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NOVEMBER 1982**

DESIGN AND DEMONSTRATION FOR AREA AND WALKWAY LIGHTING ON ELECTRIC-POWERED, MOBILE, SURFACE MINING EQUIPMENT

Contract H0387024
Advanced Systems Division
Mine Safety Appliances Company

**BUREAU OF MINES
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<u>ABSTRACT</u>			
<p>The Bureau of Mines recognized the need to develop illumination standards for work areas of surface coal mines. The January 13, 1977, Federal Register (Vol. 42, No. 9, Section 77.207, Paragraph d) proposed new regulations specifically applicable to above ground operations directly related to illumination of areas in, on and around draglines, shovels and wheel excavators. This report details the design, installation and demonstration of lighting systems of large draglines and shovels for: (1) areas 20 ft. in all directions from the main frame, (2) exterior walkways on board the mining machines, and (3) the area beneath the boom from 20 ft. from the main frame to the farthest point the equipment is capable of excavating or discharging material. The equipment utilized for this work were a 176 cubic yard Bucyrus Erie 3270 dragline, a 60 cubic yard Bucyrus Erie 1450 dragline and a 105 cubic yard Marion 5900 shovel.</p>			
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FOREWORD

This report was prepared by Mine Safety Appliances Company, Advanced Systems Division, Evans City, Pennsylvania, under the U. S. Bureau of Mines Contract No. HO 387024. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of U. S. Bureau of Mines, PMSRC, with William H. Lewis acting as Technical Project Officer. William R. Mundorf was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period September, 1978, to July, 1982. This report was submitted by the authors on November 1, 1982.

Please note that in our opinion, no patentable features of illumination systems are disclosed herein. Reference to specific brands, equipment, or trade names in this report is made to facilitate understanding and does not imply endorsement by the Bureau of Mines or Mine Safety Appliances Company.

This report deals with the design, installation and evaluation of illumination systems for one (1) power shovel and two (2) draglines that will comply with proposed MSHA standards. The specific machines utilized for this work were a 176 cubic yard Bucyrus Erie 3270 dragline, a 60 cubic yard Bucyrus Erie 1450 dragline and a 105 cubic yard Marion 5900 shovel. AMAX Coal Company, Midwest Area Office entered into a cooperative work effort to provide use of the demonstration machines and to install and maintain the illumination systems during the program. We wish to acknowledge the cooperation and the assistance of all AMAX personnel involved and especially Ben Spears, Bill Westerfield and Charles Crothers.

General Energy Development Corporation (GEDC) was involved as a subcontractor for the illumination systems designs and modifications of luminaires and their accessories for installation on board the large surface mining machines. Modifications of standard floodlights were required to prepare for their operation in an environment that generates unusual shock, acceleration and deceleration forces. We wish to acknowledge the cooperation and assistance of all GEDC personnel and especially Robert Harrow.

A change of scope was authorized for: (1) a study of tasks performed on walkways and work areas of surface mining machines, and (2) an investigation of light levels required for performance of these tasks. Bituminous Coal Research (BCR) made a comprehensive study of tasks performed on walkways and work areas, and Illuminating Engineers Research Institute (IERI) made an extensive study of light levels required for tasks associated with operation of the surface mining machines. This work was evaluated in an Interim Report. We acknowledge the contributions of Kenneth Whitehead of BCR and Cash Crouch and Richard Vincent of IERI for their work on this project.

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ABBREVIATIONS

B.E. Bucyrus Erie
CMM Computer Mathematical Model
c.y. Cubic Yard
f.c. Footcandle
HPS High Pressure Sodium
LLF Light Loss Factor
MSHA Mine Safety and Health Administration
MV Mercury Vapor
PFS Proposed Federal Standards

I SUMMARY

The Federal Coal Mine Health and Safety Act proposed mandatory safety standards for surface coal mines as listed in the January 13, 1977, Federal Register. This report deals with the part of this act that is related to off board area lighting and on board exterior walkway lighting on large electric-powered mobile surface mining equipment. Specifically, the area lighting included all areas 20 feet in all directions from the mining machines and the area beneath the boom, while the walkway lighting included the travelways aboard these machines.

Area lighting systems were designed, installed and demonstrated on three (3) large surface mining machines, namely a 60 cubic yard (c.y.) Bucyrus Erie (B.E.) 1450 dragline, a 176 c.y. B.E. 3270 dragline and a 105 c.y. Marion 5900 shovel. An evaluation of the results indicates the ability to meet the Federal Proposed Standards for area lighting with the hardware now on the market. The photometric surveys showed the average intensity under the boom area was better than three (3) to five (5) times greater than the Proposed Federal Standards (PFS). Applying a light loss factor of 0.61, the intensity would be two (2) to three and one-half (3½) times as large as the PFS. The results of the area lighting around the main frame was less definitive because the design predicted higher levels than were achieved. The average light levels for the B.E. 1450 and B.E. 3270 draglines were higher than the PFS but the Marion 5900 shovel light levels were less on all sides except the rear of the machine. These luminaires encounter difficult mounting locations and their installation and aiming instructions must be defined in closer detail in order to result in a more effective system.

Walkway lighting systems were designed, installed and demonstrated on two (2) large surface mining machines, namely the B.E. 3270 dragline and the Marion 5900 shovel. The walkways involved in the lighting demonstration were those normally used for routine night maintenance on loading docks, roofs, entries and access to platforms on the shovel gantry. They did not include walkways and work areas traversed only during the daylight hours or for unscheduled work such as cable replacements, welding or other work that results in shutdown of the machines. These walkways were located on or were immediately adjacent to the house of each machine.

In contrast to the area lighting installations where the fixtures may be aimed at locations over 400 feet away, the walkway lighting only illuminated immediately adjacent subjects. Since the walkway lighting illuminated transient areas of walkways, the relative distance from light source to reflecting surface was continuously variable, whether traversing stairways or level walks. Therefore, the change in lighting levels would vary considerably from a point directly under a luminaire to a point where the surface was shared by two or more luminaires. The walkway luminaires had to be mounted where structural members were available, so the design criteria was to achieve a minimum average called for by the specification and to accept the higher levels of illumination as a result of the minimum acceptable design standards. There were no difficulties in obtaining the specified intensity on the exterior walkways involved in the lighting demonstration.

Special electrical control panels were installed in each of the machines participating in the lighting demonstrations. These panels provided for separate control and overload protection for each individual lighting circuit. Operation of the lights was arranged for the period of dusk to dawn by use of a photoelectric control.

Although standard hardware and fixtures were used for the lighting systems, modifications were required to qualify for the severe service experienced aboard the machines. These modifications were related to fixture and ballast mountings and bulb supports to withstand the shock, vibration and unusual G forces encountered during the excavation and swing cycles of the machines.

II INTRODUCTION

Under the authority of the Federal Coal Mine Health and Safety Act, proposed mandatory safety standards for surface coal mines were published in the January 13, 1977, Federal Register, Volume 42, No. 9, Section 77.207. These standards established minimum illumination requirements for all areas where persons regularly work or travel. The primary purpose of the work authorized here was to demonstrate the benefits and feasibility of illuminating large, electric-powered mobile surface mining equipment.

The Bureau of Mines awarded Contract No. HO387024, titled, "Illumination of Electric-Powered, Mobile, Surface Mining Equipment" to demonstrate illumination systems designed to the proposed standards. Although the proposed rules were for the illumination of interior and exterior areas, the scope of work stated, "the illumination systems shall be designed to comply with only the exterior requirements of the MSHA standards". The objective then was to design, install and evaluate illumination systems for a power shovel and two (2) draglines, that would comply with the proposed MSHA standards.

Specifically, the contract stated that the surface mining machines should be a dragline 100 cubic yards (c.y.) or larger, a dragline between 40 and 100 c.y. and a shovel larger than 100 c.y. Mine Safety Appliances (MSA)/Advanced Systems Division (ASD) entered into a cooperative work effort with AMAX Coal Company, Midwest Area, for use of their machines in performance of the project. The machines utilized were:

<u>Machine Size</u>	<u>Make</u>	<u>Bucket Size</u>	<u>Location</u>
Dragline 100 c.y. or larger	B.E. 3270	176 c.y.	Marion, IL
Dragline between 40-100 c.y.	B.E. 1450	60 c.y.	Marion, IL
Shovel larger than 100 c.y.	Marion 5900	105 c.y.	Campbell Hill, IL

The lighting of the machines was divided into two (2) parts, namely the area lighting (off board illumination) and walkway lighting (on board illumination). The area lighting included that space under the boom and around the main frame of the machines, and the walkway lighting included the permissible travelways and work areas on the machines. The work areas applicable to the PFS were:

TABLE 1 - PROPOSED FEDERAL STANDARDS

<u>Location</u>	<u>Avg. F.C.</u>	<u>Uniformity Ratio</u>
1. All area 20 feet in all directions from the main frame.	5.0	10/1
2. Exterior walkways on board draglines and shovels.	5.0	10/1
3. The area beneath the boom 20 feet from the main frame to the farthest point the equipment is capable of excavating or discharging material.	1.0	10/1

The project was intended to perform the area lighting and the walkway lighting demonstrations concurrently, but due to the uncertainty of walkways affected, the walkway lighting design was rejected, while the area lighting design was approved. Work proceeded on the installation and demonstration of the area lighting while independent studies were performed to: (1) determine which walkways were traversed during machine operation, and (2) evaluate walkways and work areas on board these machines to determine the illumination required to obtain threshold vision. Upon completion of this work, the design, installation and evaluation proceeded on walkway lighting to complete the projected work.

The program objectives of design, installation and evaluation of illumination systems for large, electric-powered, mobile surface mining was achieved. Due to the lag in performance of the walkway lighting systems, there was a difference in machine use and demonstration period. The area lighting demonstration utilized the 60 c.y. dragline, 176 c.y. dragline and the 105 c.y. shovel for a scheduled test period of three (3) months, while the walkway lighting demonstration utilized the 176 c.y. dragline and the 105 c.y. shovel for a scheduled test period of two (2) months.

III METHODOLOGY

A program plan was prepared to sequentially achieve the project objectives to design, install and evaluate illumination systems for large electric-powered, mobile surface mining equipment.

A. Design

a. Survey of Mining Machines

Obtaining information essential for the defined tasks was the initial priority. Visits were made to the mine sites where the machines were located to obtain details relative to the mining operations and machines and included:

- Obtaining drawings of the machine
- Observing on board operation during the second and third shifts.
- Interviews with mine personnel
- Inspection of electrical systems
- Taking photographs

Drawings of the B.E. 1450 dragline were not available, drawings of the Marion 5900 shovel could not be located, and although drawings of the B.E. 3270 dragline were not available for file, we were able to review them since the machine was being assembled at the mine site. Some outline drawings were supplied by the companies upon formal requests, but these only showed information such as boom angle, boom length, boom height from ground, operating radius, house width, house length and house height. This information was used to develop machine specifications as shown in Figure A.1 for the B.E. 1450, Figure A.2 for the B.E. 3270 and Figure A.3 for the Marion 5900.

The on board operation of the mining machines on the second and third shifts was smooth and uneventful during our observations. The excavate, swing, dump cycle of the B.E. 1450 dragline took from 60 to 75 seconds, noting that the swing was through 360 degrees. The Marion 5900 shovel had about the same frequency, depending on amount of rock present in the excavation and had an arc swing of about 110 to 130 degrees. The only breaks in the cycles occurred when the shovel was trammed, the dragline walked or when the helper relieved the operator at the control console.

Interviews with the mine personnel working with the machines indicated they considered their duties routine, not too difficult, but requiring constant vigilance. There was no particular concern about the intensity of the lighting and no preconceived ideas about the amount of light required to perform their assigned duties. Boom and other exterior lighting was mercury vapor with some incandescents located in areas requiring special illumination. The number and duties of mine personnel assigned to each machine was generally as follows:

- 1 Operator
- 1 Helper/Oiler
- 1 Ground man
- 2 Motor/Generator house mechanics

The incoming power for the B.E. 1450 dragline is 6,900 volts used for direct operation of the motor-generator sets. A stepdown transformer is used to provide 480 and 120 volts for operation of fans/blowers, utility circuits and lighting. Both the B.E. 3270 dragline and the Marion 5900 shovel receive 22,900 volts on board, with transformers to convert to 6900 volts for operation of the motor-generator sets and 480 and 120 volts for fans/blowers utility circuits and lighting. The amount of 120 volt power available was limited, so lighting installations would require direct operation from 480 volts or provide a separate transformer to make 120 volts available.

Photographs were taken of all the participating machines to assist in designing fixture mountings and location of luminaires on the machines. Since detail drawings were not available, these prints were of great value in developing a design for the lighting systems.

b. Lighting Equipment Selection

Two major types of lighting systems were to be designed, installed and evaluated on the selected mining machines. They were the area lighting (off board illumination) and exterior walkway lighting (on board illumination).

1. Area Lighting Fixtures

The area lighting included the ground around the main frame and the ground under the boom. On visits to the mine sites mine personnel were questioned as to their opinion of existing illumination (mercury vapor) as to the type of light source, color rendition, maintenance, etc. A consensus of the personnel indicated they

were interested in using sodium luminaires. Reasons put forth in support of sodium luminaires was the ability to penetrate fog and dust, the monochromatic color of sodium light sources are less harsh than mercury vapor, and the ability to light a larger cross-sectional area with fewer luminaires (higher lumens per watt output). Since the existing mercury vapor lighting systems were to remain on the B.E. 3270 and Marion 5900, the new installation would offer a basis of comparison for the mine personnel.

