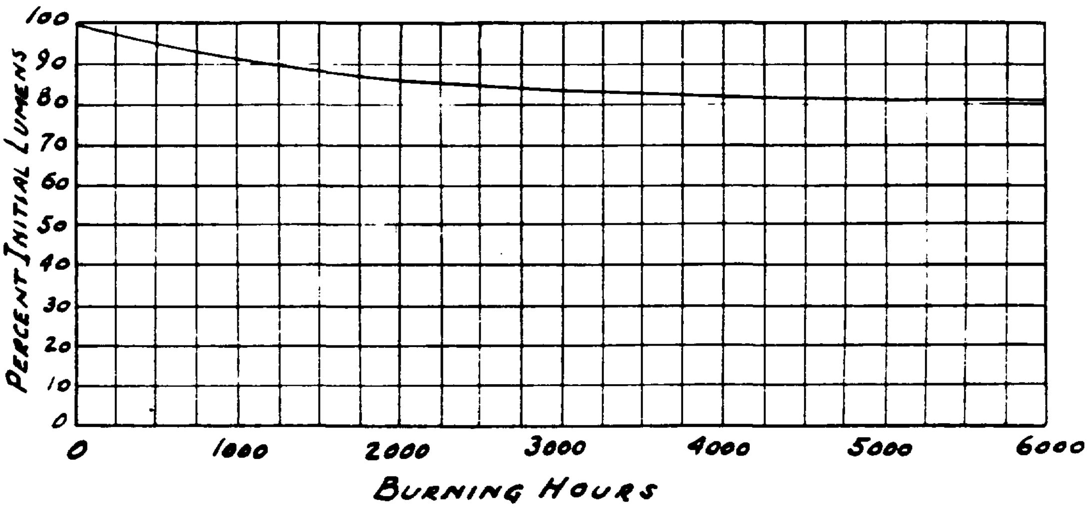
Depreciation Curve
Alternating Current Lamps
Code, 160-6NL1 and 260-6NL1

COOPER HEWITT ELECTRIC CO.
ILLUMINATING ENGINEERING DEPT.
HOBOKEN, N. J.

DATE:	DWN. BY	CKD. BY	
12-1-1927	DRG.	[illegible]	S-136

707162

CHARACTERISTIC DEPRECIATION OF LIGHT OUTPUT
DATA IN PERCENT OF INITIAL LUMENS
DIRECT CURRENT COOPER HEWITT LAMPS
DATA SHOWN FOR LAMP COMPLETE WITH REFLECTOR.



Data based on extensive tests made at
Ill. Eng. Lab.- Cooper Hewitt Electric Co. and
Ill. Eng. Lab.- General Electric Co. Schenectady, N.Y.

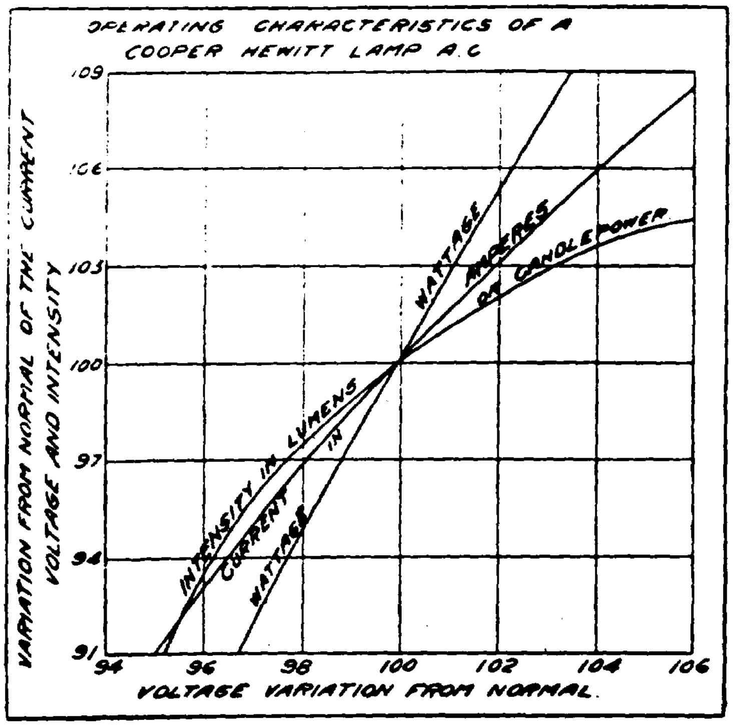
SCHEDULE	
Rated Initial Lumens	5167
Rated Watts per Unit	385
Avg. Output thru 6000-hours in percent of initial	86%

Depreciation Curve
Direct Current Lamps
Code, 110-6WL1

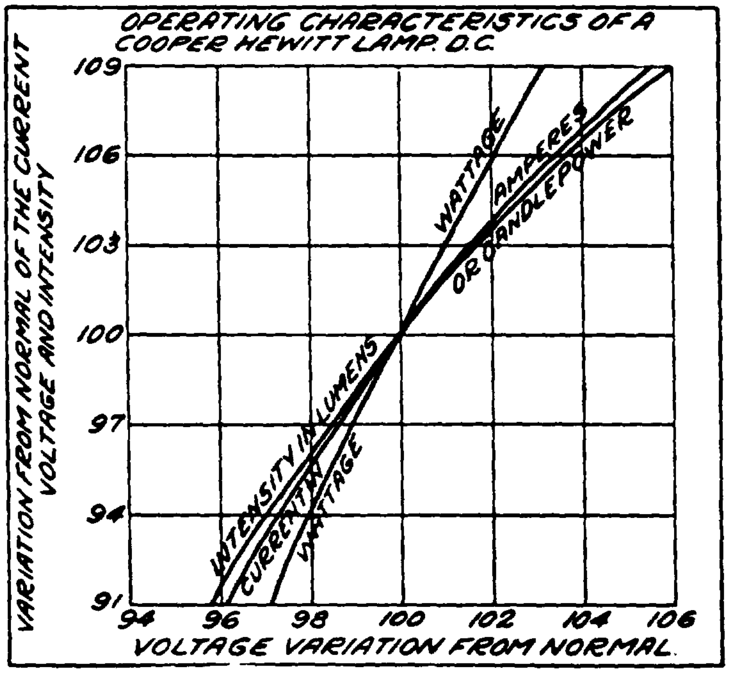
COOPER HEWITT ELECTRIC CO.
ILLUMINATING ENGINEERING DEPT.
HOBOKEN, N. J.

DATE:	DWN BY	CKD. BY	
12-1-1927	D.R.G.	[illegible]	S-137

707163

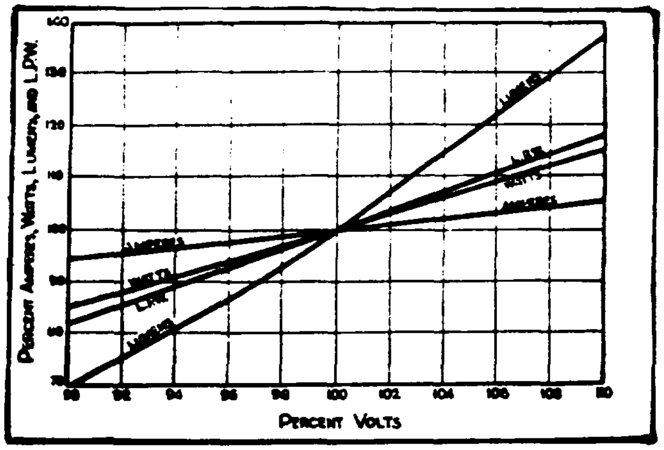


Operating characteristics of alternating current lamp unit.



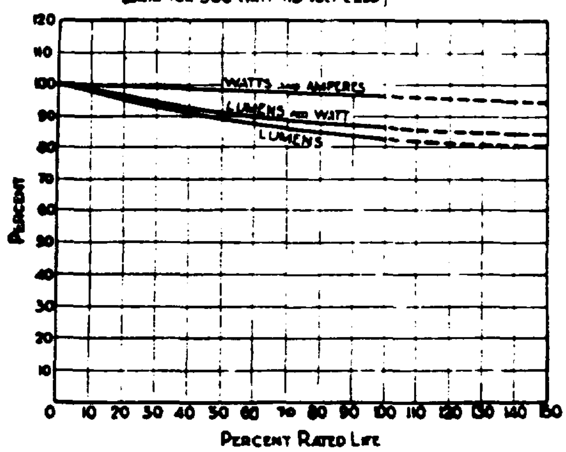
Operating Characteristics of Direct Current Lamp.

707164

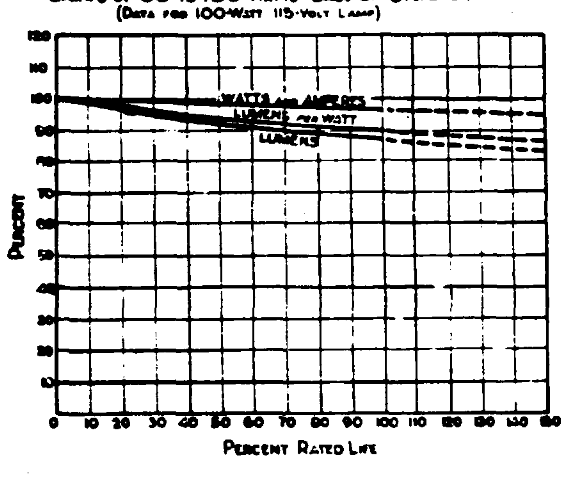


Characteristic Curves
Large Multiple MAZDA Lamps

Typical Operating Performance of Large Multiple MAZDA Lamps
Lamps of 200 to 1000 Watts - Base-Up Operation
(Data for 300-Watt 115-Volt Lamp)



Typical Operating Performance of Large Multiple MAZDA Lamps
Lamps of 60 to 150 Watts - Base-Up Operation
(Data for 100-Watt 115-Volt Lamp)

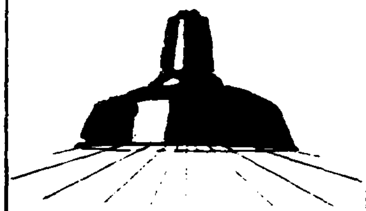


FRANKLIN SPECIFICATION LIGHTING · RED SEAL STANDARD

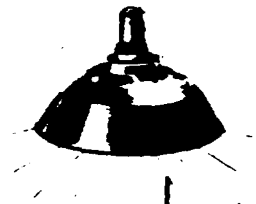
TABLE III—DETERMINATION of LAMP SIZE

Using the proper Section for the fixture selected, the Mounting Height decided upon and the Conditions Factor (found in Table II), choose such Lamp Size and Spacing as will give the desired Foot-Candles.

SECTION 1



SECTION 2



Area Per Outlet Adequately Lighted or *Approximate Spacing	Distance from Underside of Reflector to Floor to be not less than (Mount Units 12' High Wherever Possible)	Conditions Factor	Section 1 Average Foot-Candles 100 Watt	Section 1 150 Watt	Section 1 200 Watt	Section 1 300 Watt	Section 1 500 Watt	Section 2 Average Foot-Candles 100 Watt	Section 2 150 Watt	Section 2 200 Watt	Section 2 300 Watt	Section 2 500 Watt
55-65 Sq. Ft. or 7¾'x7¾' Spacing	7' 6"	Favorable Average Unfavorable	8-10 6-8 5.5-6.5	15-18 11-15 9-11	21-26 16-21 13-16			7-9 5-7 4.5-5.5	13-16 10-13 8-10	18-23 14-18 11-14		
65-75 Sq. Ft. or 8½'x8½' Spacing	8' 6"	Favorable Average Unfavorable	7-9 6-7 5-6	13-16 10-13 8-10	18-22 13-18 11-13			6-8 5-6 4-5	11-14 8-11 7-8	15-19 11-15 9-11		
75-85 Sq. Ft. or 9'x9' Spacing	8' 6"	Favorable Average Unfavorable	6-8 5-6 4-5	11-14 8-11 7-8	15-19 12-15 10-12			5-7 4-5 3.5-4.0	10-12 8-10 6-8	13-17 10-13 8-10		
85-95 Sq. Ft. or 9½'x9½' Spacing	9' 0"	Favorable Average Unfavorable	5-7 4-5 3.5-4.0	10-12 8-10 6-8	14-17 11-14 9-11			5-6 3.5-4.5 3.0-3.5	8-10 6-8 5-6	12-15 9-12 7-9		
95-110 Sq. Ft. or 10'x10' Spacing	9' 6"	Favorable Average Unfavorable	4-6 3.5-4.0 3.0-3.5	8-10 6-8 5-6	12-15 10-12 8-10	21-26 16-21 13-16		4-5 3-4 2.5-3.5	7-9 5-7 4-5	11-13 8-11 6-8	18-23 13-18 11-13	
110-125 Sq. Ft. or 11'x11' Spacing	10' 0"	Favorable Average Unfavorable	4-5 3.5-4.0 2.5-3.5	7-9 6-7 5-5.5	10-13 8-10 7-8	18-22 14-18 12-14		3.5-4.0 3.0-3.5 2.5-3.0	6-8 5-6 4-5	9-11 7-9 5-6	15-19 11-15 9-11	
125-145 Sq. Ft. or 11½'x11½' Spacing	10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 0-3.5 [illegible]	[illegible]	8-10 [illegible]-8 [illegible].5	13-17 10-13 8-10	
145-170 Sq. Ft. or 12½'x12½' Spacing	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12-15 9-12 7-9	21-26 16-21 13-16
170-200 Sq. Ft. or 13½'x13½' Spacing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10-12 7-10 6.5-7.5	18-23 13-18 10-13
200-230 Sq. Ft. or 14¾'x14¾' Spacing	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 5	8-10 6.5-8 5.5-6.5	15-19 11-15 9-11
230-260 Sq. Ft. or 15½'x15½' Spacing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.5-9 6-7 4.5-5.5	13-17 10-13 8-10
260-300 Sq. Ft. or 16¾'x16¾' Spacing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7-8 5-6 4-4.5	12-15 9-12 7-9
300-340 Sq. Ft. or 18'x18' Spacing	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5-7 4-5 3.5-4.0	10-12 8-10 6-8
340-390 Sq. Ft. or 19'x19' Spacing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.5-6 3.5-4.0 3.0-3.5	9-11 7-9 5.5-6.5
390-440 Sq. Ft. or 20½'x20½' Spacing	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4-5 3-4 2.5-3.0	8-10 6-8 5-6
440-500 Sq. Ft. or 21¾'x21¾' Spacing	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.5-4.0 2.5-3.5 2.0-2.5	6-8 5-6 4-5

* Between walls and first rows of lights allow not more than ½ spacing.

