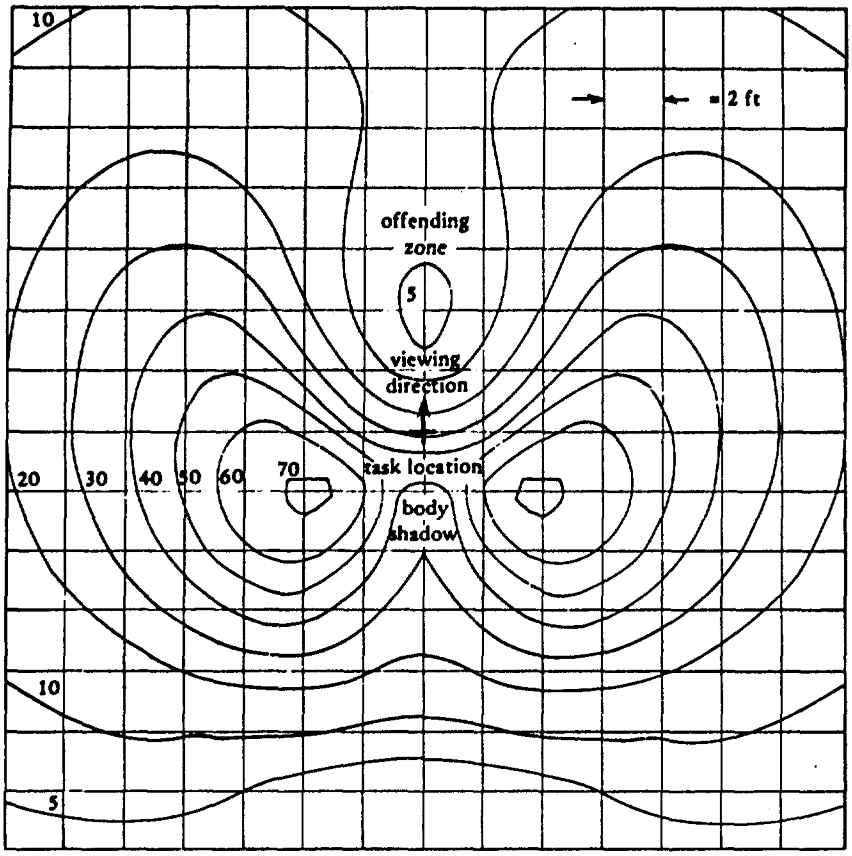

R880

TECHNICAL REPORT
CIVIL ENGINEERING LABORATORY

Naval Construction Battalion Center, Port Hueneme, California 93043

TASK-AMBIENT OFFICE LIGHTING

By William Pierpoint

September 1980

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A method is discussed for converting uniform office lighting systems to task-ambient lighting systems. The method requires only the use of a light meter and a mirror. A correlation between the method and equivalent sphere illumination is shown. Several examples of offices converted from uniform lighting to task-ambient lighting are discussed.

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CONTENTS

INTRODUCTION

When lighting is planned for an office, the designer often does not know how the furniture will be arranged. As a result, the designer will usually lay out a uniform lighting arrangement which will provide task lighting levels to all parts of the office. While this insures that proper task lighting levels will be provided to desks and other work stations regardless of location, it is wasteful from an energy standpoint since nonwork areas are over-illuminated.

Task-ambient lighting is a term used to describe energy-conserving nonuniform lighting systems. It refers to two types of illumination levels for a room: (1) task illumination and (2) ambient illumination. Task illumination covers the requirement for light on important work stations--desks, drafting tables, etc. Workers spend most of their productive time at these work stations, and proper illumination must be provided Ambient illumination covers the requirement for light on nonwork areas and on work areas with low visual requirements. For example, most file cabinets and bookcases have low visual requirements since book covers and file headings have large, high-contrast lettering In addition, prolonged work is not accomplished in areas illuminated by ambient light. A large percentage of ambient light often comes from the interreflection and "spill" of the task lighting.

BACKGROUND

Table 1 shows the growth of general lighting levels (Ref 1). This was in keeping with a general philosophy of "more light, better sight." It also reflects an era of inexpensive energy and of ever-increasing improvements in the efficiency of light sources.

Table 1. Growth of Lighting Levels

Year	Footcandles
1900	3
1910	5
1920	10
1930	20
1940	35
1950	50
1958	85
1965	100
1971	125

The 1973 oil embargo signaled the end of cheap energy. In 1974 the Federal Energy Administration (FEA) published guidelines for "Lighting and Thermal Operations" (Ref 2). This document recommended:

50 footcandles at desks, work stations, etc.

30 footcandles in work areas

10 footcandles in hallways, storerooms, etc.

Present government guidelines and regulations stem from this document. While the intent of the document was to save energy by reducing light levels, it also recognized that lighting affects productivity. Exceptions were allowed for visually difficult work (such as drafting and bookkeeping), industrial tasks, older workers, and workers with uncorrectable eyesight problems.

New illumination levels by the Illuminating Engineering Society (IES) of North America (to be published in the 6th Edition of the IES Handbook--December 1980) generally follow the same approach used by FEA. A range of task illumination levels is recommended. The designer must select a value from the low, middle, or high end depending on worker age, speed and accuracy required for the task, and task background reflectance. For offices, this range is 50 to 100 footcandles.

Does 50 footcandles provide adequate lighting for individuals who are used to working under 100 footcandles? Perhaps not. That is why another requirement was stated by the FEA: "Illumination at the task should be reasonably free of veiling reflections and body shadows." This often overlooked statement buried in the text of the FEA document is the key to quality lighting. One must recognize that 50 footcandles of lighting reasonably free of veiling reflections and body shadows will provide the same visibility as most commonly used uniform overhead direct lighting systems at 100 footcandles.

OBJECTIVE

Converting uniform office lighting systems to task-ambient lighting requires insight into the visual properties of office tasks. Once this is understood, it will be relatively easy to provide task illumination which is reasonably free of veiling reflections and body shadows. A simple method is presented which only requires:

1. a cosine-corrected illumination meter
2. a mirror about one foot square

VISUAL PROPERTIES OF OFFICE TASKS

Common office tasks which require adequate visibility include reading typewritten material, printed material, pen on paper, and pencil on paper. These tasks share a common visual property: light at the mirror angle produces substantial veiling reflections. Figure 1 illustrates that substantial veiling reflections occur when the angle of incidence equals the viewing angle. This condition is called the mirror angle since, if a mirror is substituted for the task, the offending zone will be seen in the mirror.

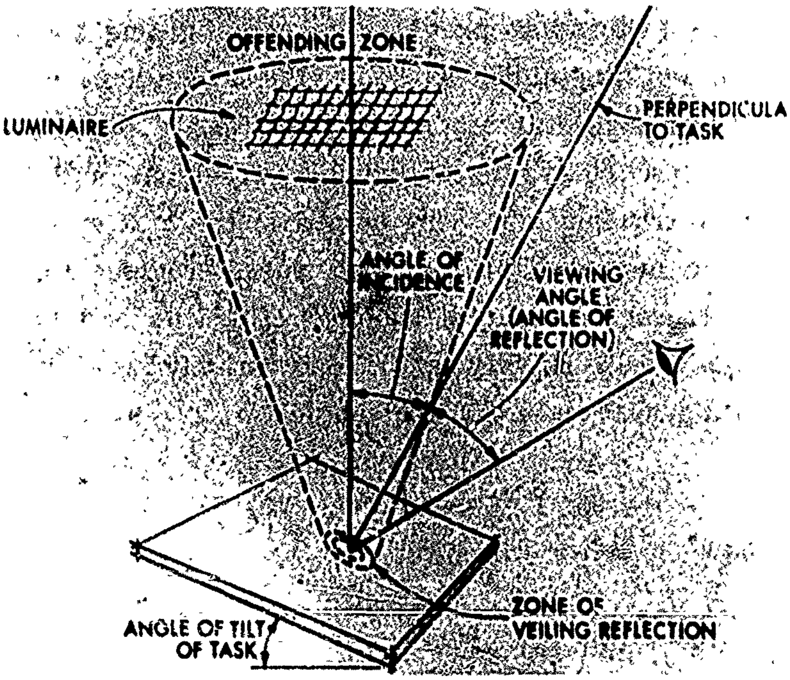

Figure 1. Veiling reflections are produced from light at the mirror angle.

Of the various office tasks, the most studied has been the number 2 pencil on white paper (Ref 3). Of the most common office tasks, the pencil task has the most difficult visual requirements. Therefore, providing adequate lighting for the pencil task will satisfy the visual requirements for the other common office tasks.

Veiling Reflections

In order to demonstrate the relationship between veiling reflections and the position of a light source, consider the two situations presented in Figure 2.

In both situations the worker is reading the pencil task. However, in Figure 2A, the light source is located in front of the task in the offending zone. In Figure 2B the light source is located out of the offending zone, to the side of the task.

