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# Office Lighting: A Review of 80 Years of Standards and Recommendations

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# Office Lighting: A Review of 80 Years of Standards and Recommendations

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*Abstract* – **This paper traces the development of quantitative office lighting standards from its beginnings to the present. It discusses the sources of recommended lighting practice, the nature of the quantitative recommendations, and trends in recommended values on a comparative basis. A critical assessment of contemporary standards is provided within this historical context.**

## I. INTRODUCTION

In exploring the development of lighting standards for office buildings, I searched the archival materials available in the University of California and the Lawrence Berkeley Laboratory library systems. I was surprised, not to find any records of office lighting codes before 1942. Fortunately, I came across a note in the foreword of the *Recommended Practice for Office Lighting*, published in the June 1956 issue of Illuminating Engineering, which stated that the first official recommendations for office lighting were published in a 1915 report entitled *Code of Lighting Factories, Mills and Other Work Places*. With that knowledge and a lot of patience while browsing through seemingly endless bookshelves, I was able to trace back the discussion of office lighting codes to the year 1913, as the following review will show. Although my investigations focus on trends in quantitative recommendations, it is necessary to evaluate those trends in the context of qualitative needs and assumptions. After all, quantitative recommendations are made in light of qualitative aspirations. Therefore, qualitative causes of quantitative recommendations, such as safety, good visibility and visual comfort, are treated as an integral part of the discussion.

## II. A NEED FOR LIGHTING CODES: WORKER SAFETY

In 1913, the Illuminating Engineering Society (IES) was called upon to assist in formulating the lighting section of the labor law of the State of New York. Increasing accidents and complaints about working conditions and employee treatment in factories and many other work places had lead state authorities to impose regulatory statutes upon their operators. Lighting conditions were among the dominant complaints from workers. Illuminating engineers recognized that inadequate lighting was responsible for many industrial accidents. Extensive data, accumulated by Simpson [1] and others provide convincing proof of this condition. The loss of visual power through improper lighting could not be so easily recorded, but ophthalmologists [2 and 3] warned about its dangers.

*"Insufficient and improperly applied illumination is a prolific cause of industrial accidents. In the past few years numerous investigators, studying the cause of accidents, have found that the accident rate in plants with poor lighting is higher than in similar plants which are well illuminated. [...] Of even greater importance, poor lighting impairs vision. [...] To preserve the eyesight of the working class is a distinct economic gain to the state, but regardless of that, humanitarian consideration demands it. Finally, inadequate illumination decreases the production of the industries of the state, and to that extent, the wealth of the people."* [from: Wisconsin Industrial Lighting Code, as quoted by 4, pp. 154-155]

In his address, *The Status of the Lighting Art*, at the 1913 Annual Convention of the Illuminating Engineering Society, its President Preston S. Millar [5] reviewed the contemporary lighting practice, perhaps in light of the organization's upcoming involvement in regulatory activities. His assessment was based primarily on about 200 responses from companies and individuals concerned with the lighting of buildings and public spaces to a survey requested by the IES. In discussing lighting intensity issues, he stated:

*"The trend in illumination intensities is upward. Higher efficiency lamps are being developed [...] With the increase in efficiency there is coming into our practise a greater insistence upon good candle-power maintenance. [...] The growing appreciation of the importance of good lighting is raising the standard, making a still further general demand for the production of more light."* [5, pp. 658-659]

Table 1, also based on the survey, was presented by Millar to identify typical illuminance levels for various types of artificial lighting in 1913.

Two bodies of the IES, the Committee on Lighting Legislation and the Committee on Factory Lighting, were cooperatively charged with preparing the Illuminating Engineering Society's contribution to the labor law. Because of difficulties in unifying the various lobbying groups (lighting engineers, electric companies, union leaders, employers, etc.) it was found impracticable in 1913 to incorporate definite lighting specifications in the law. However, a provision was made for the later adoption of such regulations by the Labor Commission. In preparation for the commission's requirement, work of drafting a code was undertaken by the Illuminating Engineering Society. The problem was found to be a very difficult one, for technical and political reasons, and many modifications were needed to satisfy the various parties involved. After almost two years of heated debates the *Code of Lighting Factories, Mills and Other Work Places* [6] was finally issued by the Illuminating Engineering Society in its November 1915 Transactions. It was intended to make available authoritative information for legislative bodies, factory boards, public service commissions and others who were interested in enactments, rules and regulations for better lighting. Eleven articles described the general provisions of the code, including minimum required and desired lighting intensities (in foot-candles, Table 2), as well as inspection and maintenance regulations. Explanatory rules and explanatory notes further described the specifics and practical concerns of the code such as layout of lighting fixtures, workspace organization for more effective lighting, recommended lamp and fixture types, and cost evaluations. In this first edition of the lighting code, no provisions were made specifically for office spaces. The code stated in Article V that the

*"[...] average illumination intensity throughout any month actually measurable in foot-candles on a horizontal plane through the work is to conform to [Table 2]. Uncertain cases which arise as to how to classify given manufacturing operations are to be left to the judgment of a lighting expert."* [6, p. 606]

Article I, covering the regulation of daylight, required the provision of adequate window area. It also stated that light levels from daylight should be at least three times those required for electric lighting.