INTENSITIES PRODUCED COOPER HEWITT LAMPS

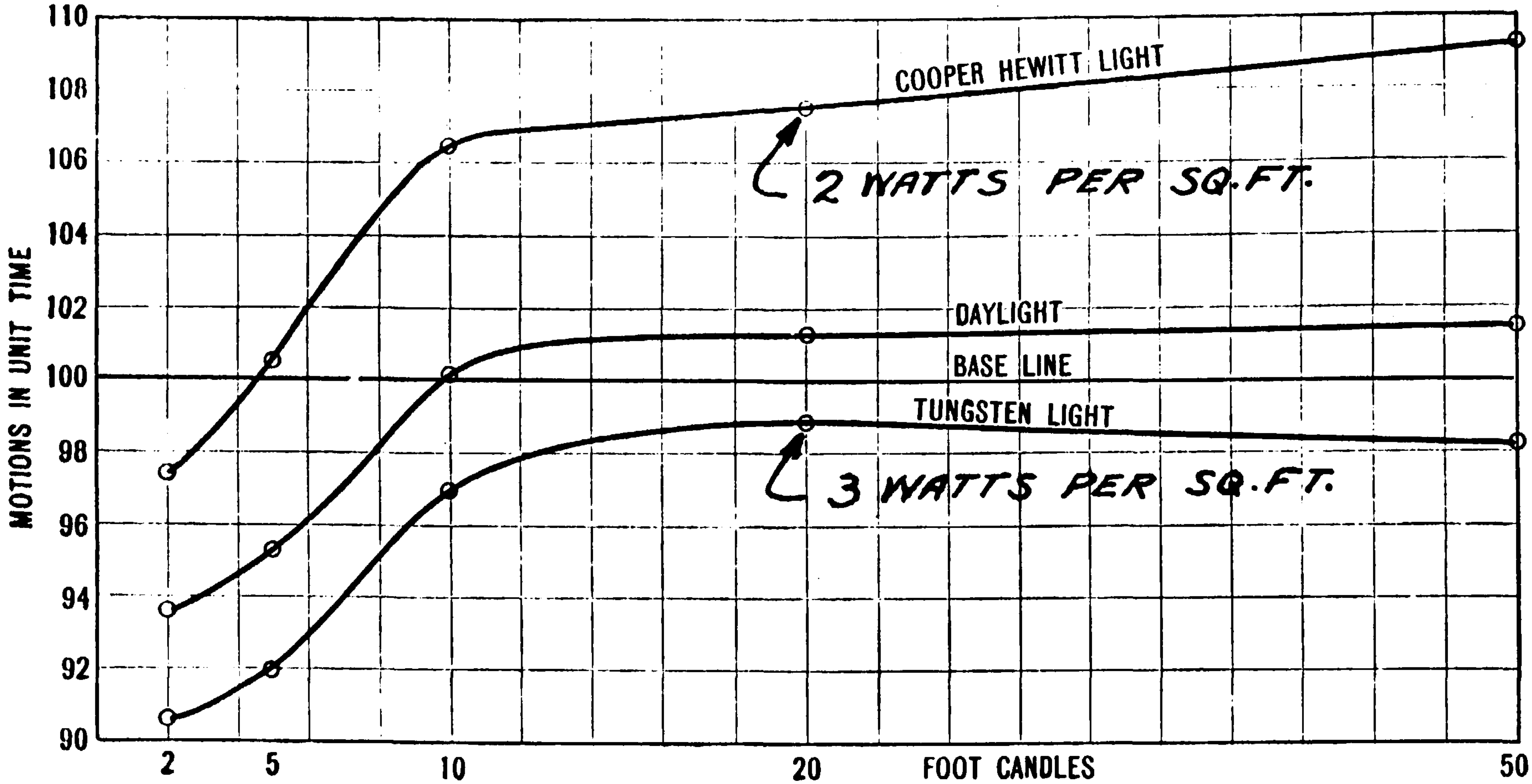
HORIZONTAL DISTANCE BETWEEN LAMPS

Height	8	9	10	11	12	13	14	15	16	18	20	24
4	55.0	40.4	24.5	23.0	17.9	15.7	11.8	9.7	7.0	5.7	3.9	1.4
5	62.1	55.4	39.6	27.6	21.6	19.7	15.4	12.2	9.2	7.4	5.4	2.3
6	65.2	58.6	42.5	30.7	24.5	22.6	17.8	14.3	10.9	7.8	6.6	3.2
7	65.2	58.4	44.3	33.0	26.5	25.0	19.3	15.9	12.5	9.9	7.7	4.0
8	64.2	57.4	45.0	34.2	28.2	27.2	20.9	17.3	13.9	11.0	9.1	4.7
9	62.1	55.2	43.7	34.8	29.2	28.0	22.0	[illegible]	15.1	11.9	9.6	5.3
10	59.7	53.0	42.3	34.3	29.6	27.6	22.8	19.1	16.0	12.7	10.1	5.8
11	57.0	50.6	40.8	33.3	29.5	27.0	23.0	19.4	16.6	13.3	10.8	6.2
12	54.1	46.0	39.2	32.3	29.0	26.2	22.5	19.5	16.7	13.7	11.2	6.3
13	51.2	45.6	37.7	31.3	28.3	25.5	22.0	19.4	16.6	14.0	11.3	6.5
Approximate Watts per Square Foot of Horizontal Surface	7.0	5.5	4.5	3.7	3.1	2.5	2.3	2.0	1.7	1.4	1.1	.78

THE SOCIETY FOR ELECTRICAL DEVELOPMENT, Inc.

707167

CURVES SHOWING REACTIONS IN UNIT TIME UNDER DIFFERENT KINDS OF LIGHT



RLM Dome Reflector

Area Per Outlet Adequately Lighted or Approximate Spacing	Distance from Underside of Reflector to Floor not to be less than	Room Conditions	Average foot-candles obtained from above reflector using lamp sizes as given at top of columns: 100 Watt	150 Watt	200 Watt	300 Watt	500 Watt	Watts per Square Foot: 100 Watt	150 Watt	200 Watt	300 Watt	500 Watt
[illegible] Sq. Ft. or [illegible] Spacing	[illegible]	Favorable Average Unfavorable	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]	21-26 [illegible]-21 [illegible]-16	[illegible] 25-34 [illegible]	[illegible]-72 [illegible] [illegible]	[illegible]	2.5	3.3	[illegible]	[illegible]
[illegible] Sq. Ft. or [illegible] Spacing	[illegible]	Favorable Average Unfavorable	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]	[illegible]-22 [illegible]-18 [illegible]	29-35 21-29 18-21	[illegible] [illegible] 32-38	[illegible]	2.1	2.8	4	[illegible]
[illegible] Sq. Ft. or [illegible] Spacing	[illegible]	Favorable Average Unfavorable	[illegible] 5-6 4-5	[illegible]-14 8-[illegible] [illegible]	15-19 12-15 10-12	24-31 19-24 16-19	[illegible]-56 [illegible] 29-34	[illegible]	1.8	2.5	3.7	6
85-95 Sq. Ft. or [illegible] Spacing	[illegible]	Favorable Average Unfavorable	5-7 4-5 3.5-4.0	10-12 8-10 6-8	14-17 11-14 9-11	22-27 18-22 14-18	39-48 [illegible] 25-32	[illegible]	1.7	2.2	3.3	[illegible]
95-110 Sq. Ft. or 10'x10' Spacing	9' 6"	Favorable Average Unfavorable	4-6 3.5-4.0 3.0-3.5	8-10 6-8 5-6	12-15 10-12 8-10	21-26 16-21 13-16	38-47 29-38 23-29	1	1.5	2	3	5
110-125 Sq. Ft. or 11'x11' Spacing	10' 0"	Favorable Average Unfavorable	4-5 3.5-4.0 2.5-3.5	7-9 6-7 5-5.5	10-13 8-10 7-8	18-22 14-18 12-14	32-39 25-32 21-25	.8	1.2	1.6	2.5	4.1
125-145 Sq. Ft. or 11½'x11½' Spacing	10' 6"	Favorable Average Unfavorable	3.5-4.0 3.0-3.5 2.5-3.0	6-8 5-6 4-5	9-11 7-9 6-7	15-19 12-15 10-12	27-34 21-27 18-21	.7	1.1	1.5	2.3	3.7
145-170 Sq. Ft. or 13'x13' Spacing	11' 6"	Favorable Average Unfavorable	3.0-3.5 2.5-3.0 2.0-2.5	5-7 4-5 3.5-4.0	7-9 6-7 5-6	13-17 10-13 8-10	23-30 18-23 14-18	.6	1	1.3	1.9	3.2
170-200 Sq. Ft. or 13½'x13½' Spacing	12' 0"	Favorable Average Unfavorable	2.5-3.5 2.0-3.0 1.5-2.0	4-6 3.5-4.0 3.0-3.5	6-8 5-6 4-5	11-14 8-11 7-8	20-25 16-20 13-16	.5	.8	1.1	1.6	2.7
200-230 Sq. Ft. or 14¾'x14¾' Spacing	12' 6"	Favorable Average Unfavorable	2.5-3.0 2.0-2.5 1.0-1.5	3.5-4.0 3.0-3.5 2.5-3.0	5-7 4.5-5.5 3.5-4.0	10-12 7-10 6-7	17-22 13-17 11-13	.5	.7	.9	1.4	2.3
230-260 Sq. Ft. or 15½'x15½' Spacing	13' 0"	Favorable Average Unfavorable		3.0-3.5 2.5-3.0 2.0-2.5	4-6 4-4.5 3.5-4.0	8-10 6-8 5.5-6.5	17-19 12-17 10-12		.6	.8	1.2	2.1
260-300 Sq. Ft. or 16¾'x16¾' Spacing	13' 6"	Favorable Average Unfavorable		2.5-3.0 2.0-2.5 1.5-2.0	4-5 3.5-4.0 3.0-3.5	7-9 6-7 5-6	13-17 10-13 9-10		.5	.7	1.1	1.7
300-340 Sq. Ft. or 18'x18' Spacing	14' 6"	Favorable Average Unfavorable			3.5-4.0 3.0-3.5 2.5-3.0	6-8 5-6 4-5	12-14 9-12 7-9			.6	.9	1.5
340-390 Sq. Ft. or 19'x19' Spacing	15' 6"	Favorable Average Unfavorable			3.0-3.5 2.5-3.0 2.0-2.5	5-7 4-5 3.5-4.0	10-12 7-10 6-7			.5	.8	1.4
390-440 Sq. Ft. or 20½'x20½' Spacing	16' 6"	Favorable Average Unfavorable			2.5-3.0 2.0-2.5 1.5-2.0	4-6 3.5-4.0 3.0-3.5	9-11 7-9 5-6			.4	.7	1.2

