/A STUDY OF VISUAL TASK LIGHTING/

by

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Lahore, Pakistan, 1979

MASTERS' REPORT
submitted in partial fulfillment of
requirement for the degree

MASTER OF SCIENCE

Department of Industrial Engineering
KANSAS STATE UNIVERSITY
Manhattan, Kansas

1985

Major Professor

DEDICATED

To my mother

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

ACKNOWLEDGMENT

The author wishes to express his gratitude towards his major professor, Dr. Corwin a. Bennett for not only his initial help and encouragement but constant guidance throughout the making of this report. The author is also thakful to Professor Jake Smaltz and Professor Charles Burton for being on the committee. Finally, a world of thanks to Mr. Randy Peterson for his cooperation at McCall Pattern Company.

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INTRODUCTION

In order to see something, there must be light. Two lighting considerations are -- quality and quantity. Quantity of illumination on a visual task is important. Generally the more difficult the visual task, the greater is the quantity of illumination required, for ease of seeing.

Visual tasks in a work a day world are those requiring a sustained seeing effort. While quantity of illumination makes a visual task easy to perform, it is the quality of illumination that keeps it easy to perform.

Quantity of Light

Quantity of light is the luminous flux which falls on a surface as illuminance (illumination). The illuminance may be reflected from a surface or transmitted through a surface. Brightness of luminance is what people see in terms of physical characteristics. The effectiveness of the lighting system depends on the flux of the source, lumens (quantity). The most widely used units of illumination are footcandles (English), fc, and lux (metric, 1 fc = 10.76 lux). A footcandle is numerically equal to an incident flux density of one lumen/square foot. One lux is the illumination produced by one lumen uniformly distributed over one square meter. Lumen, is the quantity of light which will strike a surface of one square foot, one foot distant from a light source of one candle power.

There are many kinds of sources which provide luminous flux. The common sources are incandescent lamps, fluorescent lamps, mercury lamps, metal halide lamps, high pressure sodium lamps and low pressure sodium lamps. These sources have different efficacies (amount of light produced per unit of energy). Incandescent lamps deliver approximately 11-20

lumens per watt, mercury lamps deliver 30-50 lumens per watt, fluorescent lamps deliver 50-85 lumens per watt and high pressure sodium deliver 85-140 lumens per watt.

In industrial lighting design it is very important to cut down the overhead costs and labor costs, so lamps with long lives are used frequently for continuous light sources. Ultimately the frequency of changing the lamps is low and hence the cost of operation of that particular lamp is low.

Different industrial tasks require different levels of illumination to work satisfactorily. For example, aircraft manufacturing may require 100 to 200 footcandles for production and inspection tasks respectively. Automobile manufacturing requires an illumination level of 50 footcandles for frame assembly, 100 footcandles for chasis assembly and 200 footcandles for final assembly and inspection. Ordinary industrial inspection may require only 50 footcandles but very difficult and most difficult tasks may require 500 to 1000 footcandles. In material handling 50 footcandles are recommended for wrapping, packing, labeling and 30 footcandles for picking, etc.

Quality of Light

Quality of a light source is the aspect of light which helps keep a visual task easy to perform. Quality of a light source means glare characteristics, position of source and its color. Since the eye can not render clear vision when an unpleasant bright light source is within the field of view, disability glare is one of the main factors of poor lighting. Glare reduces the sensitivity of vision. It may also be dis-

tracting and annoying to the extent of causing extreme discomfort and even pain.

Position of a light source is very important in order to predict any glare problems. Position of a light source determines how the light will fall on the task and how well one will see and how comfortable a person will feel while working. The position should be such that the angle of incidence of a light source does not create any problem after reflection. Reflection is a property of light by which, when it falls on an opaque surface it is stricken in different directions. The source should be mounted such that it does not come directly into the line of vision of the worker.

Color is also an important consideration for some particular type of tasks. There are many tasks which only require a level of illumination appropriate for that task and color is not important. For tasks where color rendering is important, however, color of the light source plays an important role. Color might present the biggest design problem in lighting store areas where it is a determining factor as to how merchandise would appear. It must be important to check the colors of these products before they even reach the stores. So color rendering at the production line could be as important as it is in the store. Fluorescent lamps and incandescent lamps are frequently used where color rendering is important.

Purpose of Study

In order to understand in more detail about the illumination in an industrial situation a plant survey was planned. The propose was to study

a production facility, regarding all the visual tasks performed within the facility. The study would deal with the description of general lighting systems, supplementary lighting systems, illumination measurements, workers attitudes and the scope of improvement in certain areas. The success of the survey also would depend on the response of the plant officials where the survey would take place.

Because of availability a plant tour was conducted at McCall Pattern Company, Manhattan, KS. The company officials were asked beforehand to permit the writer to conduct the survey. They were informed about the idea behind the survey. The first visit to the plant consisted of going through all of the production related areas and seeing all the operations done. When this tour was being conducted some areas were indicated to have problems in performing the visual tasks. The plant officials said that these areas needed immediate attention for improvement in illumination. The primary problem seemed to be an inadequate level of illumination. Hence this survey dealt primarily with the level of illumination on specific visual tasks. It was understood that the plant officials would accept a proposal for improvement which would prove feasible. The main criterion of feasibility was the cost of improvement. The cost must justify the return it would generate in the years to come. It must be noted that plant officials were thinking of changing over from flourescent to high pressure sodium in certain areas. They were still in the process of decision making as they were not sure whether the change would bring a better illumination at a lower cost.

PROBLEM

When the factory tour at McCalls was done, certain areas were pointed out as the problem areas. It was decided by the writer to study these areas in detail and possible alternatives would be suggested.

Procedure

The problem areas in McCalls were noted and marked on the plant layout sheet (Fig. 2). The project engineer at McCalls was also consulted. He agreed to provide help and guidance while the actual survey would be carried out. Also he agreed to accompany the researcher when questions would be asked from the workers. The areas studied are given in detail. They are:

(1) Hand folding

The workers in this area folded and packed the patterns in envelopes by hand. The workers were paid by the number of pieces they folded in a day. The visual task involved in this operation was reading the correct pattern number from the envelope to make sure that patterns were packed in correct envelopes. Illumination readings were taken in the horizontal plane in this workstation on different tables to see how the light was distributed.

(2) Branch Service

This area had basically the entire factory's inventory. The patterns in this area were ready for shipping. Illumination readings were taken in different aisles to have an idea of the lighting situation. The readings were taken in the vertical plane. Readings were taken in the aisles on

the opposite racks (facing each other). Thus the readings were paired for each spot in the aisle. Distance between the two racks and heights of racks was noted. The total number of fixtures was noted. The number of lamps working out of the total was noted.

(3) Guide Press

In this area the instructions to make a dress were being printed on the paper which would accompany the pattern. The complete machine consisted of a printer, dryer, cutter, folder and a stacker. The paper was fed from a roller through a printer section. Once printed the paper was dried in the dryer and then sent through the cutter. The cutter separated the two identical prints. They were then folded and sent to the stacker. There were three substations in this area, namely:

(1) working desk

(2) trimmer

(3) stacker

Most of the paper work was done on the working desk. The work was reading some instructions, notices, etc. The light readings were taken in the vertical as well as in the horizontal plane.

The trimmer was used to trim to size, a particular plate used in printing.

Level of illumination on the trimmer was noted and the technicians were interviewed.

The stacker stacked the folder instruction sheets. When the instruction sheet pile became high the workers would put them into the proper box. Illumination level was recorded for this area.

The printing unit was kept under constant check for any defective printing and supplementary lighting was provided for this section. The illumination level of the supplementary lighting was noted. The type of lamp was noted also.

(4) Fill in/book marking

Inventory books were marked in this area. The inventory discard books were received from the dealer which showed the inventory level. The book would come to the plant about four times a year, so temporary employees were called in. This book required concentration to avoid mistakes. The area dimensions as well as the number of workers on each table were noted. Two illumination readings were taken on each table in the horizonal plane. The number and type of lamps in this area were noted.

(5) Discard

In this area visual task of reading printed material was performed. This was basically a clerical job and the worker would read a variety of printed matter with bad to good contrast. The computer output of the inventory was the hardest print to read as it had very small letter size. Illumination readings were taken in the vertical as well as in the horizontal plane.

(6) Tissue cutter

The patterns to be cut were piled up near the cutter in stacks (1200 patterns/stack). One stack, 2"-3", thick would be cut at one time. The dimensions of this work station and the height of the work plane were

noted. A supplementary light source was provided. The type of supplementary lighting was recorded. Light readings were taken on the working plane at important points in the horizontal plane.

METHOD

In the survey a Simpson light meter was used to record illumination levels. An average illumination for every area surveyed was found. The area dimensions were recorded and also the number of fixtures. It was also noted as to how many lamps were working out of the total. Work plane height was noted wherever applicable.

