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The purpose of this study was to trace the history of residential lighting standards from 1906 to 1970 and to identify the research methods and instruments used in establishing present day lighting standards with consideration being given to the quantity and quality of lighting.

The procedure was to study articles, for the most part in the Illuminating Engineering Journals, pertaining to research related to recommendations for lighting standards for visual tasks in the home, noting the quantity and quality of lighting. The literature reviewed was concerned mainly with (1) the bases of the Illuminating Engineering Society standards for lighting as stated in the handbooks, (2) the test conditions such as room size, subjects, types of lighting and visual tasks, (3) the kinds of research instruments developed to measure the quantity and quality of lighting and (4) changes in footcandle recommendations for various residential tasks.

Two methods of research for illumination were used, the direct and indirect. The direct method for illumination research was used from 1906 to 1950 in which the investigator selected a task, a set of task conditions and measure of performance. From 1906 to 1917, there were few research investigations concerning the quantity and quality of lighting. Light sources were poorly developed and whatever footcandles they provided established the levels to be recommended. From 1917 to 1922, the index for increased illumination was raised as the

quantity of light from fixtures increased. In the late twenties, research was done on the four fundamental factors of seeing: size of detail, contrast of detail with background, time interval of seeing and the brightness needed for the task. This was followed by numerous research studies including the Demonstration Visual Test in 1931 and the development of the Luckiesh - Moss Visibility Meter in 1937. In the 1940's a "Recommended Practice of Home Lighting" and the "Lighting Performance Recommendations for Portable and Installed Residence Luminaires" were published in which levels of illumination for specific visual tasks were recommended and the quality of illumination of the luminaires tested were evaluated. A series of investigations followed involving specific visual tasks such as bathroom mirror lighting for shaving, lighting for reading in bed, kitchen lighting for the sink and range areas, desk or study lighting, laundry task lighting, hand sewing lighting, and piano score and keyboard lighting. These studies served as the basis for recommended levels of illumination in the first and second editions of the IES Lighting Handbook.

The indirect method of illumination research was used from 1950 to 1970. The visibility of a practical task was equated to the visibility of a standard test object for which lighting requirements had been standardized. The Visual Task Evaluator and the Field Task Simulator were used in determining the lighting requirements for visual tasks. These research investigations served as the bases for the 1959 and 1966 IES recommended levels of illumination for specific visual tasks.

THE HISTORY OF RESIDENTIAL LIGHTING STANDARDS

by

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APPROVAL PAGE

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CHAPTER I

INTRODUCTION AND PURPOSE

Man has been concerned with the quantity and quality of light needed for his work, recreation and general well being from primeval to modern times. Visual tasks vary from one extreme to the other in importance and in severity. For example, the visual task of casually viewing nature outdoors contrasts sharply with the prolonged, close visual tasks imposed by civilization under manmade lighting conditions. During the last seventy years, there has been considerable research with the aim of establishing standards for residential, commercial, and industrial lighting for visual tasks.

The purpose of this study was to trace the history of residential lighting standards from 1906 to 1970, and to identify the research methods and instruments used in establishing present day lighting standards with consideration being given to the quantity and quality of lighting.

Definition of Terms

For a better understanding of the remaining chapters, the following terms are defined according to their use in this study. All definitions are direct quotations from Reading As A Visual Task by Luckiesh and Moss, "Footcandle Levels" by Luckiesh, Light, Vision and

Seeing by Luckiesh, and "Design Criteria for Lighting Interior Living Spaces," by the Residence Lighting Committee of the Illuminating Engineering Society.

1. Brightness - (1) A term usually referring to the intensity of sensation which results from viewing surfaces from which light comes to the eye.
(2) A photometric measure of light emmission of a luminous body or reflecting surface, e.g. foot-lambert. The footlambert is the common unit of brightness. (27:386)

2. Footlambert- A unit of brightness, equal to the uniform brightness of a perfectly diffusing and reflecting surface illuminated to 1 footcandle. (27:394)

3. Contrast (brightness) - A difference in brightness between two areas within the visual field. High brightness-contrasts between an object and its background (e.g. between print and paper) result in high visibility and are desirable. High brightness-contrasts between the immediate visual field and the surrounding field (e.g. between a printed page and the general surroundings) are deleterious. (27:386)

4. Footcandle - A quantitative unit for measuring illumination: the illumination on a surface one foot square on which there is a uniformly distributed flux of one lumen. (33:44)

4a. Footcandle scale of effectiveness - An approximate geometric series of footcandle values representing equal steps in visual effectiveness, e.g. 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 footcandles. These steps represent about the smallest ones which will result in obvious and significant improvements in seeing. (27:389)

4b. Ideal footcandle levels - The levels of illumination which make it possible for specific individuals to perform specific tasks with maximum ease, or conversely, with a minimum expenditure of human resources. (29:399)

4c. Recommended footcandle levels - They are compromises between threshold and ideal footcandle levels. (29:405)

4d. Relative Footcandles - A scale of illumination values associated with the Luckiesh - Moss Visibility Meter. The values are designated as "relative" since a given illumination upon a visual task is arbitrarily assumed as a base in developing the scale of relative footcandle values. (27:394)

4e. Threshold footcandle levels - These are levels of illumination at which specific individuals can barely perform specific tasks of seeing. (29:398)

5. Reflection-factor - The ratio of the light reflected by the object to the incident light. The term reflectance is also used to denote the same characteristic. (27:393)

5a. Diffuse reflection-factor - The ratio of the diffusely reflected light to the incident light. (27:387)

5b. Specular reflection-factor - The ratio of the specularly reflected light to the incident light. Polished or glossy surfaces reflect light specularly. (27:394)

6. Normal vision - The ability to recognize test characters whose critical details subtend visual angles of 1 minute, or less. A visual rating of 20/20 is usually considered as normal. However, the ability to recognize 20/20 characters is not necessarily indicative of normal vision from the viewpoint of ease of seeing. (27:391)

6a. Visibility - A term denoting the intensity of a psychophysical stimulus which evokes a visual perception and discrimination. (27:395)

The visibility of an object, or of a visual task such as this printed page, is a measure of how far it is above threshold visibility. A device so designed and calibrated to measure how much is necessary to reduce the visibility to the threshold of barely seeing reveals how much above threshold the object or task actually is. (30:294)

6b. Visual task - A task involving the use of human resources such as eye sight, muscles, nerves, energy, and mind. i.e. reading may be defined as the visual reception and understanding of words or other symbols. (27:1)

Those details and objects which must be seen for the performance of a given activity. (33:46)

7. Visual Threshold - The border-line between visibility and invisibility. Threshold is sometimes confused with sensitivity which is actually its reciprocal or inverse; i.e. as sensitivity increases, the threshold becomes lower. (27:395)

7a. Threshold size - The minimum size barely visible under given seeing conditions. Similarly, threshold brightness or threshold contrast is the minimum perceptible under given seeing conditions. (30:279)

CHAPTER II

PROCEDURE

The history and development of residential lighting standards were reviewed, for the most part in the Illuminating Engineering Journals, and are summarized here in chronological order from 1906 to 1970. The procedure was to study articles pertaining to research related to recommendations for lighting standards for visual tasks in the home, noting the quantity and the quality of the lighting.

The literature reviewed was concerned mainly with, (1) the bases of the Illuminating Engineering Society (IES) standards for lighting as stated in the handbooks, (2) the test conditions such as room size, subjects, types of lighting, and visual tasks, (3) the kinds of research instruments developed to measure the quantity and the quality of lighting, and (4) changes in footcandle recommendations for various residential visual tasks.

A brief history of the Illuminating Engineering Society and the Illuminating Engineering Research Institute (IERI) is presented to explain the goals and aims of these two organizations and their influence and encouragement in establishing research in illuminating engineering.

The 64 year span was studied and divided into two sections: the first 44 years from 1906 to 1950, in which the direct method for illumination research was used, and the next 20 years from

1950 to 1970 in which the indirect method of illumination research was used.

In the direct method of determining illumination requirements the investigator selects a task, a set of task conditions and a measure of performance. The effect of varying levels of illumination upon the speed of performance of the task was determined for the subjects.

In the indirect method the visibility of a practical task was equated to the visibility of a standard test object for which lighting requirements had been standardized.

Since this study was concerned with reviewing the literature, the order of the text deviates from the usual in that the procedure chapter follows the introduction and purpose.

