ADEQUATE LIGHTING FOR THE SCHOOL SHOP

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CHAPTER I

THE SCOPE AND ORGANIZATION OF THE STUDY

The problem of Industrial Arts and its place in the school curriculum is of great importance. The problem of adequate illumination in a school shop and some of the basic principles involved is what the writer hopes to reveal in this study. In order for an industrial arts teacher to be able to present a functional program and in order for the student to perform his best work, there must be a shoproom or classroom that is provided with an adequate amount of illumination whether that illumination be from natural or artificial sources, or from both sources.

With these points in mind the study was organized with use of subtopics and paragraph headings. Chapter I acquaints the reader with the scope and organization of the study and the research methods that were used in obtaining information for the study. A number of definitions that will aid in avoiding any confusion that may develop are given. Chapter II gives some additional definitions, and the past and present philosophy with the objectives to be attained in industrial arts. Chapter III consists of the historical background and some of the recent developments of several different types of illumination. Chapter IV gives recommended standards of illumination for different shop and classroom activities. Chapter V includes a summary of the preceding chapters and recommendations for the improvement of illuminating conditions in the average shop or classroom.

Statement of the Problem. To determine the standards and recommendations that have been given for adequate illumination of the many special and varied classroom situations.

Divisions of the Study. This study is divided into three parts. The first gives the historical background and recent developments of several different types of illumination. The second is a study of the philosophy of the beginning of industrial arts in the United States; also the philosophy and objectives of industrial arts as of today. The third part gives recommended standards of illumination for different shop and classroom activities.

Need for this Study. Many classrooms in the schools of today are functioning under adverse lighting conditions. The writer in making this study is attempting to point the way and offer recommendations in which lighting conditions may be improved in the industrial arts classrooms of today.

Methods of Research or Investigation Used. This study is a library research in which the writer attempts to compile the information and material from various books and periodicals that have been written by numerous authors who are considered to be authorities in their individual fields.

Definitions of Significant Terms. The following definitions of terms are given in order that the reader may know and understand their use in this study. The sources of these definitions are indicated in the parenthesis at the end of each definition.

Candlepower: The unit of luminous intensity in any given direction. (1, page 295)

Fluorescence: The production of light by the transformation of invisible ultraviolet energy into visible light. Substances having this property are called fluorescent materials, and they emit light only while the exciting radiation is present. Phosphorescence, on the other hand, is the property of "shining in the dark" after exposure to light, as do radium dials on clocks, etc. (1, page 296)

Footcandle: The unit of illumination and the measure of density of the light falling on any surface. It is defined as the illumination on a surface one foot square received from a source one foot away which emits one candlepower in the direction of the surface. A footcandle is produced by one lumen received on one square foot of area. (1, page 296)

Lumen: The unit of luminous flux (the time rate of flow of light) equal to the light through a unit solid angle from a uniform point source of one candle. (1, page 296)

Lumens per Watt: The commonly used measure of luminous efficiency, that is, light output divided by wattage input. (1, page 296)

Luminescence: The production of light by a change in the nature of the luminous material, as distinguished from light produced directly by high temperature. (1, page 297)

Phosphors: The fluorescent and phosphorescent chemicals with which the inside surface of fluorescent lamps are coated. (1, page 297)

T-5 Lamps: The "T" in the bulb designation stands for "tubular," and the number gives the diameter in eighths of an inch. Thus a T-5 lamp would have an approximate diameter of 5/8 inches. (1, page 5)

The foregoing definitions should serve as a guide to clarify the differences of opinion in regard to the terms as they are currently used.

Available Literature on the Subject. Many books have been written on the subject of illumination and new phases of illumination are being expanded every day. Much information may be obtained from periodicals written on the subject. Industries such as Westinghouse will give their latest developments on illumination upon request.

It is hoped that the divisions of this study will simplify the data compiled so that the readers can see and understand the best principles of classroom illumination and apply them to their classroom situations.

CHAPTER II

A HISTORY OF ILLUMINATION

A quarter of a century ago, the term electric light meant either the bulb used for lighting purposes in the home or the arc light used on street corners and in the theater. Now there are a great many different kinds of electric lights, each of them suited to a specific purpose. Electricity gives off light when it heats wire, when it passes through gases, when it gives off rays which cause other substances to give off light, and when it jumps between two pieces of carbon in the arc light.

Incandescent Light. Soon after the electric battery was developed, men found that an electric current which flows through a wire that offers great resistance to its passage will give off both heat and light, just as a white-hot piece of iron heated in a furnace gives off light. The next problem was to discover what kind of wire or filament would be best for giving this kind of electric light. As early as 1859, Moses Farmer lit his house in Salem, Massachusetts, by electric lamps which contained a glowing platinum wire. The current was supplied by batteries. These lights were not very satisfactory, however. Thomas A. Edison worked on this problem during 1878 and 1879. He wanted to find some substance that could be heated to give off light, but that would not burn into an ash. To find such a substance, Edison tried thousands of different kinds of materials. He tried platinum, which proved to be too expensive, and even tried using a human hair. (27, page 2261)

The Carbon Lamp. After many experiments Edison found that carbon was most satisfactory material for giving off light. The carbon filament through which the electricity passed had to be enclosed in a glass container from which all except one millionth part of the air had been removed. If more air had been left in, the carbon would have combined with the oxygen in the air and burned away. Carbon was found satisfactory because it has a high resistance to electricity and it is easily brought to a white heat.

Edison's first successful carbon lamp was made in 1879. Edison had tried to make the tiny thread of carbon by charring cotton thread, paper, wood, and many other substances. Bamboo proved to be the best material for his purpose. To find the best kind of bamboo, Edison sent expeditions to many parts of the world. After examining every known kind of bamboo and spending $100,000, Edison decided that Japanese bamboo was the best source of carbon for light filaments. (27, page 2262)

Edison next found that a new kind of carbon filament could be made by squirting a solution of cellulose through glass jets into alcohol. The alcohol hardened the cellulose, which was afterward carbonized through heat. The ends of the carbon filament in the light bulb were soldered to platinum wires, which were sealed into the glass to make the connection with the electric current. Platinum was used because it expanded and contracted only as much as the surrounding glass when it was heated and cooled. Therefore no air could get in.

The Tungsten Lamp. The next step in the development of the electric incandescent lamp came with the development of the tungsten lamp. This lamp used a tungsten wire instead of carbon. The tungsten lamp gives a whiter light than the carbon lamp. It also gives almost three times as much light for the electricity it uses. Light from an incandescent lamp is not like the light given off by sunlight. It contains more red and yellow.

Men soon discovered that the tungsten filament lasted longer and was more efficient if the light bulb contained nitrogen and argon gas, instead of being in a vacuum. The filament of tungsten in a bulb from which the air had been removed gradually oxidized and was deposited on the inside of the bulb, blackening the glass. Nitrogen and argon are inert gases and prevented the filament from oxidizing. The tungsten filament was also formed into a "coiled coil." The tungsten filament was coiled once, and then that coil was coiled again into a second coil. This gave more filament in the same space, and therefore more light. Tungsten can be heated to approximately 6,143 degrees Fahreinheit without melting. Tungsten can be stretched into very small diameters which is one of the factors that make it such an economical substance to use for lighting. The nitrogen-argon filled tungsten lamp is over twice as efficient as the ordinary tungsten lamp which has its filament in a vacuum. The ordinary light bulbs used in houses require from 60 to 150 watts to operate. Some of the largest tungsten lamps used in searchlights and motion-picture studios need as much as 30,000 watts. Tungsten lamps come in all sizes. Some of the incandescent light used in instruments which are used to examine the inside of the lungs and the bladder are almost as small as a grain of wheat. (27, page 2262)

<u>The Nernst Lamp</u> was an interesting early experiment in making incandescent lights, although it is little used at present. It was invented by the great German physicist, Walter Nernst. It used a small rod of rare earths mixed with a binding material. The rod was heated by a small coil of platinum wire in order to make electricity pass through it. When the current

was turned on, the platinum wire became red hot and heated the tube. When the tube reached the proper temperature, the electricity began to pass through it and it glowed with an intense white light. Then the platinum coil was turned off. (27, page 2262)

The Mercury-Vapor Light. A tiny drop of mercury and a small amount of argon gas are placed inside the tube. The mercury weighs only a few milligrams (i.e., a few thousandths of a gram, a gram being 1/28 of an ounce). Both mercury and argon are added after the electrodes have been sealed to the tube and the air exhausted. The normal mercury-vapor pressure of a given sized lamp depends on the bulb-wall temperature, which in turn is determined by the input wattage and the area of the bulb available to dissipate the heat. Optimum pressure results in the most efficient production of ultraviolet light. Fluorescent lamps operating normally have mercury-vapor pressures in the order of only 6 to 10 microns which is around 1/100,000 of atmospheric pressure. (1, page 12)

When the metal mercury is turned into a gas, it is a very efficient conductor of electric current. It gives off a blueish-white light which contains few red rays and many ultraviolet rays, which can kill bacteria. The cathode, or negative pole, of such a lamp is mercury, and the anode, or positive pole, is iron. The light is given off in a long tube from which the air has been pumped. The tube is first placed in a horizontal position until the liquid mercury in the tube extends along the entire length of the tube and completes the electric circuit. When the circuit is completed, the tube is tilted back so that the mercury drops back to one end. The electric current turns part of the mercury into a gas or vapor, and the current continues to flow through the gas. The greater the pressure inside the tube, the whiter the light which is produced. The tube of the light is usually made of quartz, which is not so likely as ordinary glass to crack under great heat. This factor makes quartz a very good substance to use. (27, page 2262)

The gas pressure is important. Lamps having pressures only slightly greater than called for will give good light-output maintenance but are harder to start. If the pressure is slightly low, the lamps start more easily but depreciate more rapidly in light-output. Pressures are closely controlled to effect a compromise. Argon is used to facilitate lamp starting because of the relatively low voltage at which this rare gas can conduct an electric current. The initial discharge is through the argon gas, the heat from that arc quickly vaporizing the mercury, and the current is then carried entirely by the mercury vapor, the electrical path being of relatively low resistance. However, future developments and research may disclose advantages for other combinations of filling gases and pressures. (1, page 12)

Fluorescent Light. The phenomenon of fluorescence was recorded several centuries ago, but it remained for scientists of this age to assemble the fragments of related knowledge and tie them together with the many recent findings into the modern fluorescent lamp. The seemingly hopeless barrier that beset the workers in this field was low fluorescent intensity. As late as 1921 one specialist despaired at the possibility of luminescence becoming a real factor in artificial lighting.