TABLE I
TYPICAL ILLUMINANCE VALUES FOR VARIOUS TYPES OF ARTIFICIAL LIGHTING (1913)

| Class | As measured through | Foot-candles Average | Usual Range |
|---|---|---|---|
| Street Lighting | | | |
| Principal streets in cities | Horizontal plane of street surface | 0.4 | 0.25 – 2.0 |
| Important side streets | " | 0.15 | 0.1 – 0.25 |
| Residence streets | " | 0.04 | 0.01 – 0.1 |
| Store lighting | Horizontal plane 30 inches above floor | 4.0 | 2.0 – 6.0 |
| Show window lighting | " | 18.0 | 12.0 – 25.0 |
| Factory lighting | " | 3.0 | 2.0 – 6.0 |
| **Office lighting** | " | **3.0** | **2.0 – 4.0** |
| Residence lighting | " | 1.5 | 1.0 – 3.0 |
| Railway car lighting | " | 2.0 | 1.0 – 3.0 |

TABLE II
ILLUMINANCE REQUIREMENTS FOR FACTORIES, MILLS AND OTHER WORK PLACES (1915)

| Class of Work | Minimum foot-candle intensity | Desirable foot-candle intensity |
|---|---|---|
| Storage, passageways, stairways, and the like | 0.25 | 0.25 – 0.5 |
| Rough manufacturing and other operations | 1.25 | 1.25 – 2.5 |
| Fine manufacturing and other operations | 3.5 | 3.5 – 6.0 |
| Special cases of fine work | – | 10.0 - 15.0 |

*"The intensity requirements for daylight are higher than those for artificial light because the physical conditions of the eye during the daytime is usually such as to require a higher intensity of natural light for satisfactory vision than is required under ordinary well designed artificial lighting systems."* [6, p. 605]

Industrial lighting codes, based on the Illuminating Engineering Society's code were soon in force in the states of Pennsylvania, New Jersey, New York and Wisconsin. As a war measure, the Advisory Commission of the Council of National Defense, appointed a sub-committee known as the Divisional Lighting Committee. The sub-committee, working through state representatives, approached the authorities in each of the states to encourage the adoption of such codes, perhaps in an attempt to boost World War I production.

*"The industrial lighting codes are expressions of the "Safety First" movement [...] The prime function of the codes is the safeguarding of life, limb and vision of industrial workers. [...] In addition, the codes seem likely to teach practise which will enhance the earning power, not only of the workers themselves but also of the industrial plants."* [4, p. 153]

TABLE III
ILLUMINANCE REQUIREMENTS FOR FACTORIES, MILLS AND OTHER WORK PLACES (1917)

| | Foot-candles at the work | |
|---|---|---|
| | Ordinary Practice | Mini mum |
| (a) Roadways and yard thoroughfares | 0.05 – 0.25 | 0.02 |
| (b) Storage spaces | 0.50 – 1.00 | 0.25 |
| (c) Stairways, passageways, aisles | 0.75 – 2.00 | 0.25 |
| (d) Rough manufacturing such as machining, rough assembling, rough bench work | 2.00 – 4.00 | 1.25 |
| (e) Rough manufacturing involving closer discrimination of detail | 3.00 – 6.00 | 2.00 |
| (f) Fine manufacturing such as fine lathe work, pattern and tool making, light colored textiles | 4.00 – 8.00 | 3.00 |
| (g) Special cases of fine work such as watch making, engraving, **drafting**, dark colored textiles | **10.00 – 15.00** | **5.00** |
| **(h) Office work such as accounting, typewriting, etc.** | **4.00 – 8.00** | **3.00** |

In 1917, the *Code of Lighting Factories, Mills and Other Work Places* was amended to reflect the need of lighting practitioners and inspectors for more specific classifications of work spaces. The revised rules were adopted by the IES on June 26, 1917 and published in the IES Transactions of June 1918 [7]. Table 3 sets the new standards for illumination levels [7, p. 256]. Office work was introduced to the code as a separately recognized activity under (h). Its illumination requirements were equal to those for fine manufacturing processes. No other changes were made to the code at that time.

In the states which have adopted lighting codes, the action was by industrial or labor commissions, under the authority granted them by legislature, to promulgate rules in the interest of safety of industrial workers. The codes were, therefore, backed by the state police power. Since the function of the commissions was limited to insuring safety, the codes required only such lighting as was necessary for that end. Under these circumstances the codes could not demand the higher standard of illumination desirable for more economical production. For this reason, the intensities specified by the codes were minimum limits, but higher values representing more desirable practice were recommended. Although about 90 percent of the companies governed by the codes willingly complied with the requirements, none of the limitations of the code presented more of an obstacle than the fact that many of the regulators and inspectors were not versed in the principles of lighting and had little idea of the qualities and quantities necessary for the definition of appropriate lighting conditions. Therefore, the IES took on the additional challenge of publishing educational material and offering lectures supplementing the codes.

Also in 1918, the IES published the *Code of Lighting School Buildings* [8], to which I refer here only to compare required levels of illumination as they most closely relate to those in office spaces.