An illumination meter is placed on top of the task, as shown in Figure 3. The same footcandle level is provided for both cases. However, equivalent illumination levels do not mean that both lighting situations are equally good. By substituting a camera in place of the worker in Figure 2, the task is photographed under the same conditions (Figure 4). Clearly, it is much more difficult to read the pencil writing with illumination from the offending zone (Figure 4A) than with illumination from outside the offending zone (Figure 4B).

If a portion of Figure 4 is enlarged, as shown in Figure 5, a better understanding of the phenomenon can be gained. The contrast between the writing and the paper is reduced because of specular reflections from the pencil graphite. In some instances reverse contrast can occur. Notice, in Figure 5A, that although most of the writing is slightly darker than the paper, parts of each letter are actually brighter than the paper. Consequently, light from the offending zone is causing a condition of minimum contrast, since the brightness of the pencil writing is nearly the same as the brightness of the paper. On the other hand, with the light well away from the mirror angle, such as to the side of the task, good contrast is achieved (Figure 5B).

Although specular reflections are bad for office tasks, this does not necessarily mean that they are undesirable for other tasks. Referring to Figure 3, note that the photocell on the illumination meter can actually be seen more easily with light from the front (Figure 3A) than from the side (Figure 3B). For some tasks, such as looking for scratches in paint, placing the light source at the mirror angle is the ideal location. This shows why an understanding of the visual properties of the task is important when designing a lighting system. Again, referring to Figure 3, notice the effect of light position on the printed instructions on the light meter.

Mirror Angle

Lighting fixtures in the offending zone are at the mirror angle with respect to the task and the worker. Suppose for the situations shown in Figure 2, a mirror is substituted for the task (Figure 6).

Figure 2. Light source (A) in front of task and (B) to side of task.

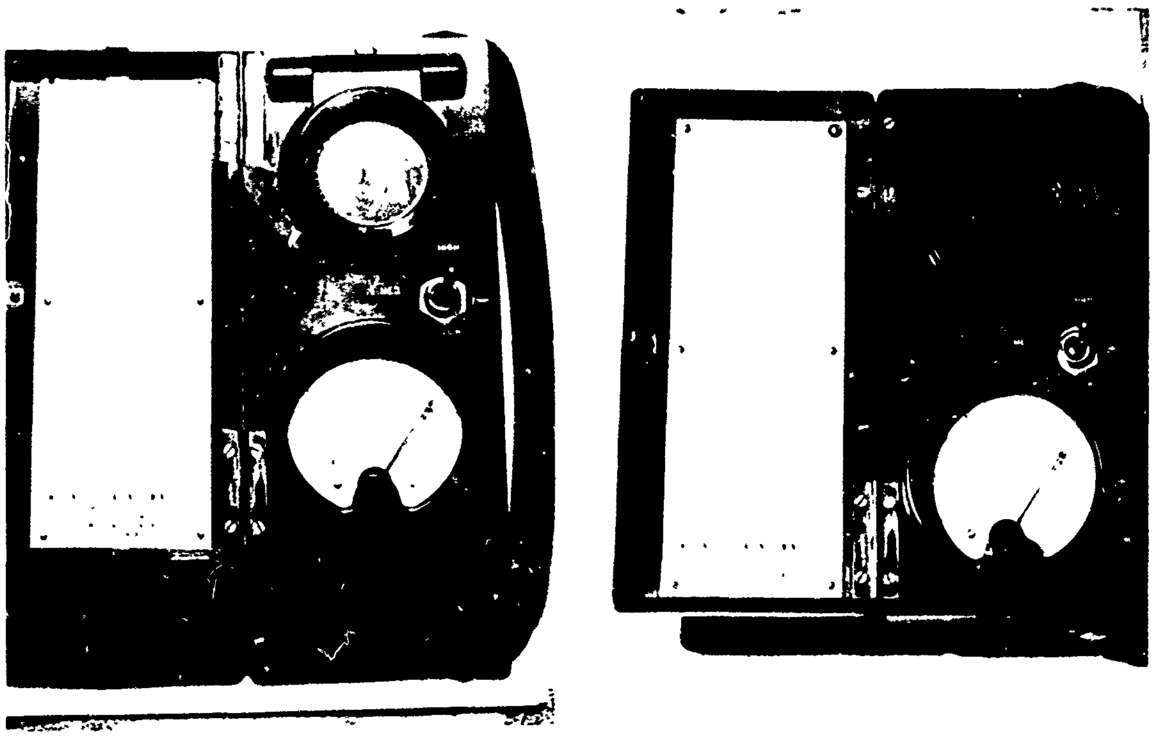

Figure 3. Illumination readings from light source (A) in front and (B) to side of task.

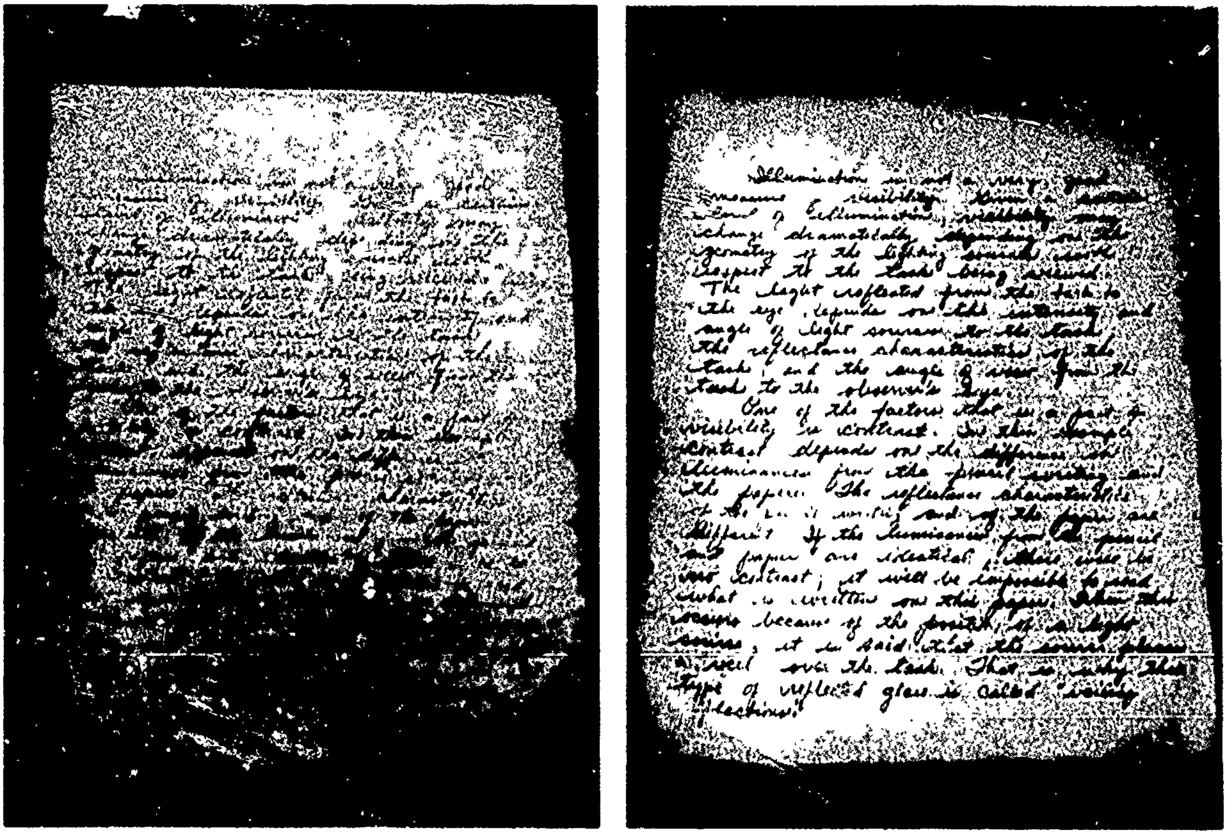

Figure 4. Pencil task illuminated from (A) front and (B) side.