In order to do a good light survey it is essential to have all the relevant information about illumination. The information once collected would be such that it would give a very clear idea of what is going on in some specific facility regarding visual tasks. A survey form "Information Sheet for Task/Work Place Lighting" was developed (Fig. 1).

This form had sixteen items for the collection of desired information. After these items were answered the form would provide comprehensive details of a particular visual task.

The order in which the sixteen items were presented is as follows:

The task name

The task description

Workers age

Accuracy (of task)

Speed (production)

Reflectance of task background

Contrast judged

Angle of light

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

Figure 1 Survey Form

TASK NAME

TASK DESCRIPTION

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

(c) Quantity of light

(d) Type of lamp

(e) Luminaire type

PERSONAL INTERVIEW

(a) Worker's job

(b) How long on this job?

(c) The worker's feelings, whether the worker likes the job or not?

(d) Does the worker feel satisfied about lighting?

(e) Is there any other aspect of light that the worker likes to comment?

Quantity of light

Type of lamp

Luminaire type

Worker's job

How long on this job?

Workers feelings whether the worker likes the job or not?

Does the worker feel satisfied about the lighting?

Is there any other aspect of light that the worker likes to comment on?

To do a lighting survey, The Illuminating Engineering Society (IES) has developed a standard practice. The IES approach towards a lighting survey is highly detailed and takes into account all the aspects of the area being surveyed. The IES survey form (Appendix A) takes into account of the factors like dimensions of the areas, description of general lighting, supplementary lighting, instruments used, brightness measurement, illumination measurements in fc (average value on horizontal plane), spacing and kinds of luminaires, maintenance schedule, daylight usage and sketch of the area. Compared to IES form, the form developed by the author was less detailed but comprehensive. The information in this form combined with the summary of results can give a complete and comprehensive understanding of lighting in the observed area. Any decision made about the lighting in the surveyed area based on the form would be appropriate. Of course this form is not as detailed as the IES approach but it is not necessary to have such an approach for all lighting surveys. Surveys are done according to the needs and demands of the situation consistent with

the observer's goals. The objective of this survey was fulfilled with the use of the form (Fig. 1) discussed earlier.

After the development of the authors survey form it was decided to do some prototype lighting exercises in the Production Process Lab situated at Kansas State University. The exercises would give practice. Three operations were chosen for these exercises. They were:

(1) To test hardness of a metalic piece on a Rockwell hardness testing machine.

(2) To see surface defects on a steel bar under a binocular scope.

(3) To perform face milling on a part (vise base).

The visual task performed in the first operation was to take readings from the callibrated dial of the hardness testing machine. The visual task in the second operation was to inspect a metalic bar for surface defects. In this case colored light was also used besides regular light to enhance the surface detail. In the third operation the visual task was to watch milling operations performed on the vise jaw and bring the piece to required measurements.

For the first operation on the Rockwell hardness testing machine, the workers were less than 40 years of age. Speed was not important but accuracy was critical. Reflectance of the task background was between 30 and 70%. Contrast was judged to be good. Quantity of light was 80 fc in the horizontal plane and 60 fc in the vertical plane. The lamps were fluorescent cool white and there were bare industrial type fixtures. The workers liked the job and were satisfied about the light. It was found that the illumination level was consistant with the standard one (Table 1)

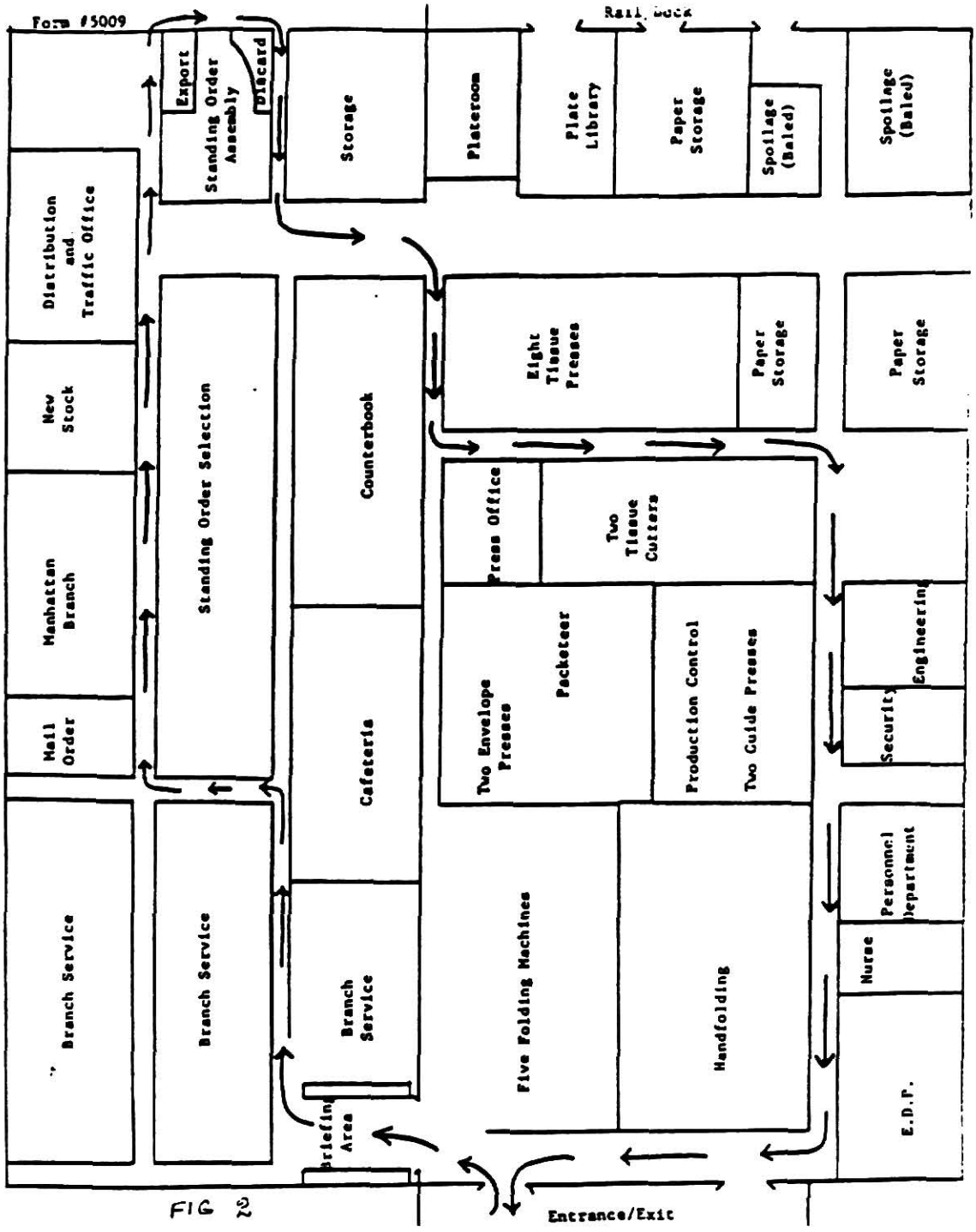
for such type of visual task. The workers did not comment on any other aspect of the lighting.

For the second operation done with a binocular scope all the characteristics were the same except for the level of illumination. With the ordinary lamps the level was 90 fc in the horizontal plane and 75 fc in the vertical plane. Due to the provision of a localized light the level was increased to 120 fc. The workers felt satisfaction over this amount of light.

For the third operation of milling, speed was important. Accuracy was critical. Reflection of task background was thirty percent. Contrast (judged) was poor for the workpiece but good for the control knobs. The level of illumination was 60 fc in the horizontal and 40 fc in the vertical plane. The workers were satisfid with the provided level of illumination. The levels of illumination for the above three operations were found to be well within the recommended levels (Table 1). the other items had the same answers as in the previous exercises.

All of these operations were common industrial tasks. There are certain levels of illumination recommended for each of these operations. There were 60 fc in the vertical plane for the first operation, which required the reading of a calibrated dial. This level was consistant with the recommended level (Table 1). For the second operation, where a metalic piece was to be inspected under a binocular scope, a supplementary lighting was provided to make the visual task easy. The 120 fc provided was consistent with the recommended level of illumination for such an inspection job. Also there was colored light which enhanced any surface defect so that it could be detected easily. The workers were satisfied

with this arrangement. In the face milling operation it was expected that there would be a glare problem from the light coming in through the window but the worker did not feel any discomfort glare when facing that side. The footcandles recorded for this operation were not consistent with the recommended level. The workers still felt comfortable with the 60 fc whereas they should be having almost 100 fc for such operations.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Export
Standing Order Assembly
Discard
Storage
Plateroom
Plate Library
Paper Storage
Spoilage (Baled)
Spoilage (Baled)
Distribution and Traffic Office
New Stock
Manhattan Branch
Mail Order
Standing Order Selection
Counterbook
Cafeteria
Eight Tissue Presses
Paper Storage
Paper Storage
Press Office
Two Tissue Cutters
Two Envelope Presses
Packeteer
Production Control
Two Guide Presses
Security
Engineering
Personnel Department
Nurse
E.D.P.
Branch Service
Branch Service
Branch Service
Briefing Area
Five Folding Machines
Handfolding
Entrance/Exit

FIG 2

RESULTS

The lamps for general illumination throughout the plant were F 96 T12/CW (slim line, 60 watt) energy conserving lamps. The length of the lamps was 96". The luminaires for these lamps were open type industrial fixtures. The lamps were replaced on burn out basis. The environment was semi-clean. The distance between the rows of fixtures was constant, (22.7 feet).