The first record of phosphorescence was around the end of the first millennium A. D. when it was noted that an oriental painting of a grazing bull continued to glow after dark. The more celebrated beginning of fluorescence and phosphorescence was the discovery in 1602 by a shoemaker in Bologna, Italy, of a substance that was luminous after exposure to a strong light. Fifty years later a scientist found that the color of the phosphorescent light was independent of the color of the exciting light, proving that the phenomenon was not due to the storage of light in a substance. The investigation of these effects became fashionable and explanations varied. For example, Newton in 1704 attributed fluorescent effects to internal reflection. Others said internal dispersion was the real cause. In 1853, the Irish physicist Stokes first published a law which was of benefit in connection with the development of fluorescent materials.

Soon afterward (1859) the French scientist Becquerel described tubes containing luminescent materials and rarified air. Although his tubes were not successful light sources, the idea was studied further in Belgium, England, France, Germany, and Holland, as well as in America. Thomas A. Edison invented a fluorescent lamp in 1896, but it was not practical.

Hundreds of mineral compounds were found which fluoresced when excited by proper radiation. Gaseous conduction lamps were coming into limited use, based on developments by Geissler, Crooks, Moore, and Claude. It is interesting to note that during the 1920's a lamp inadvertently making use of a slight amount of fluorescence was used in the sign industry. An argon-mercury discharge in uranium-glass tubing gave a much better green color when lighted. This was later explained as fluorescence of the uranium glass.

In the 1920's the idea of fluorescence was well known to scientists. Phosphorus and mercury discharges were then old subjects but the proper combination of an efficient ultraviolet source and fluorescent materials of high response to that particular type of ultraviolet radiation had never been found. By the end of the decade developments had proceeded to the point where the component parts as used today were familiar to the workers in the field.

It had been demonstrated that 10 microns of mercury pressure was the optimum value for efficient production of ultraviolet. Other work had indicated the requirements for the operation of electric discharges at low pressures, and activated cathodes and the proper pressure of the filling gases were correlated to give cathodes of long life. Practical fluorescent light sources were soon to follow. The production of light by fluorescent coatings on the inside of tubing was being employed by the French and Germans in the early thirties, and by 1934 the development of low-voltage fluorescent lamps was undertaken by United States lamp designers. By 1935, progress was rapid. Phosphors of sufficient intensity were being produced and, of equal importance, the response of such fluorescent materials had been selected to match a high efficiency source of short-wave ultraviolet energy, the low-pressure mercury arc. More and more scientists were assigned to the task, and satisfactory methods were found to apply the phosphor to the inside of the bulb. Combinations of fluorescent material were developed to give white light, and the experience in filament lamps of lumiline constructions was utilized. Too, the background of knowledge provided by long experience in the manufacture of vapor-discharge lamps and the decision to favor low-voltage operation were considerable factors in the development of commercially successful fluorescent lamps. In September, 1935, the first public exhibition in America of a practical low-voltage fluorescent lamp was made at a convention in Cincinnati. This sample was the beginning of high-efficiency fluorescent lamps which could be made uniformly in large volumes for the greatest public benefit. In November, 1936, decorative lighting effects for the 100th anniversary celebration of the Patent Office were provided with fluorescent lamps, and the two world's fairs were extensive proving grounds in 1938 and 1939. (1, pages 1-3)

The fluorescent light is much more efficient than the tungsten light, which turns only 6 to 8 per cent of the energy used into actual light. The fluorescent light turns 60 to 70 per cent of the energy into light. In the fluorescent light the mercury vapor is not used to give off light directly. Instead, the vapor gives off rays which are used to cause fluorescence, or glowing, in other substances. The inside of the fluorescent light tube is coated with materials called phosphors. They glow with a visible light when they are struck by invisible ultraviolet rays. When these substances are properly blended they can offer a white light or a light which combines different colors. Zinc silicate coated on the inside of the fluorescent light tube gives off a green light; calcium tungstate a blue light; zinc beryllium silicate a bluish-white light; and magnesium tungstate a yellowish-white light. (27, page 2263)

Equipment for quantity production of fluorescent lamps was developed, and the original line consisting of four sizes in day light, white, and four colors was offered to the public in April, 1938. Since then further research has extended the line of fluorescent lamps to other sizes. At the same time, improvements in performance data have resulted in increased efficiency and longer life ratings so that the 40-watt white lamp now gives about six times the lighting value of that size as introduced in 1939. (1, page 3)

Like the Nernst light, each fluorescent light requires a heating unit for starting. These heaters give off negative electrons which turn the mercury vapor in the tube into ions and make it conduct electricity more readily. A reactor coil chokes off currents which might become dangerously large. Often the starting voltages of these lights are greater than the ordinary 110 to 120 volts of house currents. Therefore some of these lighting fixtures need a transformer to step up the current. The two-lamp ballast and other circuit improvements are also factors in the outstanding public acceptance of fluorescent lighting. Instant starting is now available. Slimline lamps, Circline (circular) lamps, and other developments indicate a "bright" future for fluorescent lighting. Most of the Slimline lamps are rated at over 60 lumens per watt in the white color. Unlike the ordinary incandescent lamp, the goal of fluorescent lamps is not to produce a maximum of light directly, but rather to generate efficiently short-wave ultraviolet energy and then employ fluorescent chemicals or "phosphors" which can effectively convert that ultraviolet energy into visible light.

(1, pages 3-6)

<u>Neon, Neon Lights, and Other High-Voltage Signs</u>. Neon is a gas that is one of the chemical elements. It is found in the atmosphere in the proportion of eighteen parts in a million. Neon was discovered by Sir William Ramsay, an English chemist, in 1898. He made this discovery while investigating the composition of liquid air. He named this gas <u>neon</u>, meaning <u>new</u>. It is one of a group called the rare or inert gases. Other gases of this type are argon, krypton, xenon, and helium. None of these gases will combine readily with any other chemical elements, although some of them are also useful.

Today, neon is used for advertising signs and airport beacons. The light from a neon lamp is so intense that it can be seen in daylight as well as at night. The usual color is a bright scarlet. The addition of a few drops of mercury to the gas makes the light a brilliant blue. Other colors are produced by tinting the glass tubes which contain the neon gas.

Neon lamps are made by confining the gas in a glass tube from which the air has been taken out. When an electrical discharge is passed through the tube, it glows with a brilliant fiery-red tint. There is no filament in the tube as there is in an ordinary electric light, but there are two electrodes sealed within it. Between these the gas forms a luminous band.

Neon is very expensive, but only a small amount is required for a lamp, because a small amount will produce a great deal of light. The gas is separated from the other elements in the air by liquefying the air at about -200 degrees centigrade. At this temperature the neon is still a gas, since its boiling point is -246 degrees centigrade. Neon is sold in thin-walled glass bulbs which contain about a quart each, and cost about $10. One bulb contains enough gas to fill 200 to 300 feet of the tubing used for advertising signs.

Air beacons use neon light because it is especially effective in penetrating fog. Air pilots have found neon beacons visible for a distance of twenty miles, under conditions that made it impossible to see other kinds of lights. (4, page 5496)

High-voltage signs operating at more than 600 volts and using neon or other gas-filled tubes are constructed in lengths up to 40 feet, requiring voltages of about 400 volts per foot of tube to light the tube. This voltage is obtained from high-voltage transformers, enclosed in the sign, which raise the voltage from 110 or 220 volts to as high as 15,000 volts. The extremely small current required to activate the gas makes this type of sign economical to operate. A light load of this kind on the transformer produces a low, lagging power factor which is corrected by connecting a condenser in parallel with the primary winding of the transformer. Because the high-voltage terminals at the ends of the tubes are very hazardous they must project into the sign enclosure and be separated from grounded metal by at least 1½ inches of insulating material. These terminals must be isolated from combustible material and must be inaccessible to unauthorized persons and separated from grounded metal, or must be enclosed in separate terminal boxes of insulating, non-combustible material or metal. (17, page 358)

Neon lights, like mercury and fluorescent lights, are made possible by the fact that electricity can be conducted through a gas and made to give off light. They require electricity of higher voltage than the electricity used in houses. The color of the light given off depends upon the kind of gas used. Neon gives off a red light in tubes; argon gives off blue. The tubes can also be colored to effect the color of the light. Neon lights are very cheap to operate, although they required high voltages to start.

In some cases, other materials in a gas form are used for lighting. Sodium-vapor lamps have been used with success along highways, especially at intersections. They give off a brilliant yellow light, much brighter than that of ordinary street lights, and they are very inexpensive to operate. Some authorities feel that their brilliant light also serves as a traffic warning. (27, page 2263)

Some present-day lighting practitioners remember the earlier incandescent lamp in which long threads of tungsten were draped up and down inside the bulb, the filament glow and thus the light obviously being the result of the current passing through the tungsten wire. In fluorescent lamps and other electric-discharge sources, current flows between two or more electrodes that have no apparent electrical connection between them. The ramifications of this type of operation are vast and uniquely different from the known and easily predictable characteristics of filament lamps.

CHAPTER III

PHILOSOPHY OF INDUSTRIAL ARTS

Philosophies of all areas of education are changing from year to year. Experienced educators have witnessed a procession of changes in the philosophical points of view, more far-reaching than the preceding generation. The conception of education has changed much from "training for leisure," to the present emphasis on interest and activity. Each step in this change of philosophy has contributed much to the present conception of education.

Glossary of Terms

Because of the seeming lack of agreement on some of the terms of education, more particularly the new types of education, it is desirable that several of these terms be defined. The sources of these definitions are indicated in the parenthesis at the end of each definition.

