# THE ILLUMINATING ENGINEERING RESEARCH INSTITUTE AND ILLUMINATION LEVELS CURRENTLY BEING RECOMMENDED IN THE UNITED STATES

C. L. Crouch

**Mr. Crouch:** I am very happy for this conference because we are all products of each one of our experiences and if we are true to our experiences we will reflect our current state of knowledge and viewpoint. It is very helpful, of course, to have other viewpoints presented so that we can think in terms of the overall scene and make some adjustments. I must say that I think that all of the people I work with in the Illuminating Engineering Research Institute and, then, through the Illuminating Engineering Society, which uses some of our results, not all of them, we are earnestly trying to conserve on energy. We may differ on philosophy as to how to do it and I think that is where our differences with the FEA occur. We believe that large savings can be shown. May I say that the Illuminating Engineering Research Institute that I represent has recently brought out a folder, which has only come out within the last two weeks, which is called "Effective Seeing and Conservation, Too." We demonstrated in an actual office how we were able to save one-third of the wattage that was put in by architects and engineers under the module plan because they knew nothing about what would be in this building. It was a broad, open space. It ran a block long and a block wide. So they put in high-level, module lighting. So, when the partitions came in and the visual work layout was known, it was easy to reduce and conserve in that situation.

I do not wish to blame the original engineer and architect. They knew nothing about the work layout—and I am afraid this is going to be so for the future—that many times they will not know. As far as my own discussion is concerned, I try to say "Put in a great flexibility of switching arrangement." I am advocating that the architect or engineer, primarily the engineer, go back six months after the building is completed and then arrange the lighting through switching according to the work that is being carried on, the visual work. We think that this is truly the functional way, because it is almost impossible for the architect and engineer to know, in most buildings, what is going to happen.

By the way, Mr. Nelson, I am glad to meet you. I have had some conversation over the phone. I hasten to indicate, and I think it will come out in my presentation, that it is the average young, normal observer we are talking about, the average young population who have 20/20 vision, and not the poorest observer, that the current levels of illumination are based upon.

## IERI—ITS ORGANIZATION

Webster says a society is a voluntary association of individuals for common ends—an organized group living or working together, or periodically meeting or worshipping because of a community of beliefs or common profession. In 1906, Lewis B. Marks, a consulting engineer in New York City, felt the functional need of bringing together all individuals having an interest or designed concern in the application of light to seeing. This was still in the gas era of lighting and Mr. Marks himself was primarily concerned with the application of gas for lighting. Mr. Marks stated that the coverage of interest in the application of light would be broad. He stated, "The specialist in illumination, the electrical engineer, the gas engineer, the architect, the designer of electrical and gas fixtures, and of globes, shades, and reflectors, and the decorator—all will meet on common ground to discuss the question of illumination from every standpoint."

As with all societies, there is a pooling of information which underlies the progress in the development of new techniques and improved practices. Thus the practitioner, the educator, the eye specialist, the architect, the laboratories, and the company representative have all contributed papers with new information and discovery over a period of time. Some of the commercial companies found it to their distinct advantage to set up research laboratories by which to develop not only improved products, but also to discover improved ways of satisfying the visual environment.

Up to 1935, the results of research by these laboratories were used by the Illuminating Engineering Society (IES) as a basis for their recommendations to the consuming public. There was an inner desire on the part of all to produce the very best illuminated environment for seeing. We attracted many, like Ferree and Rand from Johns Hopkins University, and Dr. Lloyd Jones of Eastman Kodak—a whole series of scientists, including some of our founding members who, helped do research in this field.

From 1935 on, there were stirrings within and without the Society that there ought to be an objective research program initiated through the professional Society which would obtain results free from any possible inferences that the results would be commercially motivated. While it was believed that the research in commercial laboratories had been honest and sincere, it was now felt that the whole basis of the recommendations of illumination should be constructed from research done in university laboratories where there would be no commercial self-interest.

In August 1944 the Illuminating Engineering Research Institute was initiated as a separate, non-controlled research agency which should sponsor and stimulate research primarily in university channels. The Illuminating Engineering Society developed a Trust Agreement with a Board of Trustees who should conduct an "independent, non-profit, science-oriented organization to conduct fundamental studies of light and its relationship to seeing." These Trustees represent a broad spectrum of disciplines which shall bring all of their expertise to bear in operating a broad program of research into every phase of the application of light for the benefit and welfare of mankind. This includes not only seeing, but also the physiological effects of wavelengths as well, which is a new field we just recently started a few years ago with a seminar with fourteen medical researchers in the effects of wavelengths of light on the health and welfare of people.

The current Board of Trustees are as follows: Three university professors. Two ophthalmologists, Dr. Fonda (who is Secretary of the Joint Committee on Optics and Visio-Physiology of the American Medical Association) and Dr. Newell (who is head of the Pritsker School of Ophthalmology at the University of Chicago). One scientist from the National Research Council of Canada, Dr. John David Keys (an atomic physicist, who is Vice-President of the National Research Council of Canada and used to teach illumination in his earlier years). One architect, Mr. Herbert Swinburne (a prize-winning architect and head of the Building Research Advisory Boards Committee on Conservation). One businessman. Two IES representatives, the president and immediate past president.