CHAPTER III

THE HISTORY OF THE ILLUMINATING ENGINEERING SOCIETY

In October 1905, a young consulting electrical and lighting engineer, Mr. Louis B. Marks, wrote a letter to a friend initiating the idea of forming a Society of Illuminating Engineers. Through his persistent efforts, the first official meeting was held January 10, 1906 at which time the name of the Society, constitution and by-laws were adopted. According to Hibben, the Illuminating Engineering Society's goal was dedicated toward "... the advancement of the theory and practice of illuminating engineering and the dissemination of knowledge relating thereto." (16:150) President Marks stressed in his inaugural address the "needs for better ratings of illuminants, more exact standards, and better methods of judging quality of illumination." (16:148)

The first four years of the Society's work was dedicated to improving the organization and its internal mechanism and developing its function as a forum for discussion. Succeeding years saw the creation of a profession of illuminating engineering and efforts toward public education. Laboratory research developed slowly at first, then reports began to reach the public in the 1920's telling man the story of light as related to his work, home life, recreation, comfort and general bodily well-being. However, the acceptance or

understanding of these new concepts was not given widespread or continuous national promotion until the early 1930's. In developing the field of residential lighting, the activities were centered around disseminating the science of light and lighting in a form understandable to laymen. Lighting performance recommendations of the Illuminating Engineering Society stimulated progress in the design of portable lamps and fixtures which better fulfilled sound lighting principles. (11)

In the 1940's with the Residence Lighting Forums in operation, another independent organization, the Illuminating Engineering Research Institute, was organized. Its purpose was to make possible a continuing scientific study of the relationship of light and sight. The IERI's research aim was "to determine the quantity of light Man requires for specific working tasks, and to determine the effect of Man's luminous environment on his ability to see the task (the quality of lighting)." (17:406) The IERI's first accomplishment was to make possible the development of research instruments and measuring devices to execute the research. These developments changed some of the recommendations for levels of illumination for various visual tasks. The basis of modern day lighting practices of footcandle recommendations for working and leisure visual tasks are the practical results of this research. (15)

In reviewing the literature no listing was found prior to 1934 of recommended footcandles for visual tasks. However, Luckiesh stated

in "Footcandles for Critical Seeing" in 1921, that five to 10 footcandles were recommended for sewing on light goods and 10 to 20 footcandles for sewing on dark goods. For office work, 10 footcandles were specified. In 1930, 10 to 15 footcandles were recommended for sewing on light goods, and 25 to 100 footcandles for sewing on dark goods. (28)

The first listing of footcandle recommendations was made in 1934. (32) See Table 1. This was included in a journal article with no author indicated. Subsequently, the lighting handbooks of the Illuminating Engineering Society for the years 1947, 1952, 1959, and 1966 published recommended footcandles for visual tasks in the home. (18), (19), (20), (21) Table 1 compares the changes and increases in recommended footcandles from 1934 to 1966. Since some of the visual task headings were changed as time passed, some of the recommendations for tasks could not be compared. From 1934 to 1952, the footcandles were listed separately under the headings of casual reading, prolonged reading, writing, and study. Between 1952 and 1959, there was a change in wording from reading, writing and studying to reading and writing including studying, books, magazines, newspaper; handwriting, reproduction and poor copies; desk or study. Therefore, blank spaces resulted from 1952 to 1959. One might assume that prolonged reading corresponds to handwriting, reproduction and poor copies, and that casual reading corresponds to reading and writing including studying, books, magazines, newspaper. If so,

TABLE 1. RECOMMENDED FOOTCANDLES FOR HOME TASKS 1934 - 1966

	1934	1947	1952	1959	1966
GENERAL LIGHTING					
Dining		5	5	10	10
Living		5		10	10
Library		5		10	10
Sunroom		5		10	10
Entrance Hall		5	5	10	10
Stairways & Landings	2-5	5	5	10	10
Hallways, passage areas					
Bedrooms	2-5	5	5	10	10
Recreation or Family Room	5-10			10	10
Areas involving visual tasks					
Kitchen	5-10	10	10	30	30
Bathroom		5	5	30	30
Laundry				30	30
READING					
Prolonged periods, small type	20-50	40	40		
Casual periods, large type	10-20	20	20		
WRITING	10-20	20	20		
READING & WRITING, incl.studying books, magazine, newspaper				30	30
HANDWRITING, reproduction, poor copies				70	70
DESKS, STUDY	20-50	40	40	70	70
READING MUSIC SCORES					
Advanced			40	70	70
Advanced-score substandard size			100+	150+	
Intermediate			20		
Simple			10	30	30
SEWING					
Dark fabrics (fine detail)	100+	100+	150+	200	200
Prolonged periods (light to medium fabrics)	20-50		80	100	100
Occasional (light fabrics)	10-20	20	40	50	50
Occasional (course thread)			20	30	30
Prolonged average sewing	50-100	40			
MIRRORS					
Dressing table, make-up grooming, light on face		20	20	50	50
Bathroom, shaving, light on face	10-30	40	40	50	50
GAME TABLES					
Card table	5-10	10	10	30	30
Ping pong		40	20	30	30
KITCHEN					
Sink	10-20	40	40	70	70
Range & Work Counters	10-20	40	40	50	50
LAUNDRY					
tubs, Ironing Board, Ironer	10-20	40	40	50	50
HANDCRAFT					
Work Bench	10-30	40	40		

then the footcandle recommendations for prolonged reading and desk or study increased from 20 footcandles in 1934 to 70 footcandles in 1966.

In 1934, the footcandle recommendations ranged from two footcandles for stairways, landings and passage areas to 1004 footcandles for sewing on dark fabrics. In 1966, the footcandle recommendations ranged from 10 footcandles for stairways, landings, and passage areas to 200 footcandles for sewing on dark fabrics. No previous research had been done on reading music scores until 1950 so that in 1952 a new visual task was added to the recommendations. The most noticeable increase in recommended footcandles in all areas was between the years 1952 and 1959.

It can be noted from the recommendations in terms of footcandles that sewing on dark fabrics was considered to be the most difficult visual task not only in 1934 but in 1966 as well. The footcandle recommendations for sewing on dark fabrics noticeably increased from 1004 footcandles in 1934 to 200 footcandles in 1966.

The one visual task for which the recommendation decreased was for ping pong game tables. In 1947, 40 footcandles were recommended. In 1952, the recommendation was 20 footcandles. An increase to 30 footcandles was recommended in 1959.

CHAPTER IV

THE DIRECT METHOD OF ILLUMINATION RESEARCH

1906 - 1950

In the direct method of determining illumination requirements the investigator selects a task, a set of task conditions and a measure of performance. The effect of varying levels of illumination upon the performance index, speed of performance, was determined for the visual subjects. (2) In the direct method each visual task was studied separately.

Since the beginning of the Illuminating Engineering Society 66 years ago, the fundamental question has been the quantity and quality of light required for visual tasks. From the literature, one surmises that the committee members gathered available information together and then, by common agreement, published some levels of illumination as recommendations. Apparently in the early days, 1906 to 1917, light sources were poorly developed and whatever footcandles they provided established the levels to be recommended. From 1917 to 1922, the index for increased illumination was raised as the quantity of light from fixtures increased. The ability to see fine detail in visual tasks became the test for establishing quantity of light recommended, apparently without controlling other influencing factors such as time of viewing and contrast of background. Then in

the late twenties, Cobb and Moss determined the four fundamental factors of seeing which were interrelated. They were size of detail, contrast of detail with background, time interval of seeing, and the brightness of the task. (10) In Cobb and Moss's plan, the variables were studied over a wide range using a series of a standard test object (parallel black bars on a white ground) of various sizes ranging from the smallest visible bar to the largest bar useable on this apparatus. The test object could be shown in all grades of contrast with its background from the point of zero difference to the deepest black on white. To reduce the contrast, the subject viewed the object through a slanting unsilvered plateglass reflector. Throughout a group of experiments, it was not only possible to keep the background at any desired brightness, but by separate control of the illumination upon the reflected surface and the test object, the contrast could be varied between the object and its background. A rotating disc upon which the test object was mounted was arranged so that it could be stopped and started almost instantly, thereby accurately controlling and measuring the duration of the stopping time. The four variables were dependent and each had to be considered in relation to the others. The objective of the research was to assist the lighting engineer in determining the level of illumination for a given task. (4)

Demonstration Visual Test

From these and other evidences of visual effects, Dr. Matthew Luckiesh and his associates developed numerous research studies. The Demonstration Visual Test developed in 1931 by Luckiesh and Moss proved to be a valuable research tool and accurate measuring device which demonstrated the influence of four visibility factors: size, contrast, brightness, and time, upon rate of performing the task. The test-object consisted of a capital letter formed by small breaks in a pattern of parallel diagonal lines printed on a gray background. In the first edition of the test, each pattern was printed on a separate card. The complete test was in the form of a pack of 52 cards. Later the test was developed in booklet form. Four of the test cards were printed on each of a number of pages. Thirteen capital letters were used as in the card test. They appeared on the four patterns per page and on the various pages in haphazard order. The booklet test was comprised of thirteen pages and each letter appeared four times. The purpose of the test-object was to denote the effect of intensity of footcandles upon seeing. It was designed to be effective over a range of one to 50 footcandles. The significant result of the test was that the individual subject's rate of working increased with the higher levels of illumination. (24) In the late thirties, a new instrument was developed to measure footcandles needed for various visual tasks.