TABLE IV
ILLUMINANCE REQUIREMENTS FOR SCHOOL BUILDINGS (1918)

| | Artificial lighting Foot-candles (Lumens per square foot) at the work | |
|---|---|---|
| | Minimum | Ordinary Practise |
| Storage spaces | 0.25 | 0.5 – 1.0 |
| Stairways, corridors | 0.5 | 1.0 – 2.5 |
| Gymnasiums | 1.0 | 2.0 – 5.0 |
| Rough shop work | 1.25 | 2.0 – 4.0 |
| Auditoriums, assembly rooms | 1.5 | 2.5 – 4.0 |
| Class rooms, study rooms, libraries, laboratories, blackboards | 3.0 | 3.5 – 6.0 |
| Fine shop work | 3.5 | 4.0 – 8.0 |
| Sewing, drafting rooms | 5.0 | 6.0 – 12.0 |

The code was similar in organization and scope, but focused on increased student learning abilities due to improved lighting, rather than safety. Daylight from one or two sides

of the classrooms was recommended at a considerably greater illumination level than under artificial lighting conditions. If daylight failed to meet the lighting needs, the intensity requirements of Table 4 were to be met by electric lighting systems. Again, minimum and desirable levels were promoted.

## III. LOBBYING FOR HIGHER ILLUMINANCES

In a bulletin of General Electric's Edison Lamp Works on *The Lighting of Office Buildings and Drafting Rooms*, Powell [9] sincerely questioned the minimal illuminance levels prevailing in office lighting practice, originating from the minimum requirements set forth in the codes.

*"A careful consideration of the subject shows past standards of intensity to be too low. An analysis [...] shows the average values set down as desirable to be between three and four foot-candles. You can, of course, see to read or typewrite with less than one half a foot-candle, but severe eye strain is introduced, and no one would think of insisting on prolonged work under such conditions. Where, then, is the economic or critical limit to intensity? One hesitates to say, and can merely report that the most progressive firms are using, and the leading specialists are recommending, from 10 to 15 foot-candles for general clerical work. What the standard will be a decade from now cannot be accurately foretold."* [9, p. 4]

Developments in the science of lighting and experience gained by the operation of the industrial lighting codes in the states that had adopted the IES code as their standard (Pennsylvania, New Jersey, New York, Wisconsin, Oregon, California, and Ohio) indicated the need for further revision of the 1918 code, especially in relation to intensity (illuminance) requirements and glare rules. Revision under the coordination of the IES Committee on Lighting Legislation began in February 1920. In June 1920, the Illuminating Engineering Society accepted the invitation of the American Engineering Standards Committee to act as sponsor for the industrial lighting code. Since that date the revision of the code had been carried out under the rules of procedure of the American Engineering Standards Committee. These rules required review of the proposed code by many other engineering and governmental organizations. The new *Code of Lighting – Factories, Mills and Other Work Places* [10] was published in the November 1921 IES Transactions and was approved on December 31, 1921 by the American Engineering Standards Committee.

A departure was made from the previous code in arranging the text for ready reference by dividing the subject matter into three parts: Part I containing the rules, Part II containing suggestions and general information with notes relating to each rule, and Part III containing a statement of the advantages of good lighting. The suggested mandatory requirements for safe lighting were all set forth in Part I. A table of recommended intensities for detailed industrial operations and processes, and tables classifying light sources from the standpoint of glare, were added to meet the demand for more specific information on these subjects. Minimum levels for illumination increased slightly for many applications and due to the added table for detailed specifications of industrial operations, the required illumination values were rearranged as shown in Table 5 [10, p. 354]. For office work, the recommended illuminance levels were specified as ranging from 5 to 10 footcandles (4 to 8 footcandles in 1918), for drafting from 10 to 20 footcandles (10 to 15 footcandles in 1918).

TABLE V
ILLUMINANCE REQUIREMENTS FOR FACTORIES, MILLS AND OTHER WORK PLACES (1921)

| | | Minimum foot-candles on the space or at the work |
|---|---|---|
| (a) | Roadways, yard thoroughfares | 0.02 |
| (b) | Storage spaces, aisles and passageways in workrooms, excepting exits and passages leading thereto | 0.25 |
| (c) | Where Discrimination of Detail Is Not Essential:<br>Spaces, such as: Hallways, stairways; exits, and passages leading thereto; toilet rooms; elevator cars and landings<br>Work, such as: Handling material of a course nature; grinding clay products; rough sorting; coal and ash handling; foundry charging | 0.5 |
| (d) | Where Slight Discrimination of Detail Is Essential:<br>Spaces, such as: Stairways, passageways and other locations where there are exposed moving machines, hot pipes, or live electrical parts<br>Work, such as: Rough machining, rough assembling; rough bench work; rough forging; grain milling | 1 |
| (e) | Where Moderate Discrimination of Detail Is Essential:<br>Work, such as: Machining; assembly work; bench work; fine core making in foundries; cigarette rolling | 2 |
| (f) | Where Close Discrimination of Detail Is Essential:<br>Work, such as: Fine lathe work; pattern making; tool making; weaving light colored silk or woolen textiles; **office work; accounting; typewriting** | 3 |
| (g) | Where Discrimination of Minute Detail Is Essential:<br>Work, such as: Watch making; engraving; **drafting**; sewing dark colored material. | 5 |

The *Code of Lighting School Buildings* was revised in 1924, following the general line of improvement of the *Code of Lighting – Factories, Mills and Other Work Places* by

providing more specific and detailed information. Minimum illuminance requirements for classroom or library desktops increased from 3 footcandles in 1918 to 5 footcandles in 1924, their recommended values increased from 3.5 to 6 footcandles in 1918 to 10 footcandles. Minimum requirements for drafting or sewing rooms increased from 5 footcandles to 8 footcandles. Their recommended values were raised from 6 to 12 footcandles in 1918 to 15 footcandles. These figures already indicate a trend towards further increase of illuminance levels for every lighting application, since they were placed at the upper limit of the 1921 recommendations of the *Code of Lighting – Factories, Mills and Other Work Places.*

A *Symposium on Office Lighting* [12], organized by the Illuminating Engineering Society in 1924, was called to investigate the specific needs of engineers involved in the lighting of offices. It approached the problem through a design competition for which lighting engineers submitted design proposals for the lighting of an existing office space. Selected proposals were than presented and discussed at the symposium. Although more conservative engineers set the *maximum* level at 4 to 5 footcandles for their design schemes, many contributors argued that even the recommended illuminance values were still too low and proposed 11 to 14 footcandles for general office tasks, such as typewriting and accounting. Drisko recalled a particular incidence where more than the recommended footcandles were needed due to very high brightness of the exterior.