Now, as to the overall personnel, since this question arose a little over a year ago, I put together a listing of categories of disciplines who were our people handling, processing, leading our program processing to its final conclusion. And so, if we can have the first slide? By the way, I would like to indicate that we have very much followed a parallel course to the American Society of Heating, Refrigerating and Air Conditioning Engineers. They started in 1919 in their research program to find out the effective thermal environment and the various aspects of controlling the thermal environment. We patterned our research program after theirs, with our technical advisory committees composed of university people and practicing specialists. However, we divorced it from the parent body in order to be absolutely sure there would be no commercial interest because, in every society, there is always a play of various interests. In order to make sure it was completely uninhibited and objective, it was set up as a separate organization.

Now, here we are, the personnel of IERI.

**TABLE 1.—Personnel of IERI**

2 MEDICAL DOCTORS
 OPHTHALMOLOGIST—PROFESSOR
 OPHTHALMOLOGIST—PRACTICING
2 ARCHITECTS
 PRIZE-WINNING PRACTITIONER
 PROFESSOR
6 PROFESSORS
 3 ENGINEERING
 2 PSYCHOLOGY
 1 OPTOMETRY
2 SCIENTISTS
 BUILDING RESEARCH CENTER
 NATIONAL BUREAU OF STANDARDS
1 SCIENTIST
 NATIONAL RESEARCH COUNCIL OF CANADA
7 INDUSTRY REPRESENTATIVES
 3 CHARGE OF RESEARCH
 4 PRACTICING ENGINEERS

Out of 20 personnel there, only seven are related to commercial practice. We think that is a good balance.

## IERI RESEARCH

**TABLE 2.—Elements of Environment**

1. TASK (SURROUNDINGS IDEAL)
2. VEILING REFLECTIONS
3. BRIGHTNESS DIFFERENCES
4. DISCOMFORT GLARE
5. PLEASANTNESS OF INTERIORS
6. OLDER AND SUBNORMAL EYES
7. LIGHT AND HEAT
8. BIOLOGICAL EFFECTS

The research program is divided into several different elements.

**The task, the amount of light on the task.**—This is always the constant question over the years. How much light do we need for quick, accurate seeing? And so, first, the task—how much light is necessary for this if the surroundings are ideal. We found out from Lythgoe's work in England, in 1933, that you can depress the ability to see, the sensitivity to see, or you can enhance it, depending upon the brightness of the surroundings and the relative balance of those surroundings to the luminance of the background of the details of the task.

**Veiling reflections in offices and schools.**—While the IES has been advocating mat material for many years in their practices for schools and offices, we now find with sensitive measuring equipment that we merely drove the veiling reflections underground. They are now microscopic instead of obvious mirror type reflected images. We do not see any streaks or patches of brightness; but, if you will look through a microscope, you will see a whole brilliant array of little facets of brightness which are reflecting mirrors from the pencil graphite or inked characters and from the paper fibers themselves.

**Brightness differences.**—We have been working on this over a period of time. Dr. Boynton of the University of Rochester, and now his graduate student who is now a professor at the University of Virginia, have been conducting studies on the change of visual sensitivity due to brightness differences in the field of view—in order to keep this proper balance that Dr. Lythgoe found was so important.

**Discomfort glare.**—I really should take out the word "discomfort." We are concerned, both outdoors and indoors, with disability glare and discomfort glare. We are concerned in offices and schools and the confined environments very heavily with discomfort, because we have sort of refined out the disability glare because of control of the luminaires, but outdoors we have still very bad disability conditions. However, we are inclined to think that we should be thinking of both of them involved in interior as well as exterior.

**Pleasantness of interiors.**—Once having set up a proper seeing environment, what do we do about making this an interesting, livable, stimulating place. We believe that efficient seeing can be combined with interesting interiors that will make a lovely place to be. We have been trying to bridge the gap between the architect and engineer. The engineer is the gadgeteer who loves his gadgets and efficiency. We had one architect who has been very prominent, a former editor of *Architectural Forum,* who said, "Away with efficiency of seeing. Let's give them an interesting, stimulating place to be." Well, that is the sort of thing we want to overcome. We want to do both if we can and we are well on the way. We are instituting multidimensional psychological scaling as a new tool to try to bring out the vectors of subjective feeling in an environment and design the lighting accordingly.

**Older and subnormal eyes.**—All this other work has been done on young, normal adults, because it has been done in universities with students that come in from two to four hours at a time and make these measurements. We need to go to older and subnormal eyes and we are going to hear about this later on from Mrs. Blackwell on older eyes. We have not gotten around to subnormal yet. We need to get to these fairly soon.