Luckiesh-Moss Visibility Meter

In the Science of Seeing (1937), Luckiesh and Moss described the development of the Visibility Meter, an instrument which represented the first practical means for use in the study of visual tasks and the illumination requirements for those tasks. The instrument was comprised of two circular colorless filters having precise gradients in density so that when placed in front of the eyes it might be rotated simultaneously while the subject held the instrument in the same position as eyeglasses are worn and turned the disk which rotated the gradients until the visual threshold of the task or object was reached. The visual threshold is the level of barely seeing. The filter by means of absorption reduces the brightness of the visual field and by its diffusing characteristic, lowers the contrast of the object with its background. (26) In other words, the "Visibility Meter produces threshold conditions by simultaneously altering both brightness and brightness-contrast." (25:31) The primary function of the Visibility Meter was to determine the relative visibility of the visual task and to recommend the footcandles needed. (25)

The Luckiesh - Moss Visibility Meter was calibrated under certain prescribed visual conditons including a standard visual task consisting of eight point type (Bodoni Book Monotype) illuminated to a level of 10 footcandles. The subject with so-called normal vision viewed the task through the instrument at a distance of 14 inches. The 10 footcandles at 14 inches then became the recommendation. The

recommended footcandle scale values are meaningful if the Visibility Meter is used in a manner equivalent to that in which it is calibrated. When six point type is viewed under similar conditions, 17 footcandles are indicated on the scale of recommended footcandles. The eight point type illuminated to 10 footcandles has the same degree of visibility as that of six point type illuminated to 17 footcandles. It should not be assumed, that these two tasks having the same degree of visibility under similar conditions, may be performed with equal ease. Ease of seeing to some degree relies on other factors than the visibility of the object observed. The authors concluded the results were due to obvious "differences in the rate, exactness, and continuousness with which the task must be performed." (25:32)

The first lighting problem solved outside the laboratory by the Visibility Meter was that of a firm considering a change from (1) reading printed forms upon which certain data from legal documents was typed to (2) reduced photostatic copies of the original documents. Luckiesh and Moss were asked to evaluate the footcandle requirement for these two tasks. The visibility of the two tasks was measured under identical lighting conditions with the results being that the photostatic form required about three times as much light as the other form for equal visibility and ease of seeing. It was recommended that the footcandle level be tripled if the photostatic form were used. (25)

Luckiesh wrote that with the progression of basic research

and analysis, it had become evident that every visual task could be considered from two viewpoints, the visibility of critical details and the ease of seeing. It was clear that the only definite visibility level was threshold visibility which is "to be able to barely see". Since the visibility level of a task is influenced by the brightness level of the task, the diffuse reflectance of the task must be taken into account for the footcandle level to be meaningful. The threshold footcandle level for viewing a visual task or object is neither desirable nor acceptable for prolonged seeing. The ideal footcandle level is reached when the over all efficiency of the human seeing machine is at a maximum. Any recommended footcandle level is a compromise until it is determined an ideal footcandle level which results in maximum ease of seeing. (31)

One of the major objectives of the Illuminating Engineering Society was to establish specification of footcandles on a sound scientific basis. For a portion of the preceding years discussed, it can be noted that some of the lighting recommendations resulted from sound experiments. According to Luckiesh, the recommendations should originate only from meaningful measurements with the aid of appropriate devices and in terms of proper units. Subsequently, with the basic knowledge available from previous years, more definite steps were taken toward fitting the footcandle to various visual tasks. (28) This led to the publication of a "Recommended Practice of Home Lighting."

Recommended Practice Of Home Lighting

For the first time in 1945, the Illuminating Engineering Society issued a "Recommended Practice of Home Lighting." The purpose of this publication was to enable architects, home owners, and builders to design interior lighting systems which provided for the seeing needs of the average family. The recommendations were reprinted in 1947 with minor revisions. (6) A table for footcandle recommendations for the home for general lighting and specific visual tasks was included. These same recommendations appeared in the 1947 IES Lighting Handbook, First Edition. Considerable explanation was given to the essentials of good lighting which included the quantity of light needed for varied visual tasks in the home; the quality of lighting needed to insure comfort in viewing the visual tasks by controlling light distribution and diffusing materials; the effect of quantity of light and color characteristics of light on room colors; and the lighting needs of each major room of the average home, i.e. wattages, light distribution, type of fixture, placement of fixture.

The "Recommended Practice of Home Lighting" seemed to be a good source of information for lighting recommendations for the home based on adequate research at the time it was published.

The "Recommended Practice of Home Lighting" was followed in 1946 by the publication, "Lighting Performance Recommendations for Portable and Installed Residence Luminaires." This publication was

based on extensive research and tests. Its purpose was to provide an improved standard of lighting performance for portable or installed luminaires intended for use in the home. The recommendations, when incorporated in the design of fixtures, would produce luminaires which should provide the quantity and quality of lighting specified in the "Recommended Practice of Home Lighting." (7)

It appeared that the "Lighting Performance Recommendations for Portable and Installed Residence Luminaires" was based on satisfactory research and tests, although the IES lighting committee believed that the report was not entirely comprehensive as many gaps in research data were found. In the report, the gaps in research data were not evident. A considerable amount of information concerning quality of lighting was discussed. Many research studies were conducted after this publication. The first specific visual task studied was bathroom mirror lighting for shaving.

Bathroom Mirror Lighting For Shaving

In 1947, a study was done on "An Evaluation of Methods and Fixtures Used for Bathroom Mirror Lighting" by Fahsbender and Priest. The investigation was to study certain lighting effects of several types of fixtures installed at a bathroom mirror, specifically for the task of shaving. Also, the general lighting result was observed and illumination data assembled in some cases. There were 13 incandescent and fluorescent types of fixtures tested. Both the footcandles produced and brightness of the fixtures were the measures

used to compare the fixtures. The test room simulated a typical bathroom. (12)

The procedures for the tests were used in accordance with those set forth in the IES "Lighting Performance Recommendations for Portable and Installed Residence Luminaires." The basic test point was 61 inches above the floor and 20 inches away from the mirror. The center of a 10 inch panel was the point used for positioning a multi-cell, color-corrected, diffusing plate in accordance with the specified requirements. The test panel could be rotated horizontally making it easier to obtain readings at the following locations: a full face view, a left and a right cheek view. Illumination values in the three positions were taken with the multi-cell, color-corrected, diffusing plate combined with a microammeter. The values were calculated into footcandles. Detailed data and illustrations on each test were given showing the fixtures used and lighting results produced on the subject's face. (12)

Some conclusions from the study included the following: not many lighting bracket arrangements would maintain the five footcandles specified for general illumination stated in the "Recommended Practice of Home Lighting." Side bracket lighting contributed more acceptable lighting for shaving or make-up than a single bracket over the mirror. A lower mounting height of fixtures from five feet six inches to five feet one inch resulted in higher lighting levels under the chin. A central ceiling fixture was recommended for all bathrooms if satisfactory general illumination in the recommended range was to be not

only attained but maintained. Wall brackets were recommended as supplementary units for tasks related to the mirror. An overall evaluation of footcandle requirements was not done in this study.(12)