> Education. The development of general intelligence, either by a system of study and discipline, or by the experiences of life. (13, page 26)
>
> Secondary Education. The period of education whether public or private, which usually consists of grades seven to twelve or nine to twelve, during which pupils learn to use independently the tools of learning that they have previously mastered, in which education is differentiated in varying degrees according to the needs and interests of the pupils, and which may be either terminal or preparatory. (8, page 495)
>
> Junior High School is a school in which the seventh, eighth, and ninth grades are segregated in a building, by themselves, possessing an organization and administration of their own that is distinct from the grades above and grades below and are taught by a separate corps of teachers. (14, page 491)

Vocational Education has reference to training for useful employment in trade and industrial, agricultural, business, homemaking, vocational-technical, and other pursuits of less than college grade. (20, page 7)

Industrial Education. A generic term including all educational activities concerned with modern industry, its raw materials, products, machines, personnel, and problems. It therefore includes both industrial arts, the general education forerunner of or introduction to vocational industrial education and the latter also. (7, page 7)

Industrial Arts. a. Those phases of general education which deal with industry - its organization, materials, occupations, processes, and products - and with problems resulting from the industrial and technological problems of society. (26, page 2)

b. A study of the changes made by man in the forms of materials to increase their values, and of the problems of life related to these changes. (3, page 5)

Vocational Industrial Education. Those forms of vocational education, the direct purpose of each being to fit the individual for some industrial pursuit or trade. (19, page 547)

Trade and Industrial Education is the name given to courses and programs of shop work instruction in the text of the Smith Hughes Act. Specifically "trade and industrial" is used in speaking or writing about shopwork courses subsidized by federal vocational education funds. (11, page 2)

The foregoing definitions should serve as guide to clarify the differences of opinion in regard to the terms as they are used. Two definitions of industrial arts are included to show the different methods of approach to the subject. One originated quite early in the beginning of industrial arts while the other one is as recent as 1948.

Early Philosophy of Industrial Arts

In the high schools of the past, much emphasis was placed on abstract thinking. These schools, by a sort of inertia, have kept on educating in the traditional way--educating boys and girls to do abstract thinking. These conditions do not meet the need or practical demands of society. Industrial arts in the early beginning endeavored to alter this tradition by bringing the school system closer to the needs of society.

Manual Training. This term was the one first used to describe the work that was done in the school program similar to the industrial arts program of today. Calvin M. Woodard and John T. Runkle were instrumental in starting this type of education. The term "manual training" was used by these men to describe the program established in their respective schools. These schools used the process of analyzation of the material or information to be studied. Learn to use the tools, then construct the finished project. Manual training was placed on the same plane as science or mathematics and the same guiding principles were used in the teaching of all these subjects. Manual training was not intended to develop high skills or to prepare for a trade. Rather it was to be considered in the general education field to prepare one so that when a trade was selected, the student would have little difficulty with his progress. All work was from models formed after the Russian system. These constructions by the pupil were usually not useful, that is, they did not have a place in the home or factory. (2, pages 317-322)

Industrial Arts. The term "Industrial Arts" was first used by Charles R. Richards, director of the Manual Training Department at Teachers' College, Columbia University. He used the term in an editorial for the Manual Training Magazine in 1904 and suggested the term be substituted for that of manual training due to the changing viewpoint of its contribution to education. (2, page 453). The disciplinary thought connected with manual training was replaced with the elements of the industries and their contributions to modern civilization. The problem of the schools was to make the life of the school more real, more like the world outside of the school .

Handwork in the schools cannot take the form in a set course but must be flexible so that it may be adaptable to the life around each particular school. This will mean a variety of school shop courses as are needed by the locality and as many classes as there are teachers to teach them. Industrial arts as a school subject must justify itself on the same basis as other subjects in that it is an aid to general education. Industrial arts is not a trade training program, but it contributes to education as a whole.

One can see by the philosophy of the early leaders in the field that there were gradual changes leading to the philosophy of industrial arts of today. This philosophy was not developed by one man but rather by leaders in the field who made studies through research how to improve the total field of education. Experiments were carried on at all times to try out a new scheme or some new idea that was thought to include means for improving education.

Present Day Philosophy of Industrial Arts

Philosophy is not static, rather it is continually changing to meet the needs of the modern world. Philosophy did not originate at any one specific time or place, but was derived from a collection of experiences and ideas that have been tried, revised and tried again. By this method educational leaders are able to derive educational philosophies to fit the conditions of the changing world.

Industrial arts is considered by some to be in its infant period of our present educational system. The philosophy of industrial arts is questioned by different leaders in the field. The American way of life is essentially democratic and industrial. (26, page 37). The aims of general education should be based on those two headings. In order to meet these aims the liberalization of the course of study has been growing continually to meet the demands of industry and a democratic society.

Demands of a Democratic Society. To meet the needs for a democratic society, industrial arts can do much to prepare the student as an individual for future participation in the complex society. A personnel organization in the shops in which students are given real responsibilities develops leadership and followership abilities and will do much to develop and equip the student for future life. Some factors that will aid the student to obtain the right attitudes in the industrial arts shop are such as having a well arranged shop for the student to do his work. The shop should receive adequate natural lighting and articicial lighting that has been planned by an expert in that field. The instructor should endeavor to establish a series of real-life situations, giving the student opportunities to help plan and organize the shop procedure.

Demands of Industry. The ever-changing complexity of industry will test the teacher to the utmost. The divisions of labor, the ever-increasing amount and variety of manufactured goods, and the development of new machine processes are extremely important in the field of industrial arts. The student of industrial arts learns the processes of construction by first planning for the object to be built followed by systematic construction of the article.

Objectives of Industrial Arts. The school program should be analyzed and definite objectives or aims established. These objectives should be the guide or measuring stick in the industrial arts program. The following quoted statements of objectives may be realized from proper experiences in industrial arts:

1. To explore industry and American industrial civilization in terms of its organization, raw materials, processes and operations, products, and occupations.

2. To develop recreational and avocational activities in the area of constructive work.

3. To increase an appreciation for good craftsmanship and design, both in the products of modern industry and in artifacts from the material cultures of the past.

4. To increase consumer knowledge to a point where students can select, buy, use, and maintain the products of industry intelligently.

5. To provide information about, and--in so far as possible--experiences in, the basic processes of many industries, in order that students may be more competent to choose a future vocation.

6. To encourage creative expression in terms of industrial materials.

7. To develop desirable social relationships, such as cooperation, tolerance, leadership and followership, and tact.

8. To develop a certain amount of skill in a number of basic industrial processes. (26, pages 42-43)

If the teacher of industrial arts will keep these objectives in mind when establishing a course of study, or revising the old course, and adhere to these objectives, then, the demands of society, both democratic and industrial, will be attained. However, a teacher must keep in mind that for a student to do his or her best work the shop or classroom must be adequately lighted. If sufficient light can not be obtained from natural lighting, that light should come from artificial sources that have been designed, planned, and installed by an expert on lighting techniques. A well designed classroom, as well as clearly defined objectives are necessary for the best teaching to be effective.

CHAPTER IV

LIGHTING FOR SHOPS AND SPECIAL CLASSROOMS

Artificial light sources have been available for centuries, but they have been relatively so expensive and the illumination they gave so meager, it is to be doubted that they were often used for close work if it could possibly be done by daylight. In recent years scientists have developed light sources that are much more efficient and, when well designed, can produce illumination that rivals daylight.

The mind demands clear visual sensations. If seeing becomes difficult because of inadequate or badly adjusted lighting, the eye will call on all its powers to produce clear visual images, although strain may result. The eyes become tired and there are other symptoms whose origin is often not recognized, such as headaches, nervousness, and nausea. To what extent strain contributes to permanent impairment of vision is a matter of debate, but it does contribute to discomfort and inefficiency in doing visual work, and it increases general fatigue. If a person adopts awkward posture for working because seeing is difficult, such a position may, if prolonged, result in postural defects which can affect the health adversely. (10, page 209)

Defects of vision develop from a variety of causes, such as malnutrition, desease, and accident. There is evidence to indicate that some cases of defective sight may be the result of using the eyes under poor conditions, for investigations have shown a positive correlation between the amount of close work done, or poor lighting conditions, and the percentage of workers who suffer from defective sight. (23, pages 56-61). It seems reasonable, therefore, that every effort should be made to eliminate poor lighting so far as it is a factor in causing or aggravating strain or defects of sight. Good lighting is a common-sense precaution for better health and safety.

Advantages of Good Lighting. In addition to the possible conservation of eyesight itself and the preservation of individuals from the evils of eyestrain, many business and industrial firms have found that good lighting pays.

Increasing the amount of illumination and improving the quality of the lighting have been found to increase production. (16, page 277). Just how far the lighting must be improved before there is no further increase in production varies with the difficulty of the visual task. Seeing, however, contributes only a part of all the powers necessary to perform any task and there comes a point where other factors prevent further increases in the rate of production even when further improvement of the lighting might lessen the demands on the eyes.

Not only is production raised by improving the lighting, but spoilage is decreased. (18, pages 134-35). A large number of spoiled articles may not indicate exacting standards of work so much as it demonstrates that workers cannot see what they are doing. (24, pages 57-58)

Automobile drivers have more accidents at night than in the daytime. It is sometimes hard to disentangle the factors contributing to an accident, but there are fewer accidents in places that are well lighted.

Workers with defective vision may not do satisfactory work even when they wear proper corrective glasses, for in many cases they cannot adjust themselves to poor seeing conditions as easily as those whose eyes function well. When good conditions are provided, it is possible to make full use of skill.

Maintenance is easier and more effective when lighting conditions are good. If dirt cannot be seen, it is not likely to be removed. Likewise, damage that is slight may go unnoticed until it has become serious if seeing conditions are poor.

Employee morale is improved by more cheerful surroundings. Good morale tends to lower the labor turnover, and that in time lowers production costs.

The school should be even more interested in the welfare of students than the employer is in his employees. It may consider that it has done well if the students and the community show improvements in health, happiness, conduct, and working efficiency. Good working conditions in school are important if the school is to do its work to the best advantage.

Production in factories is increased by improved lighting and some observations indicate that learning takes place more easily in well-lighted rooms than in rooms that are poorly lighted. (10, page 227). If that is true in academic classrooms, it would be equally true in rooms where the tasks more nearly resemble those of office and factory. (5, pages 146-47)

Certain types of work done in schools have an accident factor which should be reduced to the lowest possible point. School authorities have been held responsible for accidents in the buildings or grounds which resulted from inadequacies in the safety provisions. The cost has not been negligible. Good lighting is one of the best and easiest ways to promote safety.

It is important that pupils with very defective sight should be placed in sight-saving classes, and those who have lesser defects should be shown every consideration. They will be better able to keep up with pupils with normal eyes if the seeing conditions are favorable.