*"I was called upon to look over the lighting of an office [...] There were 10 foot-candles at the point where the light was said to be unsatisfactory [...] there were large windows all around the room, and outside at that particular time of the year there was snow, so that the level of brightness to which the eye was adjusted was so much above 10 foot-candles, and [...] produced conditions under which it was almost impossible to see. It seems to me this question involves other things than the number of foot-candles."* [12, p. 549]

Stickney argued for higher illuminances from electric lighting because of the lower daylight availability in city offices, where daylight is blocked by neighboring buildings.

*"Some of our most satisfactory lighting installations have over 20 foot-candles. We were very highly complimented on such a job by a consulting engineer, who, incidentally, was the one who had to pay the bills. He considered it very profitable. [...] it must be remembered that the real demand for artificial lighting in a city office is not after dark, but rather as a supplement to inadequate daylight. This condition really requires a higher level of artificial illumination than would be necessary at night."* [12, p. 551]

A second *Symposium on Office Lighting* [13], presented before the 1927 Annual Convention of the Illuminating Engineering Society, was held under the premise that levels for good illumination of offices seemed to be fairly well standardized, and focused primarily on the lighting equipment adaptable to office lighting service and recommended improvements in the luminaire design.

The States of California, Maryland, Massachusetts, Oklahoma and Washington had adopted the 1921 *Code of Lighting – Factories, Mills and Other Work Places* as their lighting codes for industrial applications by 1927. In compliance with its policy that codes and specifications should be reviewed at least once in five years, the IES Committee on Lighting Legislation appointed a sub-committee to review during the fiscal year 1926-27 the *Code of Lighting – Factories, Mills and Other Work Places.* A proposed revision was published in December 1928 [14], but was never approved by the American Engineering Standards Committee. A new attempt was made in 1930 after complete reorganization of the code and numerous additions. The 1930 code was approved by the newly reorganized and renamed American Standards Association on August 18, 1930.

Lighting intensities, now termed more accurately *levels of illumination*, were raised more than threefold and organized according to manufacturing branches and activities, rather than general categories which simplified the appropriate selection for lighting engineers. Preferred higher values were given as the first number within a range, the lower number indicated the minimum level required to perform the task at hand. For office lighting applications, the levels in Table 6 were listed. [15, pp. 616-618]

TABLE VI
ILLUMINANCE REQUIREMENTS FOR OFFICES (1930)

| | Foot-Candles Recommended |
|---|---|
| Offices: | |
| Private and General | |
| Drafting Rooms | 25 – 15 |
| Close Work | 15 – 10 |
| No Close Work | 10 – 8 |
| Elevators | 8 – 5 |
| Toilet and Wash Rooms | 6 – 4 |
| Store and Stock Rooms | 3 – 2 |
| Aisles, Stairways, Passageways | 3 – 2 |

Note: General offices are open office spaces, many desks are usually arranged without partitions. Private offices are separate rooms with independent lighting installations.

## IV. OFFICE LIGHTING BEGINS A SEPARATE JOURNEY

In 1942, the *Code of Lighting: Factories, Mills and Other Work Places* was divided into two separate statutes, published under the titles *American Recommended Practice of Industrial Lighting* [16] and *Recommended Practice of Office Lighting* [17], prepared by the *Committee on Lighting Practice.* The new industrial lighting code was approved by the American Standards Association. However, Part III of previous lighting

codes, containing the regulations suggested for adoption by state authorities, was omitted as there was no record of any legislative body using the suggested regulations for code purposes since the issuance of the 1930 revision. No indication is available in the literature that suggests the *Recommended Practice of Office Lighting* was submitted to the American Standards Association for approval at that time. However, it functioned in practice as a standard as no other regulation was in effect. Due to the events of World War II, enforcement of codes seemed to be unnecessary as companies voluntarily raised illumination levels to increase productivity, which was demanded by the U.S. President's production drive and national pride.