The authors rated five of the 13 fixtures as good, five as fair and three as poor. The five fixtures rated as good included an incandescent lamp with two side-mirror brackets, two fluorescent lamp side-mirror brackets, one fluorescent lamp circular reflector, and one fluorescent with two side-mirror brackets and an RS sunlamp over the mirror bracket. The footcandles produced on the full face view for the fixtures rated as good ranged from 28 to 39 footcandles, on the left and right cheek (averaged together) the range was from 15 to 33 footcandles, under the chin the range was from 18 to 29 footcandles. The fixtures rated as good generally reduced the brightness of light to a comfortable level with little loss of footcandles. The fixtures rated as poor created brightnesses too great for comfort. These included an incandescent over-mirror bracket, and an incandescent recessed unit. The fixtures rated as fair created some uncomfortable brightnesses and shadows, but were considered more acceptable than the units rated as poor. (12)

"An Evaluation of Methods and Fixtures Used for Bathroom Mirror Lighting" seemed to be a comprehensive investigation of lighting fixtures available at that time and of their placement at the bathroom mirror. The method and test procedures were considered by the investigator to be sufficiently rigorous to obtain adequate data for lighting recommendations. The study stressed the need for

data of other lighting applications in the home. Both the quantity and the quality of the light provided by the fixtures were considered. Following the wide acceptance of and the need for such data as described in the study reported above, investigations were conducted in other phases of the general subject.

Lighting For Reading In Bed

In 1948, Fahsbender and Presbrey completed a study on "Performance Analysis of Available Lighting for Reading in Bed." The scope of the investigation was to study a group of luminaires used for reading in bed and the lighting results produced by them. The purpose of the study was to evaluate the local lighting effects. Observations were made of general illumination and brightness values and data was assembled. A total of 17 incandescent and fluorescent luminaires were studied. These included portable lamps, wall-mounted luminaires, and bed-mounted fixtures. A test room model of an average bedroom was constructed. (13)

The recommended level for casual periods of reading with larger type was 20 footcandles and for prolonged periods of reading with smaller type was 40 footcandles. These values were specified in "Lighting Performance Recommendations for Portable and Installed Residence Luminaires" for a reading plane of 12 inches high, 14 inches wide, and 26 inches above the floor tilted at an angle of 45 degrees from the vertical. Illumination measurements were made of five individual readings, near each corner and the center of the test plane, and then averaged. The instrument used to make the reading was a

color-corrected, multi-cell diffusing plate used in conjunction with a microammeter calibrated in footcandles. Detailed data and illustrations were given in each test and the lighting results produced on the test plane. (13)

In general, the following conclusions were reached: for illumination on the test plane 11 of the 17 luminaires produced at least 20 footcandles which is the recommended level for casual reading in the "Recommended Practice of Home Lighting." Only three of the 11 provided 40 footcandles recommended for prolonged reading. Included in the eleven 20 footcandle luminaires, two were spotlight type, two were table lamps and the others were some type of wall-mounted units. Two of the three 40 footcandle luminaires were acceptable for general as well as local illumination. Less uniform distribution of illumination was provided by spotlights, units attached to headboard and table lamps with opaque shades than by wall-mounted units and table lamps with translucent shades. Only 10 luminaires were rated as satisfactory with respect to room illumination, five were not acceptable, and seven of the luminaires tested had greater source brightness than specified in "Lighting Performance Recommendations for Portable and Installed Residence Luminaires." Spotlight and units attached to the headboard, if used as the only light source in room, were not considered satisfactory. Generally, wall-mounted luminaires were most satisfactory, as well as were table lamps with diffusing bowls. (13)

It appeared that "Performance Analysis of Available Lighting

for Reading in Bed" was a comprehensive investigation of the performance of lighting fixtures typical of those used for reading in bed. The recommended standards of lighting for reading in bed were considered adequate with regard to both quantity and quality of lighting. However, the authors emphasized the need for further study and development in this lighting field. Further investigations were conducted that same year in the area of kitchen lighting.

Kitchen Lighting For General, Sink And Range Areas

"An Appraisal of Kitchen Lighting Elements" by Reynolds and Kakilty was also done in 1948. The purpose of the study was to determine the performance of several types of luminaires for kitchen lighting. The study was divided into three parts: general illumination, sink lighting and range lighting. (34)

To measure general illumination, the test kitchen was that of an average small kitchen with counters, sink, range, cabinets, refrigerator and snack bar. A Weston Illumination Meter was used to measure the footcandle readings from 15 fixtures including incandescent and fluorescent lamps. Detailed data and illustrations were given for each luminaire tested and the lighting results produced on the general area. The results showed that: a center ceiling fixture was not the complete solution for properly lighting a kitchen, and that added local illumination was needed for good lighting to exist. All but three of the luminaires tested provided the required footcandles when no subject was standing at the various work

surfaces. When the subject was standing at the various work surfaces, the footcandles decreased because the task was in the subject's shadow. (34)

The next phase of the study pertained to the sink and under-the-cabinet lighting. First only the sink area was considered. A dummy end-wall was constructed in a completely closed in room. The test target consisting of fifteen 8 inch squares was placed horizontally on top of the sink and directly beneath the soffit ceiling. The Weston Illuminometer was used to take footcandle readings in the center of each square. Three different subjects made readings and the results were averaged. Also taken into consideration was the specular reflection from pots, pans, and the sink itself. The brightness readings were made with a brightness meter. The results showed that: only six of the over-the-sink luminaire combinations provided 40 footcandles or more. The combinations that were usually sold on the market for over-the-sink lighting provided less than 10 footcandles. The footcandle values over the test target ranged from 4.2 for one 20-watt fluorescent lamp to 99 for a 150-watt PAR-38 reflector spot. (34)

For under-the-cabinet lighting, front edge lighting was preferred over lighting at the back wall. The footcandle average was greater in front edge lighting and the work areas were more uniformly covered with light. For a 15-watt fluorescent lamp, the footcandle values were 37.8 for front edge lighting compared to 29.3 for lighting at the back wall. The test procedure for determining the under-the-

cabinet lighting values was the same as that used in the sink lighting experiments. (34)

For the range area a test was conducted to determine the efficiency of 13 lighting equipment units incorporated in the range. They were tested in complete darkness. The units utilized incandescent and fluorescent lamps both shielded and unshielded. Footcandles varied considerably on the top of each range. Practically no light reached the inside of pots, kettles, and deep-well cookers. It was the authors opinion that more thought for performance of the task should be given in designing lighting equipment incorporated in the range. No details of the test procedure were given for range lighting. (34)

"An Appraisal of Kitchen Lighting Elements" seemed to provide adequate data for making recommendations on the quality and quantity of lighting provided by the luminaires tested for general kitchen lighting, sink lighting and range lighting. The author of the present study believed that the investigation and results of range area lighting should have included more details. Immediately following the kitchen lighting study, an investigation was conducted on desk or study lighting.

Desk Or Study Lighting

In 1949, "Studies of Lighting and Seeing for the Student at Home" was done by Mary E. Webber. The purpose of the investigation was to analyze the lighting results obtained from 20 luminaires used for home study. (35)

The desk placement was in three locations: flat against the wall, corner of the room, and center of the room. The desk top finish was of flat, non-glossy paint. The subject's eye position was 44 inches above the floor and 14 inches above the desk top. Portable wall, floor and table lamps were selected for the tests. A test plane was placed on top of the desk tops where five illumination measurements were taken at both horizontal and tilted positions. A five inch diffusing test plate was used for illumination measurement. The Luckiesh - Taylor Brightness Meter was used to measure brightness. The author did not attempt to completely appraise the individual luminaires tested but to emphasize points affecting their lighting performance. (35)

The conclusions of the study included the following: the majority of luminaires tested attained the 40 footcandles recommended for studying, and several exceeded this. The most favorable illumination of the tilted plane came from four fixtures: the tallest table lamp, the floor lamp, and two luminaires placed directly over the work center. Five of the luminaires did not provide as much distribution of illumination over the desk top as did the use of two luminaires or one of lineal dimension placed over the desk center. In eight of the tests, there was an undesirable change in visibility level from one section of the test plane to the other due to non-uniformity of illumination. The brightness ratio of three to one between visual task and surroundings seemed sufficient for study situations. Seven of the luminaires provided the three to one brightness ratio without

additional room lighting. (35)

"Studies of Lighting and Seeing for the Student at Home" seemed to adequately analyse the quantity and quality of the luminaires tested for desk or study lighting. The evaluations of the luminaires appeared to be sound and fairly complete. During this same year, another study was conducted pertaining to laundry task lighting.