Pupil morale is just as important as employee morale. Pupils learn better in cheerful surroundings, while drab surroundings help to make them dislike school.

Architects and school officials should consult a lighting specialist in planning a school building so as to make certain that the lighting will be in harmony with the architecture and adequate to the uses of each part of the building, and that enough money will be set aside to meet the lighting needs. Good lighting is so important to the students' welfare that no risk should be run of having to reduce the efficiency of the lighting in order to economize on expenditures at the last minute because not enough attention was given to the problem from the start.

Principles of Good Lighting. The principles of good lighting are everywhere the same, but the applications differ. What constitutes good lighting depends chiefly on the visual task, the length of time the task is to be performed, and the surroundings. Individuals vary in their lighting needs and preferences, but where groups of people work together it is usually possible to meet only the needs of the average person.

Human eyes vary from excellent to useless. Some pupils in school have sight so poor that they are assigned to sight-saving classes. Many who are not eligible to sight-saving classes have defective sight that lessens their efficiency. Others have lesser defects, and the rest have normal vision for their age. Children entering school usually have good eyes, but their sight is not "normal" in that many are slightly farsighted. Among older pupils there are fewer cases of farsightedness, as it usually disappears with growth, but there are more cases of other types of defects. (22, pages 13-15). It has been said that children do not spend enough time in school for the conditions there alone to affect their eyes. That is possible, of course, but it is not an excuse for the school's contributing to the cumulative effect of poor conditions in and out of school by neglecting the lighting. The lighting needs of persons with different defects are not all the same. Even among those with normal sight, preferences for amounts of illumination vary. (16, pages 351-53). Unfortunately it is not possible to provide lighting ideally suited to the needs of each pupil; it is possible only to provide for a reasonable average. A reasonable average in schools will be enough better than that needed by those with normal vision to take care of those whose eyesight is affected by poor lighting. Such lighting will do no harm to normally sighted individuals.

The eye adjusts itself to the general level of illumination over a wide range of intensities which accounts for the disagreements among those interested in lighting as to the most favorable amounts of illumination for the performance of average visual tasks. However, the eye cannot adjust to different amounts at the same time. Changing from one to another means that the eye must readjust, and that takes time. Frequent changes are fatiguing.

It has been found also that for greatest comfort and ease of seeing the difference in brightness between the brightest and darkest areas within the range of vision should be small. A high contrast of brightness is desirable for seeing the details of an object being examined closely, as black print on white paper, but if the white page of a book lies on a dark desk top, or the room around it is dark, there is discomfort, the cause of which is not always recognized. Similarly, it is difficult to examine a dark object in bright surroundings. Therefore, good lighting practice demands that the ratio of brightness between the brightest and darkest areas should be as small as possible, 3 to 1 or even less.

To achieve even illumination and low contrasts of brightness, the light should be diffused and evenly distributed. Shadows are needed to define shape but they should not be too dark. One should be able to distinguish the object from the shadow. Multiple shadows are confusing, but well-diffused lighting prevents them. It may be necessary to supply extra illumination at the work space because it would not be feasible to supply a high level of illumination over a large area, but the contrast must be kept as low as possible else every time a person looks up from his work he will have to adjust to dark surroundings, which is tiring and slows down work. (9, page 6). Likewise, the limitations of the eye for adjusting to differences in the amount of illumination demand that the light be steady and not flickering.

Light that shines into the eyes in such a way as to interfere with clear and comfortable seeing is known as glare. Most people are aware of glare from bare electric bulbs, or expanses of white sand or snow in the midday sun, but there are other sources of which people are less aware. Reflections from the glossy pages of a book or magazine or any other shiny surfaces are a cause of glare. All glare should be minimized as far as possible, for many authorities on lighting and the care of the eyes consider glare one of the most potent causes of strain and possibly of defects of vision.

The reduction of glare requires that light sources be concealed or shielded. It might not be possible to shield them enough for comfort, and in this case the solution is to remove them as far from the direct line of sight as possible for a glare source is less troublesome if it is not near the line of sight. Careful shielding and placement of light sources are helpful, but they are not enough. Shiny surfaces that reflect the light in bright spots should be eliminated, as reflected glare is as bad as direct glare, and often harder to discover.

People with sensitive eyes sometimes experience discomfort if the light by which they work is not of a spectral composition that approaches daylight, indicating that daylight or "white" light is best for the eyes. (6, page 51). Most modern illuminants are near enough to white in composition to cause difficulty only in exceptional cases. The light from incandescent lamps often seems more yellow than it actually is because of the effect of shades and reflectors, but people are accustomed to it and most of them find it acceptable. Fluorescent lamps are richer in blue, violet, and yellow-green light waves than incandescent lamps. Some people object to the effect as too cold looking, but it should be possible to get used to it. It is unfortunate that some installations have not been carefully controlled according to the best lighting principles and practices. Some people have found fluorescent lighting uncomfortable, due principally to unshielded lamps or a lack of control to reduce a flickering effect. (9, pages 7-8). Fortunately the majority of people can work under illumination from any source provided it is suitable in amount and properly controlled. Daylight quality is usually necessary only where color discrimination is important. It should closely approximate the standard color temperature for daylight which is 6500 degrees Kelvin.

The amount of illumination needed varies according to the visual task. A number of factors determine whether an object is easy or difficult to see. It is easier to see black print on white paper than black thread on black material under the same illumination. Therefore, contrast with the immediate background determines how much illumination is needed. Again, small objects are harder to see than large ones, but they are made easier to see if the illumination is increased. If a visual task involves rapid seeing, as of moving parts of machinery, more illumination is needed, for tests show that it takes time to see, but the time required is less under better lighting. At night one cannot read the signs that dot the roadways because it takes too much time for the eyes to decipher them. In daylight they cause no difficulty. Light-colored objects reflect a greater percentage of the light received than do dark-colored ones, and are, therefore, easier to see. Since many objects which one must examine closely can be changed only slightly, it is necessary to change the lighting to provide good seeing. Tests indicate that for ease of seeing equal to that of reading 8-point type under 10 foot-candles of illumination, some tasks would require hundreds of foot-candles of illumination. Since the highest amounts recommended for ordinary use do not approach that high level, or even the level of daylight by the window on a clear day, they should not be considered too high, but rather a practical compromise with what many consider ultimate desirable objectives.

A difficult visual task performed for a few minutes can be done under poorer illumination than one performed for a longer time. The eye's adaptability and reserve powers make it possible, but it is a practice to be shunned. Reserve powers should not be called on for prolonged work if strain is to be avoided.

Good lighting, in short, is well diffused with a light source concealed or shielded, evenly distributed, steady, free from glare (direct or reflected), adequate in amount for the visual task, and of a color composition that is satisfactory for the use to which it is put.

Visual Tasks in Schools. The increasing variety of activities given in schools means that there is a corresponding increase in the number of different visual tasks carried on. Since good lighting varies according to the task, it follows that classrooms must have lighting which is prescribed according to the activities in each.

Among the various kinds of vocational training given in schools are courses in stenography, typing, use of office machines, drafting, woodworking, machine shop, electrical shop, welding, forge, mold, automobile repair, dressmaking, restaurant management, beauty services, practical nursing, barbering, and others. Different schools give different combinations.

Since the size and orientation of classrooms for special subjects vary, it is not possible to prescribe categorically in a few paragraphs for each type. Only general requirements can be laid down at this point and enough specific applications suggested to furnish a guide as to the factors that must be considered in planning a lighting installation. The complexity of the problem means that the lighting must be planned to fit the circumstances. While the competent electrician or contractor may be helpful, for satisfactory results specialists in the field of lighting need to be consulted.

The table given below presents a classification of visual tasks and the illumination recommended by illuminating engineers for each group of tasks as representative of present day thinking and experience. The recommendations are not to be taken as absolute or final. They represent a reasonable compromise between the illumination required for easy visibility, the cost of the installation and its maintenance, and present day practices.

Ophthalmologists' opinions in the matter of the required amounts as improvements in light sources have made it possible to provide a generous amount of illumination without glare. Illumination is measured in foot-candles (which is defined as the illumination on a surface one foot square received from a source one foot away which emits one candlepower in the direction of the surface.) (1, page 296)

TABLE I

FOOT-CANDLE RECOMMENDATIONS ON A BASIS OF THE VISUAL TASK AND REQUIREMENTS OF PERFORMANCE

<u>100 foot-candles or more</u> - For very severe and prolonged tasks, such as fine needlework, fine engraving, fine penwork, fine assembly, sewing on dark goods, and discrimination of fine details of low contrast, as in inspection.

<u>50 to 100 foot-candles</u> - For severe and prolonged tasks, such as proofreading, drafting, difficult reading, watch repairing, fine machine work, average sewing and other needlework, and machine shop inspection.

<u>20 to 50 foot-candles</u> - For moderately critical and prolonged tasks, such as clerical work, ordinary reading, common benchwork, and average sewing and other needlework on light goods.

<u>10 to 20 foot-candles</u> - For moderate and prolonged tasks of office and factory and when not prolonged for ordinary reading and sewing on light goods.

<u>5 to 10 foot-candles</u> - For visually controlled work in which seeing is important, but more or less interrupted or casual and does not involve discrimination of fine details or low contrasts.

<u>Under 5 foot-candles</u> - The danger zone for any visual task, and for quick and certain seeing. Satisfactory for perceiving larger objects and for casual seeing.

(16, page 345)

The levels of illumination recommended for schools which are given below were published in 1941. The figures are approximate, for the needs would vary from school to school. Except for levels of 10 foot-candles or less, circumstances would dictate whether variations of as much as 30 per cent lower or 40 per cent higher would be acceptable. The recommendations again represent a compromise among various factors affecting the choice of lighting. Local illumination, as referred to in the following table, does not indicate that no general illumination is required. About 30 foot-candles should be provided by general illumination. (21, page 52)

TABLE II

LEVELS OF ILLUMINATION RECOMMENDED FOR SCHOOLS

Place	Foot-candles
Auditoriums	10
Class and study rooms--desks and chalkboards	30
Corridors and stairways	5
Drawing rooms	50
Gymnasium	20
Laboratories -	
General	30
Class work - local illuminations	50
Lecture rooms -	
General	20
Special exhibits and demonstrations local illumination .	50
Lunchroom	10
Sewing room - local illumination .	100
Shops (See specific recommendations)	
General	30
Close work - local illumination	100
Sight-saving classes	50
Washrooms	10

(12, page 11)

The above list gives values that are comparable to the practice in recently installed lighting systems in offices, factories, and public buildings. It should not be difficult to achieve them with an up-to-date installation. However, the lower values given in the American Recommended

Practice of School Lighting may still be followed, and they are higher than what is found in many classrooms. It is always better to provide an excellent quality of illumination and a somewhat smaller amount than a greater amount but poor quality.