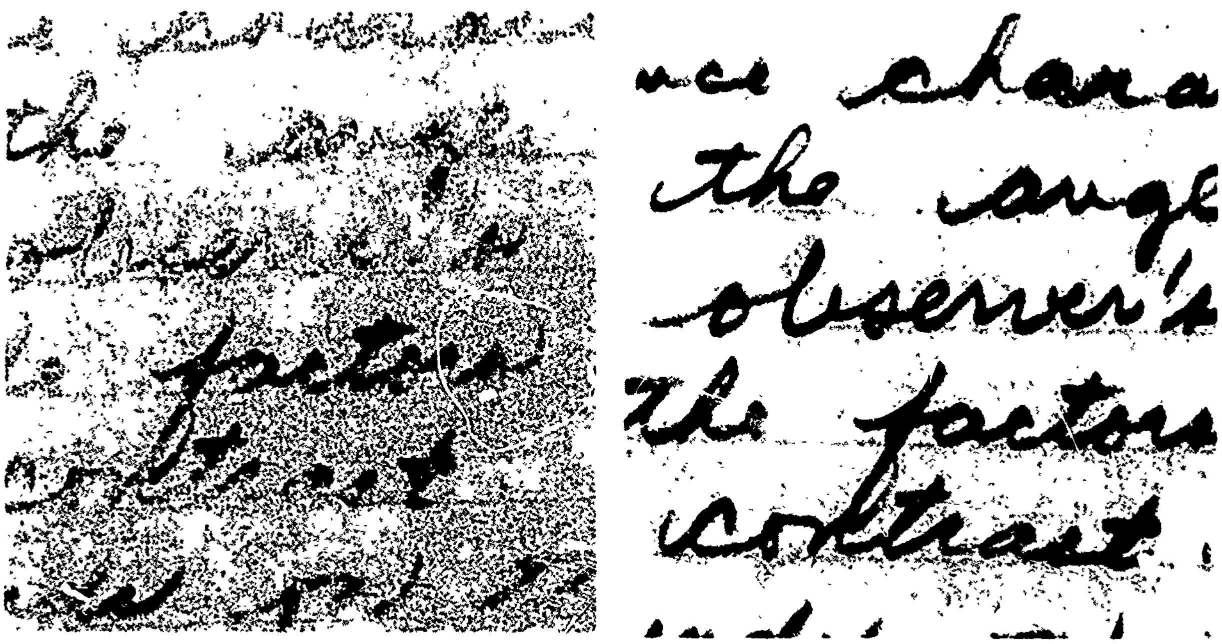

Figure 5. Enlargement of pencil task illuminated from (A) front and (B) side.

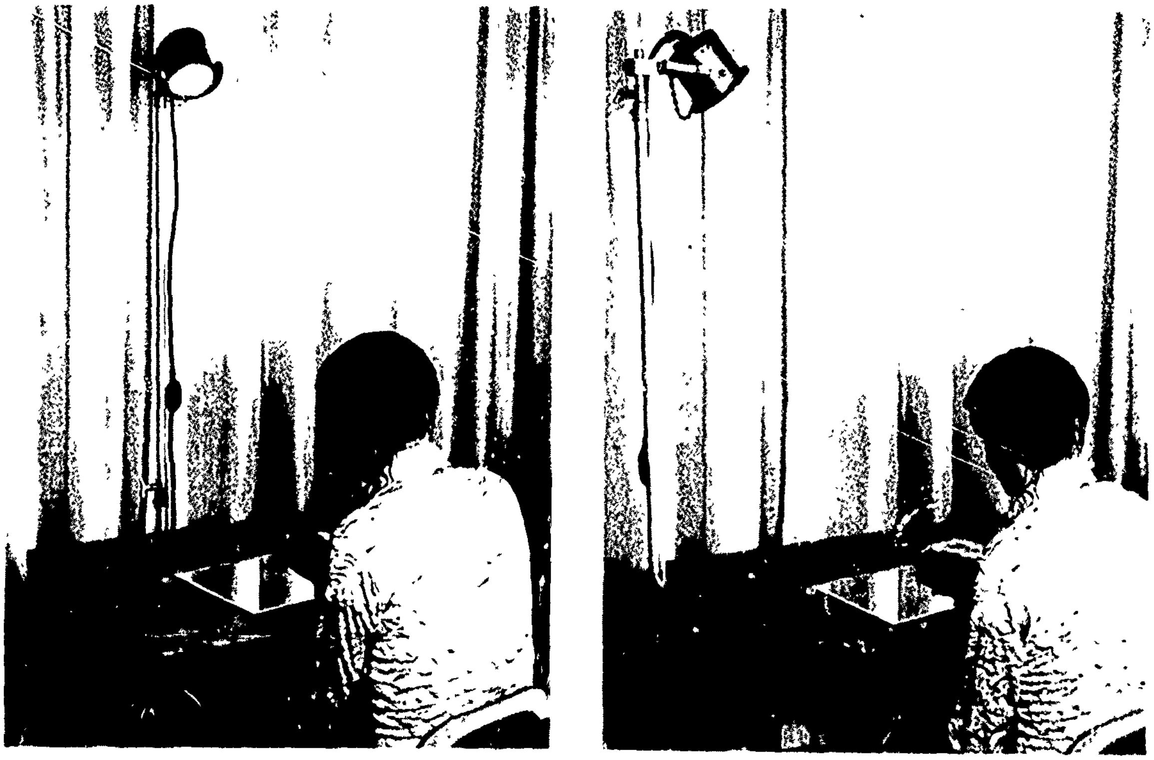

Figure 6. Mirror substituted for task with light source to the (A) front and (B) side.

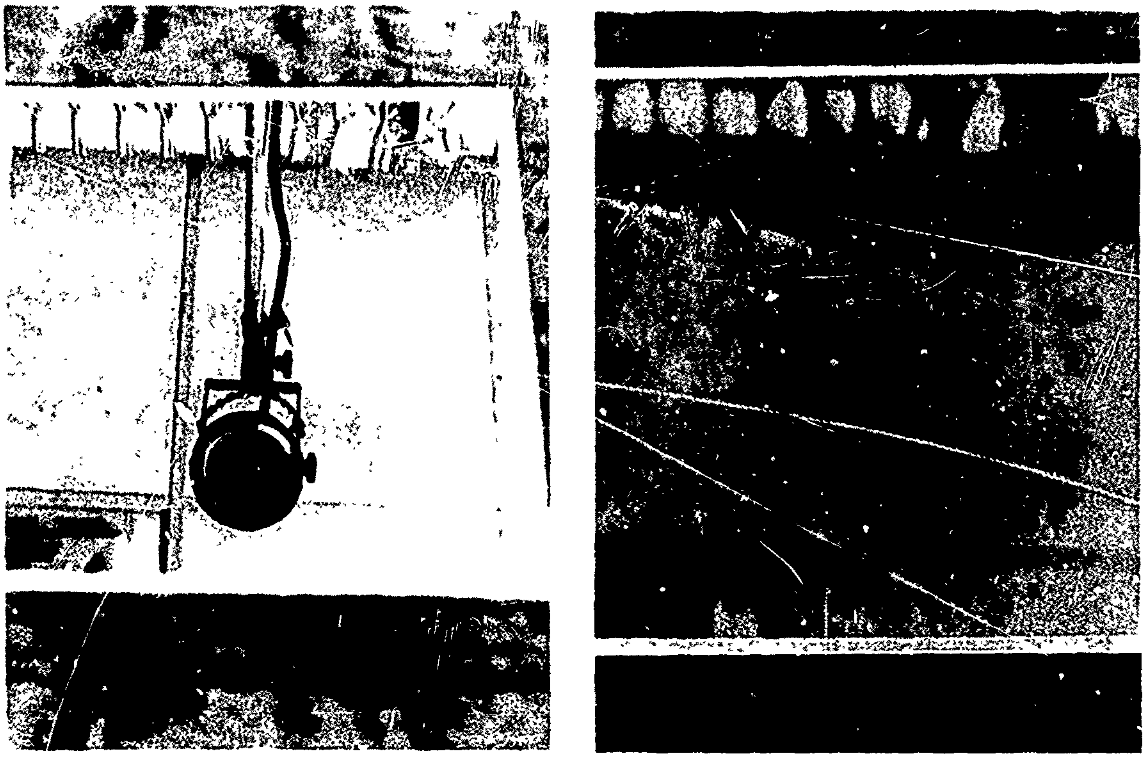

Figure 7. View of mirror with light source (A) in offending zone and (B) out of offending zone.

The view seen by the worker, analogous to Figure 4, is demonstrated in Figure 7. The light source in the offending zone can be plainly seen in Figure 7A; whereas, in Figure 7B, no light source can be seen since it is located to the side and out of the offending zone.

Body Shadow

Another situation is shown in Figure 8. If the light source is behind the worker, the body blocks the light and a shadow is placed over the task. Obviously, light obstructed by the body shadow is useless in viewing the task.

Figure 8. Body shadow blocks light to the task.

VISIBILITY

There are numerous locations away from both the offending zone and the body shadow where lighting fixtures could be located. Where are the best locations for maximum visibility? This can be answered only by (1) addressing those factors which contribute to visibility, (2) explaining the use of equivalent sphere illumination as a measure of visibility, and (3) graphing contours of illumination and equivalent sphere illumination for comparison.

Illumination

Illumination is the amount of light (lumens) shining onto a unit area of surface. In the English system it is expressed in footcandles (lumens per square foot) and in the metric system it is expressed in lux (lumens per square meter). One footcandle is equal to 10.76 lux.