Laundry Task Lighting

"Laundry Lighting Requirements" by A.W. Kakilty was presented in 1949. It was a preliminary investigation to evaluate three types of luminaires for laundry room lighting. The room was a corridor type shape where the automatic washer, laundry sink and work surfaces were situated along one wall and the freezer unit which was used as the clothes sorting table was along the other wall. The flat plate ironer was located at one end. (23)

The lighting layout consisted of three different ways to illuminate the room: four bare 100-watt lamps placed in each corner of the room, four two-tube 40-watt white fluorescent units placed in each corner of the room, three units of three 40-watt white fluorescent lamps in each unit in a row in the center of the ceiling. For general lighting, the four bare 100-watt lamps resulted in footcandle readings of 23.5 at the ironer, 12.0 at the sink, 14.5 at the washer and 8.5 at the sorting table. The footcandle readings averaged 20.5. The four two-tube 40-watt white fluorescent units resulted in footcandle readings of 25.5 at the ironer, 11.5 at the

sink, 17.5 at the washer and 8.5 at the sorting table. The average was 26.5 footcandles. For the three units of 40-watt white fluorescent lamps in a row, the footcandle readings were 40.0 at the ironer, 41.5 at the sink, 43.0 at the washer and 35.5 at the sorting table. The average was 43 footcandles. No attempt was made to compare the lighting outputs of each system. It was not intended to compare the average footcandles or the footcandles at one point in one lighting layout with the second or third lighting layout. The significance of the general lighting measurements was that out of the three possible layouts, only one system had as much light at most of the working centers as the average of the entire room. (23)

The subjects used the Luckiesh - Moss Visibility Meter to measure illumination at the various areas in the home laundry. They worked independently of each other reaching their own conclusions concerning the amount of light required for each task. The averaged results included 5.1 footcandles for loading an automatic washer, 6.2 footcandles for sorting clothes, 27 footcandles for setting dials on the washer, 9.3 footcandles for ironing on an automatic flat plate ironer. The Visibility Meter was also used to test the effects of various types and colors of lamps on samples of white clothes that had been "lightly" and "heavily" scorched with a hand iron. The footcandles required for seeing "lightly" scorched cloth ranged from a minimum of 47.5 for a 100-watt daylight incandescent to a maximum of 105.0 for two 40-watt fluorescent white. For "heavily" scorched cloth, using the same luminaires mentioned above, the footcandles

required for seeing the scorch ranged from a minimum of 15.0 to a maximum of 46.0 respectively. The authors believed that these observations seemed to indicate that not only the type and quality of luminaires but also the color characteristic had considerable effect on seeing certain items. (23)

The conclusions of this study included the following: it was recommended that all lighting in laundry areas be well diffused to avoid harsh shadows cast by the worker. The task of sorting clothes in the washer required 5.1 footcandles. These were listed as the minimum number of footcandles necessary for "threshold seeing". It would seem reasonable to recommend 10 footcandles as a good minimum over all lighting in a laundry area. At specific locations such as reading dials on automatic machines the absolute minimum was recommended to be 27 footcandles. Ten footcandles was not sufficient where careful observation was necessary, i.e. the footcandle readings required for seeing "light" and "heavy" scorching ranged from 47.5 to 105, therefore, it would seem probable to recommend a minimum of 40 footcandles over the entire working plane of the ironing board or ironer. The authors recommended that further study be done to determine whether or not color characteristics of lamps over the ironing area make a difference in the ability to see. (23)

"Laundry Lighting Requirements" utilized a different approach in appraising the luminaires investigated by using a completely equipped laundry in a home instead of simulating a test room. The

authors realized that there were other possibilities for lighting a laundry area. It appeared to be a good starting point from which further research studies could be continued. It seemed that the measurement of footcandles on the specific task areas provided satisfactory data for recommending changes in footcandle levels for the laundry area. After this study, an investigation was conducted the following year on hand sewing in the home.

Hand Sewing Lighting

"Lighting and Seeing Conditions for Hand Sewing in the Home" was done by Fahsbender and Presbrey in 1950. The purpose of the study was (1) to investigate the lighting conditions most satisfactory for hand sewing in the home, and (2) to determine what type of available light sources would provide these conditions. The two parts of the investigation are reported separately. (14) The first part dealt with studying the lighting conditions most desirable for hand sewing in the home. Since there was a wide variety of seeing tasks for the many types of sewing, it was necessary to select a simple sewing task that could be used as a standard. The task chosen was the ability to see a short section of 1/16 inch running stitch using matching thread on five materials: a plain, matte-finished, closely woven, smooth white cotton; a similar material in medium gray; a finer weave in black matte-finished cotton; and a white and a black rayon satin, covering a wide range of reflectance values and degree of specularity. The Luckiesh - Moss Visibility Meter was used for the

readings on the samples under 10, 20, 40, and 80 footcandles. From totally direct light, totally indirect light and a fifty-fifty combination of the two. All of the light sources were incandescent. The subject's eye was 14 inches from the task. (14)

The conclusions were: it appeared that differences in the specularly reflected light from the thread and from the cloth that reached the eye, and the minute shadows cast by the thread and by the slight ridges which resulted from the tension of the stitches were the main factors which enabled the eye to discern a stitch from its background. The specular reflection from the thread was found to be helpful to visibility whereas specular reflection from the material was found to be a hindrance. Indirect light was the most satisfactory for seeing on satins, however, for seeing on cottons indirect light made the line of stitch difficult to see. Under some circumstances there was a greater improvement in visibility when the angle in which the light striking the task changed rather than when footcandles were increased. Indirect illumination was less satisfactory than either direct or direct-indirect light for matte surfaced fabrics. The authors admitted that the conclusions for the first part of the study were largely based on observations rather than test results and that the actual visibility measurements were not adequately consistent to give statistical data of conditions which were apparent to the subjects. (14)

The second part of the study was to determine what type of available light sources would provide the best lighting conditions

for hand sewing in the home. The test procedure for the second part of the investigation used all incandescent light sources except for two portables which combined fluorescent and incandescent. The sources included table lamps, floor lamps, wall lamps and recessed units. The test plane was 10 by 10 inches, 30 inches from the floor, 45 degree angle with 14 inches from the subject's eyes to the center of the test plane. Footcandle measurements were made with a color-corrected, multicell diffusing plate used in conjunction with a microammeter calibrated in footcandles. The measurements were made in the center and each of the four corners of the test plane. The Luckiesh - Taylor Brightness Meter was used to take the brightness measurements. (14)

The authors made the following observations: they felt that the recommended footcandle levels published in the"Recommended Practice of Home Lighting" in 1945 were not altogether adequate or clearly defined on the basis of their test results and observations. The authors recommended higher levels which from all indications were more desirable. It was impossible to set up any one standard of optimum quantity and quality of light for all types of sewing. For most sewing tasks indirect light was less advantageous than direct light. The certified lamps or the 150-watt R-40 white indirect-lite lamp, provided in general a good quality of light for sewing. With the exception of two table lamps, the luminaires did not provide sufficient room lighting to maintain comfortable brightness ratios with any task of reasonably high reflectance. The portable lamps

tested produced a range from 30 to 100 footcandles on the sewing plane. When table lamps were tested on a 25 inch table and the subject seated on an 18 inch high chair, there was complete freedom from direct glare. Recessed reflector and projector spot and flood lamps produced a high degree of uniform illumination on the test plane. However, the footcandle level provided by the floor lamps were no greater than those provided by the portable lamps. The spot lamps provided a range of 117 to 200 footcandles, however, the footcandle levels resulted in high source brightness. (14)

It appeared that the authors had to some extent satisfactorily investigated the quantity and quality of lighting fixtures for sewing tasks. They have pointed out the need for valid measurements based on adequate research rather than guess-work. Although the sewing task encompasses many factors, it seemed the authors conducted the research fully cognizant of its limitations. By comparing the recommended levels of illumination in the "Recommended Practice of Home Lighting" in 1945 and in this particular study, it was evident that Fahsbender and Presbrey had used research techniques superior to those used previously. In this same year, 1950, another investigation was conducted concerning lighting for the piano.