**Light and heat.**—All our work described above involves light and heat, even though, now, our new light sources, white light sources (with the papers being presented at New Orleans next week), the metal halide sources are producing one hundred lumens per watt which is a considerable advance over fluorescent lighting or anything of this kind. Already, we are working on the design of new metal halide units that will fit in offices and schools and greatly save in the maintenance of miles of fluorescent lighting and will also save in wattage, in energy, greatly, because of the higher efficiency. By the way, we have in my office a new indirect torchiere using a one hundred seventy-five watt metal halide lamp and it is producing about six hundred watts of incandescent lighting, beautiful quality lighting in interiors. We got an old torchiere from a secondhand store, and a kitchen pot which we turned upside down over the base which formed the housing for the ballast and it works great. And then we have a new study lamp, certified "Better Light Better Sight" study lamp, which has a ballast in its base; and, with a hundred watts of corrected mercury we are producing the equivalent of two hundred watts in incandescent lighting. Now, these are some of the things we are working toward in a very practical way. But, nevertheless, there is always light and heat and we have to think in terms of what we are going to do with this heat. How can we best utilize the total energy from the fixture space to the living space? We have this on our program. We have not gotten into this phase yet because of the high priority of the psycho-physics of vision.

**Biological effects.**—I mentioned before the effects of the wavelength of light on health. We are now working on hyperbilirubinemia. We have set up an experimental laboratory with Dr. Jerald Lucey at the University of Vermont, who has been, I think, the leader in this country in overcoming the bilirubin buildup in premature babies, twenty percent of which have jaundice or hyperbilirubinemia. It started in England where a doctor threw light on a test tube of bilirubin and they saw a chemical reaction occur. This coincided with what the nurses were saying that, near the windows, the jaundiced babies were recovering much faster than those farther away from the window. And so he thought he would put the light on the body itself; and, sure enough, it worked. Dr. Lucey has followed two hundred cases for two years with no side effects where they have recovered in a few days from using localized lighting over the isolette. Now we are putting in a luminous ceiling where we can get various levels and find out if it is a low-level long time or high-level short time effect.

Most of the activities of life are guided by visual cues, either conscious or unconscious. If one stands facing a wall, preoccupied with conscious thoughts, and swings his arm out toward the wall, there is an unconscious visual feedback which tells him to decelerate and stop short of hitting the wall. I believe that most of us do not realize the enormous unconscious visual cues that guide one's activity from morning to night. One threads his way through the living room of a home that is littered with toys in every direction. One moves around or over the toys, avoids the chairs, and successfully negotiates the entire space while engaged in animated discussion. One drives through a mass of traffic while talking to associates and even gesticulates to emphasize his discussion. All of this involves a whole continuous train of visual images of the details involved. Of course, there are the conscious details that are involved in every industrial process, in every reading and writing task, in every form to be filled out, in every calculation that must be developed.

All of these details both conscious and unconscious are controlling the activities of life. They are visual cues that tell us whether we are on the right course or not. These visual cues are those with which IERI has to deal in providing the appropriate illumination for quick accurate seeing. With the increasing complexity of life, the missing of a few cues can set a whole train of circumstances in the wrong course. Therefore, IERI must determine the vast range of detail to be dealt with and the particular illumination necessary for each of the details. And may I quote to you recent evaluation measurements—the glass container industry, the miniature electronic circuit, the rubber tires and rubber products industry, the dairy farms, the poultry and egg processing, the atomic power generator plants, roadways, hospital surgery, airplane maintenance plants and steel mills—all done within relatively recent times to find out the amount of light necessary for those particular details and those particular industries.

In the 20's and early 30's, Weston, in England, made studies in various industries as to the effect of illumination. A series of official government reports were published as a result of these field studies. He became increasingly concerned that the relationships he obtained by increasing illumination from low levels in those days did not represent the true visual benefits obtained from improved illumination. Finally, he conceived that, in order to obtain these true relationships, he should conduct the study under simulated, controlled conditions in the laboratory where other complicating factors were not involved. He settled upon the use of Landolt rings, (the international visual test object), as the detail to be observed and he had them printed in paragraph form in different sizes, and eventually in different contrasts. He came to the conclusion that mechanical time involved in manipulation of most field tasks tended to conceal the visual responses, and, thereby, misrepresented the true relationship of visual reactions as a result of illumination. He therefore arranged for the subtraction of the mechanical time from the overall time in order to get the true visual response with illumination.

The Weston method of assessing tasks in commerce and industry was adopted by the British Illuminating Engineering Society in 1943. In 1945, the North American Illuminating Engineering Society adopted the Weston method as its basis for appraisal. However, as the Technical Advisory Committee on Light and Vision, headed by Dr. Glenn Fry of Ohio State University, began to study the Weston data, they concluded that Weston had not fully subtracted the mechanical time and also his papers did not reveal his statistical treatment of the data. They therefore decided that IERI should refine the Weston method and extend it to other factors that would be truly representative of work situations in the field.

In order to find suitable people to work in this field, the Chairman of the Board, Professor Strong, Cornell University, and the Secretary, C. L. Crouch, became participants in the Armed Forces National Research Council Vision Committee—it is the National Academy of Science Committee now and Dr. Benson is Executive Secretary—which represented millions of dollars being spent by the Defense Department in determining the visual responses of Armed Forces personnel in carrying out their military duties. It soon became obvious that Dr. H. Richard Blackwell of the University of Michigan was studying the very factors of visibility that would be of interest to IERI. The work was started in 1950 in a modest fashion, and culminated in a method of assessment in 1958. It was realized at that time that there were many other factors that needed to be investigated before a complete comprehensive method could be established. However, architects and engineers have to keep designing and building and so, at any particular time the latest information must be utilized for the best results to date.