The basic equation for direct illumination from a light source to a point on a horizontal surface is

$$E_h = \frac{I_\theta \cos \theta}{D^2} \tag{1}$$

where E_h = the horizontal illumination at the point

I_θ = the candlepower of the source in candelas towards the point

θ = the angle of the ray from the source to the point with respect to a vertical ray

D = the distance from the source to the point

These relationships are depicted in Figure 9.

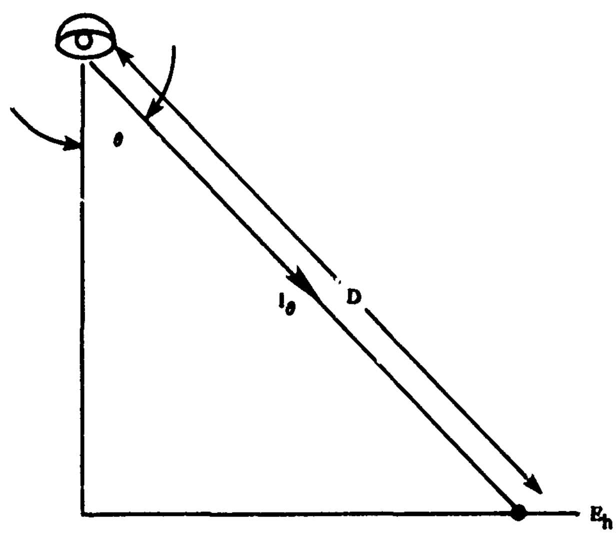

Figure 9. Horizontal illumination.

Luminance

When an object is viewed, a person perceives the object because of light reflected off of its surface. This reflected light is called luminance. It is expressed mathematically as

$$L = E \times \rho \tag{2}$$

where L = the luminance (footlamberts)*

---

*In the metric system $L = (E \times \rho)/\pi$, where E is in lux and L is in nits. One footlambert is equal to 3.42 nits.

E = the illumination (footcandles) shining onto the surface

ρ = the reflectance of the surface

In making calculations, two types of reflectance can be used: (1) lambertian or (2) bidirectional. Lambertian reflectance is the reflectance from a totally diffuse surface. The reflected light is independent of the direction of incident light except as the direction affects the incident illumination. As has already been demonstrated from Figures 4 and 5, the luminances from the pencil task do change as the incident light is moved. Therefore, use of lambertian reflectance will not be suitable for making visibility calculations.

Bidirectional reflectance is a function of the direction of incident light and the direction the eye views the surface. The Greek letter β is used to denote bidirectional reflectance. Direction is specified by using a declination angle and an azimuth angle. Thus,

$$\beta = \text{function } (\theta_i, \phi_i, \theta_v, \phi_v) \tag{3}$$

where θ_i = incident declination angle

ϕ_i = incident azimuth angle

θ_v = viewing declination angle

ϕ_v = viewing azimuth angle

The basic relationships are shown in Figure 10.

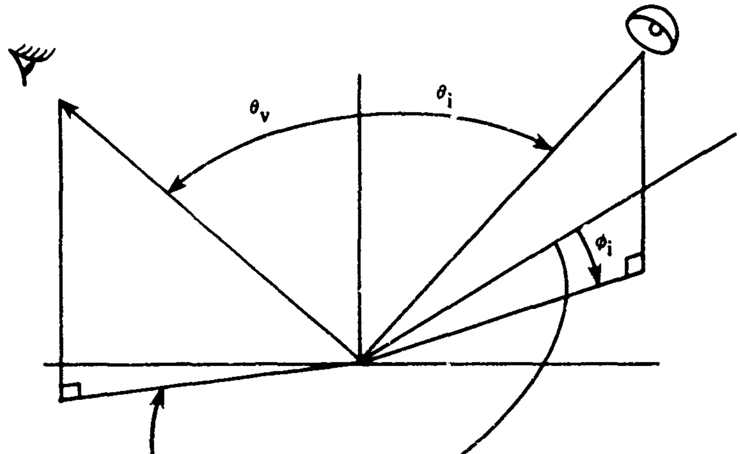

Figure 10. Incident and viewing angles.

Two luminances are important in order to see the pencil task: the luminance from the paper and the luminance from the pencil writing. The luminance from the paper is called the background luminance (L_b) and the luminance from the pencil graphite is called the target luminance (L_t). If the pencil task is lying on a desk or other horizontal surface:

$$L_b = \beta_b \times E_h \tag{4A}$$

$$L_t = \beta_t \times E_h \tag{4B}$$

where β_b = bidirectional reflectance of background (paper)
β_t = bidirectional reflectance of target (pencil)
E_h = horizontal illumination

Contrast

The pencil writing can be distinguished from the paper only if the target luminance is different than the background luminance. This is the basic concept for contrast. Contrast, C, is defined:

$$C = \left| \frac{L_b - L_t}{L_b} \right| \tag{5}$$

Relative Contrast Sensitivity

A fire in a fireplace may be romantic, but a person would probably prefer to read a book using the light from an electric fixture rather than from the fireplace. This is because the sensitivity of the eye to contrast increases as the luminance reaching the eye increases.

Data from a number of psychophysical experiments were used to empirically establish the eye's sensitivity to threshold contrast. This function is called the Relative Contrast Sensitivity (RCS) function (Ref 4). Since most of the luminance that reaches the eye comes from the paper rather than the pencil writing, RCS is a function of L_b.

In Table 1, the growth of interior lighting levels was shown from the beginning of the century. If paper has a reflectance of 80%, it is possible to correlate the growth of relative contrast sensitivity to the footcandle levels in Table 1. This is given in Table 2.

Table 2. Growth of Relative Contrast Sensitivity

Year	Footcandles	Footlamberts	RCS
1900	3	2.4	33.7
1910	5	4	40.5
1920	10	8	48.7
1930	20	16	56.2
1940	35	28	61.8
1950	50	40	65.2
1958	85	68	69.9
1965	100	80	71.5
1971	125	100	73.5

Notice that during the first half of the century, RCS increased fairly rapidly. With 50 footcandles of illumination, the RCS is about double of what it was at 3 footcandles. If illumination is increased to 100 footcandles, twice as much energy will be used compared to 50 footcandles, but RCS increases only 10%. This is a situation of "more light, slightly better sight."

Relative Visibility

Relative visibility (RV) is the product of contrast and the eye's sensitivity to contrast, or:

$$RV = C \times RCS \tag{6}$$

Or, by substituting Equation 5 into Equation 6:

$$RV = \left| \frac{L_b - L_t}{L_b} \right| \times RCS\ (L_b) \qquad (7)$$

Relative visibility may be increased either by increasing the amount of light or by changing the geometry of the light sources with respect to the task. Increasing the amount of light reaching the task (without changing geometry) increases L_b and L_t equally. Thus, it has no effect on contrast, and the gain in RV will come from the increase in RCS. However, as already demonstrated by Table 2 for illumination levels over 50 footcandles, the change in RCS is small compared to the increase in energy expended. Because of the bidirectional reflectances of the pencil and paper, it is possible to change the difference between L_b and L_t (contrast) by changing the geometry of the light sources. Attempting to maximize contrast is the most energy efficient way to increase visibility. The easiest way to increase contrast is to eliminate light from the offending zone. Most people working in spaces with uniform overhead lighting receive some light from the offending zone. Eliminating the offending light increases contrast, and in turn increases relative visibility. The increase usually is more than 10%. This is the reason for the statement made earlier: 50 footcandles of lighting reasonably free of veiling reflections and body shadows will provide the same (and often more) visibility than most commonly used uniform overhead direct lighting systems at 100 footcandles.

Equivalent Sphere Illumination

If someone says that New York City is three times farther from Los Angeles than Denver is, a person has some relative measure of the distances involved. But such information may not be of much help if one is planning a trip and has to allow for driving time, overnight stops, etc. What is needed is a measure of reference, such as "New York City is 3,000 miles from Los Angeles." Likewise, the Illuminating Engineering Society has adopted Equivalent Sphere Illumination (ESI) as a reference measure of visibility. A useful definition of ESI for a specific task is "the illumination level (footcandles or lux) produced inside a photometric sphere required to give the task the same relative visibility it has from the actual lighting system in a room." A photometric sphere is a large hollow sphere painted inside with a special high reflectance diffuse white paint. It is lighted in such a way as to produce a uniform diffuse light. Light shines equally from every direction, including the offending zone. It is therefore not the best possible lighting, but simply a reference lighting system with a fixed geometry and an adjustable light level. The equivalent illumination inside the sphere (ESI) may be higher or lower than the actual illumination under the real lighting system. Mathematically, ESI is obtained by equating the relative visibility in the real environment (RV) with the relative visibility in the sphere (RV_s). Using Equation 6:

$$C \times RCS = C_s \times RCS_s \tag{8}$$

where
- C = the contrast of the task in the real environment
- RCS = the relative contrast sensitivity in the real environment
- C_s = the contrast of the task in the sphere
- RCS_s = the relative contrast sensitivity in the sphere

Since the geometry of the light in the sphere is fixed, the sphere contrast, C_s, is a constant. The illumination inside the sphere has no effect on C_s. Therefore, solving Equation 8 for RCS_s:

$$RCS_s = \frac{C}{C_s} \times RCS \tag{9}$$

or

$$RCS_s = CRF \times RCS \tag{10}$$

where CRF = C/C_s = contrast rendition factor.