Piano Score and Keyboard Lighting

In 1950, E.W. Commery and Mary E. Webber did a study on "Lighting for the Piano in the Home." Before 1950, recommended levels for piano illumination had been based on experience and general

accepted practice. The purpose of the study was to determine illumination requirements for the three classifications of piano scores thereby providing a basis for including footcandle recommendations for pianos in"Recommended Practice of Home Lighting"; to establish and locate a test plane area and to recommend limits of illumination on it; to evaluate luminaires most frequently used for piano illumination; to give suggestions for luminaire designs to improve lighting conditions for the piano area. (5)

Reading a piano score was believed to be comparable to reading books, thus the Luckiesh - Moss Visibility Meter was used to obtain the visibility levels of the three classifications of piano scores: elementary 10 footcandles, intermediate 20 footcandles, and advanced 40 footcandles. The test plane was a 12 x 18 inch area on which five illumination values were obtained at several positions and averaged for each of the 12 luminaires tested. The Luckiesh - Taylor Brightness Meter was used for brightness measurements. (5)

The following conclusions were made: due to the high contrast and size of the keys resulting in high visibility of the keyboard, two to five footcandles were satisfactory. A pair of lamps was needed since it was difficult to obtain satisfactory illumination from floor and table lamps. The general purpose floor lamps produced the most direct light on the plane, but the amounts were inadequate. Although the light distribution was not the best, the base of the swivel arm models could be placedon either side of the piano. The rack attached luminaires offered no over-all lighting

improvement over conventional portable lamps and all created harsh brightness ratios. Ceiling mounted or recessed incandescent reflector and projector bulbs with flood distribution provided the smoothest light over the entire test plane. Four of the luminaires tested were rated as very satisfactory, three were satisfactory, two were fair, and three were poor. (5)

The authors recommended that an effort be made to obtain 40 footcandles or more in designing new luminaires; a pair of table lamps be developed for piano application; rack attachement units be improved both in scale and effectiveness. (5)

It appeared that "Lighting for the Piano in the Home" was based on sound investigations. The authors realized that the footcandle readings perhaps were not actual measurements considering the complex task of reading music scores in relation to foot and hand activity for the entire performance of the player. The footcandle measurements were made on the specific task area, i.e. reading the scores, and were not concerned with the total performance of the player. However, a rational basis for recommended levels of illumination for reading piano scores was established. The following year, another publication was published concerning recommended levels of illumination.

Functional Visual Activities In The Home

In 1951, "The Functional Visual Activities in the Home" was

published. This publication was basically an extended revision of part of the report on "Lighting Performance Recommendations for Portable and Installed Residence Luminaires." It showed pictorially where representative work planes or areas were located at certain points in the home. This information was designed to aid luminaire designers and lighting engineers in determining the performance of their designs, to measure the performance of the installation, and to help the home owner to locate portable lamps for good lighting.(8)

"Functional Visual Activities in the Home", 1951, proved to be more comprehensive in its application of information and defined more extensively the areas for applied lighting than "Lighting Performance Recommendations for Portable and Installed Residence Luminaires", 1946.

"Recommended Practice of Residence Lighting" was published in 1953, presenting an extended study of lighting requirements for family activities involving close visual tasks. (10)

It appeared that this publication was the most comprehensive investigation published to that time and was based on many research studies. The recommended levels of illumination for visual tasks in the home were the same as those listed in the 1952 IES Lighting Handbook, Second Edition.

CHAPTER V

THE INDIRECT METHOD OF ILLUMINATION RESEARCH

1950 - 1970

An eight year research program was initiated in 1950 by Dr. H. Richard Blackwell, Director of the Vision Research Laboratories at the University of Michigan. He developed a general indirect method to determine the amount of light needed for tasks involving various sizes of objects, contrasts, times of seeing and degree of accuracy evaluated by visual performance criteria. (1) Blackwell stated that "the indirect method differs in that practical tasks are only studied by visual task evaluation in comparison with a standard test object, the performance data all having been collected on the standard test object." (2:628) The performance data on the standard test object, which were circular targets, were measured and collected first. In the indirect method, the visibility of a practical task was equated to the visibility of a standard test object for which lighting requirements had been standardized. The research work was concerned only with the quantity of illumination and involved numerous investigations. Conclusions from these investigations served as the scientific basis for the footcandle recommendations in the 1959 IES Lighting Handbook, Third Edition. (1)

The subjects used for "Development and Use of a Quantitative

Method for Specification of Interior Illumination Levels on the Basis of Performance Data" were mostly college students 18 to 32 years of age. The subjects were selected on the basis of excellent sensory and visual capacities, intelligence and high motivation. It was presumed that under these circumstances, the data represented optimal performance as compared to older or younger subjects, persons with visual deficiencies or persons with less intelligence or motivation who presumably might perform less well than the young adults. (1)

Under laboratory conditions the subjects knew exactly when and where the object or task would appear and the dynamic eye movement conditions involved in performing the task. The laboratory set up consisted of a large cubicle illuminated from the sides by concealed lighting. The test spot appeared at the appropriate time in the center of the cubicle projected from the rear onto a translucent screen. There were four possible time intervals during which the test spot was projected with a buzzer sound indicating the beginning of each interval. The subject pressed one of four buttons when the disc appeared. The size, contrast, and time of viewing the disc could be varied as the brightness of the cubicle was raised. The size or angular diameter of the disc varied from one minute to 64 minutes of arc, contrast from .01 to 300, time from .001 second to one second and the background brightness of the cubicle from .001 to 800 footlamberts. (10)

The size or angular diameter of the disc is measured from one minute to 64 minutes of arc. A circle has 360 degrees with 60 minutes

in one degree. The size or diameter of the disc target is determined by the size of the angle from the radius of the circle. As the angle increases so does the diameter of the disc which is projected on the screen, or the inverse. Therefore, the diameter of the disc target projected on the screen at 64 minutes of arch would measure six inches from a determined distance.

The sizes of most field tasks range between one minute and 10 minutes, and 1/5 of a second is the time pause for the unhurried eye in scanning common tasks. It was found that seeing a task with 50 per cent accuracy or 50 per cent of the time it was exposed, was the condition for which the most accurate laboratory results could be obtained statistically. This research led to the development of two instruments: the Field Task Simulator (FTS) and the Visual Task Evaluator (VTE). (10)

Field Task Simulator

The FTS simulated a field operation such as reading or working on conveyor belt tasks where the eye must scan the details to be seen. The subject was seated in a cubicle illuminated from overhead through a translucent ceiling. There was a series of 50 circular plaques, each four inches across, mounted on a revolving platform which moved beneath the eyes of the subject. The subject's task was to inspect the 50 plaques for the presence of imperfections. (1) The results of the study showed that a factor of 15, not in footcandles but in contrast, was the difference between a static laboratory condition

and a dynamic "moving-eye" field condition. Therefore, "to see a circular disc in the field as contrasted with the laboratory, one would need the light necessary for that same size test object with a contrast of 1/15 of that of the static laboratory tasks." (10:417) Three time intervals were presented and called assimilations per second (APS). For example, if the eye can see a given test object of 1/5 second, it has the capacity to assimilate five bits of information in one second. This is called the concept of visual capacity which Dr. Blackwell has advanced as the basis for the structure of illumination recommendations. Since studies of eye movements have revealed that 1/4 to 1/5 second is the approximate pause of the eye for ordinary scanning of tasks, five APS has been established as a base for eye capacity to carry out a task. (10)

Visual Task Evaluator

The Visual Task Evaluator was the instrument used to determine the lighting requirements of visual tasks. It was a "sophisticated visibility meter by means of which the physical difficulty of a visual task is equated to viewing a four minute luminous disc test object, for which a set of standard performance data has been established through laboratory studies." (22:12) It was "constructed on the principle of reducing the contrast of the unknown configuration by placing over it a veiling brightness which, as it is increased, begins to "wash" out the details and brings the configuration to

threshold of being seen." (10:421) Thus the configuration was clearly visible to the subject until the veiling brightness was increased so that the details of the configuration washed out and became barely visible.