Glassteel Diffuser

Area Per Outlet Adequately Lighted or Approximate Spacing	Distance from Underside of Reflector to Floor not to be less than	Room Conditions	Average foot-candles obtained from above reflector using lamp sizes as given at top of columns: 100 Watt	150 Watt	200 Watt	300 Watt	500 Watt	Watts per Square Foot: 100 Watt	150 Watt	200 Watt	300 Watt	500 Watt
55-65 Sq. Ft. or 7¾'x7¾' Spacing	7' 6"	Favorable Average Unfavorable		13-16 10-13 8-10	18-23 14-18 11-14	29-37 23-29 18-23	52-66 41-52 32-41		2.5	3.3	5	8
65-75 Sq. Ft. or 8½'x8½' Spacing	8' 0"	Favorable Average Unfavorable		11-14 8-11 7-8	15-19 11-15 9-11	24-31 18-24 14-18	43-56 32-43 25-32		2.1	2.8	4	6.6
75-85 Sq. Ft. or 9'x9' Spacing	8' 6"	Favorable Average Unfavorable		10-12 8-10 6-8	13-17 10-13 8-10	21-27 16-21 13-16	38-48 29-38 23-29		1.8	2.5	3.7	6.1
85-95 Sq. Ft. or 9½'x9½' Spacing	9' 0"	Favorable Average Unfavorable		8-10 6-8 5-6	12-15 9-12 7-9	19-26 14-19 11-14	34-47 25-34 20-25		1.7	2.2	3.3	5.5
95-110 Sq. Ft. or 10'x10' Spacing	9' 6"	Favorable Average Unfavorable		7-9 5-7 4-5	11-13 8-11 6-8	18-23 13-18 11-13	32-41 23-32 20-23		1.5	2	3	5
110-125 Sq. Ft. or 11'x11' Spacing	10' 0"	Favorable Average Unfavorable		6-8 5-6 4-5	9-11 7-9 5-6	15-19 11-15 9-11	27-34 20-27 16-20		1.2	1.6	2.5	4.1
125-145 Sq. Ft. or 11½'x11½' Spacing	10' 6"	Favorable Average Unfavorable		5-7 4-5 3-4	8-10 6-8 4.5-5.5	13-17 10-13 8-10	23-30 18-23 14-18		1.1	1.5	2.3	3.7
145-170 Sq. Ft. or 13'x13' Spacing	11' 6"	Favorable Average Unfavorable		4-6 3-4 2.5-3.5	6.5-8 5-6 4-5	12-15 9-12 7-9	21-26 16-21 13-16		1	1.3	1.9	3.2
170-200 Sq. Ft. or 13½'x13½' Spacing	12' 0"	Favorable Average Unfavorable		3.5-5.0 3.0-3.8 2.5-3.0	6-7 4-5 3.5-4.0	10-12 7-10 6.5-7.5	18-23 13-18 10-13		.8	1.1	1.6	2.7
200-230 Sq. Ft. or 14¾'x14¾' Spacing	12' 6"	Favorable Average Unfavorable		3.5-4.0 2.8-3.5 2.0-2.5	5-6 3.5-4.0 3.0-3.5	8-10 6.5-8 5.5-6.5	15-19 11-15 9-11		.7	.9	1.4	2.3
230-260 Sq. Ft. or 15½'x15½' Spacing	13' 0"	Favorable Average Unfavorable		3.0-3.5 2.5-3.0 1.5-2.0	4-5 3-4 2.5-3.0	7.5-9 6-7 4.5-5.5	13-17 10-13 8-10		.6	.8	1.2	2.1
260-300 Sq. Ft. or 16¾'x16¾' Spacing	13' 6"	Favorable Average Unfavorable		2.5-3.0 2.0-2.6	3.5-4.0 3.0-3.5 2.0-2.5	7-8 5-6 4-4.5	12-15 9-12 7-9		.5	.7	1.1	1.7
300-340 Sq. Ft. or 18'x18' Spacing	14' 6"	Favorable Average Unfavorable			3.0-3.5 2.5-3.0 1.5-2.0	5-7 4-5 3.5-4.0	10-12 8-10 6-8			.6	.9	1.5
340-390 Sq. Ft. or 19'x19' Spacing	15' 6"	Favorable Average Unfavorable			2.5-3.0 2.0-2.5	4.5-6 3.5-4.0 3.0-3.5	9-11 7-9 5.5-6.5			.5	.8	1.4
390-440 Sq. Ft. or 20½'x20½' Spacing	16' 6"	Favorable Average Unfavorable				4-5 3-4 2.5-3.0	8-10 6-8 5-6				.7	1.2

Intensities Produced by Sixteen 450 Watt Cooper Hewitt Lamps Symmetrically Spaced

Height	8	9	10	11	12	13	14	15	16	18	20	24
	Horizontal Distance Between Lamps											
4	55.0	40.4	24.5	23.0	17.9	15.7	11.8	9.7	7.0	5.7	3.9	1.4
5	62.1	55.4	39.6	27.6	21.6	19.7	15.4	12.2	9.2	7.4	5.4	2.3
6	65.2	58.6	42.5	30.7	24.5	22.6	17.8	14.3	10.9	7.8	6.6	3.2
7	65.2	58.4	44.3	33.0	26.5	25.0	19.3	15.9	12.5	9.9	7.7	4.0
8	64.2	57.4	45.0	34.2	28.2	27.2	20.9	17.3	13.9	11.0	9.1	4.7
9	62.1	55.2	43.7	34.8	29.2	28.0	22.0	18.3	15.1	11.9	9.6	5.3
10	59.7	53.0	42.3	34.3	29.6	27.6	22.8	19.1	16.0	12.7	10.1	5.8
11	57.0	50.6	40.8	33.3	29.5	27.0	23.0	19.4	16.6	13.3	10.8	6.2
12	54.1	46.0	39.2	32.3	29.0	26.2	22.5	19.5	16.7	13.7	11.2	6.3
13	51.2	45.6	37.7	31.3	28.3	25.5	22.0	19.4	16.6	14.0	11.3	6.5
14	48.0	42.8	36.2	30.2	27.4	23.8	21.3	19.2	16.4	14.2	11.4	6.6
15	44.5	38.6	34.7	29.1	26.7	23.7	20.7	18.7	16.1	14.1	11.4	6.7
16	40.6	34.6	33.1	28.0	25.7	22.9	19.3	18.2	15.7	13.8	11.2	6.7
18	36.6	33.1	30.0	25.5	23.5	20.9	17.7	16.9	14.9	13.0	10.7	6.7
20	32.6	29.7	26.7	23.0	21.1	18.4	15.2	15.3	13.9	11.2	10.3	6.6
	Approximate Watts per Square Foot of Horizontal Surface											
	7.0	5.5	4.5	3.7	3.1	2.5	2.3	2.0	1.7	1.4	1.1	.78

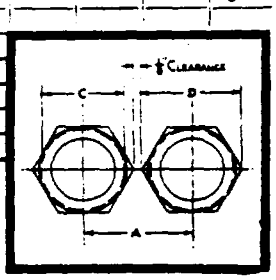
ALLOWABLE CURRENT CARRYING CAPACITIES OF WIRES

Wire Size	Area in Circular Mils	Ampere Carrying Capacity — Types of Insulation: Rubber	V. C.	Other	Number of Wires in 1 Conduit — Minimum Conduit Size: 1	2	3	4	5	6	7	8	9
18	1.624	3		6									
16	2 583	6		10									
14	4.107	15	18	20	1/2	1/2	1/2	1/2	3/4	3/4	3/4	1	1
12	6 530	20	25	30	1/2	1/2	1/2	3/4	3/4	1	1	1	1 1/4
10	10 380	25	30	35	1/2	3/4	3/4	3/4	1	1	1 1/4	1 1/4	1 1/4
8	16.510	35	40	50	1/2	3/4	3/4	1	1	1 1/4	1 1/4	1 1/4	1 1/4
6	26.250	50	60	70	1/2	1	1 1/4	1 1/4	1 1/2	1 1/2	2	2	2
5	33.100	55	65	80	3/4	1 1/4	1 1/4	1 1/4	1 1/2	2	2	2	2
4	41.740	70	85	90	3/4	1 1/4	1 1/4	1 1/2	2	2	2	2	2 1/2
3	52.630	80	95	100	3/4	1 1/4	1 1/4	1 1/2	2	2	2	2 1/2	2 1/2
2	66.370	90	110	125	3/4	1 1/4	1 1/2	1 1/2	2	2	2 1/2	2 1/2	2 1/2
1	83.690	100	120	150	3/4	1 1/2	1 1/2	2	2	2 1/2	2 1/2	3	3
0	105.500	125	150	200	1	1 1/2	2	2	2 1/2	2 1/2	3	3	3
00	133.100	150	180	225	1	2	2	2 1/2	2 1/2	3	3	3	3 1/2
000	167.800	175	210	275	1	2	2	2 1/2	3	3	3	3 1/2	3 1/2
0000	211.600	225	270	325	1 1/4	2	2 1/2	2 1/2	3	3	3 1/2	3 1/2	4
	200.000	200	240	300	1 1/4	2	2 1/2	2 1/2	3	3	3 1/2	3 1/2	4
	250.000	250	300	350	1 1/4	2 1/2	2 1/2	3	3	3 1/2			
	300.000	275	330	400	1 1/4	2 1/2	3	3	3 1/2	3 1/2			
	350.000	300	360	450	1 1/4	2 1/2	3	3 1/2	3 1/2	4			
	400.000	325	390	500	1 1/4	3	3	3 1/2	4	4			
	500.000	400	480	600	1 1/2	3	3	3 1/2	4	4 1/2			
	600.000	450	540	680	2	3	3 1/2	4	4 1/2	5			
	700.000	500	600	760	2	3 1/2	3 1/2	4 1/2					
	750.000	525	630	800	2	3 1/2	3 1/2	4 1/2					
	800.000	550	660	840	2	3 1/2	4	4 1/2					
	900.000	600	720	920	2	3 1/2	4	4 1/2					
	1.000.000	650	780	1.000	2	4	4	5					

From National Electric Code, 1931 Edition.

SPACING and DIMENSIONS of LOCK-NUTS and K. O.'s

Diam. of Lock-Nut "D"	Punch Diam. "C"	Nominal Conduit Size	Minimum Spacing of Knock-Outs "A": 1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"
1 1/8"	7/8"	1/2"	1 1/4	1 7/16	1 1/2	1 11/16	1 7/8	2 1/8	2 7/16	2 7/8	3 1/8	3 1/2	3 15/16	4 7/16
1 7/16"	1 1/8"	3/4"		1 9/16	1 11/16	1 7/8	2	2 5/16	2 5/8	3	3 5/16	3 11/16	4 1/8	4 5/8
1 5/8"	1 3/8"	1"			1 3/4	1 15/16	2 1/8	2 3/8	2 11/16	3 1/8	3 3/8	3 3/4	4 3/16	4 11/16
2"	1 3/4"	1 1/4"				2 1/8	2 5/16	2 9/16	2 7/8	3 5/16	3 9/16	3 15/16	4 3/8	4 7/8
2 5/16"	2"	1 1/2"					2 7/16	2 3/4	3 1/16	3 7/16	3 3/4	4 1/8	4 9/16	5 1/16
2 7/8"	2 1/2"	2"						3	3 5/16	3 3/4	4	4 3/8	4 13/16	5 5/16
3 1/2"	3"	2 1/2"							3 5/8	4 1/16	4 5/16	4 11/16	5 1/8	5 5/8
4 5/16"	3 5/8"	3"								4 7/16	4 3/4	5 1/8	5 9/16	6 1/16
4 7/8"	4 1/8"	3 1/2"									5	5 3/8	5 13/16	6 5/16
5 5/8"	4 5/8"	4"										5 3/4	6 3/16	6 11/16
6 1/2"	5 5/8"	5"											6 5/8	7 1/8
7 1/2"	6 3/4"	6"												7 5/8



LIGHTING INTENSITIES

PAGE

Lighting Intensities

Intensity of lighting is by no means a measure of the real value of a lighting system. Many trained engineers have the habit of strapping a meter measuring foot-candles across their shoulders and when called in to check a lighting installation, they rely solely upon what the meter does or does not read. Quality of light is set aside as a secondary issue when, in fact, it is the most important factor above all other things in lighting.

FOOT-CANDLE AS A UNIT OF MEASURE

The lumen is generally used by lamp manufacturers and many illuminating engineers to indicate the light output and efficiency of bare lamps, but for all practical purposes of comparison, foot-candle readings are generally used by practical engineers in industrial plants. They avoid the measures usually employed by theorists, eliminating errors and the necessity of using factors for reflectors, diffusers, depreciation, utilization, and other variables.

The rating of bare lamps on the lumen basis is about the same as rating automobile engines on the horsepower basis from block tests, under the most favorable conditions. However, this does not give the actual horsepower of the automobile operating under normal road conditions throughout the year.

The use of foot-candles on the job, rather than calculating from lumen output values is the safest way to obtain actual comparisons of one lighting system against another. The only thing to remember, is that quality of light cannot be measured by ordinary foot-candles, since quality is a measure of the value of light in terms of seeing-power and foot-candles are not a measure of seeing.

". . . . mercury vapor light appears to magnify details and produces visual results considerably greater than its photometric intensity would indicate."

DR. LOUIS BELL, PH. D.
Author of "Art of Illumination"

MEASURING LIGHTING INTENSITIES

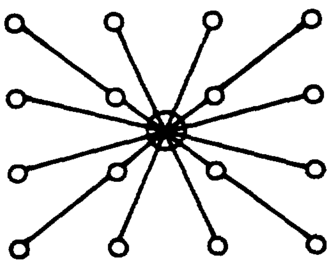
Many "foot-candle engineers" lack the proper technique in using illuminometer meters in checking the effectiveness of a lighting system. Usually, the meter is very carefully set 30" above the floor with every precaution to avoid shadows on the screen of the paddle. The meter readings are taken only on the horizontal plane because a group or average of such readings will give the highest results in general illumination.

Illumination on Horizontal Surfaces is a prime requisite in offices, drafting rooms and those shops where the problem is to provide the best illumination for sustained vision of flat surfaces on the horizontal or slightly oblique planes in which papers, books and other flat objects are usually examined. For relative performance of various units compare coefficients of utilization for any given condition.

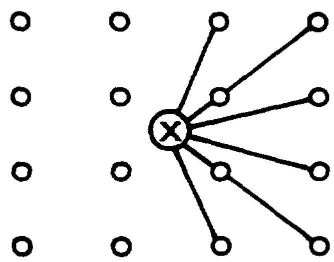
Illumination on Vertical Surfaces is essential in many industrial operations where working surfaces are in vertical or oblique planes. It is likewise important in stores with vertical shelving, rug racks, etc., in art museums, library stock rooms, office file rooms. Without supplementary units, the illumination on vertical surfaces from ordinary general lighting units is of the order of one-half to one-third of the horizontal illumination values.

Appearance of Lighted Room refers only to the general or casual effect produced by the complete system, and is not intended to rate the unit as to satisfaction from the standpoint of good vision or freedom from eye fatigue.