The illumination readings throughout the survey were taken with a Sampson light meter, in footcandles. Readings were taken in the vertical as well as in the horizontal plane. All the readings and observations were recorded in the survey form titled "Information Sheet for Task/Work Place Lighting". For each one area studied one form was utilized. The forms are attached area by area.

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Hand folding

TASK DESCRIPTION

The workers had to pack the patterns in envelopes by hand. The patterns and the envelopes were side by side. The worker had to pick one pattern and an envelope, fold the pattern, put it in the envelope and stack it. They had to make sure that the right pattern was going into the right envelope.

The dimensions of this area were 70' x 50'. The work table height was 3" above the ground. The workers were standing while performing the task.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

Not measured as the light was coming from all directions. No supplementary light was provided.

(c) Quantity of light (range/average)

It ranged from 28 fc to 35 fc. The average illumination was 33 fc in the horizontal plane.

(d) Type of lamp

F96T12/CW (slim line energy conserving 60 watts power and 96" long)
F96T12/WW

(e) Luminaire type

Open type industrial luminaires

PERSONAL INTERVIEW

(a) Worker's job

To hand fold the pattern and put it in the right envelope. Then stack it. The workers did it as fast as they could because they were paid by the pieces they prepared.

(b) How long on this job?

Approximately four years.

(c) Worker's feelings, whether the worker likes the job or not?

She liked it.

(d) Does the worker feel satisfied about lighting?

She never felt any difficulty in reading the number from the pattern and envelope.

(e) Is there any other aspect of light that the workers likes to comment?

Not to her knowledge.

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Branch Service

TASK DESCRIPTION

This area held the finished product ready to be shipped. When the worker had a shipment order he/she would come to this area, reach the proper aisle and locate the right pattern number. Then pick the number of patterns needed and bring them over to shipping and handling. The workers had to make sure the correct pattern number was picked.

The dimensions of this area were 175' x 125' and there were 13 aisles. There were 10 rows of lights; each row had 20 fixtures and each fixture had 2 lamps so there were 400 lamps.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle).

Due to the arrangement of lights and aisles it was not possible to measure the angle.

(c) Quantity of light

It ranged from 3.5 fc to 19 fc. The average value of illumination for this area was 10.75 fc in the vertical plane

(d) Type of lamp

F96T12/CW (slim line energy conserving 60 watts power and 96" long)
F96T12/WW

(e) Luminaire type

Open type industrial luminaires

PERSONAL INTERVIEW

(a) Worker's job

To reach to correct aisle and pick the desired number of correct patterns. Then the patterns were identified by the number and size imprinted on the envelope.

(b) How long on this job?

It ranged mostly from 3 to 5 years.

(c) Worker's feelings, whether the worker likes the job or not?

The workers thought is was not really highly praised.

(d) Does the worker feel satisfied about lighting?

No, they were unsatisfied and thought that greater quantity of light with better arrangement was needed.

(e) Is there any other aspect of light that he likes to comment?

Not to their knowledge.

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Guide Press

TASK DESCRIPTION

The instructions to make a dress were printed which accompanied the pattern. The complete machine consisted of a printer dryer, cutter, folder and stacker. The worker had to keep an eye on the quality of the print coming out of the printer and make sure other functions of the press were going right. There were some reading tasks involved on the working desk. Also there was a trimmer machine used occasionally. The trimmer was used to trim down a particular plate used in printing. So a worker here was doing a number of tasks.

The area dimensions were 60' x 20'. There were 24 fixtures in this area for general illumination. There were 2 fixtures for supplementary illumination.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

Not possible to measure as the light was coming from all directions.

(c) Quantity of light

It ranged from 23 fc to 43 fc. The readings had an average of a little over 30 fc (in vertical and horizontal plane).

(d) Type of lamp

F96/T12/CW (slim line, energy conserving 60 watts)

(e) Luminaire type

Open type industrial luminaires.

PERSONAL INTERVIEW

(a) Worker's job

To keep an eye on the whole guide press operations. The worker was supposed to judge the quality of print and also keep the machine in perfect running condition.

(b) How long on this job?

More than 5 years

(c) Worker's feelings, whether the worker likes the job or not.

He liked it due to the variety in the job.

(d) Does the worker feel satisfied about lighting?

He was very dissatisfied about the light on trimmer and wanted more light on the printer section.

(e) Is there any other aspect of light that the worker likes to comment?

The worker's thought there had to be a supplementary source of light over the trimmer and the supplementary lights over the printer had to be increased in order to judge the quality of the print.

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Fill-In/Book Markings

TASK DESCRIPTION

The inventory/discard books were received from the dealer. The books showed the inventory level of the dealer. The books came in about four times a year, so this was a temporary job which would last about 4-6 weeks/year. The inventory books had small square spaces, which had the number. This was the number the worker had to read and mark. The size of the number was small and the worker had to concentrate hard to avoid any mistakes. This area had 35'x15' dimensions, with five work tables.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

(c) Quantity of light

It ranged from 25 fc to 32 fc with an average value of 28 fc on the horizontal plane.

(d) Type of lamp

F96T12/CW (Slim line, rapid start energy conserving lamps, 60 watts power.)

(e) Luminaire type

Open type industrial luminaires

PERSONAL INTERVIEW

(a) Worker's job

To fill the inventory books by marking the right number.

(b) How long on this job?

Temporary job

(c) Worker's feelings, whether the worker likes the job or not?

The workers liked it.

(d) Does he feel satisfied about lighting?

The workers never complained about light. They felt satisfied.

(e) Is there any other aspect of light that the worker likes to comment?

None

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Discard. Here the visual task of reading printed material was performed.

TASK DESCRIPTION

This was mainly a clerical job. The workers had to read a variety of printed matter with poor to good contrast. The printed matter was mostly in the form of computer output. The quality of print was very poor. The word size was very small and so reading such material put a lot of strain on the reader's eyes. The readings were taken in the horizontal and vertical plane.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

45° if a supplementary source was used.

(c) Quantity of light

It ranged from 19 fc (vertical plane) to 45 fc (horizontal plane).

(d) Type of lamp

F96T12/CW (Slim line rapid start energy conserving 60 watt power)

(e) Luminaire type

Open type industrial luminaire

PERSONAL INTERVIEW

(a) Worker's job

To read different kinds of printed material and act according to the instructions.

(b) How long on this job?

More than 3 years.

(c) Worker's feelings, whether the worker likes the job or not.

No complaints heard. The worker seemed to be satisfied.

(d) Does the worker feel satisfied about lighting?

Not for the printout reading. They felt that they needed more light for poor contrast print.

(e) Is there any other aspect of light that the worker likes to comment?

None

"INFORMATION SHEET FOR TASK/WORKPLACE LIGHTING"

TASK NAME

Tissue cutter

TASK DESCRIPTION

The patterns to be cut were piled up near the cutter in stacks (1200 patterns/stack). One layer (stack) was 2"-3" thick. The different portions of the dress were cut and separated. The cutting operation was done on the band saw. This area was a critical safety area due to the high speed band saw. This area was provided with 4 lamps of supplementary lighting, two of these were F96T12/CS and the other two were F96T12/WW.

ILLUMINANCE DATA

Worker's age	under 40	40-55	over 55
Speed	not important	important	critical
Accuracy	not important	important	critical
Reflectance of the task background	greater than 70%	30-70%	less than 30%

PRESENT SITUATION ILLUMINATION DETAIL

(a) Contrast (Judged)

1. Poor
2. Good
3. Very good
4. Excellent

(b) Angle of light (estimated angle from horizontal plane and its illuminance at that angle.

30^{o} from the warm white supplementary light source

(c) Quantity of light

It ranged from 14 fc to 35 fc with an average of 25 fc on the horizontal plane.

(d) Type of lamp

F96T12/CW (rapid start, energy conserving 60 W power)
F96T12/WW

(e) Luminaire type

Open type industrial luminaires

PERSONAL INTERVIEW

(a) Worker's job

To get a stack (1200 patterns) from the right side of the table, put it on the working plane, cut the patterns into different dress portions and slide them forward.

(b) How long on this job?

Five years.

(c) Worker's feelings, whether the worker likes the job or not.

Workers liked it.

(d) Does the worker feel satisfied about lighting?

Yes, the worker was satisfied but the fact of the matter was that the light levels just by the blade were not enough according to the illumination standards.