It is necessary to turn to the recommendations for industry and office to find out what should be provided for tasks carried on in special classrooms. What follows is a list of selected tasks of office and factory. Again these requirements are not absolute, and circumstances will dictate how closely they may be followed. In general, a deviation from 30 per cent lower to 40 per cent higher would be satisfactory.

TABLE III

FOOT-CANDLE RECOMMENDATIONS FOR TASKS OF SHOP AND OFFICE

Type of work	Foot-candles
Automobile repair	50
Bookbinding -	
Folding, assembling, pasting, etc.,	10
Cutting, punching, and stitching	20
Embossing	20
Cooking -	
Baking	20
Candy making -	
Ordinary	20
Hand decorating	50
Canning and preserving	20
Clothes making -	
Cutting, inspecting, sewing -	
Light goods	30
Medium goods	100
Dark goods	200
Pressing -	
Light goods	20
Medium goods	50
Dark goods	100

TABLE III (Continued)

Type of work	Foot-candles
Forge shops and welding	10
Foundries -	
Changing floor, tumbling, cleaning, pouring, and shaking out	5
Rough molding and core making .	10
Fine molding and core making . .	20
Machine shops -	
Rough bench and machine work .	20
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	30
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing	100
Extra fine bench and machine work, grinding, fine work . . .	200
Printing -	
Presses	30
Imposing stones	100
Proofreading	100
Sheet metal work -	
Miscellaneous machines, ordinary bench work, punches, presses, shears, stamps, spinning, medium bench work	20
Woodworking -	
Rough sawing and bench work	10
Sizing, planing, rough sanding, medium machine and bench work, gluing, veneering, cooperage	20
Fine bench and machine work, fine sanding and finishing . .	50
Welding	30
Bookkeeping, typing, accounting, reading shorthand notes	50
Business machines	100
Drafting rooms	50
Filing and index references	30
Barber and beauty shops	50

(21, pages 45-54)

Wherever more than 30 foot-candles are needed, except possibly in sight-saving classes, it will probably be necessary for the sake of economy to provide it by means of a combination of local and general illumination. The general illumination in such cases should provide from 20 to 30 foot-candles with the rest provided by local lighting fixtures. It should be remembered that for some processes requiring less than 30 foot-candles, the nature of the task calls for special lighting. In some cases there must be illumination for parts of a machine not reached by light from overhead sources; sometimes directional lighting is needed, and sometimes the general lighting fixtures must be of a certain type if the effect is to be satisfactory. Moreover, it must not be taken for granted that the only way to provide proper illumination is from artificial sources. Artificial sources must be provided wherever there is the slightest possibility that the room will be used at night. Otherwise, the most practical way is to provide illumination received from a combination of natural and artificial sources, with special attention to areas distant from natural light sources.

Natural Lighting. The control of natural light is difficult. In many states only unilateral lighting (which is natural light that comes into a room from windows that are placed only on one side of the room) is permitted, but it presents the difficulty of uneven levels of illumination because the illumination falls off rapidly as one moves away from the windows, the decoration of the interior, and the placement of furniture and equipment, the difficulty may be overcome to some extent, but for really satisfactory results, it is usually necessary to combine artificial with natural lighting.

Experiments in bilateral lighting (which is natural light that is allowed to enter through windows of the usual size and position and through windows placed high on the opposite side of the room) have been successful but they usually call for sloping roofs. As sloping roofs are possible only in one-story buildings, the cost would often be prohibitive. The construction itself is expensive and the cost of land in many areas is too high to allow the schools to be spread out in one-story buildings. Saw-tooth construction, used in factories to supply natural lighting for large areas, is expensive. The land required would also be expensive. Keeping so much glass clean makes the cost of maintenance high, yet the purpose of the construction is defeated if the glass is not kept clean.

Even with the best natural lighting, it is necessary to use artificial lighting on dark days and at night, so the most reasonable arrangement is to supply a combination of the two that will give even, well-diffused, glare-free illumination in each room at a moderate cost for construction and maintenance.

The glass area of windows should be equivalent in size to 25 per cent of the total floor area. The top of the glass area should come within 6 inches of the ceiling, but the bottom should be 3 or 4 feet above the floor. Experiments show that tall windows give more light to the far side of the room than wider and shorter ones of the same area. (25, page 46). Mullions between windows should be narrow to prevent shadows. The width of the room should not be greater than two and one-fourth times the distance from the floor to the top of the glass area. To prevent glare on a chalkboard at the front of the room windows are ordinarily placed 4 feet or more from the front wall. However, the proper shading of the windows near the front of the room makes it possible to admit light without causing glare on the chalkboard. At the rear of the room the edge of the glass area should be as near to the wall as possible. In short, the glass area should be as large as the structural strength of the walls permits.

If windows receive direct sunlight, they must have shades to control the light. Ordinarily it is not necessary to use shades for any other purpose. Teachers should be encouraged not to draw the shades more than is really required, regardless of the appearance of the exterior of the building. On the other hand, it is a responsibility of teachers to be ever watchful and adjust shades whenever glare of any kind (direct or reflected) or amount comes through the windows.

If roller shades are used, they should be wide enough to permit no light to come in around the edges. It is advisable to have two shades for each window; one shade directed up and the other down. The space between the rolls should be shielded to prevent light from entering. Such an arrangement makes it possible to admit light from the top of the window which supplies most of the illumination for the far side of the room, even when there is reason to cover the lower part. The shade over the lower part of the window may be attached to the bottom of the frame and directed upward also. Shades should be light in color to reflect artificial light well, dense enough to diffuse daylight but not so dense as to cut most of it off, and sturdy enough to be washed.

Venetian blinds are generally satisfactory for they admit more light than roller shades when in use, yet they redirect it so that it is well diffused, and glare from the sky is avoided. They should be a color which reflects at least as high a percentage of the light as the side walls. Venetian blinds may be white or off-white. They can be rolled up entirely when not in use. The principle objections to Venetian blinds are that they are hard to keep clean and get out of order somewhat more easily than roller shades. Fixed louvers over the upper part of the windows have been used in some places in order to avoid objectionable glare from the sky. Instead of covering the upper part of the windows with shades or louvers, or Venetian blinds one successful experiment for spreading natural light over more of the room used frames covered with white muslin and hung at an angle over the whole upper part of the windows. Part of the light was reflected up to the ceiling and the rest diffused through the muslin into the room. The lower part of the windows was provided with shades as ordinarily is done. It has been suggested that glass block might be used for the upper part of the window space to serve a similar purpose. If carefully chosen and placed so that the light is diffused and directed up to the ceiling to be reflected throughout the room, the results might be worth it. However, such an installation must be carefully made or an expanse of glass block might turn out to be nothing but a source of glare.

Sky glare does not bother all the pupils in the traditionally arranged classroom but only those in a certain part of the room. If a line is drawn from the edge of the glass area nearest the front of the room to the rear of the opposite side at an angle of 40 degrees to the plane of the glass, the pupils seated behind the line are troubled by sky glare. (10, pages 219-24). The difficulty can be overcome by turning desks, or work benches in many cases, at an angle. The pupils in front of the line are not bothered by glare and may even get increased illumination by turning the desks slightly toward the windows. A number of possible arrangements of equipment have been suggested following this principle, and the person responsible for installing furniture and equipment should study the possibilities with a view to the best possible arrangement with respect to natural lighting.

Artificial Lighting

Artificial lighting must satisfy two needs. It must supplement natural lighting, which is often inadequate, and it must supply the amount and kind of illumination needed at night. Usually artificial light is needed all day in the inner side of any room more than 25 feet wide. Schools are more and more being used at night, especially for vocational classes. Day students sometimes wish to take courses which they cannot get during the regular school hours. Adults want additional training or refresher courses which they can get only at night because their hours of work prevent their attending daytime classes.

General lighting alone is often sufficient in special classrooms which require an amount of illumination equivalent to that of academic classrooms. More illumination can be provided by an up-to-date installation, but in the classroom of the usual size, measuring from 18 to 24 feet wide, 27 to 36 feet long, and 11 or 12 feet high, with six lighting outlets in the ceiling, it is not usually possible to do so and have a satisfactory quality of lighting.

Fixtures should be chosen according to the type of work. If reflections from shiny surfaces are a problem, the light source should be one of wide area and low brightness, as is the case with indirect lighting. If the tools and materials are nonglossy, the choice of fixtures is wider. One may select any one of a number of industrial units which meet a high standard as to efficiency, low brightness of visible parts, and ease of maintenance.

Even where the principal illumination on a work space comes from supplementary units, general lighting units must be chosen with a view to the work. For example, in a machine shop where local lighting units are often used the problem is one of reflections from metal surfaces. The local units could not entirely overcome reflections from small, relatively bright general lighting fixtures. Both general and local light sources should be of wide area and low brightness.

Usually, general lighting units must be placed high enough to be out of the normal range of vision of the person at work, except that totally indirect fixtures may be hung at the most advantageous height for the lighting effect. A brightness of visible surfaces of 3 candles per square inch is permissible though one is better. That means that both incandescent and fluorescent lamps must be shielded from direct view. (9, page 7). Sources should not be seen against a background that provides a high contrast. A ratio of brightness between source and background of 5 to 1 will serve, but a contrast of 3 to 1 is much better.

Local lighting is more properly referred to as supplementary, for it should not be used alone but to supplement general lighting when the latter does not fully serve the purpose. When in use, a local lighting unit should not furnish a high contrast between the illumination of the work space and the surroundings. A contrast in brightness of 4 to 1 is comfortable but one of 2 to 1 is more so. The light must be carefully shielded and directed so as not to provide discomfort for either the individual using it or for others working nearby. Moreover, it must be out of the way. Sometimes it may be placed within a few inches of the work space, but it may have to be placed overhead, high enough not to be bumped into.