Vertical illumination is very often more important in production areas. Normally workmen view opaque objects which can be lighted only from one side by a group of lighting units. Thus, if the object happens to be located in the very center of a room it will receive less than 50% of the light from the lighting units, on the vertical surface, whereas, a horizontal surface would receive light from all units in every direction.



Measuring horizontal intensities



Measuring vertical intensities

707173

Horizontal intensity takes no account of possible obstructive shadows that may be caused by machinery, material, or workmen. It is, therefore, a wholly unreliable measure of the value of illumination for all cases. A much more reliable measure would be the average of vertical and horizontal intensities. The most reliable measure is probably the intensity on a plane perpendicular to the line of vision of a workman in his normal position while at work. However, workmen are constantly changing positions and their line of vision is scarcely the same longer than a minute or two at a time, making measurement rather difficult.

All measurements, regardless of the method employed, are valuable only so far as comparisons between lighting systems are concerned. Neither quality nor seeing-power is revealed by these measurements. In lighting for seeing, there is only one thing that counts:

> The clearness and ease with which the workman can **seeto do his work.** All that does not directly contribute to this result can be left to take care of itself; and all rules and formulas which are not directed to this end are only useless detours, that get nowhere. So-called **working planes** toil not, neither do they spin; nor is the test screen of an illuminometer the thing a workman has to see.

PHOTOMETRIC MEASUREMENTS

The photometer is an instrument for measuring the relative physical intensity of light. A portable photometer has been assigned the name **illuminometer**, having its scale calibrated to read foot-candles. Here again the readings refer to physical brightness of light. It does not account for the light-and-shade contrast of the light which is a measure of quality.

The physical intensity of light tells but part of the story. Dr. Steinmetz stated:

> "It does not mean that any two lights, regardless of their color, have the same intensity if at the same distance from them, objects can be seen with the same distinctness; as, for instance, print read with equal ease. The only method, therefore, which permits comparing and measuring lights of widely different color is the method of reading differences as used in the so-called luminometer. After all, it is the theoretically correct method of comparison, as it compares the light of that property for which they are used. Curiously enough, the luminometer, thus, is the only correct light measuring instrument, and the photometer correct only insofar as it agrees with the luminometer."

Dr. Louis Bell found that COOPER HEWITT light had a tendency to reduce chromatic aberration and had a power of revealing detail considerably greater than its photometric intensity would indicate. Referring to mercury vapor light he states:

> "It acts as if it were a light of much higher candlepower than it really is. In fact, the assumption that a gain in acuity is due to a real difference in candlepower, instead of the spurious difference indicated by the quality of brightness comparison, would lead to an efficiency of light production in the mercury vapor tube which is, in the writer's judgment, quite inadmissable."

Both Steinmetz and Bell intimate that contrast is a true measure of lighting effectiveness. Without contrast, seeing cannot be accomplished; while maximum contrast promotes ease of vision. COOPER HEWITT light increases contrast 50% to 100% above that of incandescent light.

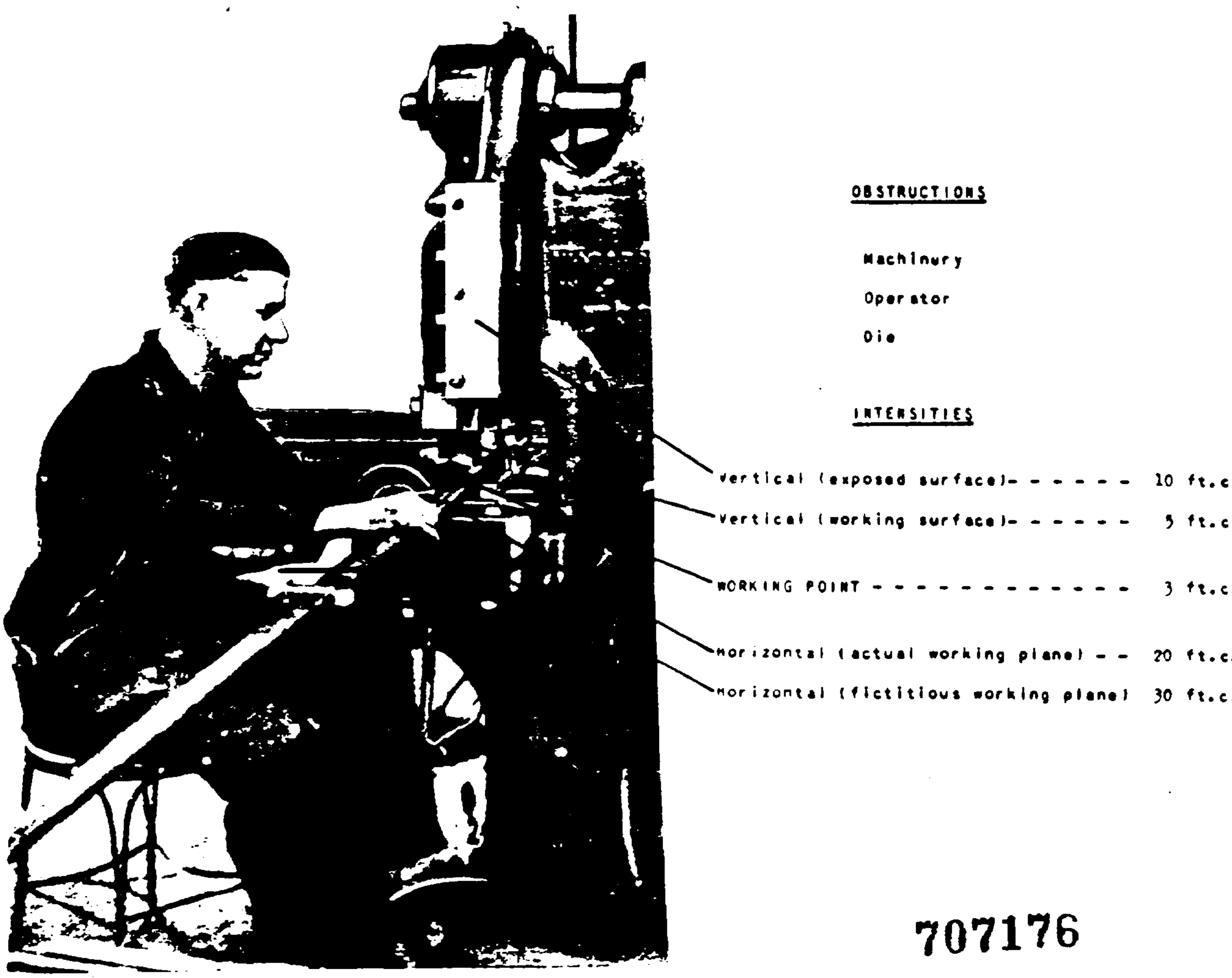
SEEING AT WORKING POINTS

It has been stated that horizontal lighting intensities on the working plane is not a true measure of a lighting system. Vertical intensities are frequently less than 1/3 the horizontal values. Thus, if 30 foot-candles are measured on a horizontal plane only 10 foot-candles exist on the vertical plane.

The so-called **working plane** is a fictitious standard having absolutely no connection with regard to production vision. The extreme care with which intensity readings are taken at such working planes indicate obviously that these intensities are incorrect **insofar as the point of seeing** is concerned. Actually, "the point of seeing" is that which is shadowed by:

1. The machine itself
2. Obstructions due to equipment
3. Tools at the cutting point
4. Workers head and arms

The shadowed intensities at these points are naturally much lower than either the horizontal or vertical intensities. Very often these readings are around 2 or 3 foot-candles.



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LIGHTING THE WORKING POINTS

It is apparent that all working points do not require the same intensity. On course work the intensity at the very point of seeing may be only 1 foot-candle and yet sufficient to enable operators to work with comfort. Some extremely fine inspection work requires as high as 1000 foot-candles or more.

Every manufacturing operation requires special attention. It is, therefore, quite impossible to set down certain limits in tabular form recommending intensities of lighting for various classes of work. Illuminating engineers must study each operation carefully and gain a thorough knowledge of what the operator is attempting to do; then and only then can lighting be recommended as a solution to the problem at hand. This may sound like a long way around and may even require many days to complete, but COOPER HEWITT light has been recommended and sold by this method for more than 25 years. It has gained a reputation that is the envy of many.

Daylight intensities are high near the windows and low in the middle floor areas.

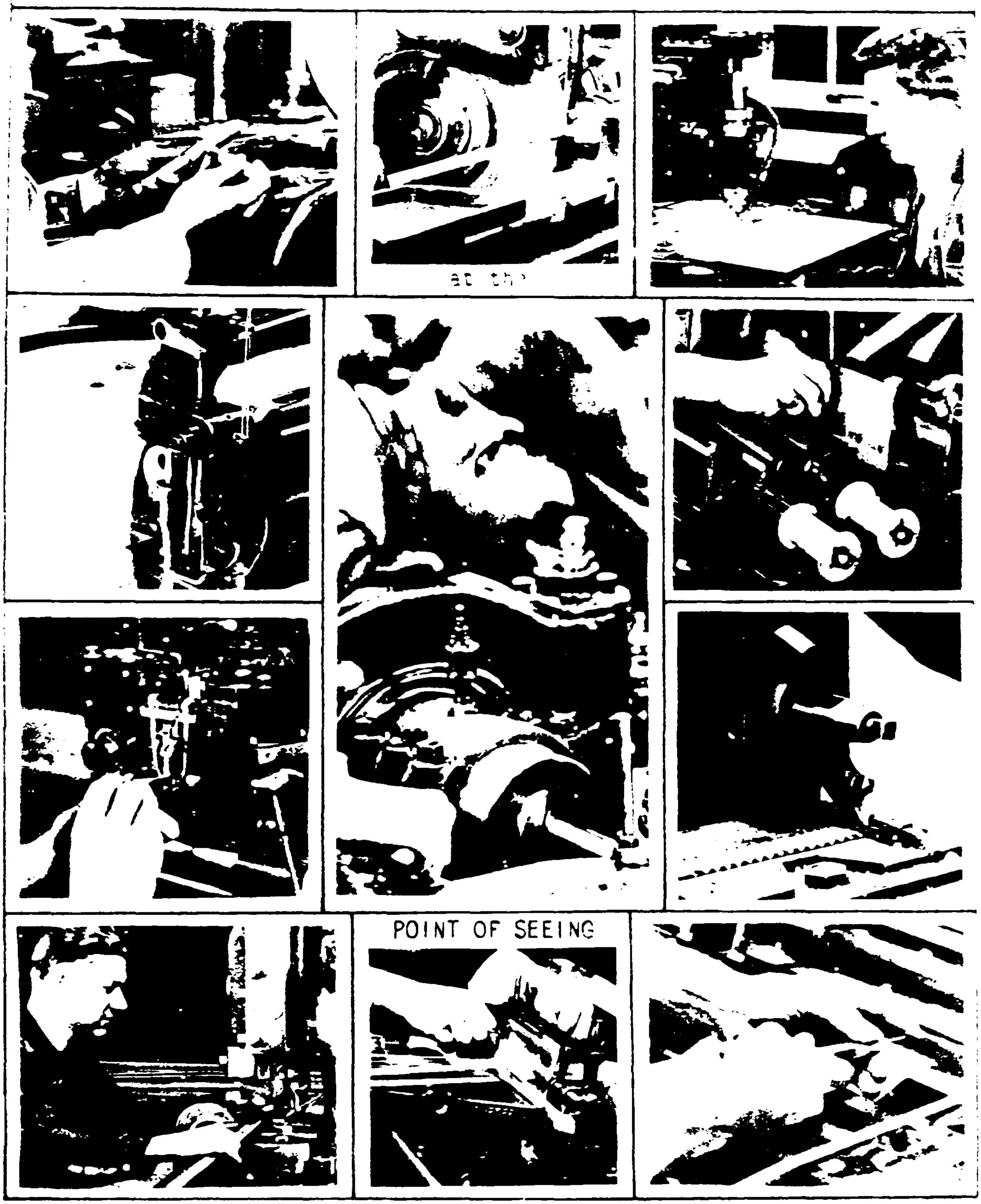
> In the largest wool treating plant in the world, engineers measured 2500 foot-candles at the windows and only 2½ foot-candles on the sorting tables.

Even with normal intensities of daylight, the amount of light on the working points is lower in quantity and lacking in quality when compared with COOPER HEWITT illumination.

On the following page are a group of close-up unretouched photographs indicating the powerful effect of COOPER HEWITT light at the point of seeing. No auxiliary light was used in "shooting" these photographs -- **mercury light penetrates to the working points** where vision is required. There is no glare and shadows are luminous -- not even daylight can compete with results as amazing as these.

"better than daylight"

BETTER SIGHT with MERCURY LIGHT



TESTS AT THE POINT OF SEEING

Several tests made in large industrial plants indicate that vertical intensities average 100% higher under COOPER HEWITTS than under incandescent when the horizontal intensities are the same. In one particular test, the horizontal intensity of incandescent units was somewhat higher than a corresponding installation of COOPER HEWITTS and yet the vertical intensity of the incandescent system was about 50% lower.

Many other tests taken at the point of seeing and in shielded places show that diffused incandescent light lacks the punch given out by COOPER HEWITT light. Incandescent light at such points may provide only a fraction of 1 foot-candle (in the recess) while the mercury vapor light under the same conditions provides 2 or 3 foot-candles at the same point. This is exemplified diagrammatically on the following page.

Incandescent lamps emit light from point sources while mercury light is distributed from a reflector over 5 feet long or an equivalent area of almost 5 square feet. On automobile lines and other equally important work, one COOPER HEWITT lamp will surpass the illumination given off by two diffused incandescent lamps.