Shortly after the move of Dr. Blackwell from the University of Michigan to Ohio State in the early 60's, Dr. Stanley Smith took over as the main researcher in the field of quantity of illumination. He continues to investigate factors that are involved in everyday work situations that will have a bearing on the eventual formulation of a complete specification of the appropriate illumination to be used. Further, Mrs. O. M. Blackwell has continued to make studies for IERI on the effect of age. (Dr. Smith is limiting his studies to the young normal adult as the basic formulation and then we will add factors of age.)

I would like to show you two slides of Dr. Smith's work. He is doing a needle task. Now, this does not represent just needles. It represents a complex task of manipulating detail in industry in particular. And so he has a nylon fiber that must be inserted in ten needles, each of which is a different size. Everyone goes from the smallest needles up to the larger needles. He does it under different levels of illumination and finds out what the production is as you change the levels of illumination—what is the production and what are the errors related to the accomplishment of this task.

Then he has the coin task, and this is the Lincoln penny test. He has the person to read the last two digits of every Lincoln penny. And there is a whole series of Lincoln pennies with decreasing reflectance and increasing crud on them, so that you have all the way from good contrast to poor contrast. This does represent, metal working industrial tasks, since I was an industrial specialist. You largely see all metal working tasks by reflection of a large image in the somewhat specular background of the details to be seen. So this represents very well the detail that you have in metal scribing, die layout work, the printing industry, the composing stones, all of this is represented in that kind of task.

Now we come to age. Here we start with the idea of advancing from infancy, elementary school, the twenties, the thirties, the fifties and the sixties; and these photos were of actual persons. One man in the sixties said, "Cash, I don't look that bad; I know I don't look that bad." But you will notice the facial characteristics that change with a period of time and Mr. Weston presented a wonderful paper in 1954 on the facial effects as evidence of the effects of age on seeing.

Here is a slide of Mrs. Blackwell at her task, at her control board, which sets up an automatic train of pulses; and here we have the older people making their measurements. This is for static viewing and right now they are engaged in dynamic viewing. This work has been published already on one hundred fifty-six observers in enough population in each one of the ten-year intervals to be able to find out what happened with every ten-year interval of age and how it shifts the visual performance curve. This is for one-fifth of a second exposure.

Now, how about the visual characteristics of age? Life expectancy has gone from forty-eight years in 1900 to seventy-five years in 1970, almost a linear line.

Here is the pupillary opening. It decreases until there is no flexibility left at seventy-five years of age; and so you can not graduate the amount of light coming in through the pupillary opening.

Here is the relative visual acuity curves over the years and decrease of that visual acuity (Figure 1).

Here is the speed of perception, and this is Weston's work on speed of perception according to age, in England; and you will see there is a dramatic change.

Here is critical flicker fusion and the change of sensitivity with age at various angles with the line of sight.

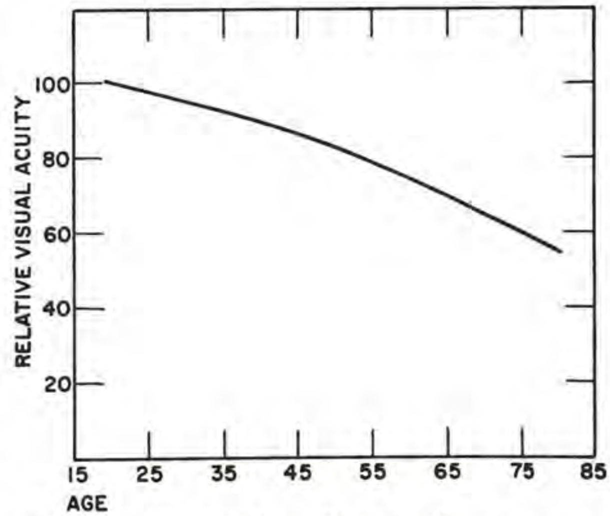

**FIGURE 1.—Relative visual acuity vs. age.**

Here is the brightness threshold, where there is no size factor involved, just the determination of the reduction of brightness sensitivity with age to one half value.

Here is the transient adaptation, where the fifteen-year-old can completely adapt in going from indoors, a brightly lighted interior, to outdoors in six minutes. But look at the seventy-five-year-old up to the eighty-five-year-old and it takes him thirty minutes. So, when he starts out driving from a brightly lighted interior, he is partially seeing, partially blind in trying to guide his vehicle.

Here is resistance to glare, which is disability glare, and this was done with several hundred thousand observers. This was disability glare with motor car headlighting involved, and you will see that he can hardly get started at the age of seventy-five. It is glaring to start with. By the way, this was a simulated two-lane roadway, object in the lane down the road, headlights coming toward you; you moved a lever, the headlights came toward you until you could see the object. The amount of movement there represented your resistance to glare.