The original Visual Task Evaluator was strictly a research model designed for laboratory use and was used to determine lighting requirements for 56 typical viewing tasks. Recognizing a need for specific improvements, Dr. Blackwell developed a portable Visual Task Evaluator for field use which was used extensively for several years after 1962. From this model several additional areas for improvement were recognized. This led to the development of the third Visual Task Evaluator which was about half the size and weight of its predecessor. In 1970, a fourth model of the Visual Task Evaluator was being developed for special uses with moving tasks and objects which are large in angular size. (22)

The Visual Task Evaluator was an optical device designed to make a practical task and standard disc targets equivalent in visual difficulty. In using the Visual Task Evaluator, the subject first viewed the visual task through one optical system and adjusted it to threshold visibility. Then the subject viewed a standard disc target through another optical system and adjusted it to threshold visibility. The fact that both tasks were set at threshold visibility made them equivalent to each other. Once the equivalence was established, it was possible to establish the lighting required to see both the disc

target and the task. (1)

In 1958, 56 visual tasks encountered in various everyday activities were evaluated with the Visual Task Evaluator. Some of the results included the following: for viewing pencil writing with a number two pencil on matte white paper, 63 footcandles were needed. Seventy-six footcandles were required for writing dictation taken with a number three pencil. Reading a fourth carbon copy of a typed letter required 133 footcandles. For seeing white lines of blue print showing through tracing paper, 400 footcandles were needed. To see orange chalkmarks on a brown tweed material, 266 footcandles were required. To find a broken black thread on a spinner bobbin required 2900 footcandles. To see a brown stain on gray cloth required 1100 footcandles. (10)

It appeared that these numerous investigations by Dr. Blackwell during this eight year program developed an accurate measure for determining footcandles for various visual tasks. It was the first time that actual lab conditions were set up and used to obtain statistical data by the indirect method for establishing recommended levels of illumination for visual tasks.

Dr. Blackwell continued his investigations which included a variety of studies. His objective was to improve upon his indirect method of determining illumination requirements for visual tasks. "Further Validation Studies of Visual Task Evaluation and Other Elements of an Earlier Illumination Specification System" were made in 1964. One of the research studies was on "visual task evaluation of

one printed sample studied in the Field Task Simulator." (10:635) Performance data on visual tasks of interest under real-life conditions of seeing could be obtained from the FTS. The task was to detect spelling errors in a printed copy using the word PEOPLE. There were no more than five incorrect samples among the 50 samples mounted on the FTS. (2)

The experiments involved using only an informational content of one word per second and only 141 footlamberts were used for the background luminance. At threshold, the length of the word samples was 15.7 minutes. "The Visual Task Evaluator was used to equate two practical tasks in difficulty, and the validity of the equation was checked with real-life performance data." (2:635) The two tasks were the printed samples on the FTS and the 5.5 minute luminous disc target. The number 5.5 refers to the diameter of the disc. (2)

In making the equivalence check, the physical contrast value was determined by interpolation to be 0.0250. Using the performance data obtained from the FTS, it was established that a 5.5 minute disc of contrast 0.0250 was equivalent to the 15.7 minute printed sample of unity contrast, when specific errors in the printed sample had to be recognized and the disc had to be detected. The Portable Visual Task Evaluator was also used to make an equivalence check of the two tasks. The printed sample was reduced in contrast until the presence of errors could be barely recognized. The 5.5 minute disc was viewed with the Visual Task Evaluator and the contrast reduced until the printed samples could be barely recognized.

The physical contrast of the disc was adjusted to visibility threshold when viewed through the Visual Task Evaluator. The result of this study was that the physical contrast was found to equal 0.0225. The value would have been 0.0250 if the equivalent check had been without error. Dr. Blackwell concluded that this experiment was good, considering the experimental difficulties. (2)

The instruments developed from Dr. Blackwell's studies were used in other experiments for recommending levels of illumination as published in "Design Criteria for Lighting Interior Living Spaces."

Design Criteria

In 1969, the Illuminating Engineering Society approved and published "Design Criteria for Lighting Interior Living Spaces." Its function was to serve as a guide for anyone who taught or designed lighting systems for interior living spaces. The lighting problems in the text were defined in detail. Discussed in the text was the evaluation of lighting as an element of design, types of lighting equipment and their potential uses, and lighting required for each specific visual task describing the task, task plane, footcandle recommendations, lighting design and typical locations for equipment. (33)

It appeared that "Design Criteria for Lighting Interior Living Spaces" was a comprehensive text based on sound research in which the Visual Task Evaluator had been used.

Illumination Specification Systems

In 1959, Dr. Blackwell first reported the development of a method to determine levels of illumination required for various visual tasks by using visual performance data. In 1970, Dr. Blackwell and Stanley W. Smith presented a paper on "Additional Visual Performance Data For Use in Illumination Specification Systems." The recommended levels of illumination in the 1966 IES Lighting Handbook, Fourth Edition were based on the research not published until Dr. Blackwell's 1970 paper appeared. (3)

Some of the tests were concerned with the collection of visual performance data under static viewing conditions. A four minute disc target with a 1/5 second exposure duration was used for ten subjects to study at various levels of background luminance. The subjects all had 20/20 vision and the average age was about 22 years. Before the experiment was begun, the subjects were given training and practice with the apparatus and procedures. Essentially the conditions of the new experiments were parallel to conditions of earlier studies and were made to verify and refine the data of the earlier studies. The subjects viewed a translucent screen through which the circular four minute disc target was projected. The diameter of the disc was four minutes. The target was presented in one of four successive two second intervals. After the last interval of each trial, the subject had to select the interval he thought most likely to contain the target, by indicating his choice by pressing

the correct one of four coded buttons. Each trial lasted 16 seconds. However, only the first half of each trial was used for the four observation intervals. The other eight seconds were used for recording the subjects responses and setting up the next trial. The target had luminance levels of 1.00, 0.69, 0.51, 0.34, 0.17 footlamberts. The background luminance was zero .001, .003, .01, .03, .1, .3, 1, 3, 10, 30, 100, 300, 1000, 3000 footlamberts. For each session, independent photometric measurements of the target and background luminances were made with a calibrated Pritchard Telephotometer. Independent measurements of the target luminance were made with a photocell-galvanometer device and of the background with a Macbeth Illuminometer. (3)

The result of these investigations was that the data from the 1959 experiments and these experiments agreed at low luminances, but disagreed appreciably at higher luminances. As the luminance was increased, the discrepancy between the two sets of data became more marked. Therefore, the results of this set of experiments was preferred to those made in 1959 because the same 10 subjects observed under all experimental conditions. Also the target size and duration presented closely approximated the target conditions of interest. The earlier data was a pooling of data of different subjects obtained under different conditions and the data for target size and duration of interest needed considerable interpolation. (3)

The Field Task Simulator was used for obtaining performance data under dynamic conditions. The subjects were selected by the

same procedure as mentioned in the previous experiment. They all had 20/20 vision. The FTS as described earlier was a rotating wheel used to present moving items for a subject to inspect. Each item consisted of a slightly curved metal disc covered with thin, white translucent plastic. Incandescent light sources and other optical elements were mounted below the wheel for 10 of the 50 items. These were not visible to the subject. The other 40 items were identical to the 10 in every way except for the additional or increment sources attached to them. The task of the subject was to inspect the 50 items indicating the detection of a target increment by pressing a button directly below the items. Before each session, a calibrated Pritchard Telephotometer was used to adjust each of the 10 target lights to the desired intensity level. (3)

The results of these experiments were more accurate than the experiments of 1959. The relations between values of threshold contrast under dynamic and static conditions were identical at very low levels of visual capacity, but they were not identical for higher levels of visual capacity. It was concluded that dynamic and static conditons must be studied with comparable subjects and under the precise conditions of target size and visual capacity of interest. (3)

It appeared that the Blackwell studies were very comprehensive and were the best research investigations to date. Dr. Blackwell has continually refined and improved the basic theory of his illumination specification system and the 1959 and 1966 IES recommendations for residential lighting levels were well founded and could be considered adequate recommendation levels for specific visual tasks.

CHAPTER VI

SUMMARY AND CONCLUSIONS

In tracing the history of residential lighting standards from 1906 to 1970, it was found that two types of research methods were used and many instruments were developed to measure the quantity and quality of lighting. The two types of research methods were the direct and the indirect. The direct type of research method was used during the years 1906 and 1950. Methods used during this time essentially involved the selection of a task, a set of task conditions and a measure of performance. The indirect type of research method was used during 1950 to 1970 by Dr. H. Richard Blackwell. The visibility of a practical task was equated to the visibility of a standard test object for which lighting requirements had been standardized.