Light emanating from a point source is bound to cast dark obstructive shadows in partly enclosed sections where important machining of surfaces is being undertaken; the result is poor vision where good vision is essential. Increasing the intensity in an attempt to better light these sections usually results in deeper, more objectionable shadows. The application of local lighting assists in increasing the intensity somewhat in these recessed areas but still falls short of providing the eyes with "seeing-power" that eliminates eyestrain and fatigue.

COOPER HEWITT light is uncanny in its ability to put light where light is needed -- it penetrates into niches and recesses where other lights fail and because of its greater detail revealing effect, by virtue of increased contrast and retinal brightness, only one half the light as measured photometrically is required, when compared with incandescent light.

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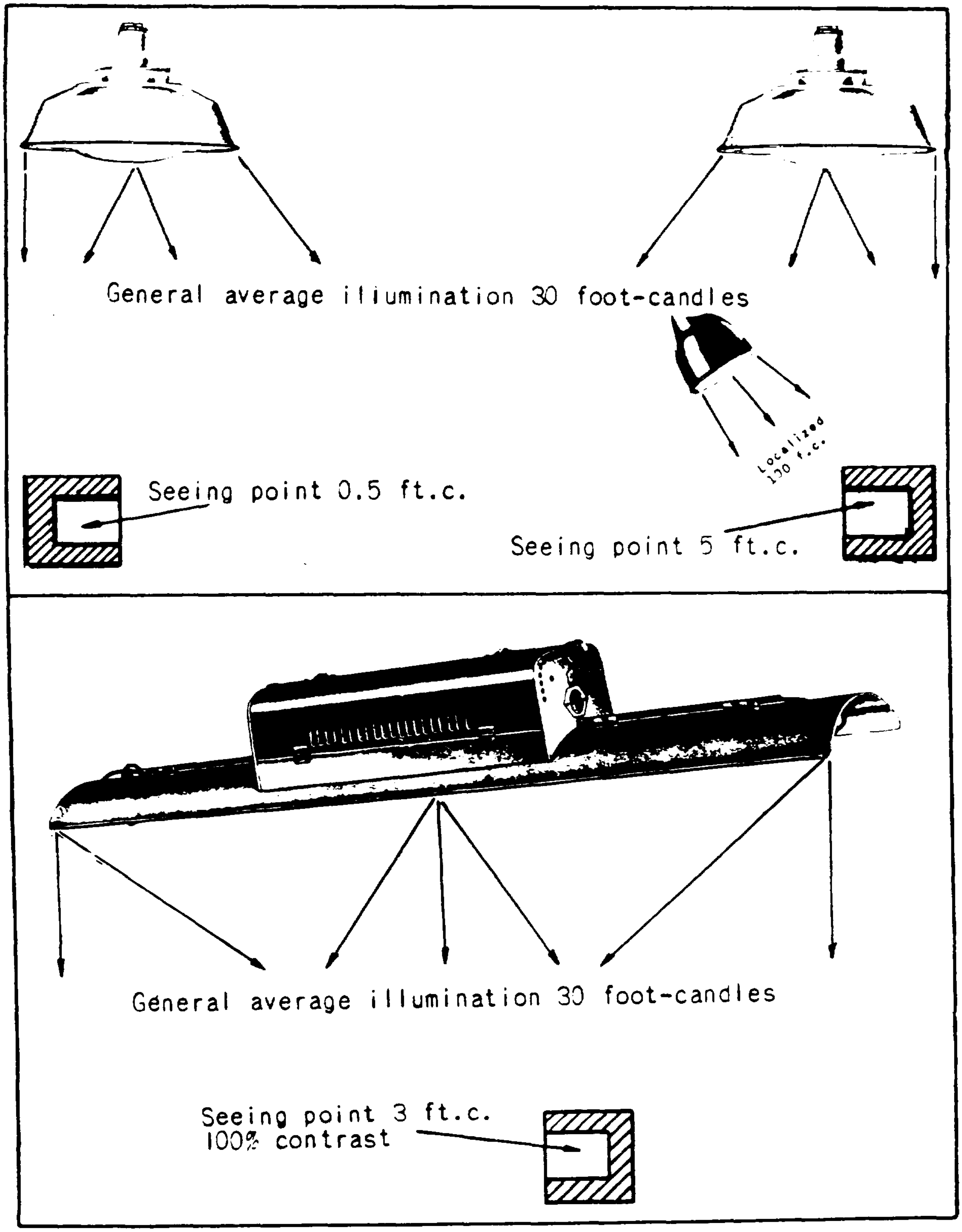
Typical examples of COOPER HEWITT and incandescent lighting with resultant intensities at the seeing points.

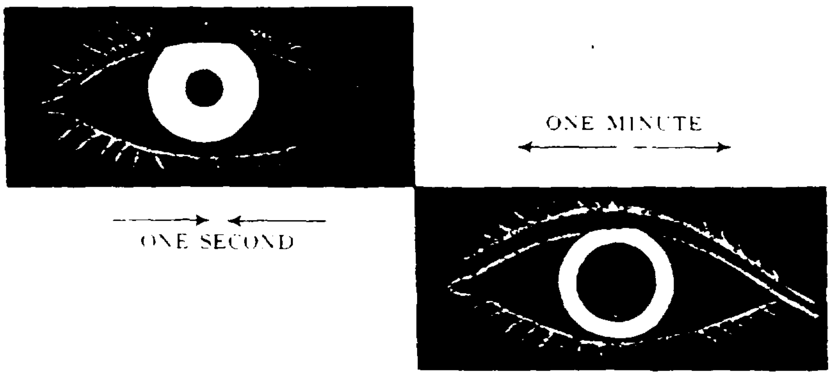


LOCALIZED LIGHTING

Wherever possible, the use of localized lighting should be avoided. Many engineers in speaking of local lighting refer to drop lights or bracket lights using incandescent bulbs. However, this is not the only form of localized lighting used in industry. COOPER HEWITT light has been used in this manner for many years.

The main consideration in local lighting is that contrast values for full vision must not exceed 1 to 10 and preferably 1 to 5. In other words, if 100 foot-candles of local lighting is used, at least 10 foot-candles of general lighting and preferably 20 foot-candles, should be used to remove the hazard of too much contrast between light at the working point and light in other portions of the working area.

The average individual considers that the human eye can endure greatly varying intensities in relatively short intervals of time. In many respects this is true, but the final outcome is eyestrain and fatigue. Insofar as the eyes affect production the effect is detrimental right from the start, as illustrated below.



The contraction of the eye to protect the sensitive retina from glare and high spot lighting takes place in one second -- but it takes 60 times longer to expand again for normal seeing.

Looking from intensely lighted areas to proportionately lower surrounding intensities, causes violent alternate contraction and dilation of the pupil, which usually occurs several thousand times a day. The amount of time wasted by eye adjustment, eyestrain, fatigue and drowsiness, are direct causes of lowered efficiency of workers and loss of operating economy.

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HIGH SPOT LIGHTING

There are a few instances when bracket lighting using low wattage incandescent lamps will prove advantageous with COOPER HEWITT lighting. The occasions are rare, but when they do arise, blue daylight incandescent lamps should be used in order to effect a better blending with the high visual rays of mercury light. This combination will give satisfactory results, diminishing eye fatigue usually experienced with bracket lights in ordinary lighting installations.

In practically all production areas bracket lighting or hot-spot lighting is unnecessary. Occasionally an extension lamp may prove helpful in setting up complicated machines, but once this is accomplished, the auxiliary lighting should be abandoned. Where these conditions are likely to exist, outlets should be provided at certain intervals for the temporary use of extension lamps.

The general application of localized lighting might well be avoided in areas where production is the keyword. Some of the most common objections to bracket or built-in lighting may be listed as follows:

1. Glaring to the eyes -- either direct or specular.
2. Spotty lighting conditions.
3. Poor eye accommodation.
4. Rapid depreciation on account of being too close to working points, therefore quickly accumulating:
    a. Oil and grease
    b. Dust and dirt
5. Where ordinary drop lights or bracket lights are used the above ingredients gather on lamp and reflector shade.
6. Where built-in lighting is used with glass cover, light absorption takes place through diffuser as well as dirt accumulation.

7. Requires constant cleaning, otherwise effect no better than general illumination.
8. Filament life in standard lamp shortened by high frequency vibrations such as caused by motor hum or high speed gearing.
9. Special lamp needed to overcome short life due to vibration and this is available only in 50 watt size.
10. Breakage of glass cover and lamps.

It is hardly necessary to mention the avoidance of bare incandescent lamps near operators, yet there are a few who disregard the hard set rule in this connection. Others forget that reflected glare may also be seriously objectionable even in properly designed units.

If the general illumination were of proper design and had the power to increase sharpness of vision as in the case of COOPER HEWITT light, neither type of local lighting indicated above would be required for the particular class of work undertaken.

PLANNING FACTORY LIGHTING

A lighting layout, in order to be satisfactory, must be designed in accordance with conditions as they exist in the particular case under consideration. Practically every factory or mill has some peculiarity which may have a distinct bearing upon the final choice and location of the lighting units. The design of a lighting system must take into account the position of machines and work benches, even in the so-called general system of lighting. Many advantages with COOPER HEWITT lamps are discovered by placing them at definite angles with certain types of work, although spacing of lamps may be uniform.

While it is apparent that many factors influence the arrangement of lamps with respect to a 'job' there are three accepted methods of lighting in general use in industrial plants:

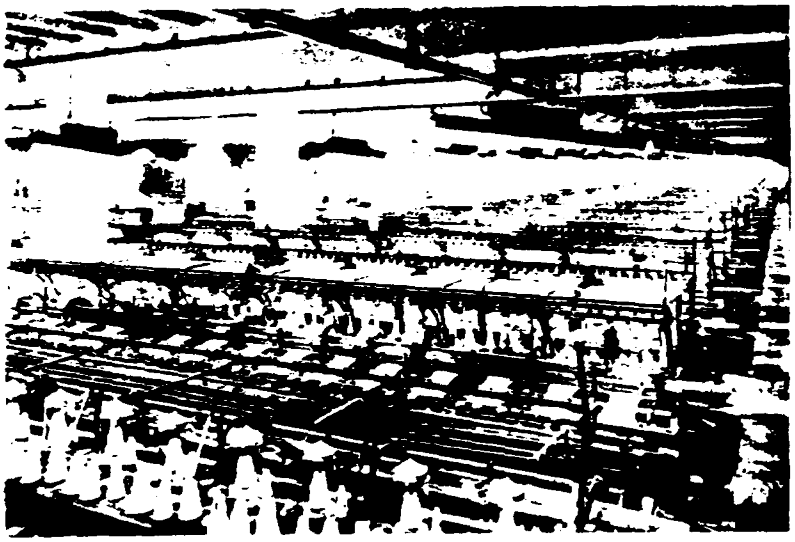
1. General or overhead lighting
2. Group or localized general lighting
3. Local lighting

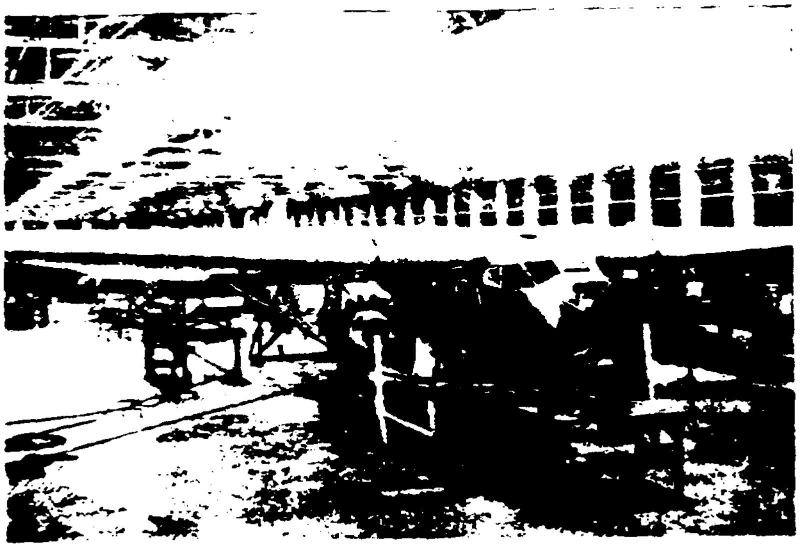
The reason for classification of lighting methods is due primarily to the intensity required to perform certain working tasks. Such intensities must be delivered to the required area in the most practical and efficient manner possible.

GENERAL LIGHTING

General lighting seems to be the most popular and in reality is the ideal method of factory lighting. However, the machines and working planes must be properly situated and of such a nature as to utilize uniform illumination efficiently. A general lighting system is one which has its lighting units mounted overhead and symmetrically arranged, as nearly as possible, to give approximate uniform illumination or even diffusion over the room to be lighted.

The height and spacing of lamps depends upon many factors, of which the most important is the intensity required. Low mounting and fairly close spacing is a necessary factor in the production of high quality hosiery as exemplified by the modern full-fashioned mill. The assembly of an airplane requires less intensity of illumination and because of the large parts handled the lamps are mounted high above the floor.