The design program was initiated with a review of existing lighting hardware available from a selected cross-section of lighting equipment manufacturers. Six (6) lighting equipment manufacturers were selected as a representative cross-section of the industry and each was asked to select one of their luminaires to best meet the application. Based on the luminaires selected by each manufacturer, a comparison was made on each using sixteen (16) criteria, as follows:

TABLE 2 - AREA LUMINAIRE SELECTION CRITERIA

<u>Criteria</u>	<u>Weight</u>
1. Lamp Orientation	4
2. Fixture Material	3
3. Reflector Design	3
4. Mounting Method	5
5. Light Source	1
6. Lamp Replacement	5
7. Photoelectric Controls	1
8. Low Temperature Starting	1
9. Vibration	5
10. Dust and Weatherproofing	5
11. Ballasting	1
12. Luminaire Angling	2
13. Standard Fixture Cost	1
14. Modification Cost	4
15. Time to Modify	5
16. Availability	3

The rating of each luminaire was determined by a simple 1 to 10 scoring system. This 1 to 10 score, multiplied by the criteria weight, resulted in the total weighted score for each manufacturer. Under this analysis, the GTE-Sylvania "Batwing" series of luminaires were selected for use in the Area Lighting. These luminaires were high pressure sodium (HPS).

2. Walkway Lighting Fixtures

The walkway lighting was to include all exterior travelways and work areas on board these machines. Since mine personnel would be working directly under these luminaires and traversing travelways adjacent to their installation, one criteria for their selection could be a low glare source.

Five (5) lighting equipment manufacturers were selected as a representative cross-section with products capable of meeting the requirements of low glare walkway lighting. Each manufacturer was asked to review the layout of walkways and recommend their luminaire that would best meet the requirements. Based on the luminaires selected by each manufacturer, a comparison was made on each using fifteen (15) criteria, as follows:

TABLE 3 - WALKWAY LUMINAIRE SELECTION CRITERIA

<u>Criteria</u>	<u>Weight</u>
1. Suggested Light Source	4
2. Basic Design	3
3. Strength of Fixture	5
4. Reflector Design	1
5. Lamp Replacement	5
6. Low Temperature Starting	3
7. Ballasting	1
8. Luminaires per Ballast	2
9. Mounting	4
10. Vibration	5
11. Dust and Weatherproofing	5
12. Availability	3
13. Standard Fixture Cost	1
14. Modification Cost	4
15. Time to Modify	5

Each luminaire was evaluated against each criteria, again using a 1 to 10 scoring system. The 1 to 10 score, multiplied by the criteria weight, resulted in the total weighted score for each manufacturer. Based on this analysis the MSA VHO LX2400 fluorescent luminaires were selected for use in walkway lighting.

c. Design of Lighting Systems

The design of the area lighting systems was by use of a mathematic model in conjunction with a computer. The construction of a mathematical model was planned for two phases. Phase 1 dealt specifically with problems relating to area lighting and phase 2 was to deal with those problems relating to on board exterior walkway lighting systems.

Mathematical models for area lighting systems were developed around the use of a computer which was programmed with all the pertinent information of the selected luminaires for the off board ground lighting. A complete analysis of the construction of the computer mathematical models for area illumination is provided in the section that follows.

It was determined that it would be impractical to use the same techniques for walkway illumination that were used for the area illumination layouts. This decision is based on an analysis of the walkways and ladderways that have been constructed on the three machines covered in this contract. The approach for illuminating the walkways was to simulate a typical walkway in a test chamber and determine by photometric tests the approximate number and placement of luminaires.

1. Area Lighting

The area lighting system design approach involved the use of a computer to simulate the design criteria. Various luminaire locations and aiming data were fed to the computer, which assimilated the inputs with the simulated program and returned a printout of the lighting intensity results. The sections that follow describe this process, which has been termed "Construction of Mathematical Models", analyzes the results and presents the final design luminaire locations and aiming diagrams for the area lighting systems for the three machines.

2. Construction of Mathematical Models

Computer Input Data

There are six (6) major data input areas necessary for computerized mathematical models of

the proposed area lighting systems. These areas are as follows:

- A. Size of machine to be illuminated by height, width and length, including separate boom angle specifications.
- B. Estimated heights at which luminaires are to be mounted.
- C. Type of luminaires to be used, including iso-intensity diagrams.
- D. Description of areas to be illuminated.
- E. Light Loss Factors.
- F. Estimated luminaire layouts and aiming angles.

Each of these data input areas is described in more detail in the sections that follow.

Machine Specifications

The external dimensions of the three mining machines were provided for computer input based on the specifications presented in Figure Nos. A.1 (B.E. 1450), A.2 (B.E. 3270) and A.3 (Marion 5900). Photographs taken of each machine were also reviewed to estimate dimensional specifications not shown on the layout drawings supplied by the mine operator and/or manufacturer. A summary of machine dimensions is shown in Table 4.

Luminaire Mounting Heights

The mounting heights for the luminaires were determined by the available areas for mounting of luminaires on the structural framework of the three machines. Previous experience with mounting of luminaires by the operator was also taken into consideration. The luminaires selected for this application provides a minimum and maximum effective height limitation based on previous use of these luminaires in industrial area lighting applications.

Selected Luminaires

Based on an objective evaluation of the relative merits of a number of luminaires, the GTE-Sylvania high pressure sodium Batwing series of luminaires was chosen for this application. Two sizes of this luminaire were used, a 400 watt unit and a 1000 watt unit.

TABLE 4 - MINING MACHINERY DIMENSIONS

BUCYRUS ERIE 3270, 176 C.Y. DRAGLINE

Boom Angle - 36°
Boom Length - 330 feet
Boom Height from Ground - 230 feet
Operating Radius - 311 feet
House Width - 116 feet
House Length - 123 feet
House Height - 60 feet

MARION 5900, 105 C.Y. SHOVEL

Boom Angle - 45°
Boom Length - 210 feet
Dumping Height - 130 feet
Dumping Radius - 213 feet
House Width - 60 feet
House Length - 87 feet
House Height - 80 feet

BUCYRUS ERIE 1450, 60 C.Y. DRAGLINE

Boom Angle - 38°
Boom Length - 250 feet
Boom Height from Ground - 170 feet
Operating Radius - 227 feet
House Width - 44 feet
House Length - 90 feet
House Height - 30 feet

The HDF-400-HPS-480 was used for the area lighting on the B.E. 1450 dragline. This luminaire has a beam spread of 137° horizontal and 101° vertical.

The HDF-1000-HPS-480 was used for the area lighting on the B.E. 3270 dragline and Marion 5900 shovel. This luminaire has a beam spread of 127° horizontal and 106° vertical.

Areas to be Illuminated

A description of the areas to be illuminated around the electric-powered, mobile, surface mining equipment were proposed by MSHA in the Federal

Register, Vol. 42, No. 9, Section 77.207. These areas were defined as follows:

1. All areas 20 feet in all directions from the main frame, including all work or travel areas beneath the main frame.
2. The area beneath the boom from 20 feet from the main frame to the farthest point the equipment is capable of excavating or discharging material.

The specified areas were not definitive enough for an accurate computer input, especially with respect to the area under the boom, and specifically for the width of the affected area under the boom. Therefore, it was necessary to determine the absolute dimensions for the boom area illumination. Subsequently, the width of the area under the boom was chosen to be the width of the main frame, plus forty feet. The affected area under the boom would then be a projected width of the main frame plus forty feet, by a length equal to the projected ground dimension of the boom. These dimensions were selected based on discussions with the operators of the participating machines and the AMAX safety director. This redefined area is typically shown in Figure B.1 and was designated as the trace area for computer input referenced in the computer printouts.

The lighting around each machine was divided into four sections. These sections included areas under the boom, in front of the machine, to the sides of the machine and to the rear of the machine. Designated as trace areas, they are defined in Figures B.1 through B.12.

Light Loss Factors

The Light Loss Factor (LLF) of a given luminaire is a factor used in calculating the level of illumination after a given period of time under given conditions. It takes into consideration temperature and voltage variations, dirt accumulation on luminaires, lamp depreciation, maintenance procedures and atmospheric conditions.

Under the conditions experienced in strip mining operations a heavy LLF has been applied primarily in three areas.

<u>Light Loss From</u>	<u>% Light Loss</u>
1. Installation and manufacturing tolerance	5
2. Lamp lumen depreciation at 3/4 rated life	15
3. Dirt accumulation on fixture	<u>19</u>
Total light loss	39%

A light loss factor of .61 (100% - 39%) was utilized in the computer program.

Luminaire Layout and Aiming Angles, Preliminary

The preliminary estimate of location of area luminaires was based on known technology in establishing uniform distribution patterns for large area lighting installations. Horizontal and vertical aiming of individual luminaires was determined after analyzing computer printouts which had luminaires mounted at angles perpendicular to the ground. Horizontal and vertical aiming angles were modified with respect to set guidelines, these being uniformity ratios and average footcandle levels for the entire area illuminated.

Area Lighting Computer Program and Analysis

The computer used in this project was programmed to analyze a proposed illumination layout with as many known quantities as possible. These quantities included such items as:

1. Dimensions of the three machines.
2. Dimensions of the areas to be illuminated.
3. Type of luminaires to be used and complete iso-intensity data on each luminaire to be used.
4. Light loss factors.

These known quantities were discussed in the preceding text.

Estimates covering such factors as mounting heights, layout and estimated vertical and horizontal aiming of luminaires were also provided for computer input. Then each point of a 10 foot by 10 foot grid pattern was analyzed with respect to the illumination intensity in footcandles. This data was exhibited in the form of a computer printout for comparison with original estimates and the lighting levels as set forth in the proposed MSHA regulations. Adjustments were made with respect to aiming angles, mounting location and height to determine the optimum illumination layout. In this application the optimum illumination layout can be defined as an arrangement of luminaires which, when operating, will provide a safe place for nighttime activities. In order to provide an efficient illumination system, the grid system as printed out by the computer becomes an essential tool. Analysis of the computer printout indicates whether too many or too few luminaires are being used and whether a higher or lower wattage luminaire would improve the quality of the illumination layout. The models for the trace areas (Figures B.1 through B.12) were constructed using a minimum number of luminaires for the areas around the exterior of the three machines covered in this project. It was found that the B.E. 3270 dragline and the Marion 5900 shovel could be illuminated most efficiently using 1000 watt high pressure sodium luminaires. The B.E. 3270 would require nine (9) fixtures and the Marion 5900 eight (8) fixtures. Using the number of fixtures, as indicated, the illumination requirements, as proposed by MSHA, would be met or exceeded.

Following the same format on a similar computerized mathematical model, the illumination of the B.E. 1450 dragline could best be accomplished by using eleven (11) 400 watt high pressure sodium luminaires.

By defining an efficient illumination system as one which makes optimum usage of a minimum number of selected luminaires, it follows that an effective illumination system is one which personnel can perform assigned duties in a potentially hazardous area with relative safety. Considerations must be made to such criteria as uniformity ratios, levels of illumination on the task area and glare. The uniformity ratio, as interpreted from the

proposed regulations can be defined by the following formula:

$$\frac{\text{Maximum Reading Taken}}{\text{Minimum Reading Taken}}$$

The uniformity ratios as defined by the IES Lighting Handbook states that the uniformity of illumination requirements should be determined by computing the ratio:

$$\frac{\text{Minimum Horizontal Footcandles}}{\text{Average Horizontal Footcandles}}$$

or as the ratio of:

$$\frac{\text{Average Horizontal Footcandles}}{\text{Minimum Horizontal Footcandles}}$$

Use of the IES Lighting Handbook formula would allow the surface mining industry to conform with accepted, tried and tested, safety regulations and illumination standards as currently used in the industry.

However, the lighting systems analyzed by this computer program will conform to or exceed the levels of illumination and uniformity ratios set forth in the Proposed Regulations. The criteria for the protection of mine site personnel from glare is basically one of distinguishing between disability glare, discomfort glare and visual comfort. Disability glare and discomfort glare are covered in the section that follows pertaining to walkway illumination, where mine personnel will be in close proximity to light sources and subject to the direct viewing of the luminaires. It is felt that disability and discomfort glare are not a problem for area lighting systems due to the aiming of the fixtures away from points of observation and toward work areas with matte surfaces.

Luminaire Location and Aiming Diagrams

In the process of construction of the mathematical models, careful attention was given to the variables of the total illumination system. After the luminaire selection, two of the most important considerations are the location and aiming of the luminaires. Another major consideration in development of an optimum design is the overall shape of the exterior of a machine. The exterior shape determines the approximate luminaire locations based

on the iso-intensity diagrams. The iso-intensity overlays of the luminaire are used to determine approximate aiming angles. These approximate aiming angles are programmed into the computer with respect to points around the machine where specified light levels are to be produced (i.e. 20 feet around the main frame and the area under the boom).

The Computer Mathematical Model (CMM) is programmed to evaluate four (4) trace areas for each machine, namely area under the boom, area 20 feet in front of the main frame, 20 feet to the side of the main frame and 20 feet to the rear of the main frame. The input to the computer generates a printout that estimates the foot-candles for each 10 foot by 10 foot grid in the defined trace area. Figures B.1 through B.12 illustrate the areas to be illuminated with associate computer printout data shown in Tables B.1 through B.12. Based on acceptable results to meet the proposed MSHA standards, installation drawings can be developed from the information supplied for the computer input. Figure A.4 illustrates the location and aiming specifications for installation of the 400 watt HPS luminaires for the area lighting system on the B.E. 1450 dragline. Figures A.5 and A.6 present the same information for installation of 1000 watt HPS luminaires for the area lighting on the B.E. 3270 dragline and the Marion 5900 shovel.

3. Walkway Lighting

The exterior walkways that exist on each machine are extensive and consist of both original equipment (installed by manufacturer) and those added by mine personnel when necessary to perform maintenance work. The travelways on the exterior of these machines are composed of a mix of walkways, ladders, stairways, and access paths. Because of this mix and the transitions and discontinuities that exist, construction of mathematical models on a computer program was considered impractical. However, sections of representative walkways could be duplicated in a test environment. The design approach chosen was the use of simulated walkways. Using the simulator approach, an accurate estimate could be made as to the number and location of luminaires to satisfy the proposed regulations.