Precautions must be taken that light is not reflected directly into the eyes of the worker or adjacent workers. A little study of the angles will show that it is not difficult. If different sorts of tasks are carried on at one spot, or students of different sizes use it, it may be advisable to mount fixtures on movable arms for adjustment as needed. However, students may regard making the changes as a nuisance, and permanent adjustments may therefore serve the purpose better.

<u>Incandescent lamps</u> are steady and it is relatively easy to provide more illumination from an existing outlet if it is needed, as the bulbs are usually interchangeable. Many types of fixtures have been designed, and almost any required distribution can be obtained. Most of the fixtures designed for commercial purposes can easily be kept clean and in good working order. Both lamps and fixtures are inexpensive. Lamps of the sizes used in schools last about 1000 hours before they become so blackened as to have a greatly lowered efficiency. They are less efficient than fluorescent lamps in the consumption of electricity for much of the electricity used is converted into heat. The expense of operation over that of fluorescent lamps is not always an important factor in average school use. The light emitted is rich in yellow and red light waves and low in blue and violet light waves. The effect is warm and pleasing to most people, but it is not good for fine color discrimination unless special filters are provided. Such filters are usually preferred to blue "daylight" bulbs because they are more carefully standardized. Filtering the light to achieve daylight quality lowers the efficiency of the lamp, but the result is often worth it.

In general, either incandescent or fluorescent lighting may be used in appropriate installations.

<u>Fluorescent lamps</u> give light with a color composition which approaches that of natural light, although the different so-called "white" lamps vary somewhat. The daylight lamps are nearest to natural light and are recommended for rooms where their light must blend with daylight. The lamps are low in red and orange light waves and rich in blue, violet, and yellow-green light waves. Blues and greens are emphasized; yellows tend to look greenish, and reds are dulled. However, the effect is lessened with high equipment but the

possibility should be considered. Much care must be used in planning the installation because the tubes vary in length. Longer tubes are more efficient, but cannot be substituted for short ones if too little illumination is provided by the latter. The fixture must be changed.

TABLE IV

RATED LIFE OF FLUORESCENT LAMPS

Lamp	Burning hours per start	Rated average life (hours)	Per cent of initial lumens per watt at 70 per cent of rated life
6-watt	3	2500	75%
8-watt	3	2500	75
15-watt T-8	3	2500	77
15-watt T-12	3	2500	82
20-watt	6	4000	78
30-watt	6	4000	76
	12	6000	72
40-watt T-12	12	6000	70
100-watt	3	3000	81
	6	4500	75
	12	6500	72
			(1, page 97)

Various objections have been made to fluorescent lamps, but with the use of slim tubes and circular or ring-shaped tubes, and with well-designed fixtures, there is no reason why they should not serve many purposes, especially those for which incandescent lamps have never been completely satisfactory. Using combinations of fluorescent and incandescent lamps according to thoughtful plans should solve most lighting difficulties. There is a definite trend in this direction at present.

The spectral composition of light is important in art work and color printing where it must be possible to discriminate color closely, but is sometimes overlooked that it is impossible to tell brass from copper under light of some compositions. Therefore, it is sometimes advisable to consider the use of daylight quality of light in the school.

Fixtures for incandescent and fluorescent lamps and for local and general lighting have been designed giving the types of distribution described in the following paragraphs.

Direct lighting units, technically speaking, send 90 to 100 per cent of the emitted light downward to the work space. Because they give more illumination per watt of electricity used, their operation is economical. Also maintenance is easy, for the ceiling and walls play comparatively little part in producing the lighting effect on the work space. However, it is difficult to diffuse the light well. Dark shadows appear and the fixture itself may be too bright for comfort. Harmful glare is more apt to be produced. Direct lighting fixtures are somewhat difficult to handle in general lighting installations but may be useful for local lighting for certain types of work. It is possible, however, to secure satisfactory fixtures which shield the brightest surfaces from the eyes.

Indirect lighting fixtures send 90 to 100 per cent of the light output up toward the ceiling from which it is reflected downward toward the work space. Spreading the light out over a wide area reduces the brightness of the light source and hence eliminates any direct glare. In large areas in which 40 to 50 foot-candles of illumination are provided, the ceiling may be uncomfortably bright, especially if low, but below that level indirect lighting furnishes one of the easiest ways to spread the light over the room with even distribution and good diffusion. The fixtures must be hung low enough to spread the light well, or the spot just above each one will be too bright. The lighting effect of a good installation is soft and generally satisfactory.

Indirect lighting blends well with local lighting which can furnish more illumination where needed and is the easiest artificial lighting on the eyes. Indirect lighting requires that the ceilings have a reflection factor of at least 80 per cent and the walls 50 per cent. They must be kept clean. Otherwise much possible illumination is lost. The reflecting surfaces of the fixture itself must likewise be kept clean. Because some light is lost by being reflected, indirect fixtures require the use of more watts of electricity for a given amount of illumination.

Semidirect fixtures send 60 per cent or more of the light downward and the rest upward. Semi-indirect fixtures send 60 per cent or more of the light upward and the rest downward. In each case, good maintenance involves keeping the ceilings and walls clean as well as the fixture itself. If the fixtures are well designed and adjusted, they may combine many of the advantages of both direct and indirect fixtures, but poorly designed and adjusted they combine all their disadvantages. They consume less current than indirect fixtures, but the amount varies.

General diffusing units (which are electrical fixtures that have large white globes that cover the bulb and diffuse the light. The globes may vary in size to fit the need.) send out light in all directions. In spite of the name, it is not easy to provide well-diffused lighting with them. The globes are frequently glare sources if they are near the direct line of vision, for they are often too bright. Care must be taken to have the globes large and dense enough in proportion to the size of the lamp used to reduce the brightness to a satisfactory point. The consumption of electricity for the illumination provided is somewhat more than for direct lighting units. Maintenance is a factor, for walls and ceiling play a part in reflecting light to the work surfaces. The globes themselves must be kept clean or there is considerable loss in efficiency.

In applying any of the types of lighting fixtures, all the requirements of good lighting must be kept in mind. If any room must be used for seeing tasks of varying severity, the most difficult tasks should govern the selection of the lighting. For instance, if a machine shop is used for both beginners and advanced students, the finest work done by the advanced students must govern the lighting.

Various types of general and supplementary lighting units are made for industrial and commercial use. Those used in classrooms must be sturdy enough to resist vibrations and other hazards, and easily kept clean. The lighting installation must provide the quality of illumination which is the best possible in the particular surroundings, and suited both to day school and night school uses.

Since school building designers, for the sake of economy, must plan lighting installations that will give satisfactory service over a long period of time, they must use care to select fixtures that are not likely to become obsolete quickly and be impossible to repair or replace. Where improvements are appearing rapidly, the possibility of obsolescence must be kept in mind and the advice of a lighting specialist sought to prevent the problem from arising.

Classrooms with Special Needs

Many classrooms have special lighting needs that are not met by ordinary classroom lighting. Some require more illumination than would be considered desirable ordinarily, especially where classes doing work of varying degrees of difficulty use the same room. Also some types of work have special needs and supplementary units furnish the easiest way to meet them. In some cases a special switching arrangement may be the answer.

Art - Natural lighting from the north sky has generally been sought for art rooms because there are fewer changes in the quality of the light during the day. Artificial lighting should give the closest possible approximation to daylight quality. The lighting should be even and diffused through the room, but since art students must study the effect of shadows, the stage or stand for casts and models should have special lighting which will allow shadows. To avoid confusing color effects, the walls should be neutral in color.

Drafting. Overhead lighting placed to cast even, diffused illumination over the whole surface of the drawing board or the table is needed. There should be no confusing shadows from rulers, T-squares, or drafting instruments. Care must also be taken that if there is any reflected glare from paper or lead pencil marks, the fixtures are so placed that the reflections are directed away from the eyes of the persons working at the tables. Diffused lighting is best because it is difficult to avoid reflections from pencil lines. When fluorescent lighting has been used for drafting rooms, it has been found that the continuous strip, multiple-tube type is possibly the most satisfactory. The fixtures may be placed parallel to the tables or diagonally for good results.

Electrical Laboratories. In electrical laboratories, various pieces of apparatus are taken apart and assembled as they are studied, and drawings are examined. Small parts are handled and connections are made and tested.

Since each piece of apparatus is turned from one position to another, and looked at from different angles, both general lighting and supplementary units may be needed. For fine work, local units should be installed at one or more benches so that light comes from both sides of the student. The units should illuminate both horizontal and vertical planes and give from 50 to 100 foot-candles depending on the fineness of details that must be discriminated. Confusing shadows must be eliminated, but at the same time the apparatus must not be flattened so that parts do not stand out from their background. Convenience outlets are needed on every table, including the demonstration table. To avoid running numerous wires from the ceiling, electric power sources must be laid in the wall so that openings can be made wherever they are needed. Many people make the mistake of having too few power outlets and it usually proves to be a great disadvantage when numerous machines are used.

Machine Shop. The fundamental task is to discriminate details on plane or curved metal surfaces. In general, the light should be reflected from a wide area of the surface, Indirect lighting fulfills the requirement if it can be used. Nearly all machines are well served by diffused light from a large area source. Outlets are needed on each machine for supplementary lighting for specific operations. Manufacturers may provide fixtures designed especially for the machine, but a lighting specialist can recommend suitable fixtures also. All local or portable units should have guards to prevent breakage and possible electric shocks.

Much of the work depends on reading measuring instruments such as metal rulers, micrometer calipers, dials, and scales. The measurements are cut into the surface and are most easily seen when the surface reflects light and the marks look dark by comparison. Preferably the whole of the instrument should be readable, as it is if the light source is of wide area. If the scale is curved, enough should be illuminated for accurate reading. For example, if a scale is divided into 100 parts with every tenth mark numbered, at least ten marks should be easily read.

Many scales and dials are in fixed positions on the machines, which complicates the lighting problem, for all must be readable. Sometimes scales are shaded by part of the machinery. In that case it may be possible to mount a reflector with a white, diffusing surface to illuminate the scale by reflected light without interfering with the operation of the machine, but keeping the white surface clean would be a problem. Often some part of a machine, the inside of the hood on an internal grinder, for instance, can be finished in white or a light color to help seeing by reflecting light to points not reached directly by light from any source.