(e) Is there any other aspect of light that he likes to comment?

None

DISCUSSION

The average illumination in the hand folding area was found to be 33 fc. This level was almost appropriate for the kind of job performed in this area. The problem in this area was the glare, due to the white color of the table tops. In the author's recent visit since making the measurements, it was found that all the burnt lamps were replaced with F96T12/WW type lamps. These lamps "warm white" were thought by McCall officials, to have the ability to cut the glare down. The illumination level of 33 fc could still be made better by lowering the fixtures to decrease the distance between the work plane and the lamps. The plant officials were already thinking of changing over the lamps from fluorescent to high pressure sodium, (HPS) due to the high efficacy of HPS lamps.

The initial cost of HPS lamps is higher than fluorescent lamps. In the long run, where color rendering is not very important, HPS lamps are the most efficient sources available today.

In the "Branch Service" the lighting conditions were very poor with an overall average illumination of only 10.75 fc (in the vertical plane). The reason was that the fixtures were mostly located above shelves, rather than in the middle of aisles. There were 10 rows of lamps for 13 aisles which shows the misproportion. There should have been the same number of light rows for the number of aisles. Out of 400 lamps, only 244 lamps were working which is only 60 percent of the total. This problem could be eliminated in a number of ways. The fixtures could be lowered to get more light on the patterns in the shelves. There could be a glare problem by

lowering the fixtures but that could be solved by putting proper shields on the luminaires. Each aisle must have one row of lamps. The other option was to change over from fluorescent to HPS lamps. There would be a high initial cost but it would prove productive in the long run. It would give a yellowish effect but it would be normally felt after the workers had worked for some time. The shelves in the aisles were movable but the possibility of increasing the aisle distance or repositioning the shelves was very remote so the first two options of rearrangement would be more applicable.

In the Guide Press area there were two places where immediate attention was needed. In the trimmer, where accuracy and precision were important, only 23 fc were recorded in the horizontal plane. The workers felt very much dissatisfied with the quantity of light on the trimmer. The increase in illumination level could easily be achieved by putting a supplementary light source above the trimmer table. The source should be such that it could be turned on and off when needed, because the trimmer would not be in use all the time. The printer section of this area was also very important because the printing was intermittently checked for any dark streaks, misprints or other printing effects. The paper was constantly moving and to judge a print in such a situation a level recommended in Table 1 has to be present which is 70 fc for such a task. A supplementary source of light was provided which was delivering only 32 fc on the horizontal plane. This source consisted of two F96T12/cw lamps, which were shielded to protect from breaking. This supplementary source should have been double that which was actually there. The work table and stacker were not complained about by the workers so the level of illumina-

tion was acceptable. There were 25 fc on the working table where most of the paperwork was done. The reason for this low level of illumination was that there were a lot of pipe lines running under the lighting, which obstructed most of the light.

In the Fill In/Book Marking the level of illumination was found to be 29 fc on the horizontal plane. This value was averaged over all the tables. The job required the worker to concentrate in order to avoid any mistakes. The workers never seemed to complain as it was a temporary job requiring the workers to work only four-six weeks/year. The illumination could be improved by either lowering the fixtures or by changing to HPS lamps.

In the "discard" the worker's job was mostly reading printed material of different quality prints. The average illumination on this desk was 36 fc. For a bigger print with good contrast, 36 fc would be acceptable but for a computer printout which was smaller than letter print with poor contrast, the illumination level should have been higher. This was very easily achieveable by an ordinary table light on that workstation. The light could be turned off or on as the reader would wish. The table lamp could be positioned over the table for the best possible results.

The "Tissue Cutter" was a critical safety area. It was felt that there was not enough light very near to the cutting blade, but for the rest of the table the level of illumination was adequate. The reason of less light just near the blade was that light from the supplementary light source was being obstructed by the driving mechanism of the blade over it. As the table top was white, increasing the supplmentary light

would increase glare which would be more dangerous. Oblique lighting from behind the worker could solve the low light problem. This light source could be an incandescent bulb in a reflector which would be pointed towards the cutting blade at an angle. Incandescent source would be preferrable over fluorescent as it is a point source and will fall on a small area.

STROBE EFFECT

The performances of the fluorescent lamps versus HPS can be judged by a number of reasons. The wattages of HPS available are greater than those available in fluorescent lamps. The lamp efficacy of HPS is 85 to 140 lumens per watt where as the fluorescent is 50 to 85 lumens per watt. The life of a HPS lamp ranges from 16,000 to 24,000 hours but the fluorescent is 12,000 to 20,000 hours. The luminaire cost for a HPS is higher but for fluorescent it is low. The color of HPS source is yellowish where as a fluorescent lamp has cool white light (white) and warm white light (yellowish).

For a ten year life cycle the cost of producing one million useable lumens for a fluorescent lamp is $80,000 but for the same number of lumens produced by HPS light souce, the cost is only $50,000. This gives a clear idea as to what should be our choice for a long term illumination facility where color of light source does not make any difference.

RECOMMENDATIONS

The average illumination in the six areas studied was approximately 35 fc (horz). This also gives a picture of a general overall illumination throughout the plant the value of which was between 30 and 40 fc. To make a recommendation about any improvement in the lighting of different areas, there must be some standard values of illumination for different visual tasks. For this purpose the "IES Lighting Handbook, 1981 Volume" was consulted. The table of values is attached (Table 1). In this table the type of activity is identified with an illuminance catagory (represented by a letter). This illuminance catagory is then designated by a range of illumination most appropriate for that activity. By looking into the industrial group of this table, it is made clear that most of the visual tasks in McCall's fall into illuminance catagories D and E with illumination ranges of 20-30-50 fc to 50-75-100 fc. Thus illumination levels of 35 to 70 fc on the average were needed throughout the plant.

In the hand folding area the average illumination was found to be 33 fc. This area falls into illuminance catagory D with a range of 20-30-80 fc. So 33 fc is well within this range but as the range is up to 50 fc so the task would become easier with the provision of 50 fc illumination level. The range actually gives an idea of increasing or decreasing the illumination level with the difficulty of visual task in this catagory. But then, greater illumination levels make a task easier. The quantity of light can be increased by either lowering the fixtures, or changing from fluorescent to HPS. The cost of changing over will be recovered within a decade so it is worthwhile to go for this change as HPS is the most

efficient source available at the present time.

In Branch Service area the average illumination was found to be 11 fc in the vertical plane. This area falls into illuminance catagory D with 20-30-50 fc range but 11 fc were way below even the lower limit. There are generally less fc's in the vertical plane than in the horizontal plane. The ratio is approximately three-fourths, so to have 35 fc in the vertical, there should be approximately 50 fc in the horizontal plane. The problem in this area was multiple. First the number of lamp rows was not equal to the number of aisles so the lamp rows could not be centered and consequently some of the rows of lamps were situated right above the shelves, thus most of the light never reaches in between the aisles (on the shelves). Secondly, only 60% of the lamps were working, thus providing such poor illumination. It would be worthwhile to change over from fluorescent to HPS because then the shelves system would be redesigned according to the present situation of aisles. HPS will certainly pay off in a period of approximately five years.

In the Guide Press area there were a number of problems for the visual tasks. The printer section falls into the illuminance catagory E with a range of 50-75-100 fc whereas the rest of the area is catagory D. The printer section had 37 fc in the horizontal plane with the supplementary source. The trimmer had 23 fc in the horizontal plane. The working desk had 25 fc in the horizontal plane. The general illumination of this area must be increased to 45-50 fc and replacement with HPS would again be recommended. The poor illumination was caused by the obstruction by the pipe lines running right under the fixtures. The pipe lines could not be moved any where else. The only things that could be lowered clear

of the pipe lines were the fixtures. It would be worthwhile to put HPS than removing the fixtures from their present place and lower them to get all the light from them. Once the general illumination were increased to approximately 50 fc the level of illumination over the printer could easily be brought up to 70 fc (in the horizontal plane) with a supplementary light source. The 70 fc are well within the catagory E range. The color rendering is not important as the printer is black and white so even a yellowish color of HPS would not hurt the performance.

In the Fill In/Book Marking the average illumination on the horizontal plane was 29 fc though this was a catagory D area, the visual task demanded at least 35-40 fc on the horizontal plane. The desired level can be achieved by either lowering the fixtures or changing over to HPS. The HPS may not be appealing in this area, as this was a temporary job and lasted only 4-6 weeks/year, the authorities might not pay much attention to this. As long as there was a low level of light, the stress on the workers would be present.

In the Discard, the work was done on a small table and all the light that fell on the work place was the general illumination. The average illumination on the horizontal plane was 36 fc. All the reading material had good contrast except the computer printout. A localized (supplementary) light would improve the illumination. The supplementary source could be a table lamp or some other localized source, to provide 50 fc for reading poor contrast print. The lamp could be switched on or off whenever desired.