Simulator Analysis

The simulator analysis for designing complete illumination systems is used for the design of lighting systems for underground coal mining machines and has proved to be an accurate and valid approach to compliance. The procedure

involves placing a representative number of luminaires in a very low reflectance area devoid of all other light sources. Light level readings taken along an area the width of a typical walkway will represent worst case illumination patterns. Then by experimenting with the various mounting heights and luminaire spacings, the desired light levels and uniformity ratios can be determined. Figure 1 illustrates this procedure using the MSA/General Energy Boston Simulator.

Test and Evaluation

The regulations for illuminating exterior walkways on board draglines and shovels call for an average illumination intensity of 5.0 footcandles and a uniformity ratio of 10/1. In the MSA/General Energy Boston Simulator, an average intensity of 12.7 footcandles and a uniformity ratio of 8.7/1 was achieved by mounting LX-2400 luminaires at a 30 inch height and locating them on 12 foot centers. Figure 2 indicates the test conditions and results.

The high light intensity and high uniformity ratio are due to the low mounting height of the luminaires. It may be possible to obtain lower light intensities and uniformity ratios by increasing the mounting height of the luminaires. However, when the luminaires are mounted anywhere close to the eye level, there is a potential glare hazard. This hazard would be in the form of discomfort glare that may be unpleasant but not detrimental to visual performance, or disability glare that would reduce visual performance and visibility. Since there is the possibility of a glare problem when the mounting height is raised, the conditions that existed for the test data were utilized.

Luminaire Location Diagram

As previously noted, the exterior walkways that exist on each machine are extensive and are composed of a mix of walkways, ladders, stairways and access paths. It was not within the scope of this project to determine which walkways fall within MSHA's definition of the term "walkway" and which do not. Therefore, all walkways were analyzed and systems designed to provide the required illumination under the proposed standards.

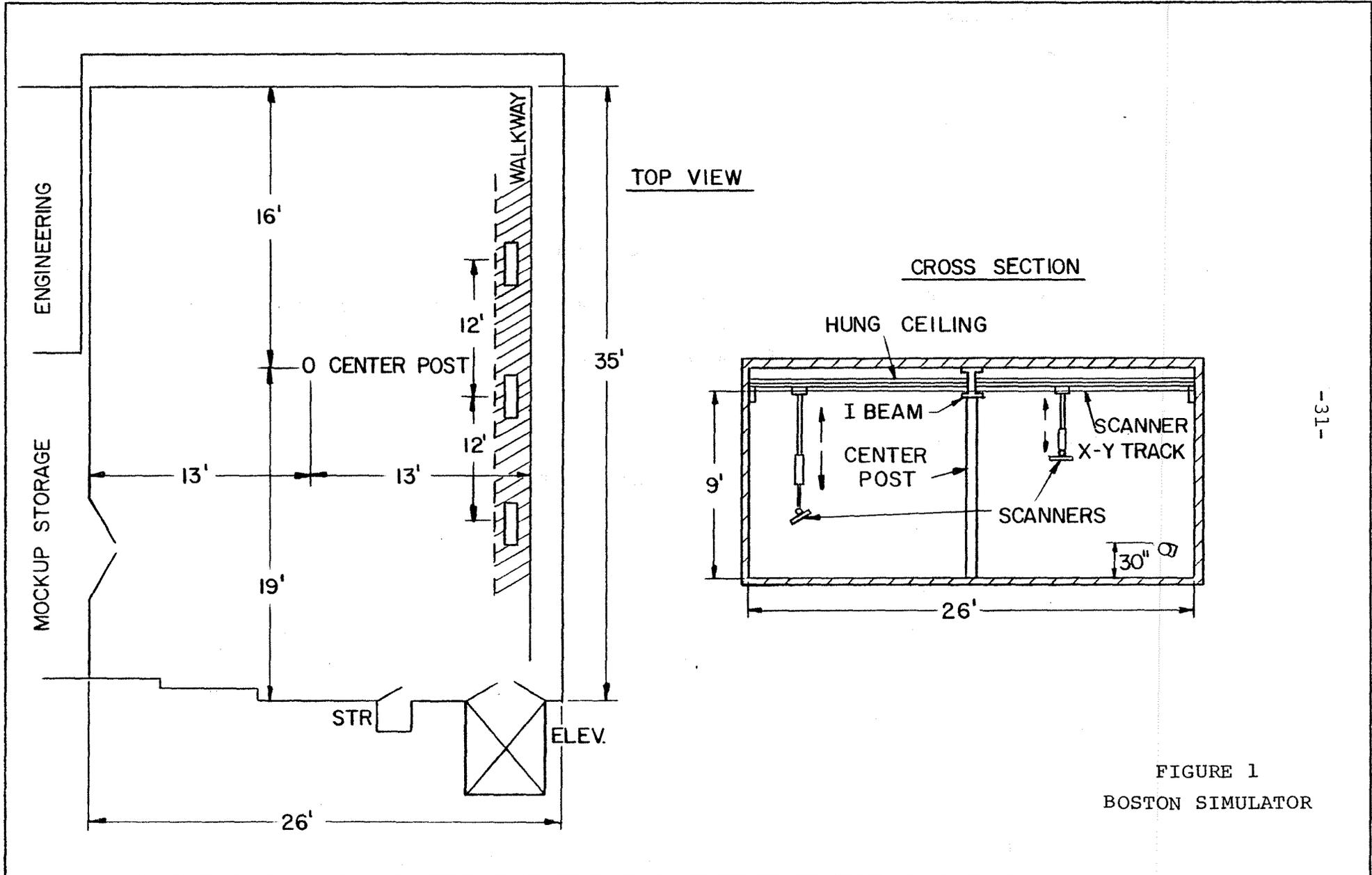


FIGURE 1
BOSTON SIMULATOR

The luminaire layout tested in the Boston Simulator, with results as shown in Figure 2, was followed as a series of typical layouts for walkways on each machine. The typical layouts of walkways are shown in Figures A.7, A.8 and A.9. In order to electrically isolate and identify the installation and control of the walkway luminaires, the installation was broken down into System identifications designating the areas to be illuminated and the number of luminaires required for each machine. A summary of this information is as shown in Table 5.

TABLE 5 - WALKWAY LIGHTING SYSTEMS

<u>Machine</u>	<u>Walkway System</u>	<u>Location</u>	<u>No. Luminaires</u>
Bucyrus 1450	A	Left Side Boom	18
	B	Right Side Boom	18
	C	Top of Machine	12
	D	Mast	6
		Total Walkway Luminaires	54
Bucyrus 3270	A	Left Side Mast	16
	B	Right Side Mast	16
	C	A Frame	16
	D	Underneath Work Area	8
	E	Left Side Boom	24
	F	Right Side Boom	24
	Total Walkway Luminaires	104	
Marion 5900	A	Left Side Boom (Upper)	17
	B	Right Side Boom (Upper)	17
	C	Underneath Rotating Frame	22
	D	Upper Machine #1	20
	E	Upper Machine #2	20
	F	Shovel Arm	12
	G	Left Side Boom (Lower)	17
	H	Right Side Boom (Lower)	17
	Total Walkway Luminaires	142	

4. Lighting Systems Power Specifications

The power requirements for each area and walkway lighting system are based on the sum total of the input power to each luminaire, including associated electrical

components such as ballasts. The power required for each specific luminaire is as follows:

<u>Luminaire</u>	<u>Power Required</u>
400 Watt High Pressure Sodium	470 Watts
1000 Watt High Pressure Sodium	1100 Watts
55 Watt VHO Fluorescent	100 Watts

B.E. 1450 Dragline

The B.E. 1450 required eleven (11) 400 watt HPS luminaires to light the areas around the main frame and under the boom. Six (6) of those luminaires were mounted on the roof and five (5) on the boom. The walkway lighting required fifty-four (54) 55 watt VHO fluorescents across four separate walkway systems. Summary of the power requirements for this machine is:

<u>Quantity</u>	<u>Luminaires</u>	<u>Watts/Luminaire</u>	<u>Total Watts</u>
11	400 watt HPS	470 watts	5,170 watts
54	55 watt VHO	100 watts	<u>5,400 watts</u>
	Total watts		10,570 watts

B.E. 3270 Dragline

The B.E. 3270 required nine (9) 1000 watt HPS luminaires to light the areas around the main frame and under the boom. Three (3) were mounted on the roof, two (2) on the front of the house and four (4) on the boom. The walkway lighting required one hundred and four (104) 55 watt VHO fluorescents across six separate walkway systems. Summary of power requirements for this machine is:

<u>Quantity</u>	<u>Luminaires</u>	<u>Watts/Luminaire</u>	<u>Total Watts</u>
9	1000 watt HPS	1100 watts	9,900 watts
104	55 watt VHO	100 watts	<u>10,400 watts</u>
	Total watts		20,300 watts

Marion 5900 Shovel

The Marion 5900 shovel required eight (8) 1000 watt HPS luminaires to light the areas around the main frame and under the boom. Three (3) were mounted on the roof, one (1) on the front of the house and four (4) on the boom. The walkway lighting required one hundred and forty-two (142) 55 watt VHO fluorescents across eight

separate walkway systems. Summary of power requirements for this machine is:

<u>Quantity</u>	<u>Luminaires</u>	<u>Watts/Luminaire</u>	<u>Total Watts</u>
8	1000 watt HPS	1100 watts	8,800 watts
142	55 watt VHO	100 watts	<u>14,200 watts</u>
		Total watts	23,000 watts

Electrical Installation

The power available for operation of the lighting systems was Y-connected 480 volts, 3 phase, 60 hertz. The area lighting systems were designed to operate at 480 volts and the walkway lighting systems from the Y-connected 277 volts. The area lighting was arranged to operate from dusk to dawn by using photoelectric controls. However, the walkway lighting was arranged to be operated by the use of manual controls on each system. This separation of controls was decided upon after discussions with the mine operator indicated a desire to be able to control these lighting systems independently, in the event a glare hazard was experienced in the operation of the walkway lighting.

Master panels were designed to receive the 480 volt 3 phase power from the machines, then control and distribute this power to the area and walkway lighting systems. The design for each of the mining machines is shown in the following figures:

<u>Mining Machine</u>	<u>Electrical Drawings</u>
B.E. 1450	Figure A.10
B.E. 3270	Figure A.11
Marion 5900	Figure A.12

It must be noted that the installations described here were redundant with the existing machine lighting. This feature was requested by the mine operators so they could be switched off if they appeared to interfere with the operation of the mining machine.

d. Review of Design

A design review meeting was held to critique the designs of the area and walkway lighting systems. Participants included personnel from the Bureau of Mines, MSHA, AMAX Coal Company, General Energy Development Corporation and Mine Safety Appliances Company/Advanced Systems Division.

After a review and discussion of the design approach, development and drawings, the attributes and shortcomings of each system was noted. The design of the area lighting systems was considered a model of what was intended by the proposed regulations, but the walkway lighting was deemed too extensive.

In the statement of work in the request for proposal, the objective was, "to design, install, and evaluate illumination systems for a power shovel and two (2) draglines that will comply with the proposed MESA standards". The applicable section of the proposed rules stated, "All areas where persons regularly work or travel shall be illuminated to not less than the average illumination intensities specified in this section," and for, "exterior walkways on board draglines, shovels and wheel excavators." Since all walkways exist because mine personnel use them in performance of their work, and since there were no exclusions indicated, all walkways were included for the lighting design. Those in attendance agreed the walkway lighting design was too extensive, with the consensus that limitations should be imposed on the number of walkways qualifying for the proposed application. In addition, the lighting level of 5.0 footcandles for walkways was suspect because the I.E.S. Handbook listed recommended lighting levels of 2.0 footcandles for exterior catwalks. This service would be similar in task performance to the work on dragline and shovel walkways.

As a result of the design review meeting, the Bureau of Mines decided to reject the walkway lighting design and to accept the area lighting design.

B. Evaluation of Task Performance and Survey of Illumination Requirements for Walkways of Large Surface Mining Machines

Since the consensus of the design review meeting was for limitations on the scope of walkway lighting, and there was some question as to the lighting level specified, an unsolicited proposal was submitted to the Bureau to study these areas. This proposal was for a change of scope and was titled, "Study of Walkways and Work Areas, Analysis of Tasks vs. Light Intensity for Safe Work Performance." The proposal resulted in the approval of a change in scope to study these areas.

This change of scope work was completed and an interim report issued on April 14, 1980. The report detailed the tasks that are performed on and around the large surface mining machines in association with their operation during scheduled maintenance (activities) and during unscheduled maintenance (activities). A summary of travelway utilization on draglines and shovels is shown in Tables 6, 7, 8 and 9.

TABLE 6 - TRAVELWAY UTILIZATION FOR SCHEDULED WORK PROCEDURES FOR DRAGLINES

MACHINE COMPONENT	TYPE OF USAGE				DAYLIGHT	NIGHT	FREQUENCY
	TRAVERSE	INSPECT	LUBRICATE	TASKS			
<u>1. House</u>							
a. Entry	x	o	o	o	x	x	General
b. Roof	x	o	o	o	x	x	General
c. Fairlead	x	x	x	o	x	o	Once/Week
d. Loading Dock	o	o	o	x	x	x	General
<u>2. A-Frame</u>							
a. Access	x	x	o	o	x	o	Once/Week
b. Top Platform	x	x	x	o	x	o	Once/Week
c. Lower Platform ⁽¹⁾	x	x	x	o	x	o	Once/Week
<u>3. Mast</u>							
a. Access	x	x	o	o	x	o	Once/Week
b. Top Platform	x	x	o	o	x	o	Once/Week
c. Deflection Sheave Platform	x	x	x	o	x	o	Once/Week
<u>4. Boom</u>							
a. Access	x	x	o	o	x	o	Once/Day
b. Point Platforms	x	x	x ⁽²⁾	o	x	o	Once/Day
c. Suspension Cable Platforms	x	x	o	o	x	o	Once/Day
d. Deflection Sheave Platform	x	x	x	o	x	o	Once/Day
<u>5. Fairlead</u>							
a. Access	x	x	x	o	x	o	Once/Week

⁽¹⁾Would normally have two platforms only on smaller draglines having no mast.