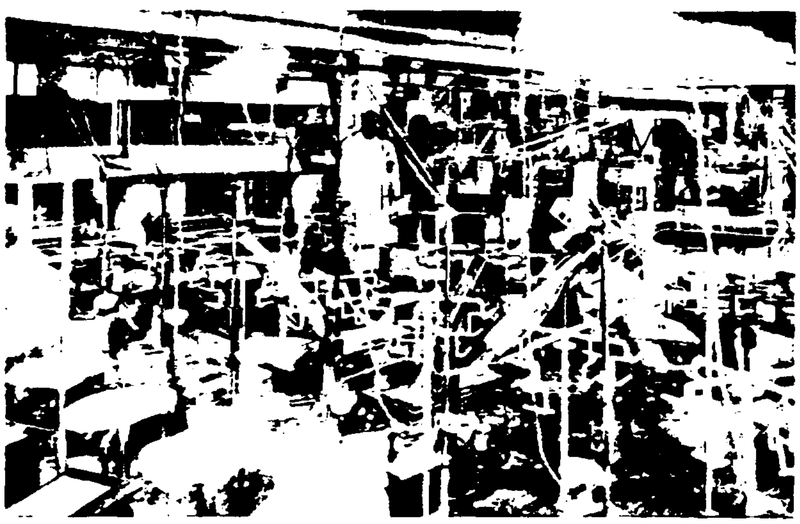




The fact that less intensity is required for one particular class of work than another, does not indicate that the task of seeing is proportionately reduced. As a matter of fact, there must be no sacrifice to accurate vision in either case. Thus, the full-fashioned hosiery mill must have a higher level of illumination than the airplane assembly plant, if an approximate equality of visual effect is to be obtained. So at the end of a working day the optical senses of a worker should be similar whether he works in the one place or the other. Note particularly how the general illumination of COOPER HEWITT light reaches every point on the giant airplane, even underneath the wings.

GROUP LIGHTING

It is obvious that general lighting is not always the most efficient to light a factory or room. Where the nature of the work and machines are the same, as in the weave shed, general lighting is unquestionably desirable.



The condition is entirely changed in the laundry room. Here the light is grouped in accordance with the type of work carried on and the grouping of machines. In general, however, group lighting is similar to general lighting, except that individual sections of a room are considered separately as far as spacing of lighting units are concerned.

The main thing to remember, however, is that units must not be grouped in such a way that extreme spotty lighting will result; this would be particularly undesirable in machine shop areas where hazardous operations are usually being performed. Avoiding excessive spotty lighting means avoiding contrast -- it is natural that men are more likely to be injured when working in shadowy places and under conditions which prevent them from seeing hazards quickly.

LOCAL LIGHTING

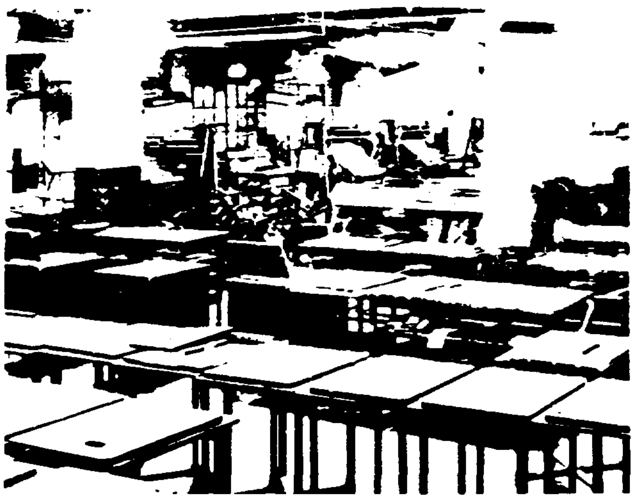
Local lighting is very often necessary where extremely high intensities are needed over small areas. Two very striking examples of this class of lighting are given below, where lens and glass inspection are being made at close range.

These are unusual cases, but give a very good conception of what is required of an illuminating engineer when planning intensities or a reliable factory lighting system. It also gives a practical demonstration of how well COOPER HEWITT light can be applied to any class of work without the usual planning of eliminating glare and shadows -- simply because COOPER HEWITTS are glareless at the source and produce only luminous shadows on working surfaces.

For the exacting work of lens inspection COOPER HEWITT makes water marks, sand holes, scratches and other minute blemishes easier to detect. The inspectors who do this work report a tremendous relief from strain.

GENERAL - GROUP - LOCAL LIGHTING

Many lighting systems use more than one of the three methods mentioned. In special cases all three may be adopted, although this would rarely occur in the same room. A general system with local lighting, or a group system with local lighting are the most common variations. The newspaper composing room illustrates group and local lighting. The local lighting



is represented by the lamps along the windows. These lamps are suspended lower and closer together than those in the foreground on the photograph. This class of work with its new cast type, demand for speed, accuracy and continuous night work, furnishes a real test for illumination. Only soft diffuse light, with lack of glare and reduction of shadows is wanted by the printing industry.

The speedometer assembly department uses what might be termed a "general-group-local" lighting system. The lamps are grouped over the assembly tables, being symmetrically spaced. The assembly of small jewel parts in this department requires work as close as watchmaking; consequently the lamps must be spaced close together and as near the assembly tables as proves necessary.

It is apparent that the planning of a suitable lighting system depends entirely upon the class of work and the distribution of machines or equipment to be lighted. Although there are three general methods of lighting, these may be combined into one when considering COOPER HEWITT installations. This one method might be called "local lighting", since any required commercial intensity can be furnished without sacrifice of a soft and evenly diffused light. The intensities of this local lighting system can be varied by a change in height, spacing or number of lamps. The intensity required depends upon the job to be lighted, while height, spacing and number of lamps depend upon surrounding conditions as well as the job.

LIGHTING ECONOMICS

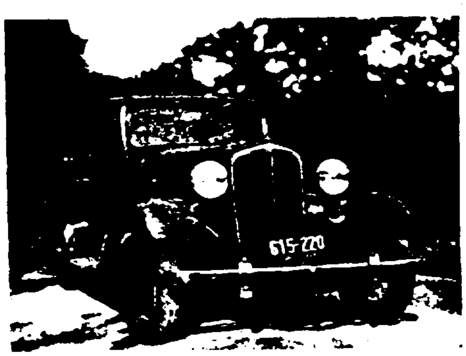
PAGE

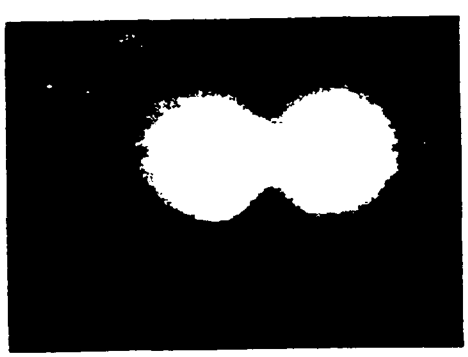
Lighting Economics

Modern machinery is built upon the efficient use of energy. It is designed to perform certain functions accurately and within a minimum time. As a feature of economy its final requisite is its life and how well it continues to perform with a minimum amount of attention and expense. Poor shop conditions or inefficient machinery have a detrimental effect on output, whereas, good shop conditions or efficient machinery tend to increase production and build up good-will. All of this is a measure of general economy.

LIGHTING A FACTOR OF ECONOMY

No matter how automatic a machine may be it requires human attention at some time or other. This attention may be required while the machine is running, during initial set-up or for ordinary repairs. In either case, light is a most essential factor in assisting the human seeing machine to perform the necessary duties accurately, easily, and efficiently.





It is difficult to explain, in words, just how lighting will accomplish accuracy, ease and efficiency of vision, but if a concrete example relating to our daily experience is taken the case is readily understood. Take then, the automobile and drive it 50 or 100 miles in the daytime -- at the end of this drive no particular exhaustion is noticed. Drive the same distance over the same road at night and body fatigue is quite apparent; yet the only difference is in the lighting. This fatigued condition is not due to the performance of actual work but is brought about by gripping the wheel more tightly and using up a terrific amount of nervous energy in trying to see clearly; the muscles of the body are tense and the whole body seems to be under a strain during night driving.

The condition of daytime driving is further improved on days that are clear and cool without the glaring effect of the sun. The intensity on the road has been cut down considerably, but the soft even diffusion is appealing to the eye and prevents any form of eye irritation. COOPER HEWITT gives the same soft even diffusion of light in a factory; it does not irritate the eye, nor does it fatigue or tire the body. Good lighting is, therefore, good economy.

COST OF LIGHTING

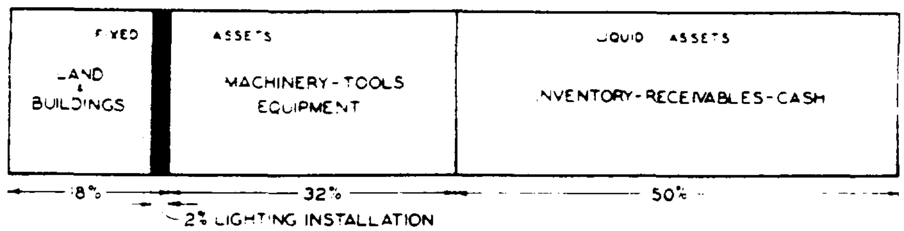
In the case of the automobile, good lighting from head lamps is an asset to the driver as far as reducing strain is concerned; it eliminates the dreaded hazard of an accident. Only the best lighting on an automobile is demanded. True, one can proceed with only one head lamp burning or an inferior set of head lamps, but travelling is slowed up and accident hazard increased. Most important of all is the fact that the cost of the best lighting available would be less than 2% of the car investment.

The cost of factory lighting is analogous to that of the automobile when considering fixed and liquid assets of a manufacturing concern. Recently Ward Harrison and C.E. Weitz published an interesting set of charts showing the distribution of capital, assets and production cost of the manufacturing industry.

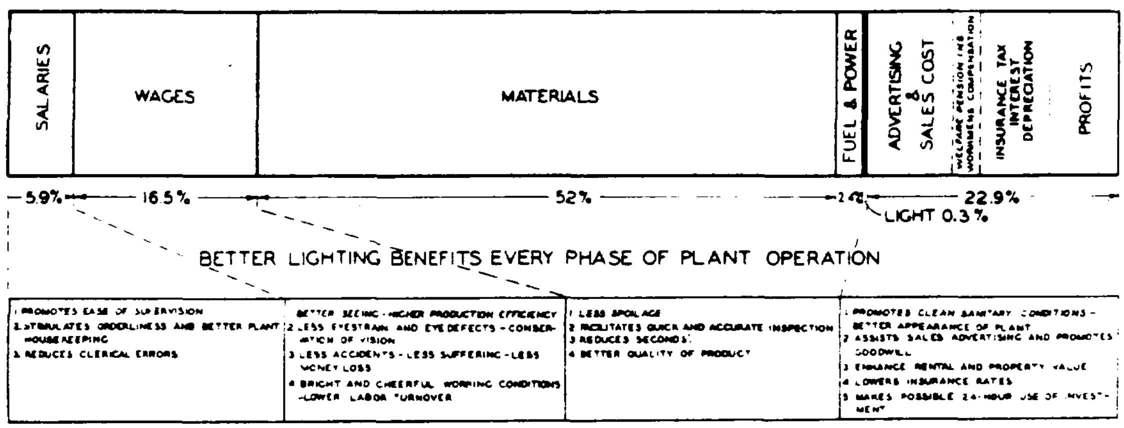
The figures on the charts are based upon statistics compiled by the Department of Commerce and general statistics and surveys by the Engineering Department of Nela Park.

The best lighting installation costs no more than 2% of total investment. Compare this with the machinery and tool investment of 32%; then consider the low cost of lighting as a protection to machinery, tools and equipment. Damage to machinery and tools alone due to inadequate lighting might well pay for a lighting system regardless of initial cost.

CAPITAL ASSETS OF MANUFACTURING INDUSTRY



PRODUCTION COST



The operating cost is given at a fraction of one percent, namely, 0.3%. This extremely small investment is protecting an investment of 52% in materials.

The two foregoing paragraphs contain a wealth of information as regards the economy of lighting and will be prominently set down as follows:

<u>CAPITAL ASSETS</u>

Lighting cost at 2%

<u>Protects</u>

Machinery }
Tools } Cost at. 52%
Equipment }

<u>PRODUCTION COST</u>

Lighting cost at 0.3%

<u>Protects</u>

Materials at 52%

Appraising lighting in terms of factory employees, the following benefits are outstanding:

1. Better seeing and consequently higher production efficiency;
2. Less eyestrain and eye defects, and general conservation of vision;
3. Fewer accidents with consequent less suffering of the worker and less actual money loss due to attendant or "hidden" costs;
4. Bright and cheerful working conditions, having favorable influence on labor turnover which in normal times may be as high as 100% per year.

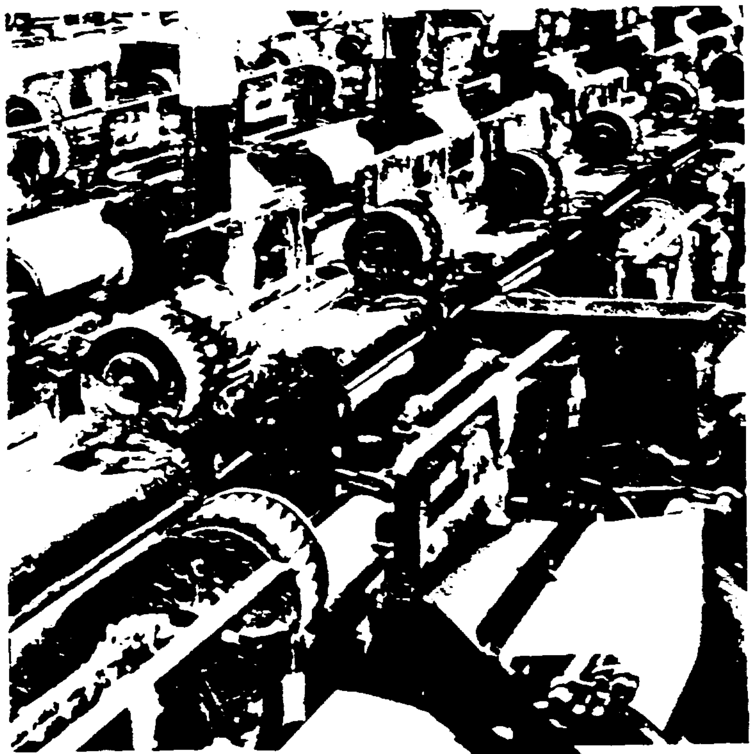
Other benefits relating to various phases of plant operation may be read off the charts.