TABLE VII
ILLUMINANCE RECOMMENDATIONS FOR OFFICES (1942 AND 1947)

| | Minimum Operating Foot-candles in Service |
|---|---|
| DIFFICULT SEEING TASKS | 50 |
| Involving: | |
| (a) Discrimination of fine detail | |
| (b) Poor contrast | |
| (c) Long periods of time | |
| Such as: | |
| Auditing and Accounting | |
| Business Machine Operation | |
| Transcribing and Tabulation | |
| Bookkeeping | |
| Drafting | |
| Designing | |
| ORDINARY SEEING TASKS | 25 |
| Involving: | |
| (a) Discrimination of moderately fine detail | |
| (b) Better than average contrast | |
| (c) Intermittent periods of time | |
| Such as: | |
| General Office Work (except for work coming under "Difficult Seeing Tasks" above) | |
| Private Office Work | |
| General Correspondence | |
| Conference Rooms | |
| File Rooms | |
| Mail Rooms | |
| CASUAL SEEING TASKS | 10 |
| Such as: | |
| Reception Rooms | |
| Washrooms, and other Service Areas | |
| SIMPLE SEEING TASKS | 5 |
| Such as: | |
| Hallways and Corridors | |
| Passageways | |
| Stairways | |

Lighting engineers realized the increasing economic importance of office work. Although the office lighting problem was viewed as a rather definite one, as office workers frequently remained in one position, it was often badly solved. An appreciation of the value of good lighting lead to a considerable amount of experimentation and publicity, and the demand for better office lighting became universal. It had also been shown that well lighted offices rented more easily and brought better returns. The *Recommended Practice of Office Lighting* was based on these premises and recognized higher illumination as an effective aid toward better seeing. Besides specifying illuminance levels, which were tabulated as minimum operating footcandles on the work surface (Table 7), the treatise covered many aspects in greater detail than previous codes, including relationships between task and visual requirements, the impact on directionality and color of light vision, the treatment of walls and ceiling to improve seeing conditions, a discussion of various lighting systems (daylight, indirect, semi-indirect or direct lighting), as well as electrical wiring and cost analysis. Many well-selected illustrations supported the treatise visually, notably images of fluorescent lighting installations. Illuminance values (footcandles) for office tasks drastically increased since the 1930 edition of the *Code of Lighting – Factories, Mills and Other Work Places.*

World War II limitations tended to slow progress on office lighting although the war did stimulate the use of fluorescent lighting in war industry offices and drafting rooms. The increased use of windowless buildings for such offices also provided a stimulus for better lighting installations since they provided the only illumination. The end of the war permitted more emphasis on office lighting, and rapid strides were made in both the design and use of office lighting equipment. Among the developments were the practical systems of predetermining the relative comfort of proposed lighting installations. High illumination levels in the order of 75 to 100 footcandles also became more common, and by 1947 installations providing over 200 footcandles were reported.

When the recommended practice was revised that year [18], it reflected a need for better organization of the topics presented and examples of the new technology. Illustrations indicated the increasing use of fluorescent lamps in office lighting applications. The more detailed treatment of direct and reflected glare problems acknowledged some of the problems arising from extended luminaires, such as continuous fluorescent rows that often created streaks of reflections on dark polished office desks. Recommended illuminance levels, however, remained basically unchanged despite the reported high illuminance installations, with the exception that ordinary seeing tasks were increased to 30 footcandles, and stairways were now categorized as casual, rather than simple, seeing tasks. A passage from *Quest for Quality in Office Lighting* [19] may illustrate why the lighting levels remained unchanged.

*"One such [high illuminance] installation consisted of well-shielded aluminum troffers having a brightness of only 20-30 foot-lamberts crosswise and a maximum of 300 foot-*

*lamberts endwise. Despite this low luminaire brightness, it was found that the installation was comfortable only when **all** room surfaces including desk bodies and kneeholes as well as the tops, cabinets, doors, files, etc.. were finished in light colors to minimize brightness differences between the bright task and the surfaces."* [19, p. 82]

The trend towards higher illumination levels emphasized the importance of light desk tops, and by 1949 desk grade linoleum with a reflectance of 30 to 35 percent was readily available. Although isolated examples of luminous ceilings have been reported, it was not until about 1949 that they became available in a form that made common usage practical. Continued improvements in diffusing materials, methods of installation, and the addition of accessory shielding and acoustical devices over the years have increased their popularity. Mass production techniques also decreased the cost of luminous ceiling installations. It seemed, in some respects, to answer the lighting engineer's dream of a uniform low brightness source that enabled him to provide high illumination levels without discomfort. But he soon found that it had to be used with discretion and within limits. Furthermore, the architect's and user's aesthetic requirements demanded more variety and versatility than the luminous ceiling offered. This eventually lead to the development of the large area luminaires.

Of interest is the 1947 publication of the first *IES Lighting Handbook* which served as a compendium of essential information on light and lighting for lighting engineers, architects, interior designers, lighting manufacturers and even their sales representatives.

The next revision of the *Recommended Practice for Office Lighting* [20] retained the topical organization of the previous edition but expanded its contents. Illustrations were updated to match the new style of office interiors (i. e. those wonderful metal desks that we still find in many offices in government agencies and universities). Recommended footcandle values stayed – and this is certainly a surprise considering all the publicity of luminous ceilings and large area light sources – at the level of 1947, but the simple seeing tasks were upgraded to casual seeing tasks, and their value of 5 footcandles was consequently abolished.

## V. ILLUMINANCE LEAPS

In 1960, when the *Recommended Practice for Office Lighting* was again revised [21], a large increase in recommended illuminance levels was put forth – primarily due to the application to office lighting of Blackwell's quantitative method of evaluating interior illumination levels on the basis of performance data [22]. The new edition now promoted the high illumination values (Table 8) that one might have expected to appear much earlier, based upon *"the best information available from researches of many investigators, including that sponsored by the Illuminating Engineering Research Institute."* [21, p. 313] In addition, much more emphasis was placed on qualitative aspects of lighting. This recommended practice was approved in 1966 by the American National Standards Institute (ANSI) under the title *American National Standard Practice for Office Lighting* as American National Standard A132.1–1966.