⁽²⁾Lubrication not required every day but at least once per week.

x Applicable

o Not Applicable

TABLE 7 - TRAVELWAY UTILIZATION FOR UNSCHEDULED WORK PROCEDURES ON DRAGLINES

Machine Component	Task Performed	Daylight	Night	Average Duration	Average Frequency	Comments
1. <u>House</u>	None					
2. <u>A-Frame</u>	Replace Suspension Cables	x	x	4 days	5 years	Initiated on daylight, continued until job completed.
	Weld Structural Members	x	o	I	as required	Can require temporary platforms.
	Maintain Deflection Sheave Wheels	x	x	I	as required	Frequency would normally be in terms of years. Initiate on daylight.
3. <u>Mast</u>	Replace Suspension Cables +	x	x	4 days	5 years	Initiated on daylight, continued until job completed.
	Weld Structural Members	x	o	I	as required	Can require temporary platforms.
	Maintain Deflection Sheave Wheels	x	x	I	as required	Frequency would normally be in terms of years. Initiate on daylight.
4. <u>Boom</u>	Replace Suspension Cables	x	x	4 days	5 years	Initiated on daylight, continued until job completed.
	Replace Hoist Cables	x	o	8 hours	2 months	Initiated on daylight, continued until job completed.
	Replace Point and Upper Deflection Sheaves +	x	x	I	as required	Travelways not used. Boom lowered to ground.
	Replace Lower Deflection Sheaves	x	x	I	as required	Initiated on daylight, continued until job completed.
5. <u>Fair-lead</u>	Replace Drag Cable	x	o	4 hours	1 month	Travelways not used.
6. <u>General</u>	Replace Lamps	x	o	I	as required	Could require travel on boom, mast, A-frame and roof.

+ These tasks are listed under different components to indicate that travelways on more than one component are required in performing tasks.

x Applicable

o Not Applicable

I Indeterminate

TABLE 8 - TRAVELWAY UTILIZATION FOR SCHEDULED MAINTENANCE ON SHOVELS

<u>MACHINE COMPONENT</u>	<u>TYPE OF USAGE</u>				<u>DAYLIGHT</u>	<u>NIGHT</u>	<u>FREQUENCY</u>
	<u>TRAVERSE</u>	<u>INSPECT</u>	<u>LUBRICATE</u>	<u>TASKS</u>			
1. <u>House</u>							
a. Entry	x	o	o	o	x	x	General
b. Roof	x	o	o	o	x	x	General
c. Loading Dock	x	o	o	x	x	x	General
d. Perimeter	x	x	x	o	x	x	General
2. <u>Gantry</u>							
a. Access	x	o	o	o	x	x	Once/Shift
b. Platforms	x	x	x	o	x	x	Once/Shift
3. <u>Boom</u>							
a. Access	x	x	o		x	o	Once/Day
b. Intermediate Platforms	x	x	x		x	o	Once/Day
c. Point Platforms	x	x	x		x	o	Once/Day
4. <u>Crowd Handle</u>	_____ (None) _____						
5. <u>Stiff Leg</u>	_____ (None) _____						

x Applicable

o Not Applicable

TABLE 9 - TRAVELWAY UTILIZATION FOR UNSCHEDULED MAINTENANCE FOR SHOVELS

<u>Machine Component</u>	<u>Task Performed</u>	<u>Daylight</u>	<u>Night</u>	<u>Average Duration</u>	<u>Average Frequency</u>	<u>Comments</u>
1. <u>House</u>	None					
2. <u>Gantry</u>	Replace Suspension Cables	x	x	2 days	5 years	Initiated on daylight, continued until job completed.
	Replace Hoist Cables	x	o	8 hours	3 months	Initiated on daylight, continued until job completed.
	Replace Crowd Handle Cables *	x	x	18 hours	6 months	Initiated on daylight, continued until job completed.
	Weld Structural Members	x	o	I	as required	Can require temporary platforms.
	Maintain Sheave Wheels	x	x	I	as required	Frequency would normally be in terms of years. Initiated on daylight, continued until completed.
3. <u>Boom</u>	Replace Suspension Cables +	x	x	2 days	5 years	Initiated on daylight, continued until job completed.
	Replace Hoist Cables +	x	o	8 hours	3 months	Initiated on daylight, continued until job completed.
	Weld Structural Members	x	o	I	as required	Can require temporary platforms.
	Maintain Point Sheave Wheels	x	x	I	as required	Frequency would normally be in terms of years. Boom lowered to ground.
4. <u>Crowd Handle</u>	Replace Crowd Handle Cables	x	x	18 hours	6 months	Initiated on daylight, continued until job completed.
	Maintain Cable Sheaves	x	x	I	as required	Frequency would normally be in terms of years.
	Maintain Universal Joint	x	x	I	as required	Frequency would normally be in terms of years.

TABLE 9 - TRAVELWAY UTILIZATION FOR UNSCHEDULED MAINTENANCE FOR SHOVELS (continued)

Machine Component	Task Performed	Daylight	Night	Average Duration	Average Frequency	Comments
5. Stiff Leg	Replace Variable Pitch Cables *	x	x	14 hours	4 months	Initiated on daylight, continued until job completed.
	Replace Dipper Door Cable	x	o	4 hours†	6 months	Failure normally occurs at bucket and can be repaired from ground in approximately 1 hour.
	Maintain Universal Joint	x	o	I	as required	Frequency would normally be in terms of years.
6. <u>General</u>	Replace Lamps	x	o	I	as required	Requires travel on boom, roof, and gantry travelways.

* Some shovel designs do not incorporate these cables.

+ These tasks are listed under different components to indicate that travelways on more than one component are required in performing tasks.

† Time required to replace entire cable.

x Applicable

o Not Applicable

I Indeterminate

Generally, the exterior travelways on surface mining draglines and shovels are used for routine inspection and maintenance scheduled for daylight shifts. Exceptions are the entry, roof and loading dock on the house of the draglines and shovels, plus the access and platforms of the gantry on shovels. The walkways on shovel gantries are traversed each shift for routine inspections, while the other walkways and work areas used during the night shifts are primarily to enter the machine or to bring supplies on board. Based on travelway utilization for scheduled work procedures, it was recommended the following areas be considered for location of permanent lighting:

1. Dragline House
 - a. Entry
 - b. Roof
 - c. Loading dock
 - d. Area under the house
2. Shovel House
 - a. Entry
 - b. Roof
 - c. Loading dock
 - d. Perimeter
 - e. Area under the house
3. Shovel Gantry
 - a. Access walkways and ladders
 - b. Platforms

The report also deals with the assessment of the visibility of unknown visual details in the field, by use of a contrast threshold meter and treatment of reflective surfaces to improve the visibility. Exterior walkways and work areas surveyed during this study indicated that the intensity of light for threshold levels ranged from 0.23 f.c. to levels approaching daylight. A statistical analysis was performed on the field data to determine the amount of light required to safely perform designated tasks on walkways. This analysis indicated 5 f.c. was adequate for these applications.

C. Walkway Design and Demonstration

Based on the recommendations in the Interim Report, a contract modification was issued for "Design and Demonstration for Walkway Lighting on Electric-Powered, Mobile Surface Mining Equipment".

These recommendations included lighting walkways normally used for routine night maintenance such as loading docks, roofs, entries, and access to platforms on the shovel gantry. They did not include walkways and work areas traversed only during the daylight hours or for unscheduled work such as cable replacements, welding or other work that resulted in shutdown of the machines. The Interim Report also indicated that a range of from 1 f.c. to 5 f.c. was required to obtain threshold vision for a majority of the walkways. Based on these reported results, the on board areas proposed for walkway lighting were as shown in Figures 3 and 4 for stripping shovels and walking draglines. Basically, these walkways were located on or were immediately adjacent to the house of each mining machine.

a. Design of Walkway Lighting

1. Survey of Mining Machines

The mining machines selected for participation in the walkway lighting demonstration were AMAX's B.E. 3270 dragline of 176 c.y. and their Marion 5900 shovel of 105 c.y. An on board visit was made to these machines to:

- Determine the extent of the existing walkway lighting
- Based on the results of the interim report, select walkways used for routine night maintenance
- Interview mine personnel
- Inspect the electrical systems
- Take photographs

Evaluation of existing lighting on the B.E. 3270 indicated that the loading dock under the machine and the main entries to the machine were adequately illuminated. The loading dock under the machine was illuminated by lights installed by the machine manufacturer and the main machine entries by overhead area lighting systems, which included high pressure sodium luminaires installed for the area lighting. The only other walkways associated with the machine house are on the roof, with access from stairs leading from the machine interior. The roof walkways are traversed primarily as accessways to the filter houses at the rear of the machine. Very little direct maintenance is required on the roof, except for periodic service of the area lighting luminaires located on the periphery of the roof.