VALUE OF GOOD LIGHTING

In discussing the value of a good lighting system, all of the benefits listed above must be carefully analyzed. Those responsible for plant improvement are apt to consider only the increase in production that is likely to occur. Naturally production increase is a vital factor in any manufacturing branch of industry. Everyone seems to be talking increased production to manufacturers without heed to its authenticity. As a matter of fact, the term is very often misunderstood. The mere fact that more yardage or machined pieces leave a machine, does not imply that all the merchandise is in perfect condition so as to be salable with a profitable return. Spoilage to materials must be eliminated or held down to a minimum.

In the process of manufacturing, materials must be clearly seen so that inspection can be made as production continues. Lighting must be adequate in prodaction areas as well as in the inspection department.

COOPER HEWITT lamps deliver the proper quantity and quality of light at the working level where it is needed.



Long light sources, high visual acuity, deep and intricate penetration all characterize Cooper Hewitt Illumination. These factors combined make it easily possible to see details clearly even in remote recesses.

Deep in the works of any machine, loom, lathe, or punch press, there are fields of reduced intensity which light does not reach directly. COOPER HEWITT provides more **seeing power** at these points than any other type of illumination.

Unless lighting reaches these points it is not serving its purpose. Operators cannot properly see their work and let defective material pass by unnoticed. If this can be avoided, the inspection department will get better goods resulting in fewer rejects and seconds. COOPER HEWITT lighting provides soft even diffusion -- high lights or glare are never prevalent. This means more accurate work with the ability of operators to catch **seconds** on the job, eliminating the necessity of **double inspection**.

We find the Cooper Hewitt lamps very efficient for our product. We find that with the use of this light we can much more clearly find defects in ball races, and also do it more accurately and quickly, than by the use of the ordinary tungsten light. We are also able to read more clearly the fine graduations on the dial indicators on our measuring instruments.

D. F. Chambers,
Works Manager
The Bearings Company of America, Lancaster, Pa.

Inadequate lighting will be a source of nuisance insofar as spoilage is concerned. Considering this and bearing in mind what has just been said, the following statement aids in clearing up a general misconception:

> Increased production does not necessarily mean more yardage or number of machined pieces turned out by a worker -- it means more material rendered usable or eligible for sale. In other words, reduced spoilage is, very often, of prime importance when considering increased production. **Seeing** the work well means doing the work well. Thus, increased production not only accounts for a saving by allowing more goods usable but also accounts for reduced manufacturing costs due to eliminating waste of workers time and spoilage to materials.

Prof. C. E. Clewell shows the value of good lighting with regard to the above statement:

> "Let us suppose a new and improved lighting system is under consideration. Two methods of lighting are proposed. The one claims a saving in the light bill of say 5% whereas the other, due to its superior illuminating quality, claims a possible saving of 1% in the manufacturing cost because the workman may be able to save as much as five minutes per eight hour day, formerly lost due to poor lighting.
>
> The first claims a saving of 5% in lighting costs, or five cents on the dollar. The other claims a saving of possibly 1% in manufacturing cost. Since for every dollar spent for light, $3000 is the value added to the manufactured product, the 1% saving would amount to $30.00.
>
> As far as values are concerned, the system which can show a saving of $30.00 per unit of time is 600 times as important to the factory as the one which claims merely a saving of five cents in lighting costs for the same interval."

Familiarity with the results of Cooper Hewitt's even intensity of cool, green light has led many practical authorities to call it "better than daylight." From an industrial standpoint, this is quite within reason considering its 24-hour availability, its uniformity, and low-cost upkeep.

RESULT OF BETTER LIGHTING

There is a great deal of literature published showing the advantages of improved lighting. The Austin Company (Engineers and Builders) reported that an investigation conducted in some 200 plants in which modern lighting systems were installed, revealed production increases from 8 to 17%.

Class of Work	Foot-Candles Old	Foot-Candles New	Production increase - %
Stamping and Pressing	0.7	13.0	12.2
Semi-Automatic Buffing	3.8	11.0	8.5
Soft Metal Bearings	4.6	12.7	15.0
Heavy Steel Machining	3.8	11.0	10.0
Carburetor Assembling	2.1	12.5	12.0
Spinning (Textile)	1.5	9.0	17.0

Most of the time increases in production are difficult to find unless a very careful series of tests are conducted over a considerable length of time. Unfortunately lighting must be classed as an intangible factor since it depends upon the human element in working faster rather than causing a machine to run faster. The results are far more tangible when spoilage or seconds are considered since the outcome is more or less of a physical nature.

Good lighting affects production particularly when manual labor is largely relied upon for a finished product. The more automatic the machinery the less important the lighting in relation to production output, but never is the point reached where good lighting is not a paying proposition. At some time or other good lighting will be required regardless of how automatic the machinery may be; when that time comes good lighting will prove a worth while investment.

Cooper Hewitt mercury-vapor lighting has proved through long experience the most efficient lighting that can be found (and the records cover more than thirty years and hundreds of mills of all types.)

COOPER HEWITTS IN INDUSTRY

During the past 25 years, thousands of economy and efficiency tests have been made in practically all the leading industries on fine and coarse work, which have proven conclusively that both men and women can do more and better work with less scrap and seconds, under COOPER HEWITT light. A few of these tests will be briefly related:

1. Mid-State Cloth Mill, Newton, N.C. Rayon Weaving Department. Modern monitor type building (Good daylight on bright days). Originally COOPER HEWITTS were used during daylight hours - - in an act to economize, lamps were turned off and seconds rose from a normal of 4% to 7%. Naturally lamps were turned on again - - the blending rays of COOPER HEWITT with daylight affords better vision during the day shift.

2. The Marion Manufacturing Co., Marion, N.C. Taking everything into consideration, their production over daylight and incandescent lamps increased about 3.5% after COOPER HEWITTS were installed.

3. Stehli Silk Mills stated that in normal times their night production was 4.1% more than the production in daytime.

4. Susquehanna Silk Mills, Sunbury, Pennsylvania, claim they secure about 4% more production at night than in the daytime.

5. Woonsocket Falls Mills, Woonsocket, R.I., since the installation of COOPER HEWITT lamps, have increased their production on the night shift two yards. The management transferred the same operators to another department on another floor using incandescent lamps, and immediately they

fell behind seven yards, in other words, they went four yards behind what they had previously done under incandescent lighting, and that continued for nearly a week; then they gradually came up to the original production.

6. Holeproof Hosiery Co., Milwaukee, Wisconsin. The improved production which COOPER HEWITT brought about in the Looping and in Holeproof Knitting Departments, stirred deep interest throughout the knitting trade. Holeproof engineers made the report, and gave COOPER HEWITTS credit for a definite production increase of 4.2%.

7. Millard Yarn Co., Ballston Spa, N.Y. Foster Winding Depastment. Mr. Millard has recorded the following data in his payroll ledger which refers to the weekly wages of 3 girls:

Girl	Earnings Before C.H.	Earnings After C.H.
M.G.	$15.06	$19.71
V.H.	14.06	20.30
A.G.	13.67	24.23

No changes were made other than painting at the same time COOPER HEWITTS were installed. The old system consisted of 3 rows of lamps with 150 watt bulbs, (total of 15 lamps) as compared with 8 COOPER HEWITT lamps.

8. In a large southern mill in a Looping Department workers turned out 25 to 30 dozen pairs of black hose before COOPER HEWITTS were installed, and 50 dozen pairs after they were installed -- an increase in production of 50%.

A page of testimonials proving why COOPER HEWITT light is preferred by pace setters in the industrial field. Hundreds of other letters with equally interesting evidence are on file at COOPER HEWITT headquarters.

We have used Cooper Hewitt lights for the past nine years. One particular fact that impresses us is that even after a tube has burned two or three years we find we can see just as well as when first installed, and by keeping our reflectors cleaned there is no noticeable depreciation in the amount of light. We are using Cooper Hewitts to equip the new looms we are installing.

J. B. Smith,
Superintendent
The Doherty & Wadsworth Co., Allentown, Pa.

In 1920 we installed the Cooper Hewitt lighting system in our weave room, slasher room and long chain beamer room. We are very much pleased with the operation of the system. Our light bill, including power and lighting apparatus, is lower. Even without this, we would certainly want this system because the operatives can do better work, especially in the weave room, with this kind of light than with the old style of lighting.

L. D. Pitts,
Treasurer
Industrial Cotton Mills Co., Rock Hill, S. C.

We find the Cooper Hewitt lamps very useful to us in certain departments where they not only give general illumination, but are free from the shadows and glare which are objectionable where we are working on polished steel.

We have one hundred four of these lamps installed in our Steel-Tape Department, and they are giving us great satisfaction.

Having used your lamps for the past eighteen years, we find them very economical. It is the nearest thing to daylight that can be produced artificially.

Fred Buer,
Pres. and Genl. Mgr.
The Lufkin Rule Co.

We do not use any individual drop lights on our machines. Our work necessitates working down to very close limits. Even on machines where we work to one half-thousandths of an inch, the operator can gauge his work accurately without eye-strain. The elimination of drop lights, we consider, is a decided advantage.

Chrysler Corporation,
Dayton Division

These operating savings (in power input, theft and breakage) are secondary in importance to the improvement in quality of lighting throughout the shop, which has resulted in a general increase in the efficiency of the operation. One worker previously turning out 70 units in nine hours is now doing 80 a day, an increase of 14% that the worker attributes to better light and to the fact that he does not have to depend on a drop light in setting up and gaging his work.

W. M. Reichart,
Plant Engineer
Chandler & Price Co., Cleveland, O.

The cost of Cooper Hewitt Lamps, to adequately light full-fashioned hosiery machines, is only about 3/4 of 1% of the cost of the machines. The best light obtainable for this class of work is, in our opinion, Cooper Hewitt Work-Light; and it is very essential to have the best light for the work that can be used. The cost of the Cooper Hewitt Lamps, as compared to the other investment, is practically nothing and we consider them a good investment.

William Nebel,
President
Nebel Knitting Company, Charlotte, N. C.

We have no direct comparison of absolutely equal operations under the two different lights. The closest comparison we have is between two loom floors. The floor equipped with Cooper Hewitt lights is working on more difficult work than the floor equipped with incandescent light. There appears an increase in production of between $3\frac{8}{10}$ and 4% on the Cooper Hewitt lighted floor as against the incandescent lamp lighted floor.

We feel that the reduced eye strain with the Cooper Hewitt lights makes them worth while and we are thoroughly convinced that they do reduce the eye strain in a great many of our operations.

C. H. Masland, 2nd.
C. H. Masland & Sons, Inc., Philadelphia, Pa.

We find the Cooper Hewitt lamps very efficient for our product. We find that with the use of this light we can much more clearly find defects in ball races, and also do it more accurately and quickly, than by the use of the ordinary tungsten light. We are also able to read more clearly the fine graduations on the dial indicators on our measuring instruments.

D. F. Chambers,
Works Manager
The Bearings Company of America, Lancaster, Pa.

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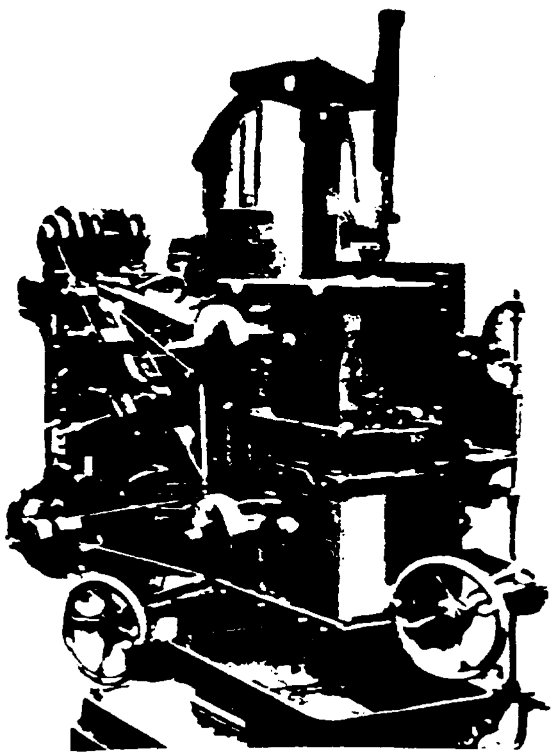
COOPER HEWITT LIGHTING INEXPENSIVE

Earlier in this section lighting was shown to represent only 2% of initial investment and 0.3% of operating cost. This is indeed an excellent way to chast the low cost of lighting but there are more convincing ways to prove the economy of lighting in a practical manner. A few of the more prominent conditions will be listed.