Among the tasks done at a bench, scribing the metal (scratching lines on the surface as a guide to the work) is one of the most difficult seeing tasks. If a large area, low brightness source is used, the lines on the metal should look dark in the light surface. It is helpful sometimes to use one of the easily removed dark stains on the surface, for the scribed lines will then appear light in the dark surface. A similar seeing task is that of milling to a scribed line, and it is complicated by the presence of the milling tool. A diffusing source mounted close to the work surface, but illuminating a large portion of it, is recommended to solve the difficulty.

The drill press presents a different problem, that of seeing that the drill is centered at a given point on the surface of a piece of metal. If a unit of low brightness is mounted on the press behind the drill to cast diffused light at the work surface, the light will be specularly reflected from the metal and the drill silhouetted against the light surface, making the seeing task much easier. Actually better visibility is obtained if the source is on the same side as the eye, but in practice it is difficult to attain this position.

The inspection of polished surfaces in a machine shop presents a variety of difficulties. The lighting need varies according to the type of mark and the size and shape of the piece. Deep marks are best seen by contrast with a light surface, made so by specular reflection of a light source of wide area. Slight scratches may be seen if the surface appears neutral and directional light is reflected by the sides of the scratches. Chatter marks (ripples on the polished surface) show if a luminous panel marked with parallel black lines is reflected by the surface as by a mirror. The black lines will appear distorted if there are chatter marks.

For good visibility it is possible to finish machines in colors that provide a contrast between the work space and the remainder of the machine, and between stationary and moving parts. It should be given careful consideration. The question is discussed more fully in the section on classroom surroundings.

Print shop. The variety of tasks found in printing demands different sorts of lighting in different parts of the shop. General lighting is required and local units must take care of special needs. At the desks where copy is prepared or proofs read, a high amount of diffuse illumination is needed. Units must be placed to prevent reflected glare from the paper. For examining printed material to determine whether the ink is of the proper color (for to the printer black is a color) or to compare color printing with the artist's copy, daylight quality illumination is required. If not much such work is done, it may be enough to examine proofs at the windows, but daylight varies to such an extent and night school work is so important that it would be wiser to provide light of known spectral composition for uniform results.

Typesetting by hand should be done under illumination that is well diffused, as from indirect lighting, and covers both the copy and the type cases. The slanting cases of type are sometimes placed back-to back with the workers facing each other. A fixture mounted over the two cases low enough to shield the eyes of the workers from direct glare should cast a diffuse illumination that will not cause troublesome reflections from the type or confusing shadows from the workers' hands. If a school is equipped with linotype and monotype machines, there should be diffuse illumination over copy and keyboard, and the place where the matrices are delivered, so that they may be examined. The general lighting should be adequate for making adjustments of the machinery.

Type presents the problem of reflections from the metal surfaces, sometimes very confusing reflections when the type is old. A large-area, low-brightness fixture hung high enough to be out of the way over the imposing stone where the forms are worked on should solve the seeing problem. If there is storage space under the stone, general lighting should be adequate to see into it if the worker has to get out supplies.

At the presses it is necessary to see the type, ink rollers, controls, and the paper as it is fed into and removed from the press. Just where extra lighting units should be hung will depend on the type of press and its relation to other equipment. The movement of a small press may cause a flickering of light that will bother someone near by. Therefore, the placement of presses should be studied. Often if the press is close to the wall, the worker stands where he casts a shadow on the press, but if it is close to the window, he looks at the press with light from the window in his eyes. That is why careful placement of a local unit is important.

A special fluorescent fixture is made to be attached to a paper cutting machine (guillotine) to enable the worker to see under the jaws of the machine to make sure paper is evenly stacked and to see the blade. Safety demands its use, or one similar to it.

Bookbinding is often done in a print shop, and one machine in particular needs special lighting. A stitching machine needs the unit made for it for otherwise either the machine or the worker is likely to cast a shadow directly on the work space, reducing the illumination much below what is required, although bookbinding operations do not require high illumination as a rule.

Numerous supply cabinets are another print shop problem. These are made as separate units or are built under imposing stones and type cases. General lighting units should be so placed in relation to such cabinets that they enable one to see into drawers and storage spaces. Hence there should be adequate illumination below the 30-inch height at which measurements are usually taken.

Sheet Metal Shop. The visual problem in sheet metal shops is reflection of light by the metal. The light sources are mirrored on the surface and the bright spots make seeing difficult. If a large area source is used, it is reflected in a large spot, or possibly the whole surface of the metal reflects the source uniformly. This makes it easier to see surface irregularities and the scribed lines (lines scratched into the surface to guide the work) for they appear lighter or darker than the surface according to the angle from which they are seen. Hence, indirect lighting, if the ceiling permits, is adapted to sheet metal shops, for with it the light source has the widest possible area. Otherwise a canopy-style fixture with a wide, low-brightness, reflecting surface, using silvered bowl lamps to prevent shadows from the student's heads or hands, will serve. The silvered bowl lamps direct the light upward so that sharp shadows are not formed. Such a fixture gives, in effect, indirect lighting. Other fixtures can give the same effect. One will be needed over each bench where the sheets of metal are scribed, because that is the most exacting task. A fixture to produce a similar effect is needed for cutting the metal because the scribed lines must be followed accurately. The light from artificial sources should be of a color composition that makes it easy to tell one metal from another. Solder tables have hoods over them, and the tables should be placed so as not to interfere with natural light. Lighting for these tables should be from special vaporproof fixtures.

Woodworking. Ordinary operations require diffused illumination of about 20 foot-candles causing no confusing shadows from worker or tools. A good quality of general lighting will be satisfactory in most schools. However, fine work requires about 50 foot-candles of diffuse illumination. If all the students using the shop are doing fine work, general lighting can be installed that provides it, but in most schools it would be better either to install general lighting which gives more or less illumination as needed, or general lighting as for an average academic classroom with additional units that can be turned on at will. The illumination should be diffuse but should not eliminate perception of depth. Light directed obliquely across the surface of the wood helps in the detection of flaws on the surface and it should be possible to have it in some part of the room. Furthermore, there are some machines used that may require special lighting. A supplementary unit attached to the machine will usually serve, especially if it is designed by the manufacturer for the purpose.

Automobile Shop - General, diffuse illumination of about 50 foot-candles is needed. It should not rob objects of their natural appearance of depth. Troffer lighting (lamps set into the ceiling in long troughs, with diffusing panels or louvers on the under side and flush with the ceiling) has been found satisfactory in service.

The most difficult problem is that of providing enough illumination inside and under the automobiles in the shop, and enough extra illumination when needed for tasks requiring fine visual discrimination. A very usual solution is to provide portable units on extension cords. Each unit must be furnished with a guard to prevent breakage, and it must be thoroughly insulated to prevent shock. The cords must be resistant to oil, with vapor-proof switches and fixtures on them.

Sometimes, in addition to portable units on cords, several units are mounted on a stand which can be moved where needed. Each fixture consists of an industrial angle reflector to direct light to the interior or sides of the automobile. In some shops pits are constructed over which automobiles can be placed for convenience in working under them. Lighting units are placed at each side of such pits to direct light upwards to the underside of the automobile and away from the eyes of the worker.

Instead of moveable stands of fixtures, it is possible to provide a number of stalls, one for each automobile, with supplementary lighting fixtures which can be turned on or off as desired. Even here it will be necessary to provide units on extension cords. For a school shop such an arrangement is less satisfactory because it makes demonstrations to the group more difficult.

To avoid having numerous long extension cords, which in themselves form a hazard, use should be made of portable panels. Each panel is connected by one cord with a wall outlet, and is provided with outlets, and fuses or circuit breakers for extension cords for four or six automobiles.

Underwriters' requirements regarding the height above the floor for wall outlets (usually four feet), the desirable types of fixtures and equipment, and all other safeguards should be closely followed not only for automobile shops but for all others as well.

Classroom Surroundings

No lighting is thoroughly satisfactory if attention is not given to the surroundings and equipment, for they can greatly reduce the effectiveness of the fixtures.

As in other classrooms, the ceilings of special rooms should be white or slightly off-white so as to reflect 75 to 85 per cent of the light received (reflection factor, 75 to 85 per cent). The upper part of the walls can often be white also. However, generally, somewhat darker colors are chosen for the walls, but the reflection factor should be from 50 to 60 per cent. Paint dealers can usually supply tables showing the reflection factors of various colors of paint under different types of lighting. Light reflected from walls and ceiling can greatly increase the general level of illumination without there being needed any increase in the amount of electricity consumed. (25, pages 17-26). In passing, attention should be called to the fact that the walls may be darker than the upper for the sake of maintenance, but it should be as light as possible. Some factories have "white" cement floors reflecting as much as 40 per cent of the light received, and for some operations, seeing may be materially aided by light diffusely reflected from the floor. Light-colored floors also make it easier to find objects that have been dropped, and they aid in maintaining cleanliness and safety as well.

Generally, people prefer to work in a cool atmosphere, and soft greens and blues which suggest coolness are often preferred in places of work. In cold climates other colors might be preferred, but much depends on the orientation of the room and the quality of the natural illumination received. Drab and lifeless colors are to be avoided simply because they are cheerless even if they reflect enough light. However, intense colors are not desirable either.

Shiny surfaces are to be avoided. It will not always be possible to have equipment and supplies that are not glossy, but woodwork, furniture, and painted surfaces should have a dull finish. Glass in doors and cabinets should have a rough finish.

Wherever wooden furniture is used, in typing and sewing rooms for example, it should be the natural color of the wood with a suitable wax finish for protection, for it provides a more comfortable contrast in brightness to white paper or material. Dark woods can be bleached to good advantage. The black of typewriters and other machines is not always necessary. They can be finished in lighter colors. Several colors suitable for machinery have been developed and are satisfactory in use.

Finishing ceilings, walls, floors, woodwork furniture, and equipment in white or light colors as indicated not only helps to raise the level of illumination without the use of extra current, but it helps to provide a desirable balance of brightness between the work space and the surroundings.

There is one place where a high contrast of brightness is needed and that is for all written work, books, and visual aids. The paper for written work and books should be opaque, white, and nonglossy. Even scratch paper for pencil work should not be a poor quality and deeply tinted. Ink for printing should be black and nonglossy and that used for writing should never be a watery, pale blue that will not produce a clear, dark line. It may need to be washable, but that need not interfere with good performance. Pencils should be soft enough to make a good black line, but they do not have to be so soft as to smear easily. Pencil work should be avoided because it takes about three times as much illumination to see most pencil writing easily as it does to see print. (16, page 181).