In the early years, 1906 to 1917, there were few research investigations concerning the quantity and quality of lighting. Light sources were poorly developed and whatever footcandles they provided established the levels to be recommended. From 1917 to 1922, the index for increased illumination was raised as the quantity of light from fixtures increased. In the late twenties, Cobb and Moss did research on the four fundamental factors of seeing: size of detail, contrast of detail with background, time interval of seeing and the brightness of the task. After their experiments,

more accurate research began to take place. This was followed by numerous research studies by Dr. Matthew Luckiesh which included the Demonstration Visual Test in 1931 and the development of the Luckiesh - Moss Visibility Meter in 1937. In the 1940's a "Recommended Practice of Home Lighting" and the "Lighting Performance Recommendations for Portable and Installed Residence Luminaires" were published in which levels of illumination for specific visual tasks were recommended and the quality of illumination of the luminaires tested was evaluated. After these publications a series of investigations occurred involving specific visual tasks such as bathroom mirror lighting for shaving, lighting for reading in bed, kitchen lighting for the sink and range areas, desk or study lighting, laundry task lighting, hand sewing lighting, and piano score and keyboard lighting because the need for such data was pertinent. These studies served as the basis for recommended levels of illumination in the first and second editions of the IES Lighting Handbook.

In 1950, Dr. H. Richard Blackwell started a series of research studies developing a general method of indirect research using visual performance data to determine levels of illumination required for various visual tasks. From these studies, he developed the Visual Task Evaluator and the Field Task Simulator which were used to determine the lighting requirements of visual tasks. Dr. Blackwell continued to refine and improve his use of the illumination specification system and his research investigations served as the basis for the 1959 and 1966 IES recommended levels of illumination for visual tasks.

At the beginning, 1906, simple observations were used to establish recommendations for lighting. As time passed, the research for establishing standards became more refined and complex and the results more accurate. The instruments that were developed for use in the research investigations became more and more accurate as measuring devices and contributed much to the validity of the IES lighting recommendation levels. Without the development of these instruments, much of the research would not have been possible. The lighting recommendation levels published in the IES Lighting Handbooks were recommended minimum requirements for persons with normal vision.

In the future it is probable that even more scientific and accurate methods of measuring lighting requirements for specific visual tasks may be developed.

Since a great deal more is known about lighting standards than is applied, perhaps more research needs to focus on methods of disseminating information. Some contractors who are cognizant of lighting requirements may be hampered by the budget. The client needs to be made aware that optimum lighting conditions will facilitate visual task performance. Lighting consultants may need to make the availability of their services known to the public so that the uninformed may gain realization of the importance of this aspect of an environment.

Research to date has been concerned mainly with the quantity of lighting for particular visual tasks. The quality of light needs

equal emphasis. For example, in addition to adequate quantity, living and working spaces are enhanced when the three dimensional characteristics of forms are easily distinquished. To date there has been little research on the effect of lighting on shadow and texture. Likewise, the quality of color in environments are dependent on lighting quantities and qualities. Lighting fixtures need to be designed that provide both the quantity and quality of lighting required for specific visual tasks in accordance with recommended lighting standards.

There are indications that in the future some research is planned on the effect of age on vision and the performance of specific visual tasks. In addition, farsightedness, nearsightedness, astigmatism and other eye abnormalities need to be studied. All lighting research tests need to be checked with situations encountered in every day life. Such checking may result in more applicable data.

These are some of the factors that need to be considered before excellence in lighting standards can be achieved.

BIBLIOGRAPHY

1. Blackwell, H. Richard. Development and use of a quantitative method for specification of interior illumination levels on the basis of performance data. Illum. Eng., 1959, 54, 317-353.

2. Blackwell, H. Richard. Further validation studies of visual task evaluation and other elements of an earlier illumination specification system. Illum. Eng., 1964, 59, 627-641.

3. Blackwell, H. Richard, and Smith, Stanley W. Additional visual performance data for use in illumination specification systems. Illum. Eng., 1970, 65, 389-410.

4. Cobb, Percy W. and Moss, Frank K. Four fundamental factors in vision. Trans. of the Illum. Eng. Soc. 1928, 28, 496-506.

5. Commery, E. W. and Webber, Mary E. Lighting for the piano in the home. Illum. Eng., 1950, 45, 383-354.

6. Committee on Residence Lighting of the Illuminating Engineering Society. Recommended Practice of home lighting. Illum. Eng., 1945, 40, 339-372.

7. Committee on Residence Lighting of the Illuminating Engineering Society. Lighting performance recommendations for portable and installed residence luminaires. Illum. Eng., 1946, 41, 521-548.

8. Committee of Residence Lighting of the Illuminating Engineering Society. The functional visual activities in the home and the location and extent of the associated areas to be illuminated. Illum. Eng., 1951, 46, 375-382.

9. Committee on Residence Lighting of the Illuminating Engineering Society. Recommended practice for residence lighting. Illum. Eng., 1953, 48, 413-445.

10. Crouch, C.L. New method of determining illumination required for tasks. Illum. Eng., 1958, 53, 416-422.

11. Dodds, Mary E. Residence lighting forums of the illuminating engineering society. Illum. Eng., 1946, 41, 897-901.

12. Fahsbender, Myrtle, and Priest, Beryle. An evaluation of methods and fixtures used for bathroom mirror lighting. Illum. Eng., 1947, 42, 999-1027.

13. Fahsbender, Myrtle, and Presbrey, Priscilla. Performance analysis of available lighting for reading in bed. Illum. Eng., 1948, 43, 1189-1217.

14. Fahsbender, Myrtle, and Presbrey, Priscilla. Lighting and seeing conditions for handsewing in the home. Illum. Eng., 1950, 45, 242-252.

15. Ferree, J.W. Illumination research...bellwether of the future. Illum. Eng., 1967, 62, 334-335.

16. Hibben, Samuel G. The society's first year. Illum. Eng., 1956, 51, 145-150.

17. IERI - a year in review. Illum. Eng., 1964, 59, 405-410.

18. IES Lighting Handbook, First Edition. New York: Illuminating Engineering Society, 1947.

19. IES Lighting Handbook, Second Edition. New York: Illuminating Engineering Society. 1952.

20. IES Lighting Handbook, Third Edition. New York: Illuminating Engineering Society. 1959.

21. IES Lighting Handbook, Fourth Edition. New York: Illuminating Engineering Society. 1966.

22. Instruments and methods: visual task evaluation. IERI Annual Report 1970 1-4.

23. Kakilty, A.W. Laundry lighting requirements. Illum. Eng., 1949, 44, 671-676.

24. Luckiesh, Matthew, and Moss, Frank K. A Demonstration Visual Test. Nela Park, Cleveland: Lighting Research Laboratory, 1931.

25. Luckiesh, Matthew, and Moss, Frank. K. Prescribing light and lighting. Trans. of the Illum. Eng. Soc., 1937, 32, 19-48.

26. Luckiesh, Matthew, and Moss, Frank K. The Science of Seeing. New York: D. Van Nostrand Co., 1937.

27. Luckiesh, Matthew, and Moss, Frank K. Reading As A Visual Task. New York: D. Van Nostrand Co. Inc., 1942.

28. Luckiesh, Matthew, and Eastman, A. A. Footcandles for critical seeing. Illum. Eng., 1946, 41, 828-846.

29. Luckiesh, Matthew. Footcandle levels. Illum. Eng., 1948, 43, 395-415.

30. Luckiesh, Matthew. Light, Vision and Seeing. New York: D. Van Nostrand Co. Inc., 1948.

31. Luckiesh, Matthew. Important concepts underlying lighting for critical seeing. Illum. Eng., 1949, 44, 226-230.

32. Recommended lighting intensities for the home. Trans. of the Illum. Eng. Soc., 1934, 29, 607.

33. Residence Lighting Committee of the Illuminating Engineering Society as a Recommended Practice. Design criteria for lighting interior living spaces. Illum. Eng., 1969, 64, 5-48.

34. Reynolds, Jan., and Kakilty, A.W. An appraisal of kitchen lighting elements. Illum. Eng. 1948, 43, 1015-1043.

35. Webber, Mary E. Studies of lighting and seeing for the student at home. Illum. Eng. 1949, 44, 255-266.