TABLE VIII
ILLUMINANCE RECOMMENDATIONS FOR OFFICES (1960)

| Type of Office Work | Footcandles on Task * |
|---|---|
| Cartography, designing, detailed drafting | 200 |
| Accounting, auditing, tabulating, bookkeeping, business machine operation, reading poor reproductions, rough layout drafting | 150 |
| Regular office work, reading good reproductions, reading or transcribing handwriting in hard pencil or on poor paper. Active filing, index references, mail sorting, critical visual tasks in conference rooms | 100 |
| Reading or transcribing handwriting in ink or medium pencil on good quality paper, intermittent filing | 70 |
| Reading high contrast or well-printed material, tasks and areas not involving critical or prolonged seeing such as conferring, inter-viewing, inactive files and washrooms | 30 |
| Corridors, elevators, escalators, stairways | 20** |

* Minimum on task at any time
** Or not less than 1/5 the level in adjacent areas

The Committee on Recommendation of Quality and Quantity of Illumination (RQQ) submitted its Report *Visual Comfort Ratings for Interior Lighting* [23], which was approved by the IES that same year, but the new procedure was limited to flat-bottomed, non luminous-sided luminaires. In 1972, the RQQ Revised Report #2 [24] was approved to include luminous-sided luminaires. The *Visual Comfort Probability (VCP)* method, as it was subsequently called, was approved by the Illuminating Engineering Society as an accepted practice. In 1970, the IES also adopted a system for evaluating veiling reflections. This system was called *Equivalent Sphere Illumination (ESI)*, an indicator of the visibility of a visual task.

The revised *American National Standard Practice for Office Lighting* (A132.1-1973, approved by the IES in December 1972 and the ANSI on June 21, 1973) [25] introduced these qualitative concepts and several important luminaire design developments. New technology in this revision related to wise and efficient use of lighting systems and energy, as well as to improvements of visual and total environmental comfort, as the VCP and ESI concepts

indicated. The recommended levels of illumination remained unchanged in the new edition, although they were presented in a slightly different fashion and included metric as well as imperial illuminance measures. For the first time, computer work tasks were listed and described as a particular lighting problem. Four appendices, including a description of instruments used in the lighting survey and a glossary of lighting terms, were presented as very helpful background information to the user, although they were not part of the actual standard.

But not only positive developments were evident in this standard. Despite all the emphasis on efficient use of lighting systems and energy, and improvements in visual comfort, the concept of daylighting design for office spaces, that was so much part of every previous code, practice or standard, was lost completely in this treatise. Only one single sentence in the standard mentioned the word *daylight*, referring to the principle that daylight and electric lighting systems *"should be coordinated in design to assure the effective contribution of both."* [25, p.8] How to achieve that goal, was not further explained and did not even seem desirable. Was this an example of lighting manufacturing industry control of the Office Lighting Committee? Why the American Institute of Architects, that is listed as one of the approving organizations, did not raise protest remains a mystery.

## VI. THE CURRENT STANDARD

The 1982 revision of the *American National Standard Practice for Office Lighting* [26] (now denoted ANSI/IES RP-1-1982) was presented to the IES Board of Directors for approval on August 9, 1981. It was subsequently approved by the American National Standards Institute on September 2, 1982 and is still in effect today. Most notably, this standard introduced a new method for selecting illuminance values for design purposes and recognized the many new office tasks, such as computer and multimedia use, and trends in office operations and layouts. After a short description of general considerations in designing for office tasks, the standard outlined the lighting design process with its objectives, considerations and criteria, as well as development and evaluation. A complete section was devoted to visual performance and visual comfort and includes the recommended values for illuminances. They were now listed by illuminance categories that supply a range of appropriate illuminances in footcandles and lux for generic types of activities in interiors [26, p. 6], also used for other lighting standards. Specific office activities were identified and correlated with one of the illuminance categories depending on the lighting level needed for efficient visual performance (Table 9 [26, p. 12]). If veiling reflections were of concern for visual comfort while performing the particular activity, it was also marked in the table. A section entitled *Lighting of Areas* provided specific information on particular lighting requirements and considerations.

Overall, recommended illuminance values decreased since the 1973 standard edition, roughly by about 25 to 50 percent. This probably has to be seen in the light of rising energy costs and environmental concerns, but also in the realization that high illuminance levels alone cannot guarantee high visual performance and comfort. Consistent with the nature of the Office Lighting Committee's recommendations, an

TABLE IX
CURRENTLY RECOMMENDED ILLUMINANCE CATEGORIES FOR TARGET MAINTAINED LIGHTING LEVELS (1982)

| Type of Activity | Illuminance Category | Ranges of Illuminances | | Reference Work-Plane |
|---|---|---|---|---|
| | | Lux | Footcandles | |
| Public spaces with dark surroundings | A | 20-30-50 | 2-3-5 | |
| Simple orientation for short temporary visits | B | 50-75-100 | 5-7.5-10 | General lighting throughout spaces |
| Working spaces where visual tasks are only occasionally performed | C | 100-150-200 | 10-15-20 | |
| Performance of visual tasks of high contrast or large size | D | 200-300-500 | 20-30-50 | |
| Performance of visual tasks of medium contrast or small size | E | 500-750-1000 | 50-75-100 | Illuminance on task |
| Performance of visual tasks of low contrast or very small size | F | 1000-1500-2000 | 100-150-200 | |
| Performance of visual tasks of low contrast and very small size over a prolonged period | G | 2000-3000-5000 | 200-300-500 | |
| Performance of very prolonged and exacting visual tasks | H | 5000-7500-10000 | 500-750-1000 | Illuminance on task, obtained by a combination of general and local (supplementary lighting) |
| Performance of very special visual tasks of extremely low contrast and small size | I | 10000-15000-20000 | 1000-1500-2000 | |

extensive treatment of energy management and lighting control systems was also provided, a novelty for lighting codes.