In 1958, the illumination levels were changed because of the new, more comprehensive basis as compared with the previous meager data. The new visual performance method asserted that contrast is the dominant factor in visibility of the range of sizes of details that are critical for seeing in commerce and

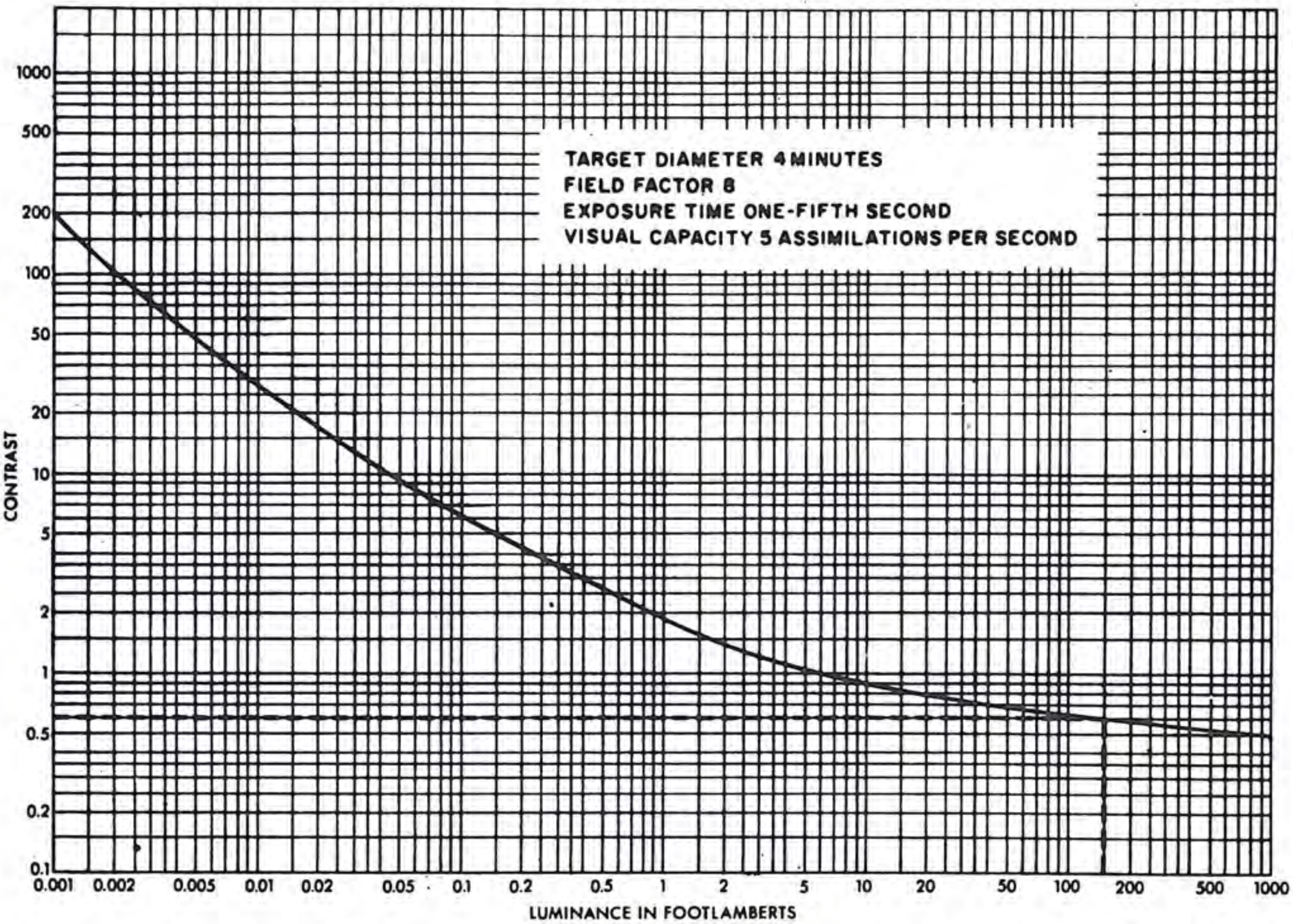


**FIGURE 2.—The relationship for the standard four-minute target to which practical tasks are equated.**

industry (1 to 10 minutes subtended visual size). It had been found over the last 50 years (Ferree & Rand, Luckiesh, Cobb, and Weston) that three to four minute size represented the weighted average of the critical seeing tasks in working situations. Therefore, the basic curve of contrast versus luminance for a four-minute circular disc laboratory test object formed the foundation of the method for determining the light necessary for seeing in commerce and industry. This basic curve shown in Figure 2 was established in the laboratory at a threshold of 50 percent correct seeing. We could go into the philosophy of why it was done at that point on the probability curve.

Of course, there must be field factors between 50 percent probability of seeing in the laboratory and the actual conditions in the field. It has been found that these field factors, determined in the laboratory, displace the base curve upward on the contrast scale until one arrives at a working curve that represents all of the elements contributing to seeing the task in the field. (Actually, the working curve was determined by experiments with a field task simulator. The elements contributing to the final working curve were estimated from other experiments relating to these particular factors.) Thus there is a family of parallel curves, each one representing the additional component of that element found in the field.