In the Tissue Cutter the table was getting light from the general plant illumination and also four supplementary lamps. This falls into catagory E due to the critical safety. The average illumination on the horizontal plane was approximately 30 fc. Two of the four lamps for the supplementary light were warm, white fluorescent. The glare problem was present due to the white color of the working plane top. The glare problem would be reduced if the white color of the table top was changed to a darker one, so that less light would be reflected. It would also depend upon the angle of light striking on the table, with respect to the position of worker's eyes. If the supplementary source was increased, after changing the color to a darker one, the situation would improve, especially near the cutting blade, where the light level was only 20 fc.

Talking of the plant as a whole, most of the lights could be changed to HPS, purely due to its high efficiency. Of course, there are some areas like the color printer, where color rendering is extremely important. So cool white fluorescent light is most appropriate for such a purpose and changing over to HPS would not make any improvements. Most of the other areas could be provided with HPS. This would save money and increase the quantity of light to the desired level. This would just be killing two birds with one stone.

Table 1

Recommended Illumination Levels

I. Illuminance Categories and Illuminance Values for Generic Types of Activities in Interiors

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

II. Commercial, Institutional, Residential and Public Assembly Interiors

Area / Activity	Illuminance Category	Area / Activity	Illuminance Category
Air terminals (see Transportation terminals)		**Barber shops and beauty parlors**	E
Armories	C'	**Churches and synagogues**	(see page 7-2)*
Art galleries (see Museums)		**Club and lodge rooms**	
Auditoriums		Lounge and reading	D
Assembly	C'	**Conference rooms**	
Social activity	B	Conferring	D
Banks (also see Reading)		Critical seeing (refer to individual task)	
Lobby		**Court rooms**	
General	C	Seating area	C
Writing area	D	Court activity area	E
Tellers' stations	E	**Dance halls and discotheques**	B

For continuation, see page 2-19

II. *Continued*

Area / Activity	Illuminance Category
Music study (piano or organ)	
Simple scores	D
Advanced scores	E
Substand size scores	F
Reading	
In a chair	
Books, magazines and newspapers	D
Handwriting, reproductions and poor copies	E
In bed	
Normal	D
Prolonged serious or critical	E
Desk	
Primary task plane, casual	D
Primary task plane, study	E
Sewing	
Hand sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Machine sewing	
Dark fabrics, low contrast	F
Light to medium fabrics	E
Occasional, high contrast	D
Table games	D
Restaurants (see **Food service facilities**)	
Safety	(see page 2-45)
Schools (see **Educational facilities**)	
Service spaces (see also **Storage rooms**)	
Stairways, corridors	C
Elevators, freight and passenger	C
Toilets and wash rooms	C
Service stations	
Service bays (see Part III, Industrial Group)	
Sales room (see **Merchandising spaces**)	
Show windows	(see page 8-6)
Stairways (see **Service spaces**)	
Storage rooms (see Part III, Industrial Group)	
Stores (see **Merchandising spaces** and **Show windows**)	
Television	(see Section 11)
Theatre and motion picture houses	(see Section 11)
Toilets and washrooms	C
Transportation terminals	
Waiting room and lounge	C
Ticket counters	E
Baggage checking	D
Rest rooms	C
Concourse	B
Boarding area	C

III. Industrial Group

Area / Activity	Illuminance Category
Aircraft maintenance	(see page 9-12)[2]
Aircraft manufacturing	(see page 9-12)[2]
Assembly	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Automobile manufacturing	(see page 9-17)[2]
Bakeries	
Mixing room	D
Face of shelves	D
Inside of mixing bowl	D
Fermentation room	D
Make-up room	
Bread	D
Sweet yeast-raised products	D
Proofing room	D
Oven room	D
Fillings and other ingredients	D
Decorating and icing	
Mechanical	D
Hand	E
Scales and thermometers	D
Wrapping	D
Book binding	
Folding, assembling, pasting	D
Cutting, punching, stitching	E
Embossing and inspection	F
Breweries	
Brew house	D
Boiling and keg washing	D
Filling (bottles, cans, kegs)	D
Building construction (see Part IV, Outdoor Facilities)	
Building exteriors (see Part IV, Outdoor Facilities)	
Candy making	
Box department	D
Chocolate department	
Husking, winnowing, fat extraction, crushing and refining, feeding	D
Bean cleaning, sorting, dipping, packing, wrapping	D
Milling	E
Cream making	
Mixing, cooking, molding	D
Gum drops and jellied forms	D
Hand decorating	D
Hard candy	
Mixing, cooking, molding	D

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5

III. *Continued*

Area / Activity	Illuminance Category
Die cutting and sorting	E
Kiss making and wrapping	E
Canning and preserving	
Initial grading raw material samples	D
Tomatoes	E
Color grading and cutting rooms	F
Preparation	
Preliminary sorting	
Apricots and peaches	D
Tomatoes	E
Olives	F
Cutting and pitting	E
Final sorting	E
Canning	
Continuous-belt canning	E
Sink canning	E
Hand packing	D
Olives	E
Examination of canned samples	F
Container handling	
Inspection	F
Can unscramblers	E
Labeling and cartoning	D
Casting (see Foundries)	
Central stations (see Electric generating stations)	
Chemical plants (see Petroleum and chemical plants)	
Clay and concrete products	
Grinding, filter presses, kiln rooms	C
Molding, pressing, cleaning, trimming	D
Enameling	E
Color and glazing—rough work	E
Color and glazing—fine work	F
Cleaning and pressing industry	
Checking and sorting	E
Dry and wet cleaning and steaming	E
Inspection and spotting	G
Pressing	F
Repair and alteration	F
Cloth products	
Cloth inspection	I
Cutting	G
Sewing	G
Pressing	F
Clothing manufacture (men's)	
Receiving, opening, storing, shipping	D
Examining (perching)	I
Sponging, decating, winding, measuring	D
Piling up and marking	E
Cutting	G
Pattern making, preparation of trimming, piping, canvas and shoulder pads	E
Fitting, bundling, shading, stitching	D
Shops	F
Inspection	G
Pressing	F
Sewing	G
Control rooms (see Electric generating stations—interior)	
Corridors (see Service spaces)	
Cotton gin industry	
Overhead equipment—separators, driers, grid cleaners, stick machines, conveyers, feeders and catwalks	D
Gin stand	D
Control console	D
Lint cleaner	D
Bale press	D
Dairy farms (see Farms)	
Dairy products	
Fluid milk industry	
Boiler room	D
Bottle storage	D
Bottle sorting	E[22]
Bottle washers	
Can washers	D
Cooling equipment	D
Filling: inspection	E
Gauges (on face)	E
Laboratories	E
Meter panels (on face)	E
Pasteurizers	D
Separators	D
Storage refrigerator	D
Tanks, vats	
Light interiors	C
Dark interiors	E
Thermometer (on face)	E
Weighing room	D
Scales	E
Dispatch boards (see Electric generating stations—interior)	
Dredging (see Part IV, Outdoor Facilities)	
Electrical equipment manufacturing	
Impregnating	D
Insulating: coil winding	E
Electric generating stations—interior (see also **Nuclear power plants**)	
Air-conditioning equipment, air preheater and fan floor, ash sluicing	B
Auxiliaries, pumps, tanks, compressors, gauge area	C
Battery rooms	D
Boiler platforms	B
Burner platforms	C
Cable room	B
Coal handling systems	B
Coal pulverizer	C
Condensers, deaerator floor, evaporator floor, heater floors	B
Control rooms	
Main control boards	D[23]
Auxiliary control panels	D[23]
Operator's station	E[23]