1. The cost of lighting averages about 1½ cents per man per day -- which is equal to the cost of about 2 minutes of a man's time -- the time it takes to get a drink of water.
2. There are 480 minutes in an 8 hour day -- a waste of 5 minutes (1% of 8 hours) will pay for light -- lighting costs less than 1% of the payroll -- consequently light is cheaper than 5 minutes of a workers time.
3. The average life of a COOPER HEWITT tube is 6000 hours -- 25 cents per month -- or 1 cent per day.
4. The cost of operating a COOPER HEWITT lamp is about 1 cent per hour.
5. A COOPER HEWITT lamp will light 150 to 250 square feet of floor area -- providing good illumination for 4 or 5 men.
6. The total cost of lighting including current, renewals and cleaning -- amounts to 2 cents per hour -- or 2 cents per man per day.
7. The automobile industry estimates that by saving 10% on lighting -- they might save 1 cent per car -- if the 10% was applied on good lighting -- production would increase 1% -- resulting in a saving of 25 cents per car.
8. One COOPER HEWITT lamp lights machinery costing $5000.00 to $15,000.00 -- at a total cost of approximately 2 cents per hour.

COMPARATIVE COSTS OF LIGHTING AND MACHINERY

BETTER THAN DAYLIGHT



Cost of Lighting

$25.00 per unit (COOPER HEWITT lamp)

Interest (6%)	$ 1.50
Depreciation (10%)	2.50
Current (2000 x .450 x .015)	13.50
Tube maintenance (2000/6000 x 10.80)	3.60
Total cost per 2000 hours	$21.10
Total operating cost per hour	0.01055

Cost of Machinery

$25,000 per unit (Keller Die Sinking Machine)

Interest (6%)	$1500.00
Depreciation (10%)	2500.00
Maintenance (including Tools, oil, etc.) estimated	200.00
Total cost per 2000 hours	$4200.00
Total operating cost per hour	2.10

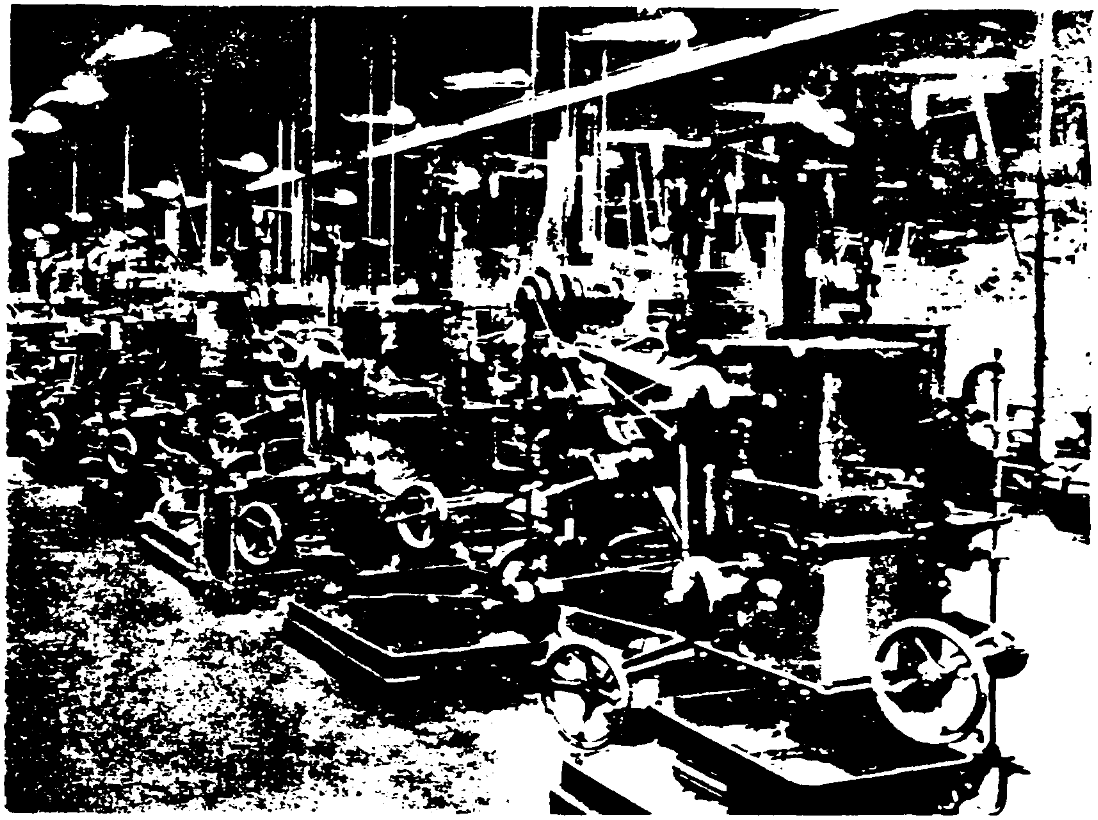
Cost of Labor

Cost of skilled labor per hour	$ 1.00

The above comparison can be applied to varying prices of machinery by rough approximations. If the cost of a machine is $2,500 the total operating cost per hour would be about $0.20; on the basis of $5000 -- $0.40 per hour, etc. The labor may vary somewhat but will probably be close to that given for skilled labor. These actual figures prove conclusively that lighting represents only a small fraction of the total shop expenditure.

PRACTICAL COOPER HEWITT LIGHTING

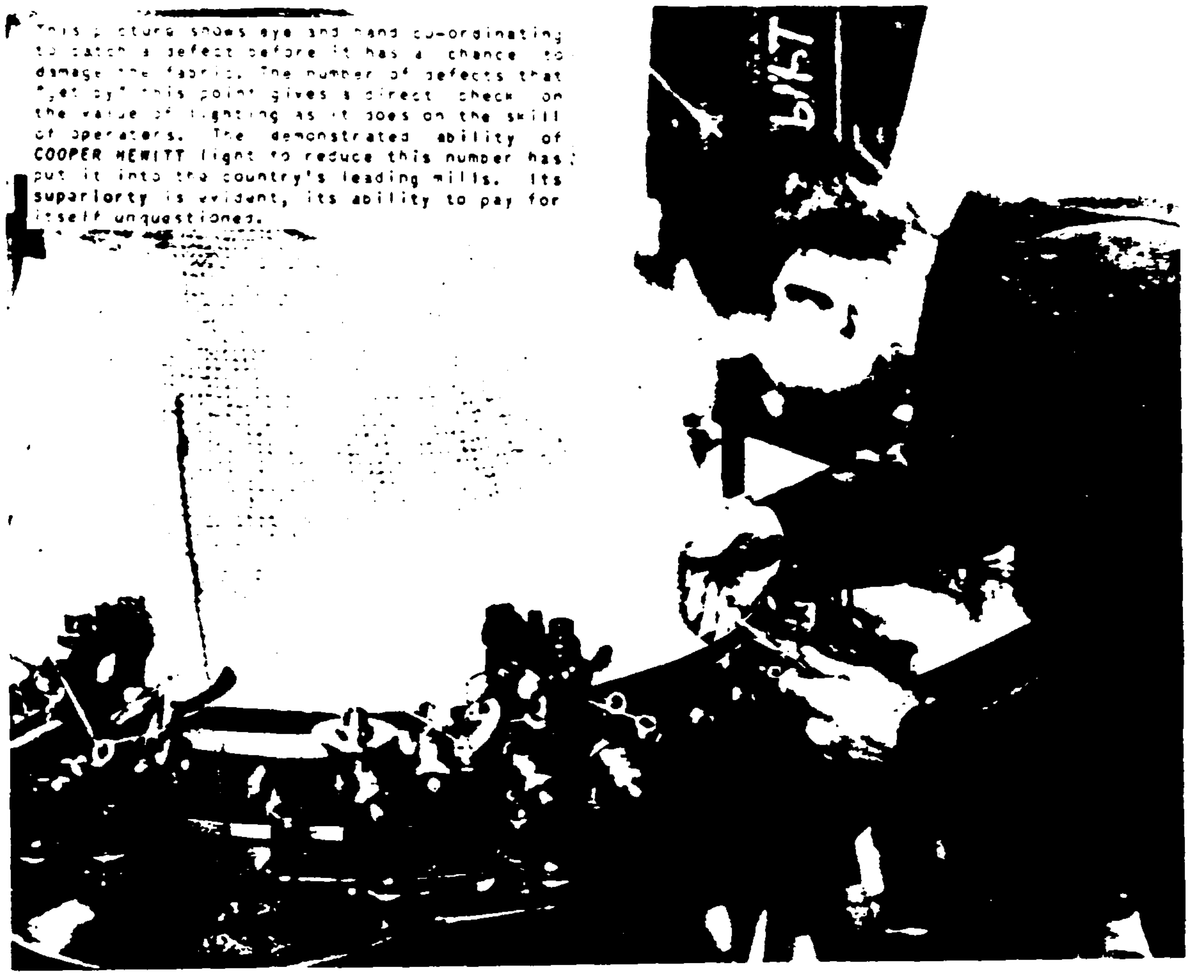
EXAMPLE NO. 1



Above is shown a close-up of six Keller electrically operated automatic die sinking machines in the Forge Plant of Dodge Brothers (Chrysler subsidiary), which copy impressions as intricate as engravings. Note how thoroughly lighted these machines are top and bottom -- and a difficult vertical plane to light, too!

There are 456 COOPER HEWITT lamps in this installation, arranged 8' x 12' and 12' high at about 4½ watts per sq. foot. Each $25,000 machine is lighted at a cost of approximately 2 cents per hour; and that covers current, renewal tubes and periodic cleaning of lamps. Twelve cents per hour represents the total cost of lighting perfectly a group of six machines worth $150,000.

EXAMPLE NO. 2



Above is a close-up of a Seamless Knitting Machine. Modern machines of this type are priced at $470.00 each. Ordinarily one COOPER HEWITT lamp will light eight knitting machines. Thus, the investment in machinery is $3760.00, against $25.00 for lighting; representing less than 3/4 of 1%. The first cost of a COOPER HEWITT lamp per machine is $3.12. A saving of only 1 cent a day with better lighting will pay for the investment in a years time.

Other examples of a similar nature can be cited for every department where industrial work is carried on. Exceedingly small increases in production, reduced seconds and spoilage to materials will pay for COOPER HEWITT lighting in a surprisingly short time.

OFFICE AND PRODUCTIVE AREAS

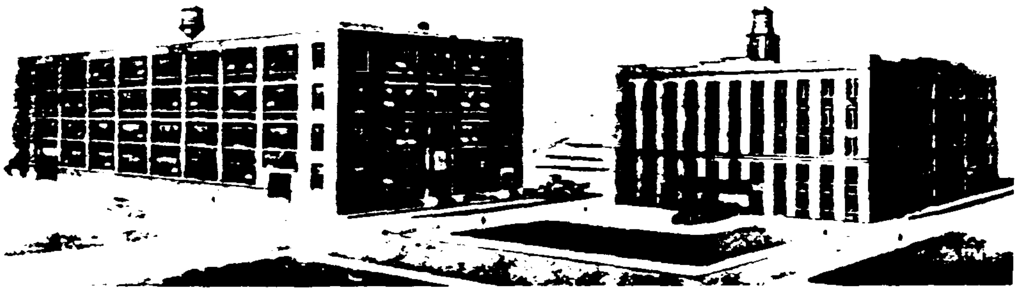
A comparison between General Office areas and production areas will reveal some very interesting points. Some of these are listed in comparative numerical order below:

Office (Non-productive)

1. Comprises 2% of floor area
2. General comfort carefully considered
   a. Good diffuse lighting
   b. Clean windows
   c. Clean light walls
   d. Comfortable chairs
   e. Typewriters equipped with soft green pneumatic keys
3. Stenographers paid $25.00 to $30.00 a week
4. Typewriters worth $50.00 to $75.00
5. Material used, probably 50 cents a day
6. Spoilage to materials
   a. Bond paper
   b. Carbon paper
7. No precautionary measures of precision work
8. No hazardous operations — accidents unlikely
9. DIVIDENDS -- little or none

Factory (Productive)

1. Comprises 98% of floor area
2. Very little comfort provided
   a. Small percentage of factories have good lighting
   b. Conditions usually not clean
   c. Chairs or stools rare fixtures
   d. Parts handled usually steel
3. Skilled labor paid $40.00 to $60.00 a week
4. Machines worth $2500.00 to $25,000.00 each
5. Materials used worth $5.00 to $50.00 or more
6. Spoilage to materials
   a. Costly machined pieces
   b. Expensive castings
7. Abundance of precision work constituting large expense
8. Many hazardous operations involving considerable expense charged to
   a. Accidents
   b. Damage to machines
   c. Large labor turnover
   d. Lowered morale
   e. unhealthy conditions
9. DIVIDENDS -- represents practically 100%



General Office and Works—Hoboken, N. J., U.S.A.

GENERAL ELECTRIC VAPOR LAMP COMPANY

HOBOKEN, NEW JERSEY, U. S. A.

Atlanta, Ga.: 187 Spring St., N. W.
Boston, Mass.: 250 Stuart St.
Charlotte, N. C.: 200 S. Tryon St.
Chicago, Ill.: 37 West Van Buren St.
Cincinnati, Ohio: 107 East Fourth St.
Cleveland, Ohio: 1365 Ontario St.
Detroit, Mich.: 3044 West Grand Blvd.
Hollywood, Calif.: Keese Engineering Co., 7380 Santa Monica Blvd.
Philadelphia, Pa.: 424 Chestnut St.
Pittsburgh, Pa.: 307 Fifth Ave
Rochester, N. Y.: 183 Main St. East.
San Francisco, Calif.: Keese Engineering Co., 557 Market St.
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