In any classroom where machines are used, especially dress-making, office machines, and machine shop, attention should be given to the question of improving visibility at the work space. If the machine and the materials used are the same color and brightness, the effect is one of camouflage. Making a difference in brightness at the work space helps, but it is still better to introduce a difference both of color and brightness. Moreover there should be a distinct difference in color between moving and stationary parts, operating levers, and the work space. A person thoroughly familiar with the working of the machine, the materials to be used with it in the classroom, and good seeing practices is the one to determine how desirable contrasts of color and brightness are to be achieved. Manufacturers have developed several colors, suitable for machinery, such as light buff, medium green, and neutral gray, to aid seeing. It must be remembered that high brightness contrasts at the work space are desirable, but not between the work space and the surroundings. School officials should consider these possibilities in buying machinery, for improved visibility makes work easier and reduces the accident hazard.

Most classrooms have some chalkboard space, but usually it does not need to cover the major part of the walls. These boards should have special lighting that can be turned off when they are not in use. Such lighting goes far to eliminate glare from windows which are not properly placed with relation to the board. Chalkboards are made that can be turned over easily when not in use. In old buildings it would be wise to consider converting most of the chalkboard space into bulletin boards, leaving a small space for demonstrations by the teacher. Light-colored chalkboards using dark chalk have been used in some places, and they present interesting possibilities, though care should be taken that they do not provide too bright an area for comfortable seeing.

No notice or displays of work should ever be placed on the walls between windows or next to them. The displays will be almost impossible to see because of the light from the windows shining into the eyes. Bulletin boards should be placed where they will get a high amount of illumination.

Maintenance of Lighting

Light-colored interior finishes cooperate with the lighting to produce adequate illumination and a comfortable balance of brightness. To do their part well always, ceilings and walls must be kept clean and be repainted at intervals. As much as 50 per cent of the possible illumination can be lost if ceilings and walls are dark or allowed to become darkened from soot and smoke. Good maintenance not only preserves the desired level and quality of illumination but it helps to preserve the building from too rapid deterioration.

The frequency of washings should vary according to the location of the school and the nature of the work carried on in each room. If soot and grime fill the air, the walls and ceilings may need washing three or four times during each school year and repainting about every two years. In other locations washing once or twice a year might be enough, with repainting as infrequently as once in five years.

Natural illumination is reduced by dirty windows and skylights. In some places they may need washing as often as once a week on the inside and once a month on the outside while in others they stay clean much longer.

Lighting fixtures themselves lose their efficiency if surfaces which reflect or transmit light are not clean. In order to make fairly frequent washing feasible, fixtures should not be located in inaccessible places. Neither should it be difficult to take them apart for washing.

Lighting maintenance does not end with cleanliness of fixtures and surroundings. Lamps tend to darken after long use. When first installed, they should give more than the performance desired because of normal deterioration. It is the average performance which should meet the stated requirements, not the initial performance. Sometimes lamps darken but continue to give some light long after their normal life is over. Incandescent lamps of the sizes commonly used in schools are intended to give good service for about 1000 hours. Fluorescent lamps are built to last considerably longer. [See table page 41.] After that time they use up just as much electricity as ever but give less light. Because they have become inefficient, consideration should be given to replacement. In order to save time it may be necessary to work out a combination schedule for washing fixtures and replacing lamps. A simple light meter costing less than $20 can be used to survey the lighting of schoolrooms. Local electric power companies might be willing to lend one for a survey of school lighting, but each school should have its own and take care to see that it is calibrated from time to time. Directions for using them may be secured when they are purchased.

Wiring Design

Good lighting is closely associated with wiring. Most communities specify safety regulations, but they might all be followed without the installation giving good illumination where needed.

First of all the consumer of lighting equipment and electricity should know what the lighting specifications are, and then he must weigh the factors that go into making a good wiring installation in order to determine a balance between initial cost and maintenance.

Large sizes of copper wire offer less resistance to the free flow of electrical energy and there is less waste, but they cost more to install. The balance to be struck will depend on the circumstances of each case.

Good voltage conditions must be maintained. There is some lessening of the voltage delivered to any point. If the general design for wiring is not good, there may be enough loss to decrease the efficiency of lamps and appliances, some of which are quite sensitive to a drop in voltage below that at which they are supposed to operate.

The wiring installation should be flexible enough to take care of reasonable changes in use and to allow for increased demands in the future. To make sure that the wiring is adequate, it is necessary to consider the number of branch circuits needed. The number depends entirely on the illumination requirements for the building and can be determined only after those requirements are specified. Convenience outlets, of which most schools need more than they have both for lighting and appliances, should be on separate circuits. The size of wire for these circuits depends on the expected maximum load.

If panelboards are conveniently located on each floor, fuses can easily be replaced or circuit breakers reset. For future expansion there should be at least one spare circuit position for every five circuits installed at the beginning. The "Dead Front" panel should be installed as a protection against shock. Underwriters' codes call for them, but many "Live Front" panels are in use and should be replaced.

It is advisable to install panels in each shop where any power machinery is used. The panel should include a switch that will disconnect all the machinery, but not the lights, at one motion.

Feeder wires as well as branch circuits should be installed with an eye to increased demands. It should be possible to increase the load without having to install a new set of wires. The size of feeders depends on the number of branches and the estimated load on each. Local ordinances and Underwriters' codes must be consulted to know permissible loads and other factors to be provided for.

There should be switches at each principal entry to each room. A switch should usually control one row of fixtures. Usually each row of fixtures parallel to the windows should be separately controlled in order that as daylight fades those farthest from the windows can be turned on first. A switch for each fixture may be helpful where different activities are carried on in different parts of the room. Switches should be placed systematically so that they may be easily found. Automatic control by photoelectric cells for each row of fixtures is advisable since the turning on of the lamps does not depend on the eye which does not always warn us promptly that there is too little illumination.

No figures have been given for wiring because each installation must be planned to fit the need. In judging the possibilities presented by an architect, the consumer is wise to remember that no lighting system is better than its foundation of wiring, and it is expensive and wasteful to rewire a building if the original installation is unsatisfactory.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

How to achieve the best lighting in a school shop or for any school installation for the least amount of money has been a problem of school districts for many years. To this day the problem is not entirely solved, but more modern means of illumination have been invented and are being used by the newer and larger schools. People who are responsible for building and improving school installations are realizing the need for better illumination and are making provisions for those improvements in their building and maintenance plans.

A Summary of Findings. The problem of illumination has been on the minds of people for centuries. As early as 1859, Moses Farmer lit his house in Salem, Massachusetts, by electric lamps which contained a glowing platinum wire. The current was supplied by batteries. However, these lights were not very satisfactory. In 1879, Thomas A. Edison made the first successful carbon lamp. Edison decided that Japanese bamboo was the best source of carbon for light.

The next step in the development of the electric incandescent lamp came with the development of the tungsten lamp. This lamp used a fine tungsten wire instead of carbon. The tungsten lamp gives almost three times as much light as the carbon lamp for the same amount of electrical energy used.

The Cooper-Hewitt mercury-vapor lamp was made in 1901. This lamp made use of the metal mercury. The mercury was turned into a gas which proved to be a good conductor of electricity. The greater the pressure inside the tube, the whiter the light which is produced.

The fluorescent light makes use of the principle of mercury vapor and it is much more efficient than the tungsten light. The tungsten light turns only 6 to 8 per cent of the energy used into actual light. The fluorescent light turns 60 to 70 per cent of the energy to light.

In addition to the possible conservation of eyesight itself and the preservation of individuals from the evils of eyestrain, many business and industrial firms have found that good lighting pays dividends. More and more schools are acting upon this realization and are taking the proper steps to see that improved and adequate lighting is made a part of their building program. What constitutes good lighting depends chiefly on the task, the length of time the task is to be performed, and the surroundings. The increasing variety of activities given in schools means that there is a corresponding increase in the number of different visual tasks carried on. It follows that classrooms must have lighting which is prescribed according to the activities in each.

Table I (page 30) gives recommended foot-candles on a basis of the visual task and the requirements of performance.

Table II (page 31) gives levels of illumination recommended for schools. These values or standards are given in the _American Recommended Practice of School Lighting_.

Table III gives foot-candle recommendations for tasks of shop and office. In general, a deviation from 30 per cent lower to 40 per cent higher should be satisfactory.

Conclusions Indicated by the Study. Wherever more than 30 foot-candles are needed, except possibly in sight-saving classes, it probably will be necessary for the sake of economy to provide optimum illumination by means of a combination of artificial and natural illumination. The natural illumination in such cases should provide from 20 to 30 foot-candles with the remainder provided by artificial lighting. It should be remembered that for some processes requiring less than 30 foot-candles, the nature of the task calls for special lighting (such as presses and shearing machines in sheet metal work).

The fluorescent lamp is a more efficient lamp than the tungsten incandescent lamp. The fluorescent light turns 60 to 70 per cent of the energy to light, whereas, the tungsten light turns only 6 to 8 per cent of the energy used into actual light. The fluorescent light is a more satisfactory light to use in the classroom than the incandescent light because the fluorescent gives light with a color composition which approaches that of natural light. Natural light that is free from glare is known to be the best source of light that can be obtained for any task, however, there are situations in which sufficient natural lighting can not be obtained and must be supplemented by artificial lighting. Students, who can work under this type of artificial lighting rather than being subjected to inferior forms of incandescent lighting, do not experience eyestrain and are therefore in a better position to give their best performance to their work.

Recommendations. The wiring installation should be flexible enough to take care of reasonable changes in use and allow for increased demands of the future. The problem of lighting in any public building project should be placed in the hands of a lighting specialist.

In judging the possibilities presented by an architect, the consumer is wise to remember that no lighting system is better than its foundation of wiring, and it is expensive and wasteful to rewire a building if the original installation is unsatisfactory.

Any person or group of persons, who are responsible for the planning of any public building, should realize the grave importance of providing adequate lighting. A fully qualified lighting specialist would be able to determine the most suitable form of lighting which should be used to harmonize with the architecture of the building. Therefore, careful study should be made in planning public school buildings to meet the standards established by the *American Recommended Practice of School Lighting*.

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