This is the field task simulator. This represents what we find in commerce and industry time and again. Here are fifty four-inch plastic discs with optics below them in a cylinder. The black items are switches. And so the person stood in this booth and the levels of illumination were changed and the wheel speeds were changed and the discs came through—there were six of these in the cubical

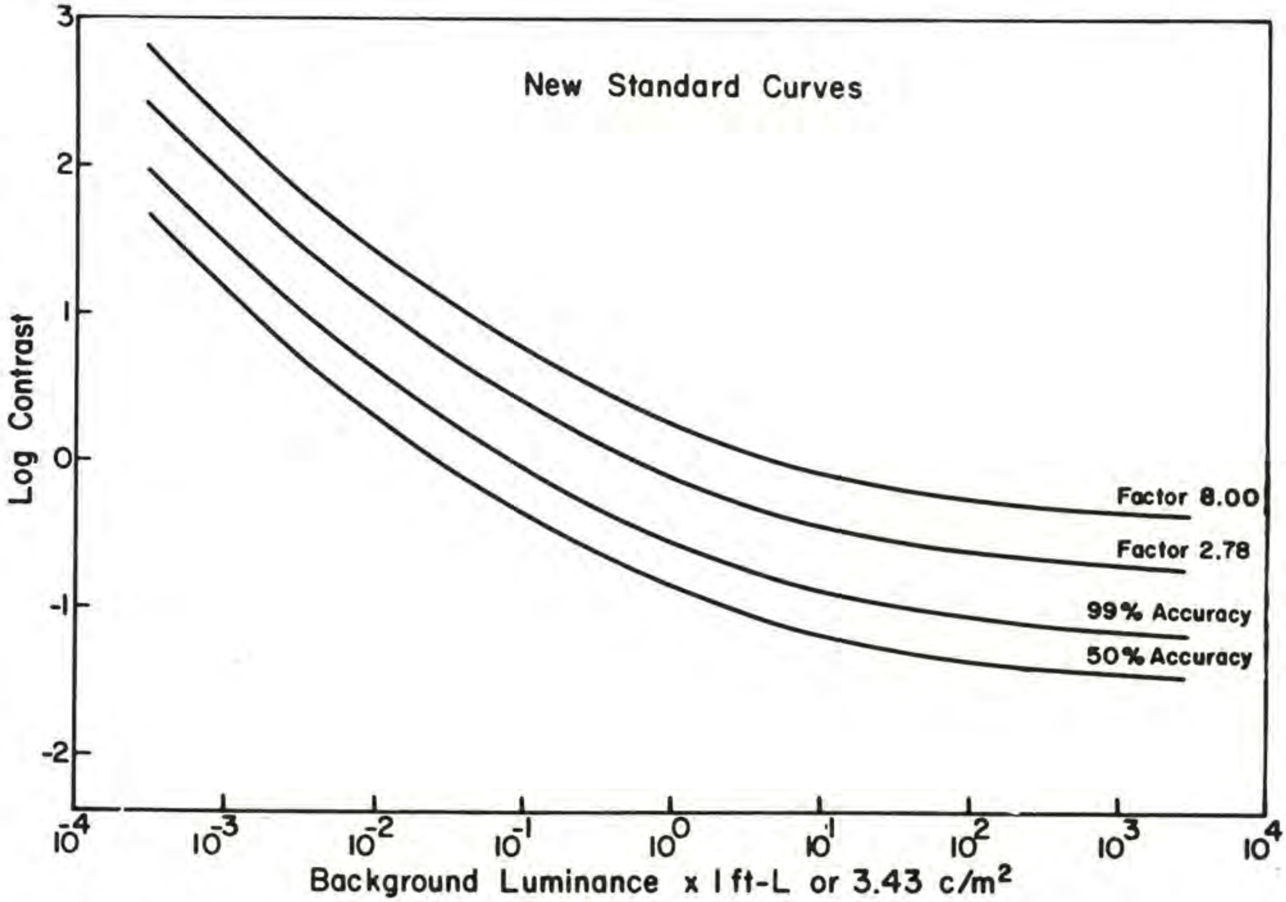


**FIGURE 3.—The relationship between threshold contrast and background luminance for the field factors of 2.78 and 8.00 and for 50 percent and 99 percent accuracies.**

at any moment of time. The person discovered there was something wrong out of the corner of their eye, fixated briefly, and slammed the switch which recorded automatically. Then they kept on cycling in their study. Now, this is commonly found in industry, on conveyor belts and inspection jobs of this kind. This established the working curve. And it is found in offices, because of the constant scanning movements that one goes through in offices and schools.

Here are the parallel curves showing, in Figure 3, fifty percent accuracy, ninety-nine percent accuracy; the unknown location, 2.78; and, finally, the moving-eye conditions, dynamic conditions, resulting in a working curve of eight above the threshold, displacement on the log contrast scale of eight. We used the upper curve as our working curve and we relate all tasks in the field to that upper curve. We find a particular contrast of a particular object out in commerce and industry and we bring it in as an equivalent contrast and locate it on the ordinate. Then we go over to the curve and down to the background luminance and find out how much luminance is supposed to be used, divide by the reflection factor and we get the footcandles involved.

Here is the visual task evaluator in our office being used on an office task. We run calibration curves on all of these observers to know what their relationship is to the population of the thirty to forty-year-olds. And so we maintain our relative calibration all the way through.

Here is the optics of the visual task evaluator which is merely a contrast threshold meter which maintains the adaptation constant so that you do not change the sensitivity of your eyes. You change the contrast wedge and find out what the contrast threshold of that particular object is in the field.

Here is a typical task found in the field, reproduced material which the observer was looking at through the visual task evaluator.