## VII. A NEW TASK: LIGHTING THE COMPUTERIZED OFFICE

Today's lighting designers can safely assume that computer visual display terminals (VDTs) will be used in every office at some time. The locations and orientation of VDTs may be unknown, and if known, they could be changed in the future. Therefore, lighting solutions should function for any office worker at any location and orientation, which is a very difficult task. When computers are installed in an existing office, it is very likely that the lighting system will have to be modified or replaced to be appropriate for the changed visual task. To address these issues, the IES Office Lighting Committee prepared the *IES Recommended Practice for Lighting Offices Containing Computer Visual Display Terminals (IES-RP-24-1989)* [27]. Whereas, the 1982 office lighting standard recommended minimum illuminance levels (5 to 10 footcandles) for areas containing visual display terminals, the new recommendations allow for much higher illuminances, dependent on the types of lighting systems used and the characteristics of the visual display task.

TABLE X
SUMMARY OF ILLUMINANCE RECOMMENDATIONS FOR OFFICE LIGHTING (1915 TO PRESENT)

| Illuminances in Footcandles | 1915 | 1918 | 1921 | 1930 | 1942 | 1947 | 1956 | 1960 | 1973 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Difficult Seeing Tasks** | | | | | | | | | | |
| Detailed Drafting, Designing Layout Drafting | 3.5 | 5 | 5 | 15 | 50 | 50 | 50 | 200 | 200 | 100-200 |
| Auditing & Accounting<br>Business Machine Operation<br>Computer Operation (since 1973)<br>Tabulation<br>Reading Poor Reproductions | 1.25 | 3 | 3 | 10 | 50 | 50 | 50 | 150 | 150 | 50-100<br>5-10<br>50-100<br>100-200 |
| **Ordinary Seeing Tasks** | | | | | | | | | | |
| Reading Fair Reproductions<br>Reading Pencil On Paper<br>Active Filing, Mail Sorting | | | | | | | 100 | 100 | | |
| Critical Conference Documents | 1.25 | 3 | 3 | 8 | 25 | 30 | 30 | 70 | 70 | 50-100 |
| Reading Ink Handwriting<br>Intermittent Filing | | | | | | | | | | |
| Reading High Contrast Or Well-Printed Materials | | | | | | | 30 | 30 | | 20-50 |
| Conference Rooms | | | | | | | | | | |
| **Casual Seeing Tasks** | | | | | | | | | | |
| Bathrooms, Reception Rooms | 0.25 | 0.25 | 0.5 | 4 | 10 | 10 | 10 | 30 | 30 | 10-20 |
| **Simple Seeing Tasks** | | | | | | | | | | |
| Elevators, Escalators | 0.25 | 0.25 | 0.5 | 5 | 5 | 5 | 10 | 20 | 20 | 10-20 |
| Hallways, Stairways, Corridors | | | | 2 | | | | | | 5-10 |

Notes: Due to the fact that classifications of seeing tasks and associated areas often varied from one code edition to the next, boundaries of illuminance values do not necessarily conform to the visual task categories at all times, but occasionally overlap. Values are taken from the respective standards or codes and are referenced within the main text of this paper.

*"Local task lighting should be designed so that it will not cause direct or reflected glare in any operator's VDT screen. It should provide 300 to 450 lux [30 to 45 footcandles] on the work surface – assuming 200 to 300 lux [20 to 30 footcandles] on the work surface from the general lighting system."* [27, p.20]

The lack of research results in the field of computer VDT lighting, however, does not allow for well-supported recommendations. Lighting design problems for VDTs have to be considered on a case-by-case basis, and variables have to be carefully weighed to achieve satisfactory results.

## VIII. WHERE DO WE GO FROM HERE?

The message seems to be clear: High illuminance values alone are not the solution to lighting design problems. Recommended illuminance values, after being on the rise for almost a century, have reached their peak and have descended to a more appropriate level. The emphasis in lighting design has gradually shifted from illuminance to luminance and qualitative lighting aspects. Changing visual needs of office workers, particularly those associated with modern office equipment – such as computers – will continue to spark critical reviews of current lighting practice. Computer VDTs have moved the work surface, at least for those tasks associated with their use, from a horizontal to an essentially vertical position, requiring a different set of lighting criteria to achieve worker comfort and satisfaction. In light of the increasing number of office buildings – often speculative – major changes in the organizational structures and technological media of daily office work, and rising concerns for human well-being and the environment, the current office lighting standard has offered a step into the right direction. General lighting levels will most likely be reduced further in exchange for a more efficient design and placement of task lighting, as well as better visual ergonomics of office furniture and equipment. Speculative office buildings – if no other benefit will be found – will at least require more flexible lighting design schemes than we presently encounter in that building type, possibly integrated with the furniture as some of the thermal control devices already offered by several companies. An increasing desire for more privacy and personal control, possibly resulting from the forced interaction strategies of the open-office culture of the 70's and 80's, may provide additional fuel for such a development. Better fenestration products and daylighting control schemes will allow for a more comfortable and cost-effective utilization of natural light, currently often barred from office design because of added construction costs, lack of design recommendations, and potential problems with discomfort glare in computerized rooms. More home-based work contracts may also effect the design of office spaces, possibly towards a direction of versatility. Offices, intermittently used by workers otherwise working at home, may serve several purposes, from computer room to conference facility. A room at home, devoted to office work during the day, may function in a completely different capacity at night or on weekends and, therefore, requires a very different approach to the lighting problem. Portable office equipment will travel wherever we go. Varying lighting conditions will be a major factor in the design of such equipment. Will lighting evolve as a built-in amenity of visual display terminals? Unlikely, but whatever direction office lighting will take, lighting experts will be needed to define it. Their education in all matters related to the problem and their willingness to work towards a better lighting environment will shape the outcome. Research guided towards worker comfort, satisfaction and productivity, as well as energy efficiency of integrated office building systems will be an essential part of the developments.