The contrast rendition factor (CRF) is simply the ratio of contrast in the real environment to the sphere contrast. Once RCS_s is calculated, the equivalent background luminance inside the sphere, L_s, can be determined from the standard RCS function. Like sphere contrast, the reflectance of the task background in the sphere, ρ_s, is also a constant. The ESI is calculated by

$$ESI = \frac{L_s}{\rho_s} \tag{11}$$

A flow diagram for the mathematical procedure described is shown in Figure 11.

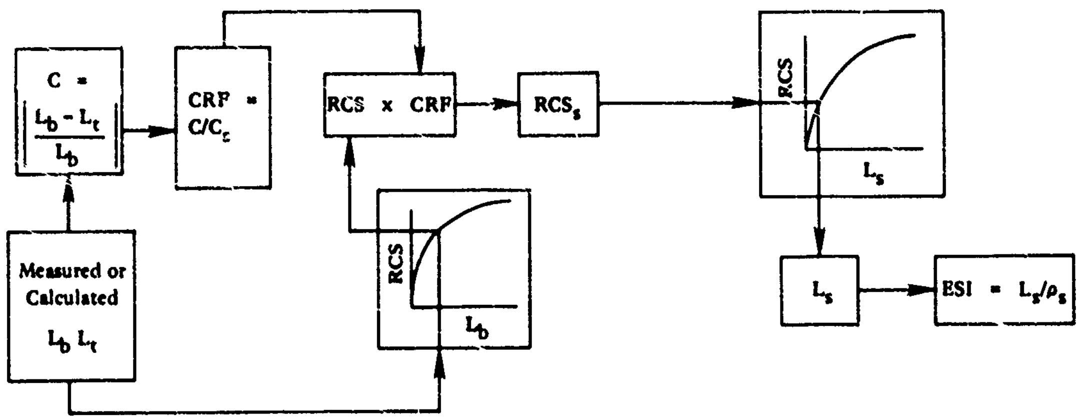

Figure 11. Flow diagram for the calculation of ESI.

At present ESI can be measured using only laboratory equipment. Prototype ESI measurement systems suitable for field use have been developed by several firms, but these are not yet commercially available and will probably be relatively expensive.

Contours

Figure 12 shows a plan view of a desk, task location on the desk, and a 2 x 2-foot ceiling grid system at a 6.5-foot mounting height above the desk top.

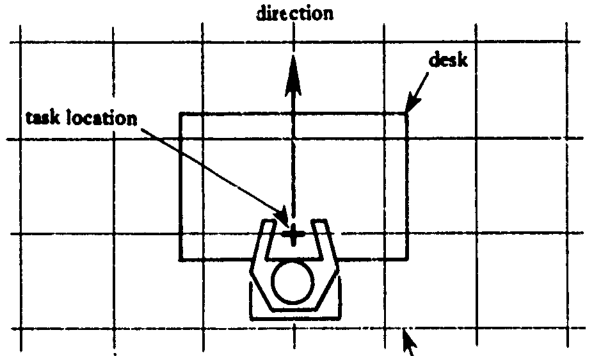

Figure 12. Plan view of work station.

Suppose a small light is placed directly over the task location and provides 100 footcandles for this location. From Equation 1, the light would require a candlepower of

$$I = \frac{E_h D^2}{\cos \theta} = \frac{100 \times 6.5^2}{\cos 0°} = 4{,}225 \text{ candelas}$$

The contours shown in this report will be based on a constant 4,225-candela candlepower from a single light source to the task location. The source is restricted to ceiling locations. For a real lighting fixture, the candlepower to the task will vary with ceiling location. The contours <u>cannot</u> be scaled to calculate ESI for real fixtures since the effect of the RCS function produces nonlinearities in the calculations. There are computer programs which can calculate and generate contour plots for real lighting situations. Nevertheless, the contours are instructive for showing the differences between illumination and equivalent sphere illumination, and for verifying some of the concepts discussed.

First, if a contour plot of illumination is made for the reference 4,225-candlepower source, it would look like Figure 13.

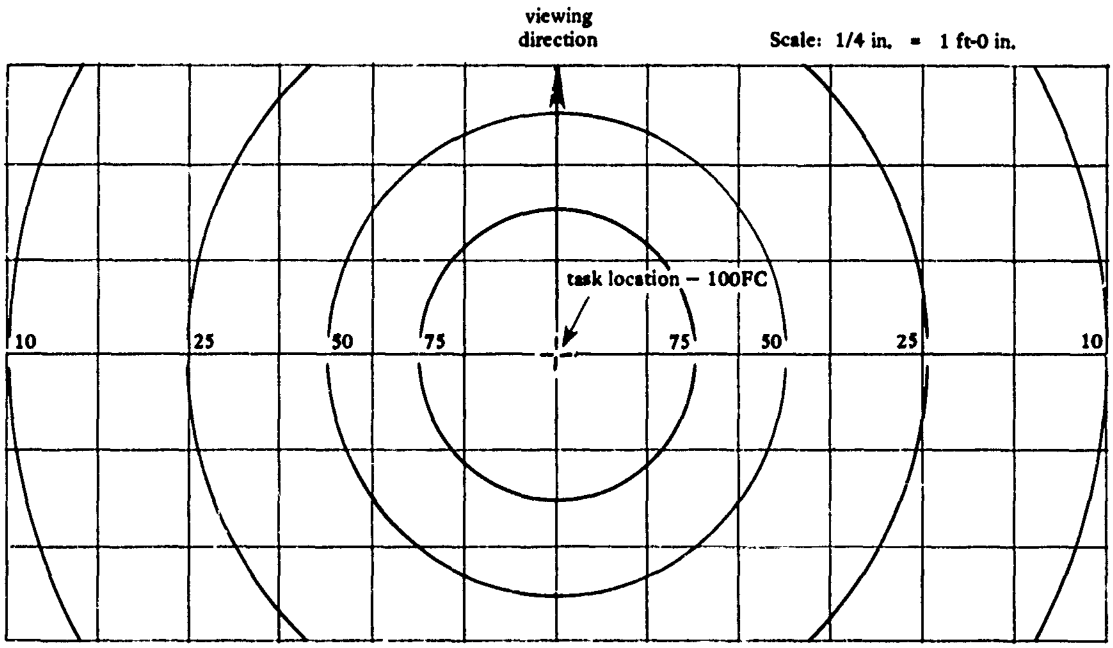

Figure 13. Illumination contours (without body shadow).

Next, a contour plot is made of ESI for the pencil task (number 2 pencil on white paper; viewing declination and azimuth angles statistically weighted, task restricted to lying flat on desk surface) as shown in Figure 14. The effect of the offending zone and body shadow are clearly seen.

By comparing Figures 13 and 14, several things can be learned. Placing a light directly over the task may intuitively seem like the best location for task lighting. Indeed, from Figure 13, the 4,225-candlepower light produces the maximum illumination (100 footcandles) directly over the task. But the visibility for the pencil task is no better than that produced by 27 footcandles of illumination inside a sphere (ESI). On the other hand, maximum ESI occurs at two points which are about 5 feet away from the maximum illumination location, each point to one side and slightly behind the task. The illumination is

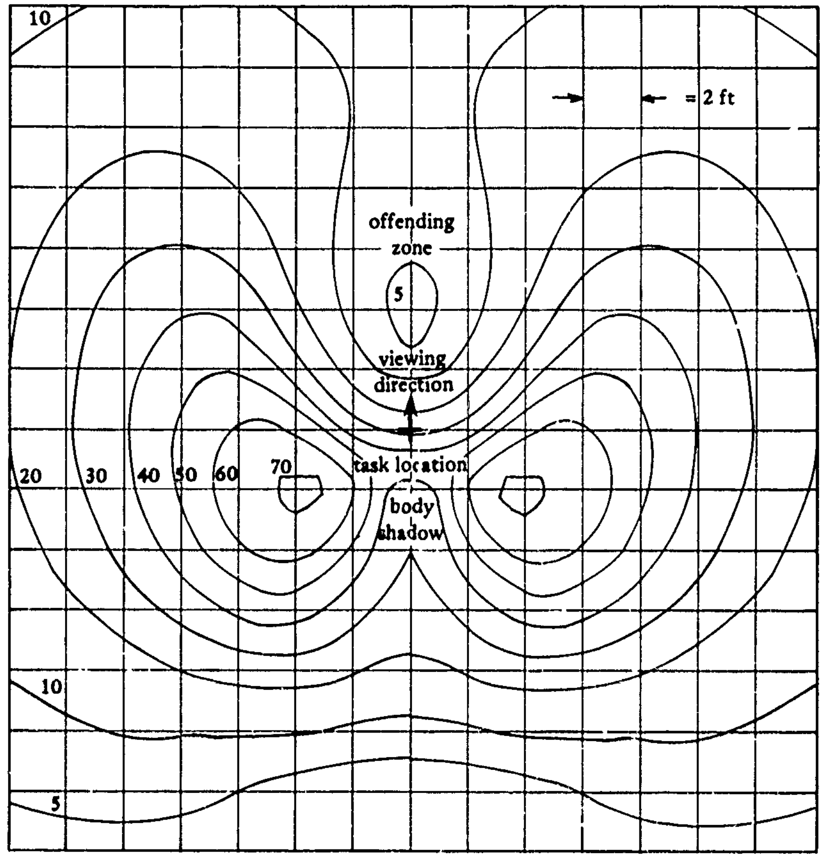

Figure 14. ESI contours.