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

III. *Continued*

Area / Activity	Illuminance Category
Maintenance and wiring areas	D
Emergency operating lighting	C
Gauge reading	D
Hydrogen and carbon dioxide manifold area	C
Laboratory	E
Precipitators	B
Screen house	C
Soot or slag blower platform	C
Steam headers and throttles	B
Switchgear and motor control centers	D
Telephone and communication equipment rooms	D
Tunnels or galleries, piping and electrical	B
Turbine building	
Operating floor	D
Below operating floor	C
Visitor's gallery	C
Water treating area	D
Electric generating stations—exterior (see Part IV, Outdoor Facilities)	
Elevators (see Service spaces)	
Explosives manufacturing	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	D
Mechanical furnace, generators and stills, mechanical driers, evaporators, filtration, mechanical crystallizers	D
Tanks for cooking, extractors, percolators, nitrators	D
Farms—dairy	
Milking operation area (milking parlor and stall barn)	
General	C
Cow's udder	D
Milk handling equipment and storage area (milk house or milk room)	
General	C
Washing area	E
Bulk tank interior	E
Loading platform	C
Feeding area (stall barn feed alley, pens, loose housing feed area)	C
Feed storage area—forage	
Haymow	A
Hay inspection area	C
Ladders and stairs	C
Silo	A
Silo room	C
Feed storage area—grain and concentrate	
Grain bin	A
Concentrate storage area	B
Feed processing area	B
Livestock housing area (community, maternity, individual calf pens, and loose housing holding and resting areas)	B
Machine storage area (garage and machine shed)	B
Farm shop area	
Active storage area	B
General shop area (machinery repair, rough sawing)	D
Rough bench and machine work (painting, fine storage, ordinary sheet metal work, welding, medium benchwork)	D
Medium bench and machine work (fine woodworking, drill press, metal lathe, grinder)	E
Miscellaneous areas	
Farm office (see Reading)	
Restrooms (see Service spaces)	
Pumphouse	C
Farms—poultry (see Poultry industry)	
Flour mills	
Rolling, sifting, purifying	E
Packing	D
Product control	F
Cleaning, screens, man lifts, aisleways and walkways, bin checking	D
Forge shops	E
Foundries	
Annealing (furnaces)	D
Cleaning	D
Core making	
Fine	F
Medium	E
Grinding and chipping	F
Inspection	
Fine	G
Medium	F
Molding	
Medium	F
Large	E
Pouring	E
Sorting	E
Cupola	C
Shakeout	D
Garages—service	
Repairs	E
Active traffic areas	C
Write-up	D
Glass works	
Mix and furnace rooms, pressing and lehr, glass-blowing machines	C
Grinding, cutting, silvering	D
Fine grinding, beveling, polishing	E
Inspection, etching and decorating	F
Glove manufacturing	
Pressing	G
Knitting	F
Sorting	F
Cutting	G
Sewing and inspection	G
Hangars (see Aircraft manufacturing)	
Hat manufacturing	
Dyeing, stiffening, braiding, cleaning, refining	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

III. *Continued*

Area/Activity	Illuminance Category
Forming, sizing, pouncing, flanging, finishing, ironing	F
Sewing	G
Inspection	
Simple	D
Moderately difficult	E
Difficult	F
Very difficult	G
Exacting	H
Iron and steel manufacturing (see page 9-63)[21]	
Jewelry and watch manufacturing	G
Laundries	
Washing	D
Flat work ironing, weighing, listing, marking	D
Machine and press finishing, sorting	E
Fine hand ironing	E
Leather manufacturing	
Cleaning, tanning and stretching, vats	D
Cutting, fleshing and stuffing	D
Finishing and scarfing	E
Leather working	
Pressing, winding, glazing	F
Grading, matching, cutting, scarfing, sewing	G
Loading and unloading platforms (see Part IV, Outdoor Facilities)	
Locker rooms	C
Logging (see Part IV, Outdoor Facilities)	
Lumber yards (see Part IV, Outdoor Facilities)	
Machine shops	
Rough bench or machine work	D
Medium bench or machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	E
Fine bench or machine work, fine automatic machines, medium grinding, fine buffing and polishing	G
Extra-fine bench or machine work, grinding, fine work	H
Materials handling	
Wrapping, packing, labeling	D
Picking stock, classifying	D
Loading, inside truck bodies and freight cars	C
Meat packing	
Slaughtering	D
Cleaning, cutting, cooking, grinding, canning, packing	D
Nuclear power plants (see also **Electric generating stations**)	
Auxiliary building, uncontrolled access areas	C
Controlled access areas	
Count room	E[23]
Laboratory	E
Health physics office	F
Medical aid room	F
Hot laundry	D
Storage room	C
Engineered safety features equipment	D
Diesel generator building	D
Fuel handling building	
Operating floor	D
Below operating floor	C
Off gas building	C
Radwaste building	D
Reactor building	
Operating floor	D
Below operating floor	C
Packing and boxing (see **Materials handling**)	
Paint manufacturing	
Processing	D
Mix comparison	F
Paint shops	
Dipping, simple spraying, firing	D
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	D
Fine hand painting and finishing	E
Extra-fine hand painting and finishing	G
Paper-box manufacturing	E
Paper manufacturing	
Beaters, grinding, calendering	D
Finishing, cutting, trimming, papermaking machines	E
Hand counting, wet end of paper machine	E
Paper machine reel, paper inspection, and laboratories	F
Rewinder	F
Parking areas (see page 14-24)	
Petroleum and chemical plants (see page 9-51)[21]	
Plating	D
Polishing and burnishing (see **Machine shops**)	
Power plants (see **Electric generating stations**)	
Poultry industry (see also **Farm—dairy**)	
Brooding, production, and laying houses	
Feeding, inspection, cleaning	C
Charts and records	D
Thermometers, thermostats, time clocks	D
Hatcheries	
General area and loading platform	C
Inside incubators	D
Dubbing station	F
Sexing	H
Egg handling, packing, and shipping	
General cleanliness	E
Egg quality inspection	E
Loading platform, egg storage area, etc.	C
Egg processing	
General lighting	E
Fowl processing plant	
General (excluding killing and unloading area)	E
Government inspection station and grading stations	E
Unloading and killing area	C

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

III *Continued*

Area / Activity	Illuminance Category
Feed storage	
Grain, feed rations	C
Processing	C
Charts and records	D
Machine storage area (garage and machine shed)	B
Printing industries	
Type foundries	
Matrix making, dressing type	E
Font assembly—sorting	D
Casting	E
Printing plants	
Color inspection and appraisal	F
Machine composition	E
Composing room	E
Presses	E
Imposing stones	F
Proofreading	F
Electrotyping	
Molding, routing, finishing, leveling molds, trimming	E
Blocking, tinning	D
Electroplating, washing, backing	D
Photoengraving	
Etching, staging, blocking	D
Routing, finishing, proofing	E
Tint laying, masking	E
Receiving and shipping (see Materials handling)	
Railroad yards (see Part IV. Outdoor Facilities)	
Rubber goods—mechanical	(see page 9-56)[21]
Rubber tire manufacturing	(see page 9-56)[21]
Safety	(see page 2-45)
Sawmills	
Secondary log deck	B
Head saw (cutting area viewed by sawyer)	E
Head saw outfeed	B
Machine in-feeds (bull edger, resaws, edgers, trim, hula saws, planers)	B
Main mill floor (base lighting)	A
Sorting tables	D
Rough lumber grading	D
Finished lumber grading	F
Dry lumber warehouse (planer)	C
Dry kiln coiling shed	B
Chipper infeed	B
Basement areas	
Active	A
Inactive	A
Filing room (work areas)	E
Service spaces (see also Storage rooms)	
Stairways, corridors	B
Elevators, freight and passenger	B
Toilets and wash rooms	C
Sheet metal works	
Miscellaneous machines, ordinary bench work	E
Presses, shears, stamps, spinning, medium bench work	E
Punches	E
Tin plate inspection, galvanized	F
Scribing	F
Shoe manufacturing—leather	
Cutting and stitching	
Cutting tables	G
Marking, buttonholing, skiving, sorting, vamping, counting	G
Stitching, dark materials	G
Making and finishing, nailers, sole layers, welt beaters and scarfers, trimmers, welters, lasters, edge setters, sluggers, randers, wheelers, treers, cleaning, spraying, buffing, polishing, embossing	F
Shoe manufacturing—rubber	
Washing, coating, mill run compounding	D
Varnishing, vulcanizing, calendering, upper and *sole cutting*	D
Sole rolling, lining, making and finishing processes	E
Soap manufacturing	
Kettle houses, cutting, soap chip and powder	D
Stamping, wrapping and packing, filling and packing soap powder	D
Stairways (see Service spaces)	
Steel (see Iron and steel)	
Storage battery manufacturing	D
Storage rooms or warehouses	
Inactive	B
Active	
Rough, bulky items	C
Small items	D
Storage yards (see Part IV. Outdoor Facilities)	
Structural steel fabrication	E
Sugar refining	
Grading	E
Color inspection	F
Testing	
General	D
Exacting tests, extra-fine instruments, scales, etc.	F
Textile mills	
Staple fiber preparation	
Stock dyeing, tinting	D
Sorting and grading (wool and cotton)	E[16]
Yarn manufacturing	
Opening and picking (chute feed)	D
Carding *(nonwoven web formation)*	D[24]
Drawing (gilling, pin drafting)	D
Combing	D[24]
Roving (slubbing, fly frame)	E
Spinning (cap spinning, twisting, texturing)	E
Yarn preparation	
Winding, quilling, twisting	E
Warping (beaming, sizing)	F[16]
Warp tie-in or drawing-in (automatic)	E

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

III. *Continued*

Area/Activity	Illuminance Category
Fabric production	
Weaving, knitting, tufting	F
Inspection	G[16]
Finishing	
Fabric preparation (desizing, scouring, bleaching, singeing, and mercerization)	D
Fabric dyeing (printing)	D
Fabric finishing (calendaring, sanforizing, sueding, chemical treatment)	E[16]
Inspection	G[16,25]
Tobacco products	
Drying, stripping	D
Grading and sorting	F
Toilets and wash rooms (see Service spaces)	
Upholstering	F
Warehouse (see Storage rooms)	
Welding	
Orientation	D
Precision manual arc-welding	H
Woodworking	
Rough sawing and bench work	D
Sizing, planing, rough sanding, medium quality machine and bench work, gluing, veneering, cooperage	D
Fine bench and machine work, fine sanding and finishing	E