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## REFERENCES

[1] R. E. Simpson, "Illumination as a safety factor in industrial plants," *Transactions of the Illuminating Engineering Society*, Vol. 9, p. 459, July 1914.

[2] E. M. Alger, "Conservation of vision," *Illuminating Engineer*, Vol. 7, p. 618, February 1912.

[3] E. M. Alger, "Illumination and eyestrain," *Transactions of the Illuminating Engineering Society*, Vol. 8, p. 130, March 1913.

[4] G. H. Stickney, "Present status of industrial lighting codes," *Transactions of the Illuminating Engineering Society*, Vol. 14, No. 4, pp. 153-208, June 1919.

[5] P. S. Millar, "The status of the lighting art," *Transactions of the Illuminating Engineering Society*, Vol. 8, pp. 652-682, December 1913.

[6] 1915 "Code of lighting factories, mills and other workplaces,"*Transactions of the Illuminating Engineering Society*, Vol. 10, pp. 605-641, November 1915.

[7] 1917 "Code of lighting: revised rules of the code of lighting factories, mills and other workplaces," *Transactions of the Illuminating Engineering Society*, Vol. 13, pp. 256-257, June 1918.

[8] 1918 "Code of lighting school buildings," *Transactions of the Illuminating Engineering Society*, Vol. 13, pp. 185-200, April 1918.

[9] A. L. Powell, "The lighting of office buildings and drafting rooms," *Lighting Data*, Edison Lamp Works of General Electric Company, Index 35, Bulletin L. D. 108, May 1920.

[10] 1921 "Code of lighting – factories, mills and other workplaces," *Transactions of the Illuminating Engineering Society*, Vol. 16, pp. 359-396, November 1921.

[11] 1924 "Code of lighting school buildings," *Transactions of the Illuminating Engineering Society*, Vol. 19, pp. 375-410, May 1924.

[12] 1924 "Symposium on office lighting," *Transactions of the Illuminating Engineering Society*, Vol. 19, pp. 531-567, July 1924.

[13] 1927 "Symposium on office lighting," *Transactions of the Illuminating Engineering Society*, Vol. 23, No.1 , pp. 51-87, January 1928.

[14] 1928 "Code of lighting: factories, mills and other workplaces," *Transactions of the Illuminating Engineering Society*, Vol. 23, pp. 1209-1230, December 1928.

[15] 1930 "Code of lighting: factories, mills and other workplaces," *Transactions of the Illuminating Engineering Society*, Vol. 25, pp.607-636, September 1930.

[16] 1942 "American recommended practice of industrial lighting," *Illuminating Engineering*, Vol. 37, pp. 279-321, May 1942.

[17] 1942 "Recommended practice of office lighting," *Illuminating Engineering*, Vol. 37, pp. 449-488, September 1942.

[18] 1947 "Recommended practice of office lighting." *Illuminating Engineering*, Vol. 42, pp. 673-715, July 1947.

[19] "Quest for quality in office lighting," *Illuminating Engineering*, Vol. 51, pp. 73-85, January 1956.

[20] 1956 "Recommended practice of office lighting," *Illuminating Engineering*, Vol. 51, pp. 419-445, June 1956.

[21] 1960 "Recommended practice of office lighting," *Illuminating Engineering*, Vol. 55, pp. 313-344, June 1960.

[22] H. R. Blackwell , "Use of performance data to specify quantity and quality of interior illumination," *Illuminating Engineering*, Vol. 50, pp. 286-299, June 1955.

[23] Committee on Recommendation of Quality and Quantity of Illumination of the IES, "Visual comfort ratings for interior lighting," *Illuminating Engineering*, Vol. 61, pp. 643-666, October 1966.

[24] Committee on Recommendation of Quality and Quantity of Illumination of the IES, "Outline of a standard procedure for computing visual comfort ratings for interior lighting, RQQ Report No. 2 (1972)," *Journal of the Illuminating Engineering Society*, Vol. 2, pp. 328-344, April 1973.

[25] 1973 "American national standard practice for office lighting (American National Standard A132.1-1973)," *Journal of the Illuminating Engineering Society*, Vol. 3, pp. 3-40, October 1973.

[26] 1982 *American National Standard Practice for Office Lighting (American National Standard ANSI/IES RP-1-1982)*, Illuminating Engineering Society, New York, 1982.

[27] 1989 *IES Recommended Practice for Lighting Offices Containing Computer Visual Display Terminals (RP-24)*, Illuminating Engineering Society, New York, 1990.

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