**Visual Task Evaluator (VTE).**—Here it is taken out in the roadway, West 76th Street, on crime study, cooperated by the New York City Lighting Department—they were very enthusiastic about this. You want to know who the people are that are coming toward you two hundred feet away, one hundred feet away and fifty feet away. And so we made measurements of a Caucasian, a Negro and a Spaniard, so that we would have all of those characteristics.

Here is the visual task evaluator being operated at the left and the City man is in the back, and the disability glare meter which can measure the loss of your sensitivity right here.

Then we have used it in hospitals, Montifeore Hospital; and we were measuring the tissues, the sutures and other details. This happened to be preparation for open heart surgery. We got this shot to show the setup of our arrangement. We were in another room, and we projected through a small window to a mirror and looked right down into the operation itself. We were able to make measurements. This slide is just a rough idea of the type of tissue—some tissue is bad, it is fatty, and some is lean that you can tie to and it will not break loose; and the sutures vary all the way from tiny, tiny sutures for openheart surgery to heavier sutures.

These elements of the formula for required illumination include: degree of accuracy of seeing the detail out of the number of times it is present, the unknown location of detail versus the known location, and the dynamic viewing (eye movements involved in performing an actual task) versus static viewing. The top curve of Figure 3 representing the incorporation of all these elements becomes the field use reference curve.

For the last fourteen years this has been the framework of arriving at the working curve for specifying the illumination levels. The working reference curve has not changed much even though the values of the elements contributing to it have changed. It was expected from the start that the values of the elements might change as a result of further research and even the location of the working reference curve might change depending on the magnitude of the elements contributing to it. For instance, the element of dynamic viewing might change radically, depending on the complexity of eye movements involved in particular visual work in commerce, industry or sports.

This item, together with uncertain or unknown location, probably accounts for the greatest impact on the location of the working reference curve (and therefore, the illumination required). To aid in the resolution of the two elements, it has been necessary to develop an eye-movement recorder and to carry out practical tasks of sufficiently different characteristics to record a range of eye-movement patterns. With a series of particular eye-movement patterns, the laboratory can establish field factors for different categories of patterns. It may be that there will evolve several working reference curves for diagnostic field use. This work is now underway.

There has existed from the beginning of the system a need to answer the question as to whether it pays off in real gain of performance of field tasks over previous empirical systems of determining illumination values. A few case histories of production gains and reduction of errors were available to show the difference between former levels—before 1958 and those after—and the system determined levels. Since the question keeps recurring, and it is recognized that field location tests are subject to many complexities of physical and psychological factors, it was decided to conduct a series of representative tasks under carefully controlled conditions and varying illumination levels. From these production tests, one could determine if there were meritorious gains from the system-determined levels. These tests validate the system and this work is now underway.

As a homey illustration of the rationale for the current footcandle levels, I am calling your attention to three eye charts based upon the original American Medical Association eye charts (which is the reverse of the Snellen). The black on white represents reading of textbooks and printed material in schools and offices; the gray on white represents sewing on light cloth in the home and shop or pencil-work carbon copies and duplicated material in the school or office; the black on dark gray represents sewing on dark materials, cooking dark foods in the kitchen or working on dark materials in industrial processes.

Now, what light did it take to see the charts? We took twenty young, normal adults and put them at a twenty-foot distance from the full sized charts. They rheostated the illumination up and down until they could just barely see it. They found that one footcandle illumination was the average—half of them could not see it and half could—for the 20/20 line, one footcandle illumination. The gray letters on white (21% contrast) required one hundred twenty footcandles under the same set of conditions; and the black on dark gray chart required five hundred and twenty footcandles. All they did, really, was proportion the illumination in accordance with these various factors. We have, now, a formula for doing it, but we knew the principle all along. Further, when people come to the bifocal age, they walk over to the window immediately where there are hundreds of footcandles.

We recommend that you try it for yourself. I have little eye charts now that are miniaturized; you can hold them up at two-foot instead of twenty feet. I want you to use it on yourself and see whether you have normal vision or not. If not, see your doctor. Then I want you to turn off the lights and go over here in the darkest corner and see how far up you can see on the chart. And, then, holding it there like that, walk over to the window where you have hundreds of footcandles and see it come out—the whole thing comes out. Even the dark chart comes out. It takes more, much more light; but, under normal daylight, with hundreds of footcandles of illumination outdoors, this will come out as well. So, really, we have a rationale, a homey rationale, for the use of illumination.

So many people talk about reading. This is the very best contrast, ninety to ninety-five percent contrast, and you do not need high levels. IERI data shows this and IES recommends only low levels. Some people jump at the conclusion, because of reading tasks like this, that IES and IERI recommend several hundred footcandles. On the other hand, we have found on perching boards for suiting material that we need two thousand footcandles. We find they can not see defective threads with less than two thousand footcandles provided by localized lighting. IERI is not interested in how you do it; we are only interested in the light on the task to be seen and the brightness balance of the environment. So the story has been distorted. People use the higher levels and say the IES and the IERI recommend this sort of thing.

Of course, you have noted in all of this discussion as to the background of the current levels of illumination, that the research has all been related to visual performance and the general subject has been called the psychophysics of vision. Naturally, in our type of civilization and culture, the emphasis has been on the ability to see quickly and accurately because our concepts have to do with production in commerce and industry. In general, our thinking has not encompassed the physiological aspects of vision or the possible visual dysfunction and stress that may occur with the lower levels of illumination.