50 footcandles, but the ESI is 70 footcandles, nearly a three-fold ESI increase. In a real lighting situation, practical tradeoffs can usually be made to achieve reasonably high values of both illumination and ESI.

The best location is to place fixtures to the sides of the task, and slightly behind the task if possible. Almost any location to the side, if not too far away, can be effective. Ceiling fixtures with "batwing" candlepower distributions can be usefully applied since illumination to the side is increased. Sidelighting from windows is also an advantageous way to achieve good ESI.

Another possible location is to place the light source above the worker (not above the task). This location should be used with care because of the high gradients of ESI. Slight changes in geometry can drastically alter the ESI provided.

The rule of thumb learned here: light should come to the task over the worker's shoulders.

ADJUSTMENT OF LIGHT LEVELS

Converting uniform lighting systems to task-ambient lighting systems requires adjustment of light levels. Two of the easiest and least expensive ways are to use (1) integral lighting switches and (2) light-reducing lamps.

An integral lighting switch is simply a switch that is installed inside an individual fluorescent lighting fixture. A typical integral switch is shown in Figure 15. A wall switch operates all the lights on the circuit, whereas the integral lighting switch controls only the fixture in which it is installed. Fixtures can have a multiple position integral lighting switch. For instance, if a three-lamp fluorescent fixture is equipped with a multiple position integral switch, it can provide four levels of light output: completely off, one lamp on, two lamps on, or all three lamps on. Although these light levels could also be achieved by removing lamps from the fixture, integral lighting switches have the advantages of being convenient and eliminating the transporting and storage of lamps. But their most important function is to turn off the energy-consuming ballast. Restrictions on the application and installation of integral lighting switches are found in the National Electrical Code and other codes and standards. Consult applicable codes and standards prior to installation of integral lighting switches (Ref 5).

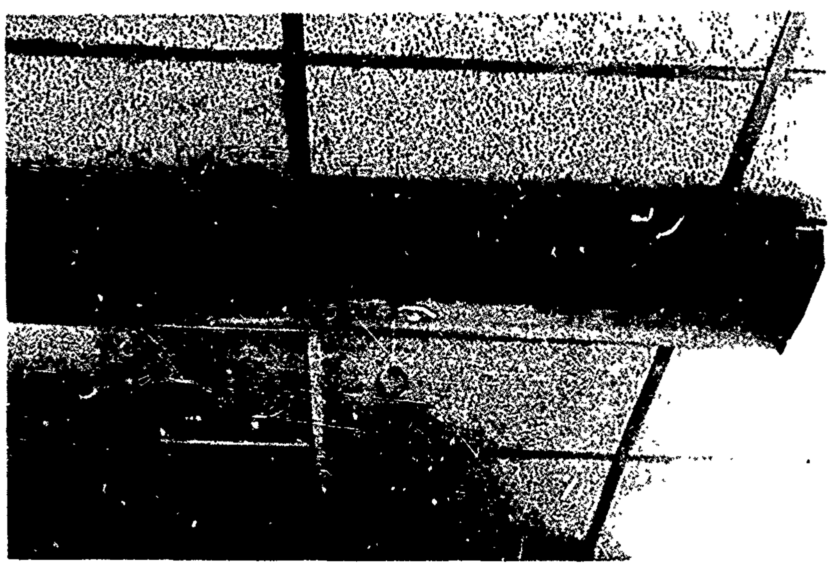

Figure 15. Typical integral lighting switch.

A variety of commercially available, light-reducing lamps are available for retrofit into fluorescent fixtures. Reductions in light output from 10 to 66 percent are possible. The drop in power consumption is approximately equal to the drop in light output.

When adjusting light levels, attention should also be paid to the condition of the fixtures and the age of the lamps. Dirty fixtures and old lamps may produce as little as 50% of the light output of clean fixtures and new lamps. Dirty fixtures should be cleaned, and periodic inspections should be made. Old fluorescent lamps will usually have very dark ends and should be replaced. Moderately dark bands near the ends of fluorescent lamps are normal and should not be confused with the very dark ends indicating end of life. Implementation of a group lamp replacement and periodic fixture cleaning program should be considered.

MIRROR METHOD

Based on the principles presented here, a straightforward, step-by-step method for converting uniform office lighting systems to task-ambient office lighting systems can be used. This is the mirror method, so designated since it uses a mirror to locate light fixtures in the offending zone and in the body shadow. In addition, an illumination meter is required.

Step 1. Determine the illumination and tolerance criteria. Commonly used criteria originally developed by GSA are given in Table 3.

Workers performing visually difficult tasks (bookkeeping, drafting, etc.), older workers (over 50), and workers with uncorrectable eyesight problems may require additional light on work stations (75 to 100 footcandles). In addition, consideration must be given to the maintenance of lighting systems when adjusting light levels; dirty fixtures and old lamps may substantially reduce light output.

Table 3. GSA Illumination Criteria

Task or Area	Footcandle Level	How Measured
Hallways or corridors	10 ± 5	Measured average, minimum 1 footcandle
Work and circulation areas surrounding work stations (ambient illumination)	30 ± 5	Measured average
Work station, normal office work (task illumination)	50 ± 10	Measured at work station; reasonably free of veiling reflections

Step 2. Establish a management organization of building energy monitors. Many Navy activities have already established such organizations. This should be a grassroots organization, to the extent that every government employee should know who his or her energy monitor is. Larger buildings may require more than one energy monitor.

Task-ambient lighting is customized to the needs of building occupants. Since organizations are constantly moving workers and desks, gaining and losing personnel, etc., lighting arrangements must also change accordingly. This is why use of integral lighting switches is so convenient. Local building energy monitors are intimately involved when these changes affect their co-workers. They can insure conservation of energy without sacrificing productivity. They can provide a network to take care of complaints, to watch for conservation opportunities, and to promote energy conservation. Without a network of building energy monitors, continued energy conservation becomes unmanageable.

Step 3. Reduce illumination in circulation areas surrounding work stations to ambient levels. Use an illumination meter to take measurements.

Step 4. Sit at each work station in a normal working position. Look into a mirror placed on the work station and see if any light fixtures are in the offending zone (Figure 16). Turn off all fixtures in the offending zone.

Step 5. Sit at each work station in a normal working position. Place a mirror on the work station and tip it up so that you see yourself in it (Figure 17). Turn off all fixtures that are significantly blocked by the body shadow provided the fixtures are not needed for lighting at other work stations or for ambient lighting.

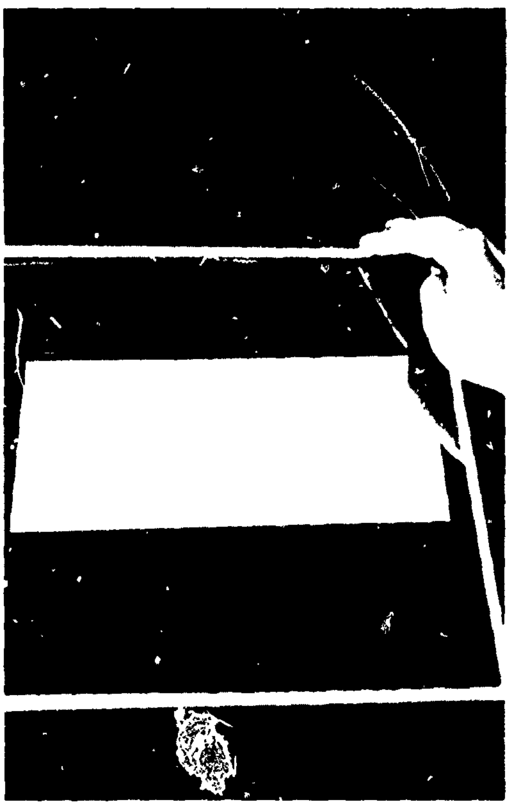

Figure 16. Light fixture in offending zone.

Figure 17. Light fixture in body shadow.