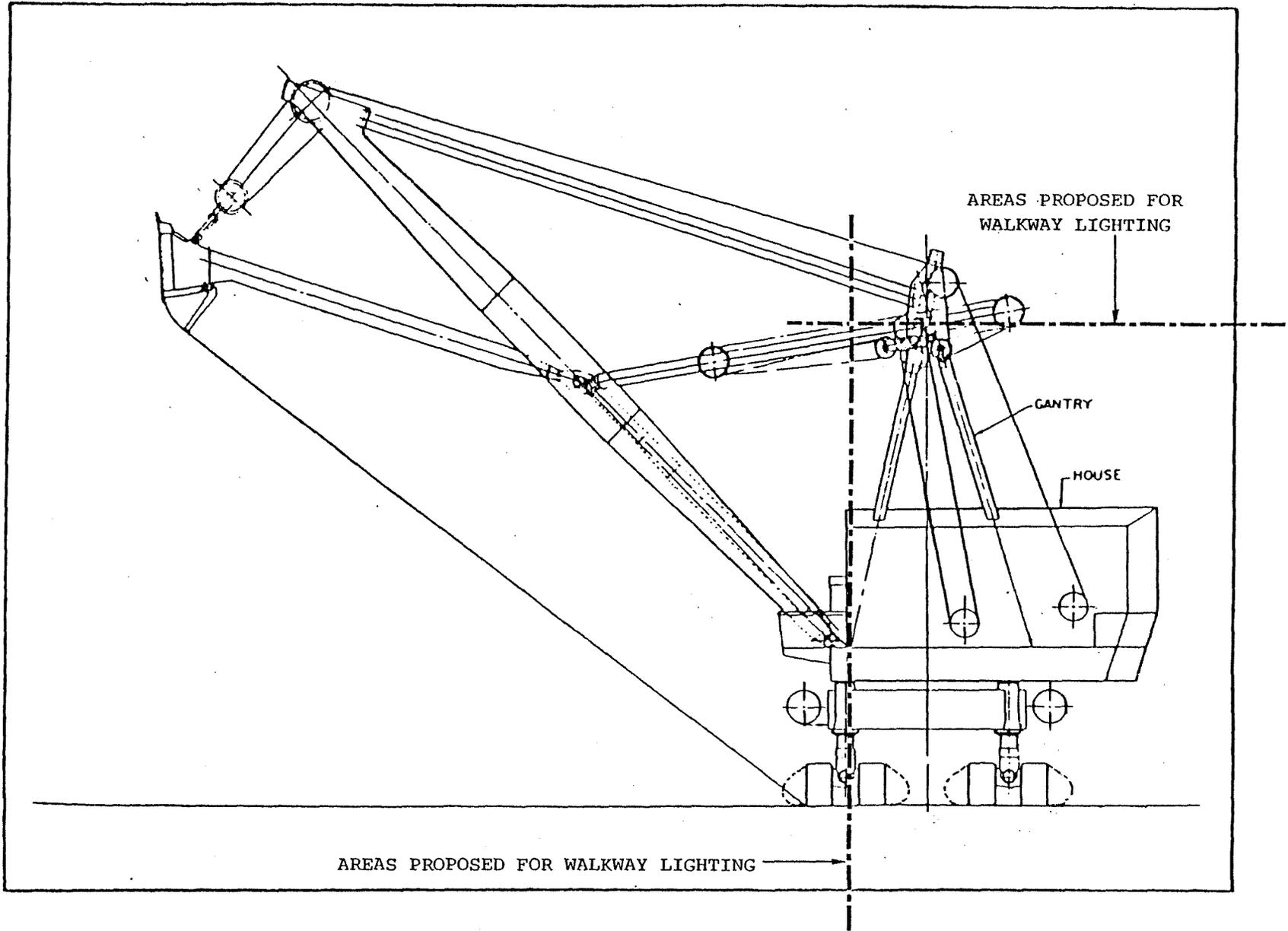


FIGURE 3 RECOMMENDED WALKWAY LIGHTING
STRIPPING SHOVEL

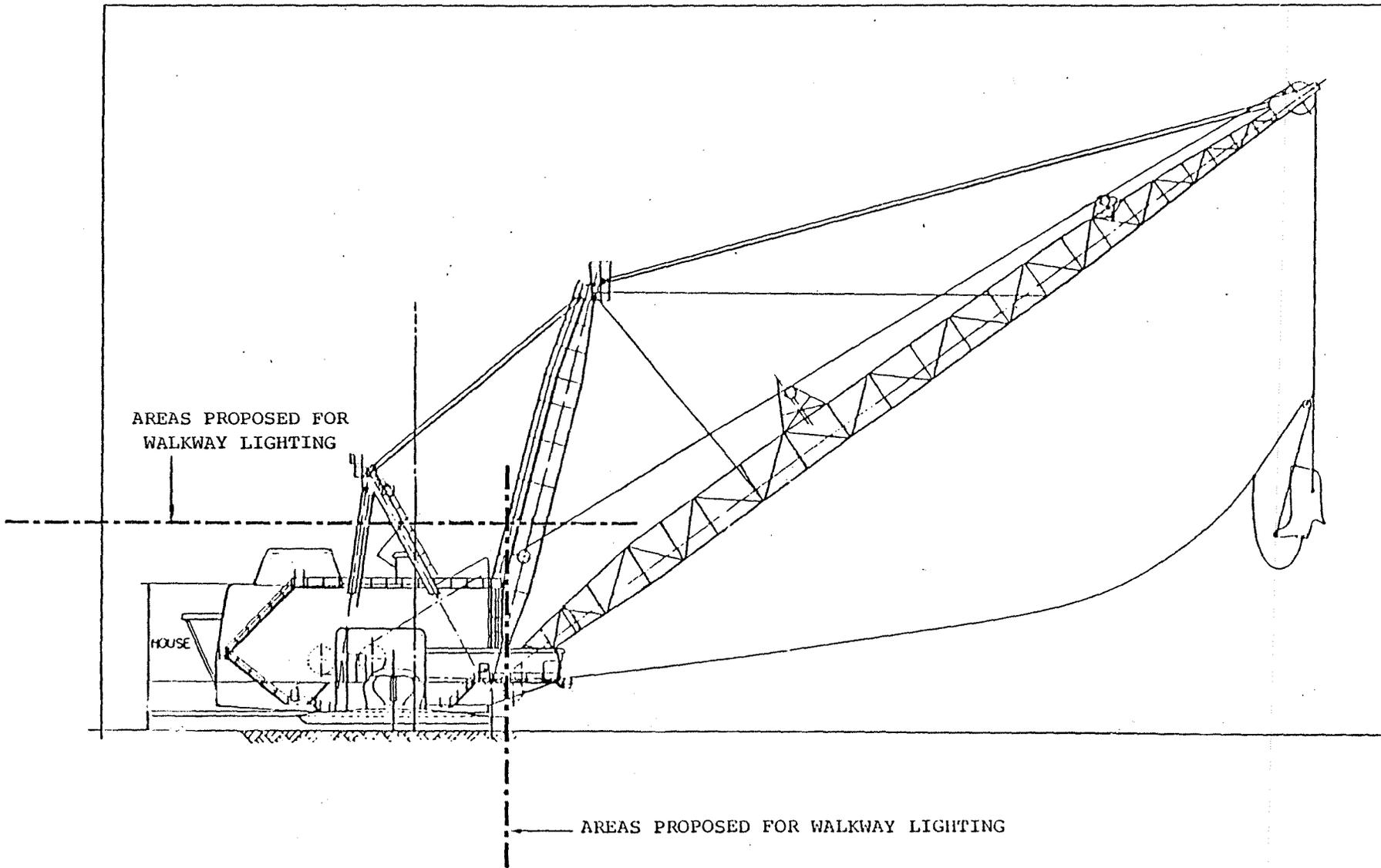


FIGURE 4 RECOMMENDED WALKWAY LIGHTING
WALKING DRAGLINE

The Marion 5900 utilizes a completely different group of walkways for general night maintenance. They are:

House

1. Main machine entries
2. Tram control platform
3. Lower frame walkway
4. Roof walkways

Gantry

1. Access stairs on gantry
2. Lower and upper crowd handle platforms
3. Crane platform

As found on the B.E. 3270, the main machine entries were sufficiently illuminated by existing lights and by the area lighting system already in place. The Marion 5900 uses an elevator to carry mine personnel to the gantry, so the roof walkways are used infrequently, usually when the elevator is out of order. The remaining walkways are used for general night maintenance and were selected as requiring additional illumination.

Electrical control panels had been installed on the B.E. 3270 and Marion 5900 for operation of the installation of area lighting. These panels provided for on/off, dusk to dawn operation by means of a photoelectric cell, overload protection and distribution of the lighting circuits by means of circuit breakers. This panel provided for integration of all walkway lighting with the area lighting systems previously installed.

2. Walkway Lighting Fixtures

Important criteria for selection of a walkway luminaire were:

1. Low glare source.
2. Capability of providing good illumination at various mounting heights
3. Easily modified for severe service
4. Fixture strength
5. Availability

Based on these criteria, the Sylvania 70 watt HPS Alleycat luminaire was selected for this service.

3. Walkway System Design

Based on machine photographs of available mounting surfaces and iso-intensity diagrams of the luminaire, the lighting systems were designed with fixture placement as shown on Figure A.13 for the B.E. 3270 and Figure A.14 for the Marion 5900. It must be noted that the scarcity of suitable mounting surfaces precluded the use of any singular design solution. Each walkway to be illuminated presented its own particular conditions and resulted in individual attention to design for each luminaire mounting location.

Only the roof walkways required lighting on the B.E. 3270. Seven (7) 70 watt HPS luminaires were used for these locations, one (1) for the stairway entrance from the house interior to the roof proper and six (6) to light the walkways traversed to service the filter houses. Locations were as shown on Figure A.13.

The tram control platform and the gantry required lighting on the Marion 5900. Ten (10) 70 watt HPS luminaires were used for these locations, two (2) on the tram control platform and eight (8) on the stairways and platforms of the gantry. Locations were as shown on Figure A.14.

4. Electrical Installation

The electrical installation for the walkway lighting is as shown in Figure A.18 for the Marion 5900 and Figure A.19 for the B.E. 3270. Interface with the previously installed area lighting was made through a circuit breaker (CB3) with a transformer installed to reduce the 480 VAC supply to the 120 VAC utilization voltage required by the luminaires. Control of the walkway lighting operated from the installation of the area lighting system, activated by a photoelectric cell for dusk to dawn operation.

D. Installation of Lighting Systems

AMAX Coal Company made the complete installation of the area and walkway lighting systems. Prior to the installations an orientation meeting was held at each mine site to review the lighting designs. Information presented included a discussion of the design approaches, presentation of the installation

drawings describing the mounting and aiming of the luminaires and the electrical controls. A summary of the lighting system installation for each machine is as follows:

B.E. 1450 Dragline

Area lighting - 11 - 400 watt HPS luminaires

Installed per Figure A.4 B.E. 1450 Area Lighting System

Location and Aiming

Walkway lighting - no installation

B.E. 3270 Dragline

Area lighting - 9 - 1000 watt HPS luminaires

Installed per Figure A.5 B.E. 3270 Area Lighting System

Location and Aiming

Walkway lighting 7 - 70 watt HPS luminaires

Installed per Figure A.13 B.E. 3270 Roof Walkway Lighting System

Marion 5900 Shovel

Area Lighting - 8 - 1000 watt HPS luminaires

Installed per Figure A.6 Marion 5900 Area Lighting System

Location and Aiming

Walkway lighting - 10 - 70 watt HPS luminaires

Installed per Figure A.14 Marion 5900 Walkway Lighting System

All lighting systems were controlled by electrical panels installed on board each machine. Dusk to dawn operation of the systems was provided for by the use of photoelectric cells.

IV RESULTS

A. Demonstration of Area Lighting

Design of a lighting system is only an orderly method of prediction of its operation, based on the application of available engineering information. The integrity of the design must be verified by accepted standards of tests and measurements. To perform these tasks a photometric survey procedure was developed. The procedure developed for this work included verification of the installation according to design by checking:

1. Mounting heights and distances
2. Aiming angles
3. Physical obstructions to the light patterns
4. Operation of electrical controls
5. Photometric measurements

To correlate the actual lighting designs with the installed systems, a portion of the ground under consideration was divided into test areas of the same 10 foot by 10 foot grid set-up as planned for the computer design printout. (Figures A.20, A.21, and A.22) Readings were taken at each grid area, with repeat measurements at a key test point with a frequency to assure stability of the system and repeatability of results. It was expected that the test readings would be much higher than the computer projections, since the lamps were new and the LLF of 0.61 not applicable.

Two complete photometric surveys were conducted on each machine. The first survey was made at the completion of the installation of the area lighting systems on each machine and the second at the end of the demonstration period. It must be noted that the installation on each machine was contingent with the time the machine may be out of production due to scheduled and unscheduled maintenance. The B.E. 3270 dragline was a new machine in the process of construction, so the lighting system was installed prior to its completion. The B.E. 1450 dragline and the Marion 5900 shovel lighting systems were installed when the machines were taken out of production.

The demonstration period was to be for three (3) months, but was of different lengths of time because of the inability to install the lighting systems simultaneously on each machine: The demonstration period started at the time of the first photometric survey and was considered complete at the time of the second photometric survey. The second photometric survey was performed on all machines on the same date. The length of the demonstration period for each machine is shown in Table 12.

a. Analysis of Area Lighting

The results of the photometric surveys for the area lighting are recorded as follows:

First Photometric Survey

- Figure No. C.1
Light Levels B.E. 3270 Photometric Survey #1
- Figure No. C.2
Light Levels B.E. 1450 Photometric Survey #1
- Figure No. C.3
Light Levels Marion 5900 Photometric Survey #1

Second Photometric Survey

- Figure No. C.4
B.E. 3250 Photometric Survey #2
- Figure No. C.5
B.E. 1450 Photometric Survey #2
- Figure No. C.6
Marion 5900 Photometric Survey #2

Analyses were made of the surveys to each other, to the computer Mathematical Models (CMM), and to the Proposed Federal Standards (PFS).

A review of the computer printouts for the various trace areas under the boom and around the main frame show that the average computer calculated foot candles is greater than required by the PFS. The above average CMM intensities were high because they are expected to depreciate due to uncontrollable loss factors. These above average CMM intensities also represent the lighting produced from an optimum luminaire selection which dictated that mixed lamp wattages within the system would not be advantageous toward long term maintenance of the system. The comparative averages for the CMM and the PFS for the specific machines are shown in Table 10.

Field photometric survey No. 1 was conducted on each machine soon after the lighting systems were installed and operational. The comparative averages between the No. 1 photometric survey and the Computer Mathematical Model (CMM) for specific machines are shown in Table 11.

TABLE 10 - COMPARATIVE AVERAGES FOR COMPUTER MATHEMATICAL MODELS
(CMM) AND PROPOSED FEDERAL STANDARDS (PFS)

B.E. 3270

<u>AREA</u>	AVERAGE FC	
	<u>CMM</u>	<u>PFS</u>
Under Boom	3.2	1.0
20' from Main Frame, Front	16.3	5.0
20' from Main Frame, Side	8.3	5.0
20' from Main Frame, Rear	6.5	5.0

B.E. 1450

<u>AREA</u>	AVERAGE FC	
	<u>CMM</u>	<u>PFS</u>
Under Boom	3.0	1.0
20' from Main Frame, Front	9.8	5.0
20' from Main Frame, Side	7.3	5.0
20' from Main Frame, Rear	7.2	5.0

MARION 5900

<u>AREA</u>	AVERAGE FC	
	<u>CMM</u>	<u>PFS</u>
Under Boom	3.4	1.0
20' from Main Frame, Front	12.1	5.0
20' from Main Frame, Side	7.2	5.0
20' from Main Frame, Rear	7.2	5.0

TABLE 11 - COMPARATIVE AVERAGES PHOTOMETRIC SURVEY NO. 1
COMPUTER MATHEMATICAL MODEL (CMM)

B.E. 3270

<u>AREA</u>	AVERAGE FC	
	<u>SURVEY NO. 1</u>	<u>CMM</u>
Under Boom	3.4	3.2
20' from Main Frame, Front	14.2	16.3
20' from Main Frame, Side	8.1	8.4
20' from Main Frame, Rear	L O	6.5
L O Luminaire Out		

B.E. 1450

<u>AREA</u>	AVERAGE FC	
	<u>SURVEY NO. 1</u>	<u>CMM</u>
Under Boom	5.3	3.0
20' from Main Frame, Front	N A	9.8
20' from Main Frame, Side	4.0	7.3
20' from Main Frame, Rear	3.3	7.2
N A Not Aimed		

MARION 5900

<u>AREA</u>	AVERAGE FC	
	<u>SURVEY NO. 1</u>	<u>CMM</u>
Under Boom	4.0	3.4
20' from Main Frame, Front	3.3	12.1
20' from Main Frame, Side	3.3	7.2
20' from Main Frame, Rear	3.5	7.2

Certain discrepancies can be noted in Survey No. 1 which are attributed to the inability to properly aim the luminaires, especially around the main frame of the machines. Obstructions and overhangs were encountered which were not evident in the review of the machine drawings. For example, a 1000 watt HPS luminaire mounted on the side of the Marion 5900 had a light intensity of only 43 percent of the same luminaire mounted on the B.E. 3270, although the B.E. 3720 is a larger machine. This intensity can be increased by mounting the Marion 5900 main frame luminaires at lower points under any obstructions, although this may inhibit the ease of maintenance of these fixtures. Multiple fixtures (placed at top corners) may be a more feasible solution. Areas under the booms of the three machines had higher average intensities than predicted by the CMM and considerably above the PFS.

The second series of field photometric surveys were conducted from four to eight months after the machines had been operating with the new lighting systems. The comparative intensity averages of the two photometric surveys, the CMM and the PFS are shown in Table 12.

Discrepancies noted in the second series of photometric surveys were similar to those experienced in the first surveys. Boom area readings, for example on the B.E. 3270 in the second survey tended to average higher than the first survey. This may be attributed to the slight shifting of luminaires under vibration and shock. Point readings at the end of the boom were lower in the second survey with a tendency for the light pattern to shift toward the main frame. Lamp lumen depreciation cannot be expected to have any measurable effect after eight months of operation, since the sodium lamps are rated at 24,000 hours, which is equivalent to 2-3/4 years.

Several luminaires experienced maintenance difficulties during the demonstration period and required replacement of lamps and brackets. It is possible that luminaire aimings were disturbed during this maintenance. This would appear to have happened with the front and side lighting on the Marion 5900 which shows a degradation in light levels between Survey No. 1 and Survey No. 2.