IV. Outdoor Facilities

Area/Activity	Lux	Footcandles
Building (construction)		
General construction	100	10
Excavation work	20	2
Building exteriors		
Entrances		
Active (pedestrian and/or conveyance)	50	5
Inactive (normally locked, infrequently used)	10	1
Vital locations or structures	50	5
Building surrounds	10	1
Buildings and monuments, floodlighted		
Bright surroundings		
Light surfaces	150	15
Medium light surfaces	200	20
Medium dark surfaces	300	30
Dark surfaces	500	50
Dark surroundings		
Light surfaces	50	5
Medium light surfaces	100	10
Medium dark surfaces	150	15
Dark surfaces	200	20
Bulletin and poster boards		
Bright surroundings		
Light surfaces	500	50
Dark surfaces	1000	100
Dark surroundings		
Light surfaces	200	20
Dark surfaces	500	50
Central station (see Electric generating stations—exterior)		
Coal yards (protective)	2	0.2
Dredging	20	2
Electric generating stations—exterior		
Boiler areas		
Catwalks, general areas	20	2
Stairs and platforms	50	5
Ground level areas including precipitators, FD and ID fans, bottom ash hoppers	50	5
Cooling towers		
Fan deck, platforms, stairs, valve areas	50	5
Pump areas	20	2
Fuel handling		
Barge unloading, car dumper, *unloading* hoppers, truck unloading, pumps, gas metering	50	5
Conveyors	20	2
Storage tanks	10	1
Coal storage piles, ash dumps	2	0.2
Hydroelectric		
Powerhouse roof, stairs, platform and intake decks	50	5
Inlet and discharge water area	2	0.2
Intake structures		
Deck and laydown area	50	5
Value pits	20	2
Inlet water area	2	0.2
Parking areas		
Main plant parking	20	2
Secondary parking	10	1
Substation		
Horizontal general area	20	2
Vertical tasks	50	5
Transformer yards		
Horizontal general area	20	2
Vertical tasks	50	5
Turbine areas		
Building surrounds	20	2
Turbine and heater decks, unloading bays	50	5

For footnotes, see page 2-19. For illuminance ranges for each Illuminance Category, see page 2-5.

REFERENCES

1. Frier, John P., Frier, Mary E. Gazley, "Industrial lighting systems." McGraw Hill Book Company, 1980.

2. Kaufman, John E., "IES Lighting Hand Book." Illumination Engineering Society, Fifth Edition, 1972.

3. Kaufman, John E., "IES Lighting Hand Book." Illumination Engineering Society of North American, 1981.

4. McGuiness, William J., Reynolds, John S., Mechanical and Electrical Equipment for Buildings. Wiley, 6th Edition, 1980.

5. Parson, J. F., "Illuminating Engineering." Illuminating Engineering Society, Vol. VIII, No. 2, 1963.

"APPENDIX A"

IES LIGHTING SURVEY FORM A

GENERAL INFORMATION

Company name and address .....

Contact .....
(Name and title of individual through whom arrangements were made for making this survey)

Survey by .....
(Record name, title and affiliation of surveyor)

Area surveyed ..... Date ..... Time ..... AM-PM
(For future, give name of area and/or building and room numbers)

DESCRIPTION OF ILLUMINATED AREA

Type of work performed in area *(See instruction A-1)* .....

Length Width Height Room Temperature ..... F.

TABLE 1. *(See instructions A-2–A-5)*

Interior surfaces	Material	Texture	Color	% Reflectance	Condition
Ceiling					
Walls					
Dado					
Trim					
Floor					
Shades or blinds					
Work surface					
Equipment					

DESCRIPTION OF GENERAL LIGHTING SYSTEM

TABLE 2. LUMINAIRES *(See instructions B-1–B-8)*

Quantity	Wattage	Light source	Distribution	Description	Spacing	Mounting	M.H. or susp.	Condition

Date of installation Approximate hours used since installation *(See instruction B-9)* .....

Rated voltage of incandescent lamps Full load voltage (1) (2) *(See instructions B-10 & B-11)*

Color of lamps *(See instruction B-12)* .....

DESCRIPTION OF SUPPLEMENTARY LIGHTING

TABLE 3. SUPPLEMENTARY LUMINAIRES *(See instructions C-1–C-7)*

Item No.	Work surface lighted	No. of luminaires	Luminaire distribution	Lamp watts-type	Luminaire description, location and mounting	Condition
1						
2						
3						
4						

Further details *(See instruction C-8)* .....

TABLE 4. (*See instruction D*)

Measurement	Manufacturer	Name and model	Last calibration date and by whom
Illumination			
Brightness			
Reflectance			
Color			
Voltage			

ILLUMINATION MEASUREMENTS—AVERAGE

(Footcandles on a Horizontal Plane 30" Above the Floor from General Lighting Only.)

GENERAL.

Position the measuring instrument so that when readings are taken the surface of the light sensitive cell is in a horizontal plane and 30 inches above the floor. This can be facilitated by means of a small portable stand of wood or other material that will support the cell at the correct height and in the proper plane.

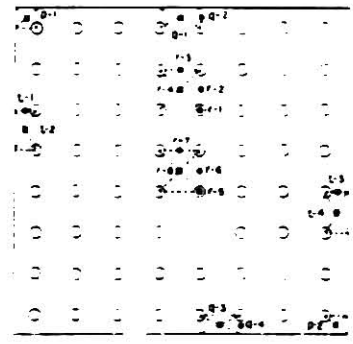
Exclude daylight during illumination measurements. Take readings at night or with shades, blinds or other opaque covering on the windows and/or skylights.

Readings should not be obstructed by surveyor or worker.

Select from Tables 5A through 5F *only* the table suited to the area and fill in the footcandle values required.

TABLE 5A. REGULAR AREA WITH SYMMETRICALLY SPACED LUMINAIRES IN TWO OR MORE ROWS (*See instruction E-1*)

Step 1		Step 2		Step 3		Step 4	
Station	fc	Station	fc	Station	fc	Station	fc
r-1		q-1		t-1		p-1	
r-2		q-2		t-2		p-2	
r-3		q-3		t-3			
r-4		q-4		t-4			
r-5							
r-6							
r-7							
r-8							
Total							
Average R =		Q =		T =		P =	



Step 5. Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{R(N-1)(M-1)+Q(N-1)+T(M-1)+P}{NM}$$

where: N = Number of luminaires per row; M = Number of rows.

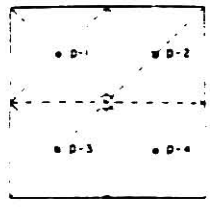
=

= ☐ fc on plane 30" above floor (IES Method)

TABLE 5B. REGULAR AREA WITH SYMMETRICALLY LOCATED SINGLE LUMINAIRE (*See instruction E-2*)

Step 1	
Station	fc
p-1	
p-2	
p-3	
p-4	
Total	
Average P =	

Step 2. Average illumination equals P

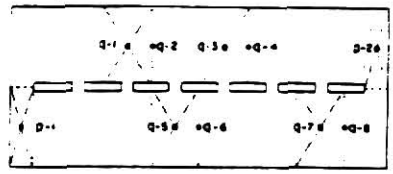


Average Illumination = ☐ fc on plane 30" above floor (IES Method)

ILLUMINATION MEASUREMENTS—AVERAGE

TABLE 5C. REGULAR AREA WITH SINGLE ROW OF INDIVIDUAL LUMINAIRES (*See instruction E-3*)

Step 1		Step 2	
Station	fc	Station	fc
q-1		p-1	
q-2		p-2	
q-3			
q-4			
q-5			
q-6			
q-7			
q-8			
Total			
Average Q =		P =	



Step 3. Determine the average illumination in area by solving the equation:

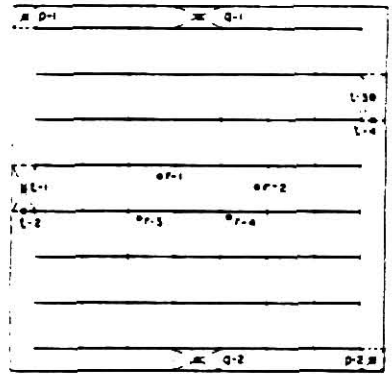
$$\text{Average Illumination} = \frac{Q(N-1)+P}{N}$$ where: N = Number of luminaires.