In earlier years in the IES and medical literature, there had been an expression of the relationship of lower levels of illumination to eyestrain. Dr. Lancaster, a famous ophthalmologist, described eyestrain and described its relationship in a medical text as to the illumination level. Ferree and Rand, and Luckiesh and associates pointed out in the 20's and 30's that there were fatigue effects related to lower levels of illumination and there appeared to be a relationship between this fatigue and the physical symptoms that eye specialists described as eyestrain. Little follow-up has been done in recent years because of the preoccupation with quick, accurate performance. It would now appear that we should have been pursuing some of these earlier studies in order to answer the questions posed by NIOSH today.

However, we do have a possible approach to this situation through the recent work of Dr. F. W. Hebbard. He found that there is apparently a much greater requirement of ocular motor adjustment with low levels as compared with high levels. He found this was true also with glare versus freedom from glare. At this point, we are inclined to think that there may be a real change of pattern of eye performance with lower levels as compared with higher. This could be construed as evidence of visual dysfunction from the normal pattern of eye performance under nature's levels of illumination. You will hear much more about this from Dr. and Mrs. H. R. Blackwell.

And, now, I just want to end with a few slides. What are the kinds of tasks we are dealing with because we are talking largely about offices, and, to a slight degree, about schools? This is Dr. Hebbard and his setup at Ohio State University. He put on the eye of the observer a contact lens with an arm with a mirror on it and he shot a beam of light toward the mirror and by the lever arm it was amplified and recorded on the recorder back at the back of the room. This is his setup and bite bar to hold the head rigid. He found out there was a great deal more ocular adjustment action with low levels than with higher levels and with glare than without glare. I want you to hear about that from Dr. Blackwell.

Now, what are the tasks found in government buildings? A survey was made and here is a typical type of printed material. Here is a form that was taken right from the offices where they were performed. The survey was made in the Department of the Navy, the Internal Revenue Service, and the Veterans Administration. Here is a young lady who does this work all the time, transcribing from pencil handwriting to typewriter form. This is the thing that she was working on. This is the sort of thing where you have poor contrast in this operation.

Here is a young lady working on forms. Here are the forms that she is working on and the contrast is not good. Here is another form. If you take those figures, the contrast is pretty good; but other details are not so good.

Here is a general office and how it was lighted and the typical interior. Here is a man at the Veterans Administration analyzing medical reports all day long. Here are the forms that he was working on. And here is a closeup of the detail he had to work with.

Here is a lady working on some more forms; and, again, the contrast was poor. Certain things are good. You can see the black ones show right up boldly, but the others are grey. Here is a closeup of some of this work. Here is another form normally made out in pencil. Here is another one.

Here is a lady who may experience age effect. In IERI and IES we are talking only about young, normal adults in all recommendations. I just wanted to give you a taste of what actually occurs in the field and the relatively poor contrasts involved.

Thank you, Mr. Chairman.

## DISCUSSION

**Chairman Heins:** One point that has been brought to my attention is that we are using the term "low levels of illumination" rather loosely. By "low levels" we are referring to levels which are below the values recommended by the American National Standards Institute (ANSI A132.1–1973—Office Lighting, ANSI A11.1–1973—Industrial Lighting). Perhaps we should be a little more specific in our use of the term.

**Dr. Blackwell:** Why do we not just leave it that the problem here is at what point in reduction of illumination do you get into health problems? That is what you really want to know.

**Dr. Halldane:** My general comment is, because of the energy crisis, our problem here is lowering lighting levels. And so, it is a political problem of lowering at the moment, because we are going into a lowering process. It is not as though that we are going to a lower level or what it is, but here GSA and NIOSH are involved in a political process of lowering the levels because of energy conservation. I think that "lowering" is the better description which reflects the political and the technical problem that they have at hand.

**Dr. Weale:** Would we get around this by using the term "reduced" rather than "lowered"? The term "low level" has certain connotations which are obviously causing the difficulty which the Chairman has just mentioned.

(And so, the word "low" was replaced by the word "reduced" in the title of the symposium.)

NIOSH

# The Occupational Safety and Health Effects Associated with Reduced Levels of Illumination

**Proceedings of Symposium**

**Cincinnati, Ohio**

**July 11 - 12, 1974**

NIOSH
NIOSH
NIOSH

# THE OCCUPATIONAL SAFETY AND HEALTH EFFECTS ASSOCIATED WITH REDUCED LEVELS OF ILLUMINATION

**Proceedings of Symposium**

**Cincinnati, Ohio**

**July 11 - 12, 1974**

**Allan P. Heins, Ph.D.**

**Symposium Chairman**

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Laboratories and Criteria Development

Cincinnati, Ohio 45202

**MARCH 1975**

**These proceedings were compiled and arranged by Allan P. Heins[1] with the assistance of William E. Murray of the Physical Agents Branch, Division of Laboratories and Criteria Development, NIOSH.**

[1] Western Area Occupational Health Laboratory, National Institute for Occupational Safety and Health.

**HEW Publication No. (NIOSH) 75—142**