Step 6. With the light meter, measure the illumination at each work station. If the illumination is higher than the task illumination criteria, reduce the illumination. If the illumination is lower than the task illumination criteria, provide supplemental portable lighting or rearrange the work stations.

Step 7. Stand in the doorway to the office and scan the room. If some parts of the room seem overly dark, or the lighting seems too spotty, adjust the ambient lighting.

EXAMPLES

Large Office

Figure 18 shows a typical large office with a uniform lighting system that has been converted to task-ambient lighting using integral lighting switches. Approximately half of the fixtures in the room have been turned off (Figure 18B), yet if one excmines the room below the fixtures, very little difference can be seen. Lights in this room are primarily turned off over circulation areas, in the offending zones, and near windows.

Sometimes fixtures in the offending zone cannot be turned off since another occupant needs the light from the fixture. Two possible solutions to this problem are (1) turn off the light anyway and provide supplemental task lighting to occupants who need additional light or (2) block the light in the offending zone with an obstruction, such as a partition.

Supplemental Task Lighting

When overhead lighting provides insufficient task illumination, one way to increase the illumination level is through use of supplemental lighting. The most common supplemental task light is the desk lamp (Figure 19). Unfortunately, most people place the desk lamp in precisely the wrong location on the desk--directly in the offending zone! The zone of veiling reflection can be clearly seen (compare Figure 19 to Figure 1), with the task placed directly into it.

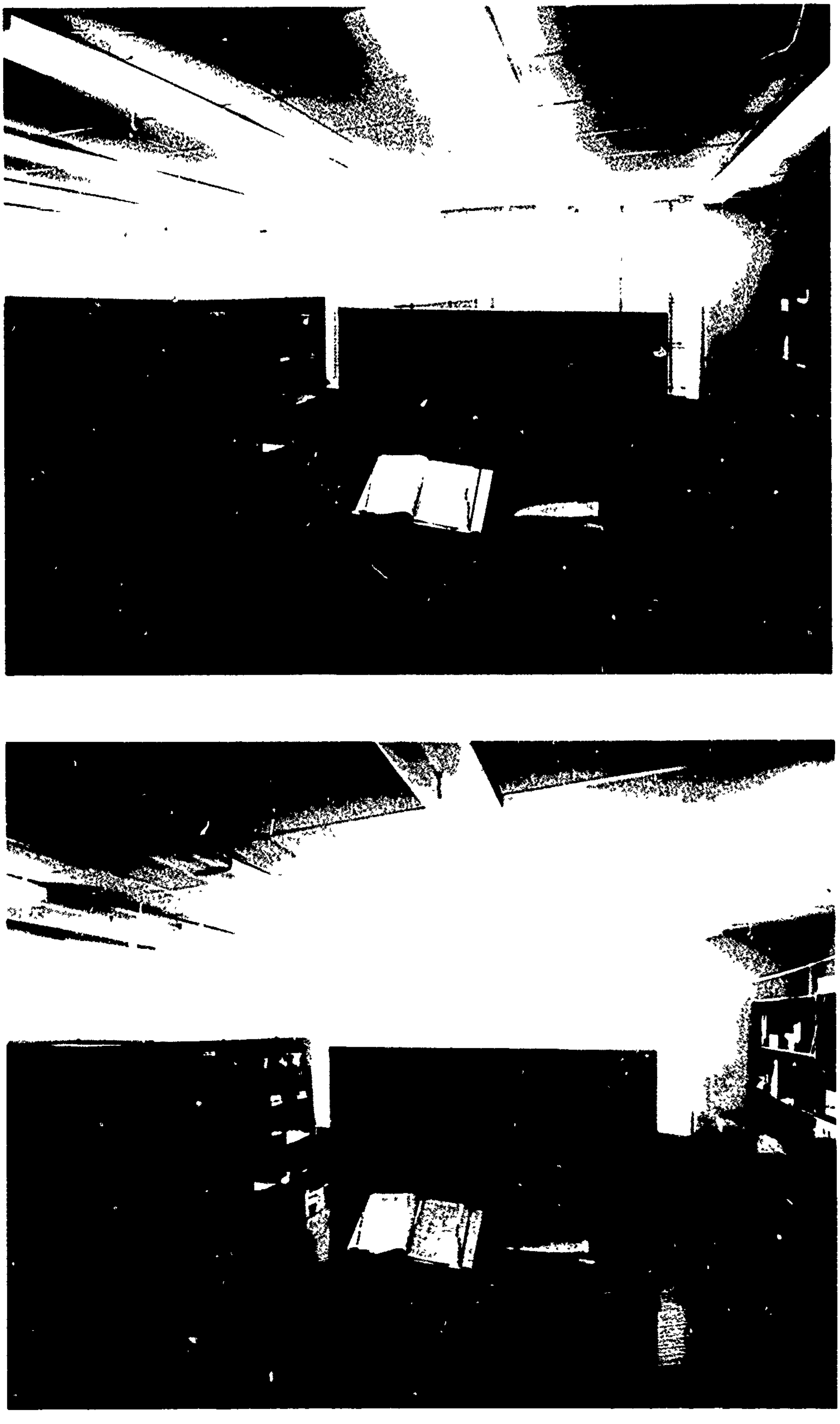

Figure 18 Large office with (A) uniform lighting and (B) task-ambient lighting.

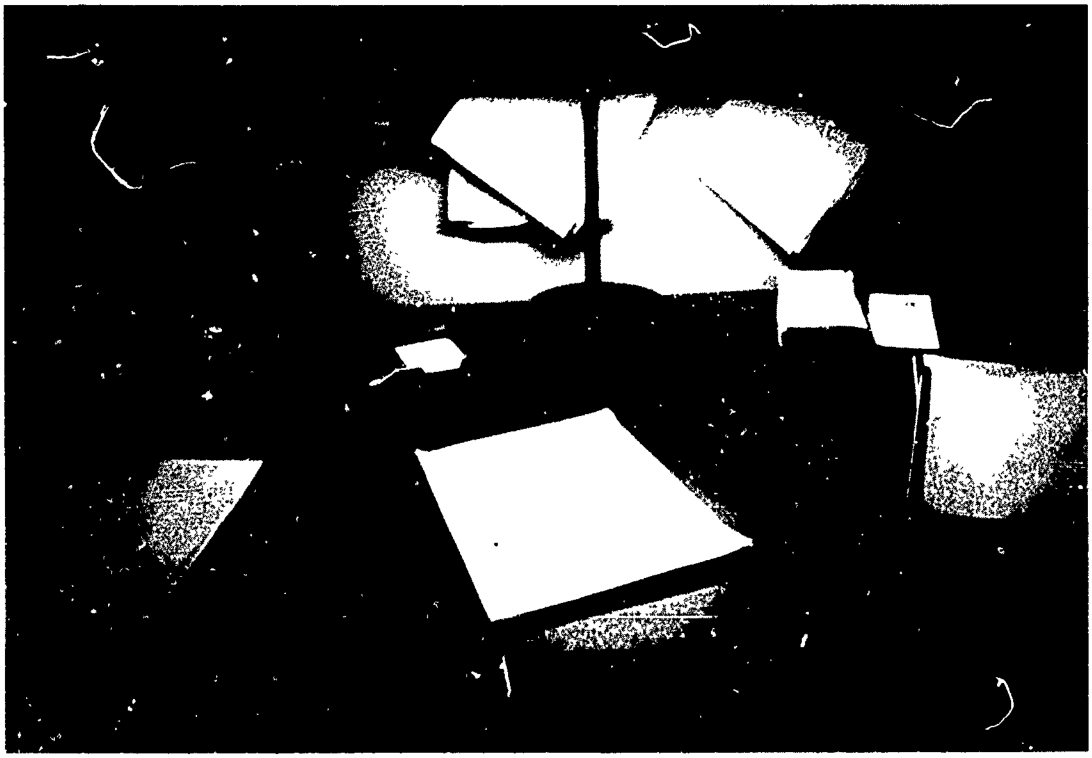

Figure 19. Desk lamp placed in offending zone.