TABLE 12 - SUMMARY OF COMPARATIVE AVERAGES

B.E. 3270 8 Months of Operation
3025 Hours

AREA	AVERAGE FC			
	SURVEY No. 2	SURVEY No. 1	CMM	PFS
Under Boom	3.6	3.4	3.2	1.0
20' from Main Frame, Front	15.5	14.2	16.3	5.0
20' from Main Frame, Side	7.4	8.1	8.4	5.0
20' from Main Frame, Rear	3.2	L O	6.5	5.0
L O Luminaire Out				

B.E. 1450 4 Months of Operation
1529 Hours

AREA	AVERAGE FC			
	SURVEY No. 2	SURVEY No. 1	CMM	PFS
Under Boom	5.7	5.3	3.0	1.0
20' from Main Frame, Front	N A	N A	9.8	5.0
20' from Main Frame, Side	5.9	4.0	7.3	5.0
20' from Main Frame, Rear	L O	3.3	7.2	5.0
L O Luminaire Out				
N A Not Aimed				

MARION 5900 6 Months of Operation
2314 Hours

AREA	AVERAGE FC			
	SURVEY No. 2	SURVEY No. 1	CMM	PFS
Under Boom	4.0	4.0	3.4	1.0
20' from Main Frame, Front	1.9	3.3	12.1	5.0
20' from Main Frame, Side	1.9	3.3	7.2	5.0
20' from Main Frame, Rear	4.8	3.5	7.2	5.0

B. Demonstration of Walkway Lighting

Verification of the installation of walkway luminaires according to a design plan was simpler than the procedure required for the area lighting installation. Where the area lighting may require adjustments of vertical and horizontal aiming, and aimed at locations over 400 feet away, the walkway luminaires were attached to flat surfaces to light immediately adjacent areas. Therefore, verification of the installation according to design

included checking:

1. Mounting height
2. Operation of the electrical controls
3. Photometric measurements

Since the walkway lighting illuminated transient areas of walkways, the relative distance from light source to reflecting surface was continuously variable, whether traversing stairways or level walks. Therefore, the change in lighting levels would vary considerably from a point directly under a luminaire to a point where the surface lighting was shared by two or more luminaires. Since the fixtures had to be mounted where structural members were available, integrated system designs were difficult to develop to meet the proposed average of 5 footcandles with a 10/1 uniformity ratio.

Two complete photometric surveys were conducted on each machine. Installation of the walkway lighting systems was completed at the same time, so the demonstration period of each machine ran concurrently. Scheduled for a two month period, the actual demonstration time from the initial to the final photometric survey extended to three months.

a. Analysis of Walkway Lighting

The results of the photometric surveys are shown on Figure C.7 for the B.E. 3270 dragline and Figure C.8 for the Marion 5900 shovel.

Comparison of the No. 1 and No. 2 photometric surveys for roof walkway system on the B.E. 3270 were as follows:

Photometric Survey No. 1 (4/6/82) = 6.257 avg. f.c.

Photometric Survey No. 2 (7/1/82) = 5.809 avg. f.c.

Δ f.c. average = 0.448 f.c.

These results indicate the roof walkway system degraded by an average of 0.448 f.c. or approximately 7 per cent during the demonstration period. Since none of this can be attributed to the lamp, it is assumed that the deterioration in luminaire output is due to the ballast deterioration and dust accumulation on the lens. Figure C.7 shows the results of both the No. 1 and No. 2 photometric surveys.

The measurements of the No. 1 and No. 2 photometric surveys on the Marion 5900 shovel are shown on Figure C.8.

An analysis of the results is as follows:

<u>System</u>	<u>Figure C.8 As Shown in View</u>	<u>FC Avg. First Survey 4/7/82</u>	<u>FC Avg. Second Survey 7/2/82</u>	<u>% Depreciation</u>
1.	Front view--upper gantry	4.99	4.43	8.6
2.	Note 1	10.30	9.90	3.9
3.	Note 2	6.07	5.67	6.6
4.	Note 3	8.83	8.75	1.0
5.	Note 4	9.58	9.08	5.0
6.	Note 5	<u>15.80</u>	<u>14.80</u>	<u>6.0</u>
	Average	9.26 fc	8.77 fc	5.3% avg.

The Marion 5900 walkway lighting systems also show very small illumination depreciation, slightly more than 5 percent. As with the B.E. 3270, this depreciation can be attributed to ballast depreciation and dust accumulation on the lens.

The deterioration of the walkway lighting was very small during the three (3) month operating period. This was as expected because the total operating time between the first and second photometric survey was 869 and 890 hours for the B.E. 3250 and the Marion 5900. Based on typical curves of lamp lumen deterioration, no change should be noted for the comparatively short operating period. The largest factor contributing to the luminaire output depreciation is dust accumulation on the lens. These particular mines generate much dust in removal of the overburden, so it is a factor that must be considered in the lighting installations, although its effect may vary from mine to mine, machine to machine or because of the type of overburden to be removed.

V CONCLUSIONS AND RECOMMENDATIONS

Although standard commercial luminaires were modified for service aboard these large surface mining machines, it appears that a luminaire specially designed for these installations would reduce the maintenance requirements. The luminaires used are normally installed as stationary fixtures, but were modified by strengthening the fixture mountings, design of special bulb supports and use of remote mounted ballasts (area lighting only). Based on long term observations on the service of these modified fixtures, it would appear that luminaires designed specially to meet the hostile environment, shock and vibration that exists on these machines, would be a preferable alternate. In long term operation, this should result in operational and economical advantages. A starting point would be the installation of sensors on the machines to determine the mechanical shock and vibration that occurs and interviews with mine personnel that maintain the luminaires.

A. Area Lighting

The ability to meet the Proposed Federal Standards for area lighting appears to be easily accomplished with hardware now on the market. In fact, the photometric surveys showed that the average intensity under the boom was better than three (3) to five (5) times greater than the PFS. Even applying a LLF of 0.61, the intensity would be two (2) to three and one-half (3½) times as large as the PFS.

The results of the lighting systems installed for illumination around the main frame was less definitive. The CMM predicted higher levels than were achieved although the average levels were higher for the B.E. 1450 and B.E. 3270 draglines than the PFS. However, the Marion 5900 shovel light levels were less than the proposed standards on all sides, except the rear of the machine. Apparently the luminaires used for lighting the main frame encounter difficult mounting locations. It appears that main frame lighting, from a luminaire mounting and aiming standpoint, is more complex than assumed and must be defined in closer detail in order to result in a more effective system.

Although standard hardware was used for illumination of the large surface mining machines, they required modifications to qualify for the hostile services aboard the machines. These modifications were related to mountings and bulb supports to withstand the shock, vibration and unusual G forces encountered during the excavation and swing stages of the machines.

The results of the lighting demonstration indicate that a CMM approach can be an effective tool in the design of area lighting systems for electric-powered, mobile, surface mining equipment. The tangible results of the photometric surveys of the areas under the booms of the three machines demonstrate the feasibility of this approach. From an illumination standpoint, the luminaires are capable of providing more than enough light to meet the PFS for lighting around the main frame. However, because mounting the luminaires on the machine roofs does encounter obstructions, moving the mounting locations from the roofs to the sides of the machines will result in a better lighting pattern, but will do so at a sacrifice in the ability to provide maintenance to the fixture.

This project involved the design, installation and demonstration of the area lighting systems to a specification. The specification was proposed to provide a uniform set of standards that would result in a level of illumination that would enhance safety in the designated work areas. Other than the accumulation and statistical evaluation of long term data on the safety of an operation, the comments of the workers can serve as a gage for the operations. Three visits were made to each machine during the demonstration period to check their operation and interview the mine workers. Following are favorable and unfavorable comments elicited for the area lighting on each machine:

B.E. 1450 Dragline

- Favorable

1. Helps in fog and dust.
2. Side and rear lights a big improvement for working dozer.
3. Color is more favorable when HPS and MV lights are both used.
4. Bulbs are easier to change.
5. Operators think they can't work without new system.
6. Project has been worthwhile.

- Unfavorable

1. Had to refashion some support springs.
2. Need more light at bottom of pit.
3. Rear center light has an overheating problem.
4. Bulb support is flimsy.

B.E. 3270 Dragline

- Favorable

1. New system adds a lot of light.
2. Not safe without side and rear lights.
3. Good light in the pit.
4. 100% improvement.
5. Groundman has no trouble with glare.
6. New system is safer.
7. New and old systems together (HPS & MV) has good color.
8. Everyone likes new lights.

- Unfavorable

1. Lights on top of cab are no good with snow.
2. Electric eye (photoelectric cell) needs moved because lights shut off too early in the morning, while the pit is still dark.
3. Needs a better bracket mount.
4. Front corners need more light.
5. Light levels on side too low when compared to front.
6. Not enough light when new system is run by itself.
7. Rear center bulb replaced three times. Too much vibration.
8. Needs better bulb supports.
9. Lights give off bad reflection in the rain.
10. Lights on top of operator's cab should be placed under cab to eliminate reflected light from dust.

Marion 5900 Shovel

- Favorable

1. Helps with fog.
2. Crews like them.
3. Going to place two more on boom when project is finished.
4. Wouldn't be without new system.
5. No problem with electric eye.
6. Prevented shutdowns due to fog.
7. New system is better.

8. Dust more of a problem with old system.
9. No glare problem with dozer.
10. Lights turn on early enough.
11. Everyone likes new lights.

- Unfavorable

1. In fog, bucket disappears at top of travel.
2. Dark spots on corner rotate with machine.
3. Need more light for high wall.
4. At sunrise, lights turn on and off on swings. Eye must be in shadow.

We have attempted to include all of the comments made by the mine personnel interviewed, in the vernacular in which it was received. Some of the comments are vague and, depending on the interviewee, the observations are in conflict. However, as in many cases where personal opinion influences an observation, diametric opposite responses are to be expected.

The observations of insufficient light at top of the bucket travel for the shovel and in the pit area for the draglines, are very real. For example, the area beneath the boom of the shovel has a light intensity that exceeds the proposed specification, but no light is provided for the high wall where the bucket dumps the overburden. The maximum height at times nearly approximates the height of the boom, so that luminaires aimed at the ground level under the boom have little or no effect to illuminate the high wall. A different case exists for the draglines with the possibility of insufficient light levels in the pit. Where the shovel may move up a valley of its own making, the dragline will dig a pit as it retreats, the depth of the pit as deep as the seam it uncovers. With an area lighting system installed to meet the proposed specifications at a zero pit depth (level at which the dragline sits) any excavation of the pit area reduces the lighting level under the boom. In a worse case example, where the B.E. 3270 dragline can excavate to a depth of 180 feet, if the average height of an installed luminaire is 180 feet, then the illumination at the bottom of the pit will be reduced to one-quarter of the value measured at a zero pit depth.

Since the shovel and the dragline exhibit different working methods in stripping the overburden, they should each receive special treatment in any attempt to develop regulations for area lighting systems under the booms. Special attention should be

given to provide light to the maximum depth a dragline is capable of digging and provisions made to light the high wall at the maximum height a shovel is capable of dumping the overburden.

B. Walkway Lighting

Although the walkways on the B.E. 3270 dragline and the Marion 5900 shovel were different, the capability of lighting them to the proposed specification was easily accomplished using 70 watt HPS luminaires. The uniformity ratios for walkway lighting were high in contrast to the area lighting because of the use of a relatively wide angle beam to light transient surfaces. However, the uniformity ratio was within the 10/1 specified value.

Demonstration of walkway lighting on the B.E. 3270 involved only the roof walkways plus access steps to the roof. The average intensity for this system was 6.3 footcandles for the first photometric survey and 5.8 for the second photometric survey. These values exceed the 5 f.c. specified. Only one failure was experienced on these luminaires during the demonstration period.

The Marion 5900 shovel required walkway lighting on the tram control platform, lower frame and gantry walkways. As with the B.E. 3270 dragline, high uniformity ratios were experienced due to the nature of the lighting installation. The average intensity for this system was 9.3 footcandles for the first photometric survey and 8.8 for the second photometric survey. Only two luminaires experienced failure during the demonstration period, and since maintenance had not been completed on the repairs, it is not known if it was a luminaire failure or an electrical fault.

The demonstration period for walkway lighting extended for three (3) months, during which time two inspection visits were made to survey the lighting and interview the mine workers. Following are favorable and unfavorable comments relative to the walkways lighting on each machine.

B.E. 3270 Dragline

- Favorable

1. Any light is an improvement
2. These lights are not appreciated until you need them.
3. All walkways are bright enough for safe access to all areas.
4. Parts are easy to replace once globe and reflector are removed.
5. To increase coverage on front A-frame lights, move up to crossbrace.

- Unfavorable

1. Light at top of stairway not working
2. Ballast poorly constructed for vibration.
3. Spring around bulb too fragile.
4. Globe difficult to remove.

Marion 5900 Shovel

- Favorable

1. More than enough light for safety.
2. Good lights for walkways (some dark spots in work areas).
3. Good placement of lights.
4. Made access to top of machine a lot safer.
5. No glare from walking lights mounted below cab level.

- Unfavorable

1. Need lights around tracks on ground.
2. Need lights inside house. (Beyond scope of work)

These observations on the walkway lighting were offered by the mine personnel working on the machines. The consensus is that adding lights to the affected walkways was a worthwhile project.

Installation of the walkway lighting systems offers a challenge that does not exist for area lighting. Area lighting offers a possibility of mounting clusters of luminaires to be aimed at relatively large areas some distance away, so that mountings can be located on a convenient surface. Walkway lighting illuminates relatively long narrow areas that become discontinuous where stairs or corners exist. To effectively cover these areas, the luminaire is mounted immediately adjacent to the walkways at a height that will result in proper light distribution without glare. The only surfaces available for mounts are structural support members that abut the walkways. These conditions make it imperative that prior to any walkway lighting design, the subject machine should be visited and observations made on the location of structural supports for mounting of walkway luminaires.