=

= ☐ fc on plane 30" above floor (IES Method)

TABLE 5D. REGULAR AREA WITH TWO OR MORE CONTINUOUS ROWS OF LUMINAIRES (*See instruction E-4*)

Step 1		Step 2		Step 3		Step 4	
Station	fc	Station	fc	Station	fc	Station	fc
r-1		q-1		t-1		p-1	
r-2		q-2		t-2		p-2	
r-3				t-3			
r-4				t-4			
Total							
Average R =		Q =		T =		P =	



Step 5. Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{RN(M-1)+QN+T(M-1)+P}{M(N-1)}$$

where: N = Number of luminaires per row;
M = Number of rows.

=

= ☐ fc on plane 30" above floor (IES Method)

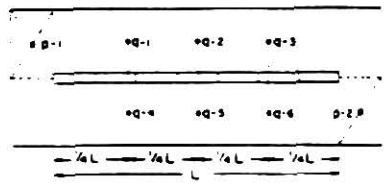
TABLE 5E. REGULAR AREA WITH SINGLE ROW OF CONTINUOUS LUMINAIRES (*See instruction E-5*)

Step 1		Step 2	
Station	fc	Station	fc
q-1		p-1	
q-2		p-2	
q-3			
q-4			
q-5			
q-6			
Total			
Average Q =		P =	

Step 3. Determine the average illumination in area by solving the equation:

$$\text{Average Illumination} = \frac{QN+P}{N-1}$$

where: N = Number of luminaires.



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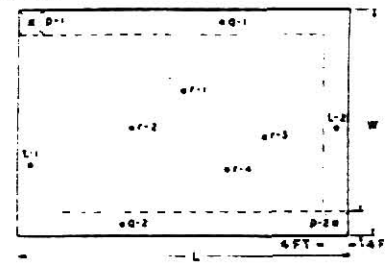
= ☐ fc on plane 30" above floor (IES Method)

ILLUMINATION MEASUREMENTS—AVERAGE

TABLE 5F. REGULAR AREA WITH LUMINOUS OR LOUVERALL CEILING (*See instruction E-6*)

Step 1		Step 2		Step 3		Step 4	
Station	fc	Station	fc	Station	fc	Station	fc
r-1		q-1		t-1		p-1	
r-2		q-2		t-2		p-2	
r-3							
r-4							
Total							
Average R =		Q =		T =		P =	



Step 5. Determine the average illumination in the area by solving the equation:

$$\text{Average Illumination} = \frac{R(L-8)(W-8)+8Q(L-8)+8T(W-8)+64P}{WL}$$

$$=$$

where: W = Width of room in feet;
L = Length of room in feet.

$$=$$ [ ] fc on plane 30" above floor (IES Method)

ILLUMINATION MEASUREMENTS—SPOT

(Footcandles at Point of Work and in Plane of Work)

GENERAL

Position the measuring instrument so that when readings are taken the surface of the light sensitive cell is in the plane of the work or of that portion of the work on which the critical visual task is performed, horizontal, vertical or inclined.

Record work position in Table 6.

Take readings at night or with windows and/or skylights covered.

Take readings with workers in normal working positions.

TABLE 6. (*See Instruction F*)

Work point	Description of work point	Height above floor in feet	Plane (horizontal, vertical, or inclined)	Footcandles	
				Total (general + supplementary)	General only
1—(max.)					
2—(min.)					
3—					
4—					
5—					
6—					

BRIGHTNESS MEASUREMENTS

(Footlamberts from Specified Work Point Locations)

GENERAL

Footlambert surveys, unlike footcandle surveys, are to be made under actual working conditions with the combinations of daylight and electric lighting facilities available. Consideration should be given to sun position and weather conditions, both of which may have marked effect on brightness distribution. All lighting in the area, both general and supplementary, should be in normal use. Work areas used only in the daytime should be surveyed in the daytime; work areas used both daytime and nighttime should preferably have two brightness surveys made under the two sets of conditions, as the brightness distribution and the possible comfort or discomfort will differ markedly at these times. Nighttime surveys should be made with shades drawn. Daytime surveys should be made with shades adjusted for best control of daylight.

Read the instructions for using the brightness measuring instrument employed if not familiar with its use. Take practice readings to acquire facility in balancing the brightness of the instrument fields before making the survey. A tripod mounting for the instrument will facilitate its use.

Check the dial pointer on the instrument frequently during the survey and keep the pointer on the index mark by adjusting the rheostat knob. If appreciable intervals of time must intervene between readings, it is well to turn off the comparison lamp in the instrument.

On the floor plan sketch of the area, indicate which exterior wall or walls, if any, were exposed to direct sunlight during the time of the survey by writing the word "Sun" in the appropriate location.

BRIGHTNESS MEASUREMENTS (Continued)

TABLE 7. (*See instruction G*)

Location	Brightness in Footlamberts					
	A	B	C	D	E	F
Luminaire at 45° above eye level						
Luminaire at 30° above eye level						
Luminaire at 15° above eye level						
Ceiling, above luminaire						
Ceiling, between luminaires						
Upper wall or ceiling adjacent to a luminaire						
Upper wall between two luminaires						
Wall at eye level						
Dado						
Floor						
Shades and blinds						
Windows						
Task						
Immediate surroundings of task						
Peripheral surroundings of task						
Highest brightness in field of view						

Description of highest brightnesses, A through F .....

Were brightness readings taken during daytime or nighttime? .....

DAYLIGHTING

What daylighting means are provided? (*See instruction H-1*) .....

What daylight control means are provided? (*See instruction H-2*) .....

MAINTENANCE

What is regular cleaning schedule for luminaires? .....

When were luminaires last cleaned? .....

What is lamp replacement schedule (*See instruction I-1*): On burnout? Group replacement? .....

If group replacement, when was last replacement made? .....

What is group replacement interval? .....

Percentage of lamp burnouts found (*See instruction I-2*) .....

What is regular painting schedule? (*See instruction I-3*) .....

When was area last painted? .....

Is working atmosphere clean, average or dirty? .....

GENERAL OBSERVATIONS ON THE VISUAL ENVIRONMENT (*See instruction J*)*

What percentage of workers are subjected to undue direct glare conditions from: General lighting system? Supplementary lighting? Daylighting? .....

What percentage of workers are subjected to undue reflected glare conditions from: General lighting system? ..... Supplementary lighting? ..... Daylighting? .....

If there are adjustable daylight control means, are they being used as effectively as possible to minimize glare? .....

What percentage of workers are subjected to troublesome shadows at work point?

What is your opinion of the general lighting system? (*good, fair, poor*) .....

What is your opinion of the supplementary lighting? (*good, fair, poor*) .....

Rate the room as a whole from the standpoint of pleasantness and visual comfort of workers (*good, fair, poor*) .....

What changes, in your opinion, would effect the most obvious improvement of the visual environment? .....

Other comments: .....

*Observers who are not skilled in the art and science of illumination should not rely on their judgment in answering these questions, but should call on a competent illuminating engineer.

SUMMARY

A plant tour was conducted at McCall Pattern Company, Manhattan, KS. The purpose of the visit ws to study visuual task lighting. Six areas in McCalls were noted as having lighting problems. It was decided to study these six areas in detail. A survey form "Task/work place lighting" with sixteen items was used to collect the required information.

A Sampson light meter was used to record light readings in the vertical as well as in the horizontal plane. Throughout the plant the light was provided with F96712/CW,WW 60 watt lamps. The rows of the fixtures were 22.7 feet apart.

Overall illumination averge value was found to be 35 fc (horizontal). To determine needed illuminance, the table in the IES Lighting Handbook was consulted. All the activities at McCall's fall into catagory D (Task with large size) or E (Task with small size) according to Table 1, with recommended illumination levels of 20-30-50 fc and 50-75-100 fc respectively.

In Branch Service, Tissue Cutter, and Guide Press Areas the levels of illumintion were below these standards and needed immediate improvement. In the other three ares, Hand Folding, Fill in, and Discard the levels of illumination barely met the standards. This situation of substandard lighting can be improved either by lowering the fixtures, giving supplementary lighting and replacing the burnt lamps or changing the system to High Pressure Sodium (HPS). HPS lighting is 50% more efficient than fluorescent lighting. If the company decides to spend money on the improvement of lighting this would be a good choice except where color must be discrimminated. From the author's viewpoint, it is strongly recommended that the fluorescent system at McCall's should be replaced with HPS.

A STUDY OF VISUAL TASK LIGHTING

by

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Lahore, Pakistan, 1979

AN ABSTRACT OF

MASTERS' REPORT

submitted in partial fulfillment of

requirement for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1985

ABSTRACT

A lighting survey was conducted in McCall Pattern Company, Manhattan, Kansas. This was done in order to study some visual tasks performed there and the lighting conditions provided for each task. In order to record the information required for the survey, a form titled "INFORMATION SHEET FOR TASK / WORKPLACE LIGHTING" was used. This form was developed by the author. After the plant tour six areas were decided to be studied in detail because these areas were found to have illumination problems. Every necessary information was recorded in order to analyze the situation and then suggest some good alternatives which would prove better and feasible in the years to come. It was found that in most of the aras, changing over from fluorescent to high pressure sodium would produce better illumination at lower cost.