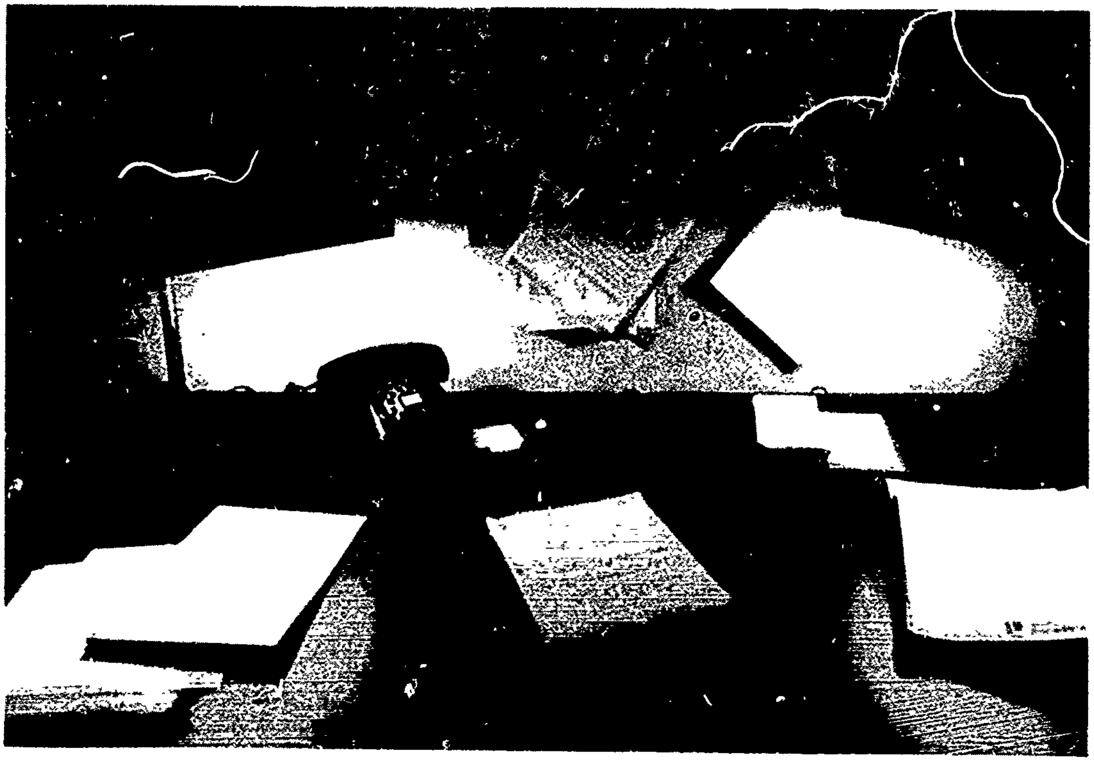

Figure 20. Desk lamps placed to the sides of the task

Placing one or two desk lamps to the side of the task gets the task out of the zone of veiling reflections (Figure 20). This results in better desk lighting, but the close proximity of the lights to the desk creates high luminance gradients. Luminance ratios no greater than 1 to 5 are recommended as a worst case (Ref 6). With the one desk lamp shown in Figure 19, the luminance ratio is 1 to 100. With the two desk lamps shown in Figure 20, the luminance ratio is reduced to 1 to 15, but this is still three times the recommended practice.

Better types of supplemental lighting get the source farther away from the desk, which creates more uniform luminance gradients across the work station. Of course, being farther away, they require more energy to provide the same amount of illumination. Often these fixtures use high-intensity-discharge (HID) lamps, and provide both downlight for task lighting and uplight for ambient lighting (Figure 21).

A really energy-effective and visual-effective desk lamp has not yet been marketed (Ref 7). Manufacturers are working on better supplemental lighting. For now, be cautious when providing supplemental task lighting.

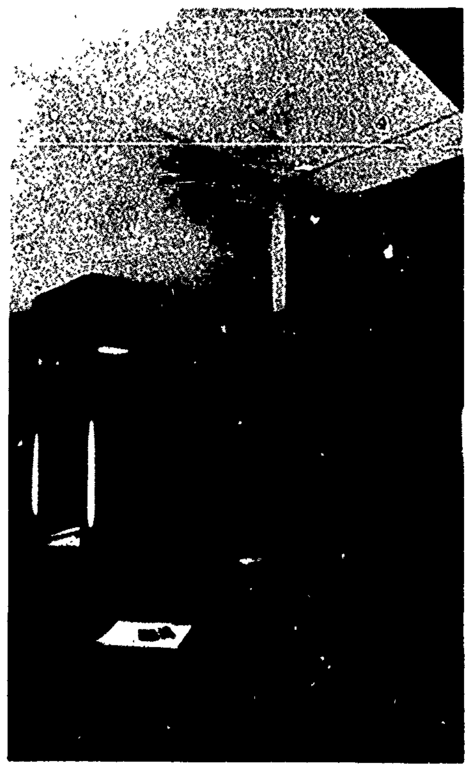

Figure 21. Portable HID task-ambient fixture.

Small Office

Figure 22 shows a small office with an older worker who was having visual difficulties with her work. An examination of the room showed that most of the light to the desk was coming from the offending zone, or was blocked by the body shadow.

Fixtures in the offending zone were turned off, as was one fixture in the body shadow. This left only one fixture on in the room, which was over the occupant's head, but slightly to one side. The single

Figure 22. Small office with uniform lighting.

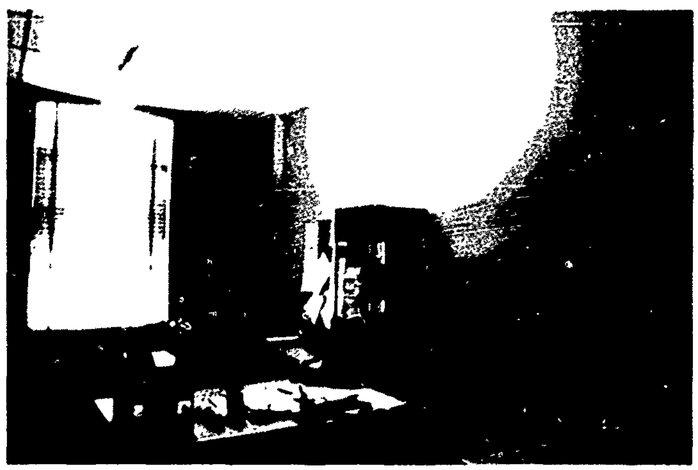

Figure 23 Small office with task-ambient lighting.

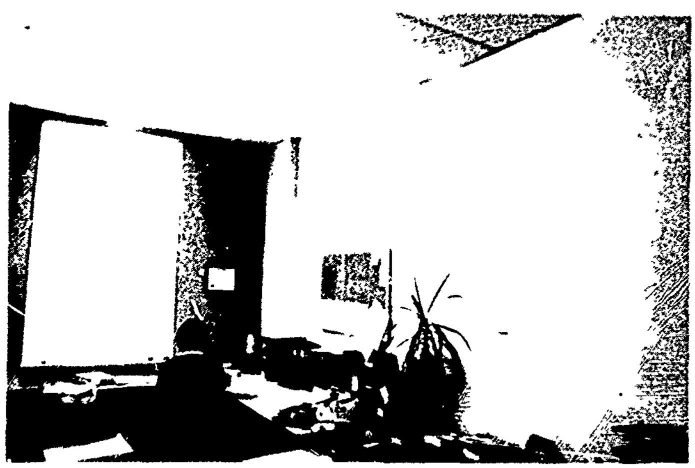

Figure 24 Small office with relocated work stations.

fixture could not provide sufficient task or ambient lighting. One solution was to provide supplemental indirect lighting from a portable HID fixture located next to the desk. This increased both the task and ambient illumination to the proper levels (Figure 23).

Rather than turning off the fixtures in the offending zone, another possible solution is to relocate the work stations away from the offending zone. This is shown in Figure 24.

In the office shown in Figures 22-24, the window wall had been painted a different color for aesthetics. Unfortunately, a darker, rather than a lighter, color was chosen. A lighter color would have reduced the sensation of glare from the window, allowing occupants to open the venetian blinds more frequently and let in more daylight.

Reception Area

Figure 25 shows a well-designed reception area. In the background is soft indirect ambient lighting for individuals waiting in the lobby. Task lighting for the reception desk is provided by a 4- by 4-foot parabolic louver fixture. The parabolic louver is used to shield

Figure 25. Reception area task-ambient lighting.

direct glare for people coming up to the reception desk; it is so effective, one can only tell that the fixture is turned on by the pattern of light on the wall. Work areas surround the receptionist on three sides, so the fixture was located over her head. This provides light over her shoulders, well out of the offending zone, regardless of the work area. Some light is blocked by the body shadow, but this is minimized by using a large 4- by 4-foot fixture.

FINDINGS

The visual properties of office tasks have been examined. Light at the mirror angle produces substantial veiling reflections because of specularities in the task. Light sources in this offending zone can be identified using the mirror method. The mirror method also identifies light sources obstructed by the body shadow. Light sources in the offending zone and behind the body shadow reduce visibility. Visibility may be measured in terms of equivalent sphere illumination (ESI). A correlation between ESI and the mirror method was described.

CONCLUSION

The quality of task office lighting is better quantified using equivalent sphere illumination (ESI) than using illumination. Since most activities do not have a readily available method of determining ESI (computers or meters), the mirror method described in this report can be used as a practical substitute. The only equipment required is an illumination meter and a mirror approximately one foot square.

RECOMMENDATION

Uniform office lighting systems should be converted to task-ambient lighting using the mirror method. Task-ambient lighting will save electrical energy, and the mirror method will insure visually effective lighting.

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