The consensus of the interviews with mine personnel was that the installation of the area and walkway lighting systems for this project improved the working conditions on the large, mobile surface mining equipment. If working conditions are improved, then we must assume that safety is improved. Along with improved working conditions, good visibility can also result in increases in productivity. Increased safety and productivity are hypothesized due to adequate levels of lighting.

APPENDIX A - MINING MACHINE DETAILS/INSTALLATION DRAWINGS

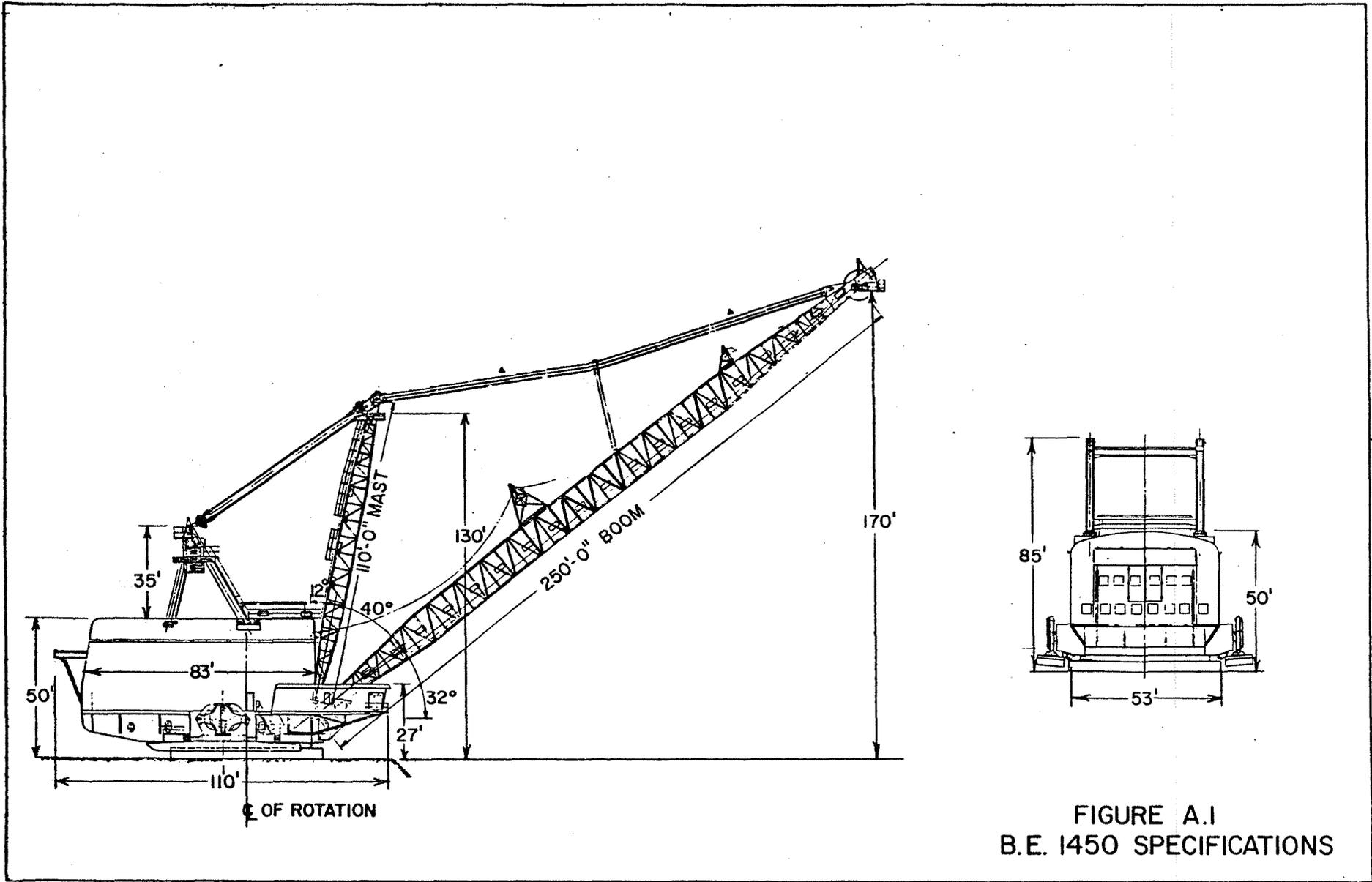
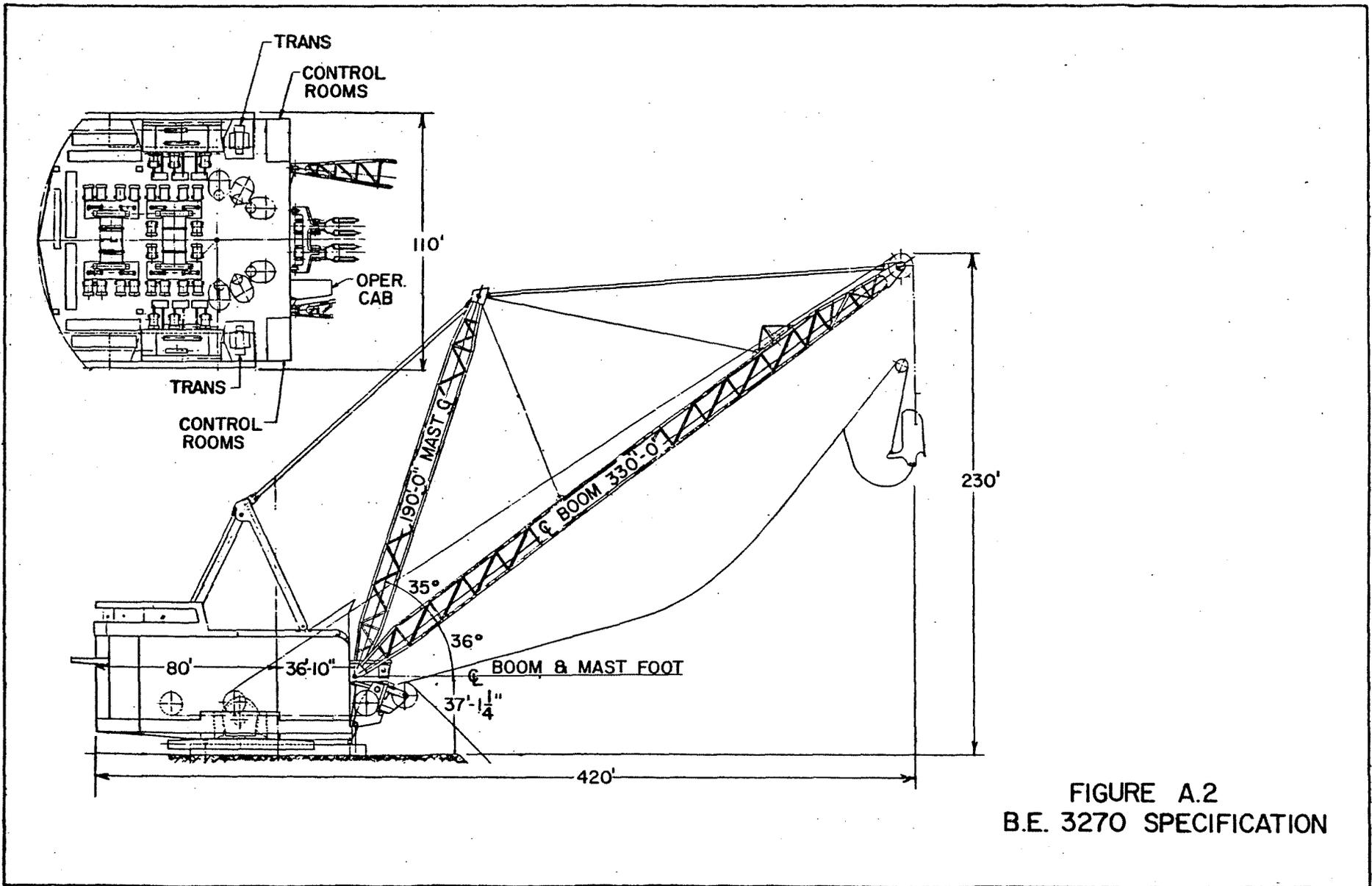


FIGURE A.1
 B.E. 1450 SPECIFICATIONS



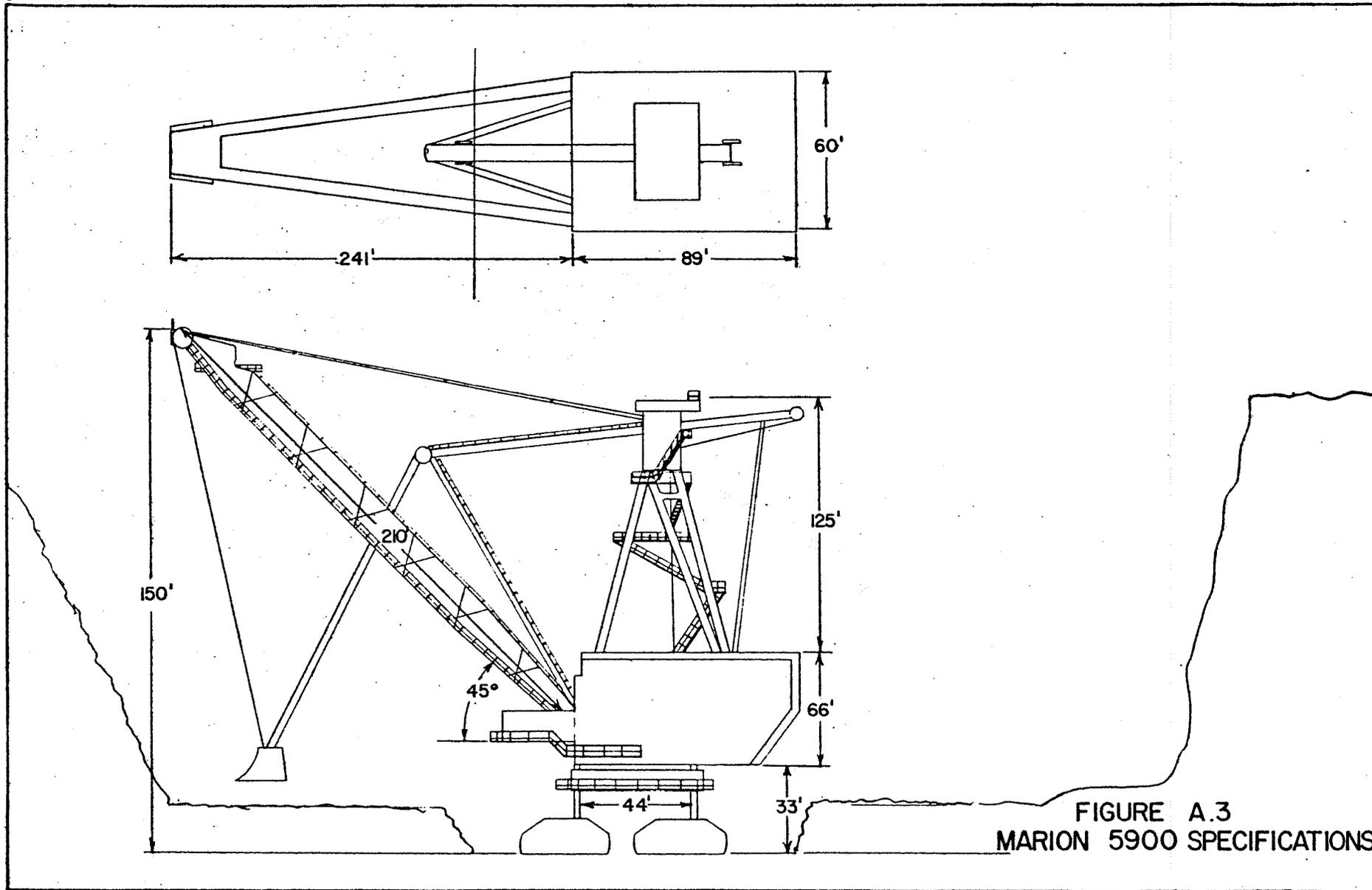
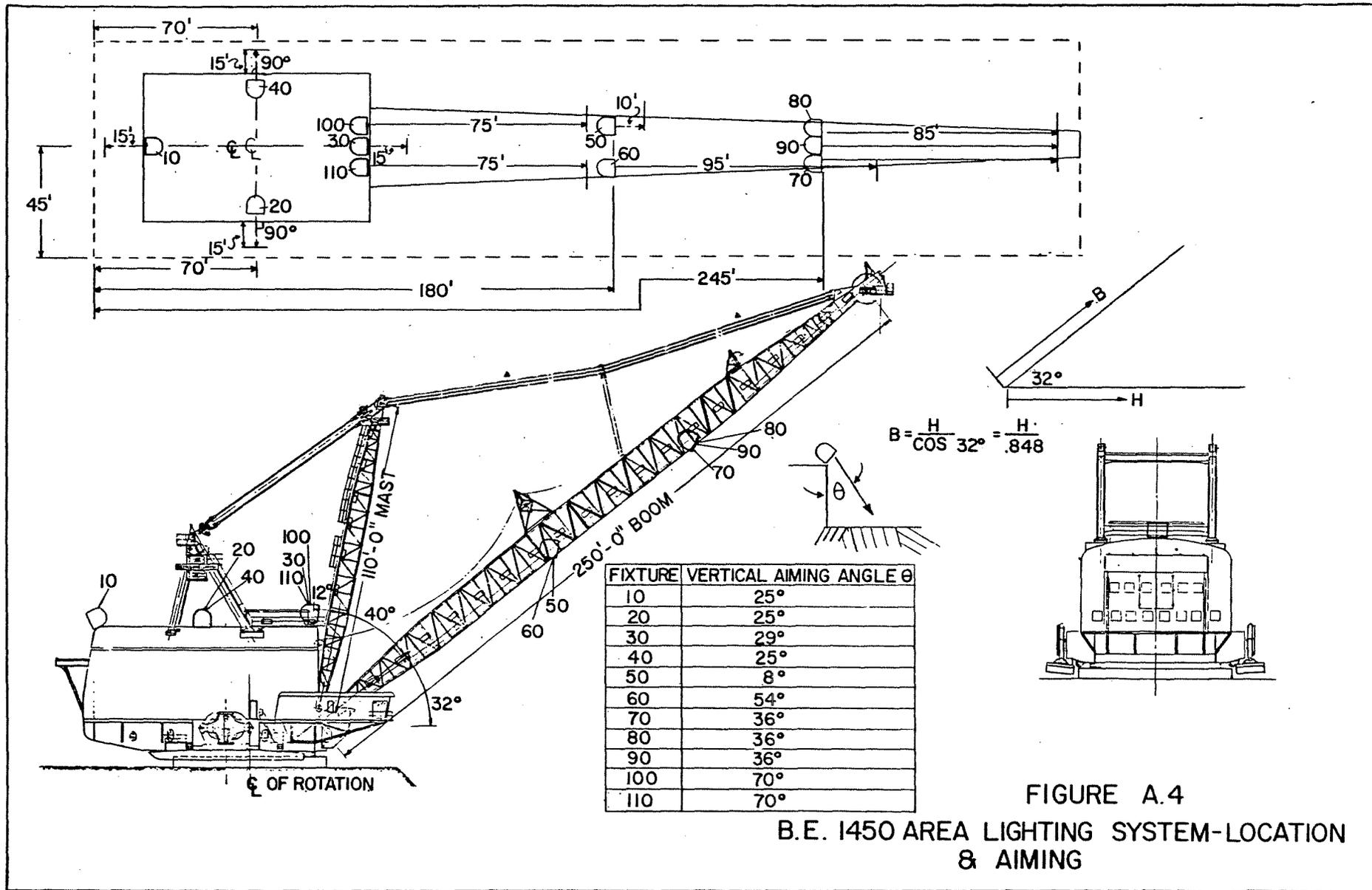
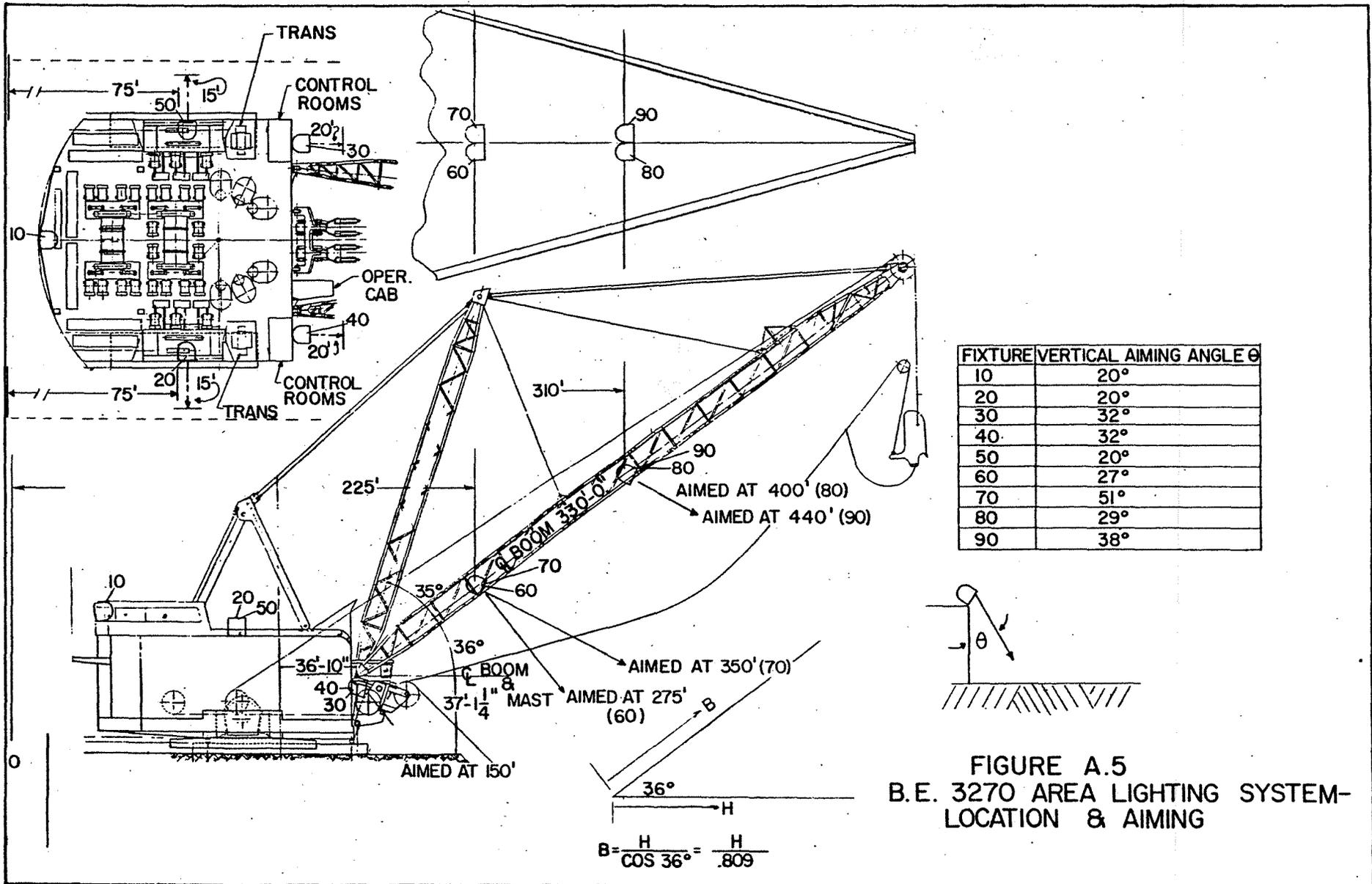
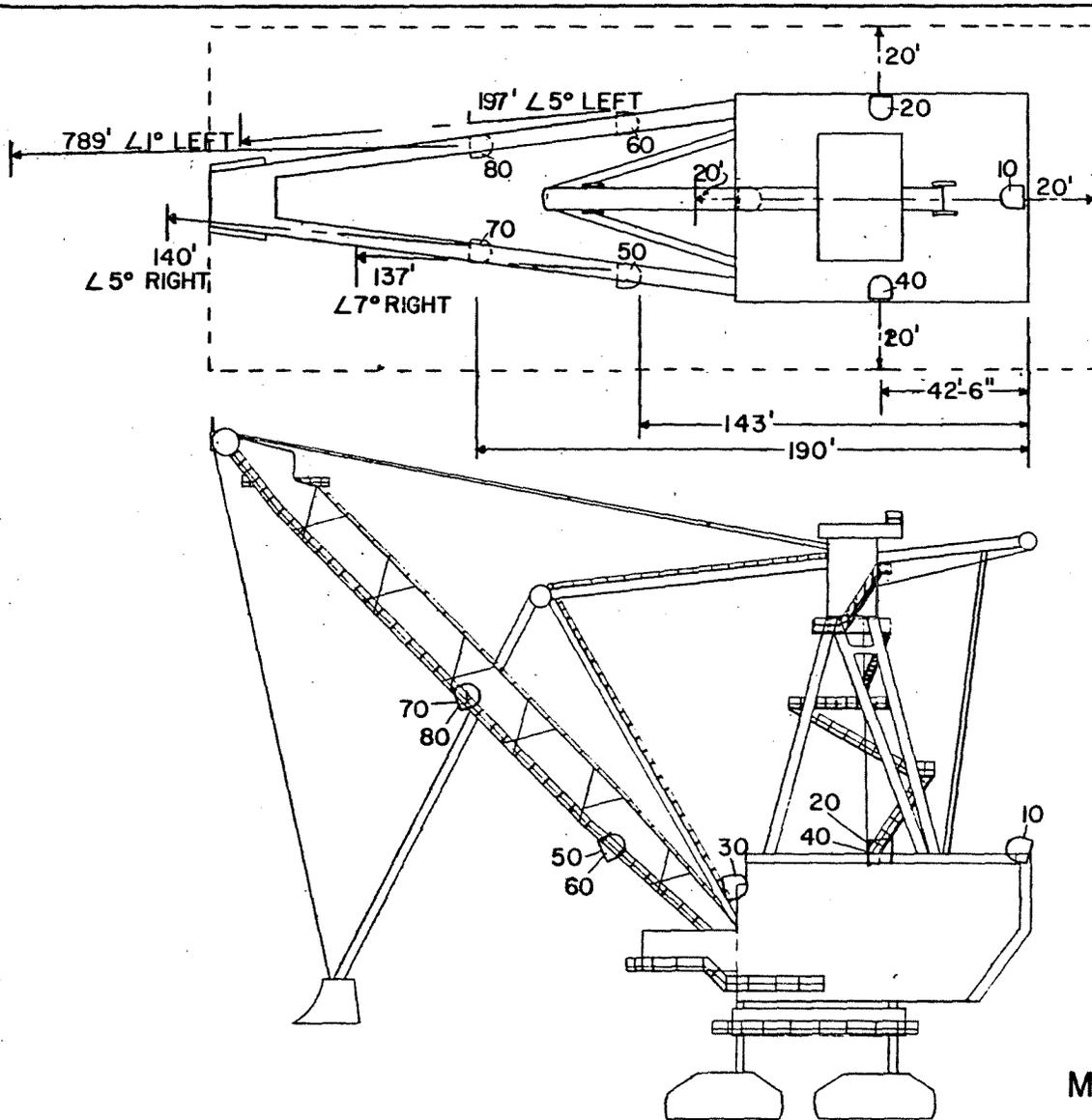


FIGURE A.3
MARION 5900 SPECIFICATIONS







FIXTURE	VERTICAL AIMING ANGLE θ
10	15°
20	15°
30	24°
40	15°
50	55°
60	63°
70	44°
80	80°

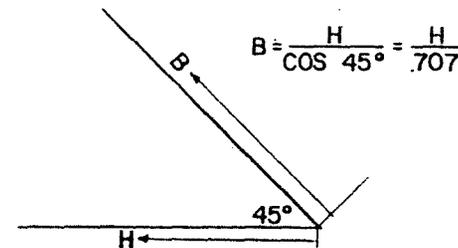
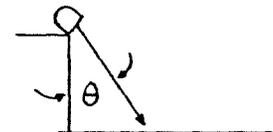


FIGURE A.6
MARION 5900 LIGHTING SYSTEM-
LOCATION & AIMING



TYPICAL WALKWAY WITH LX-2400'S ON
12' CENTERS AT A MOUNTING HEIGHT OF
APPROX 24" TO 30"

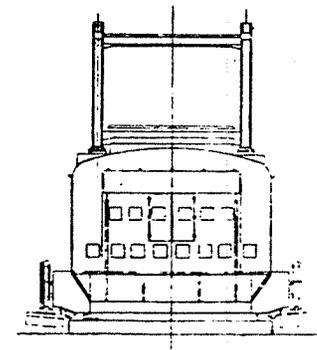
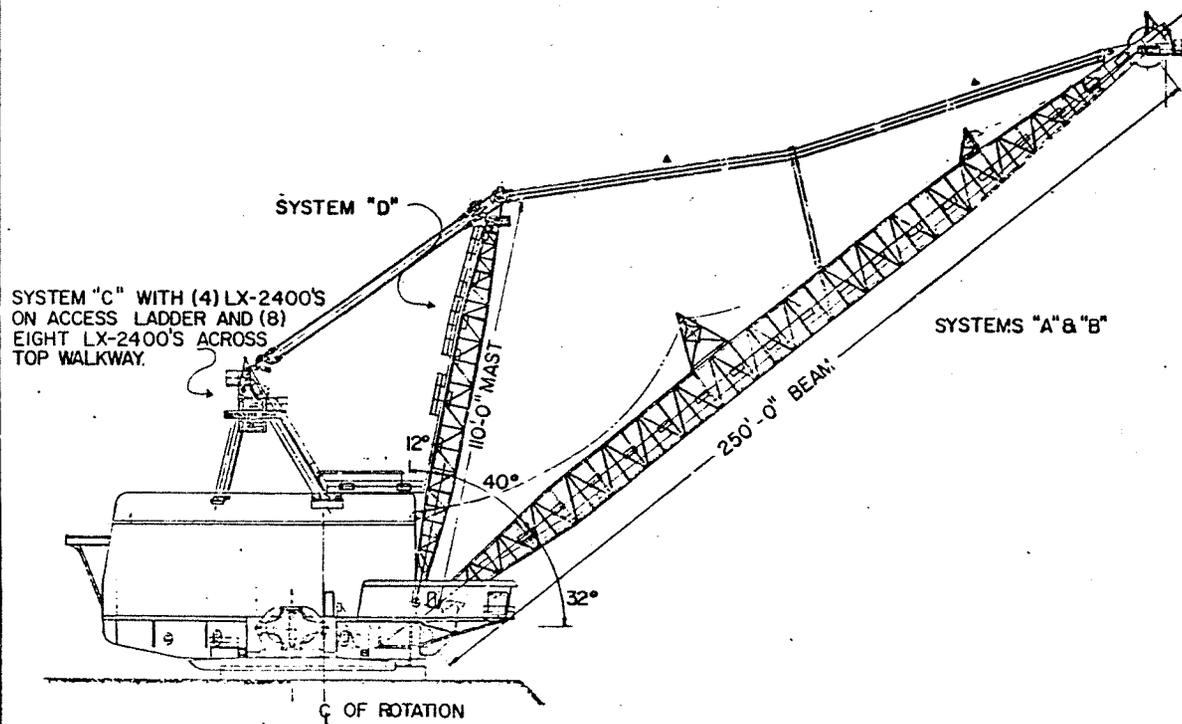
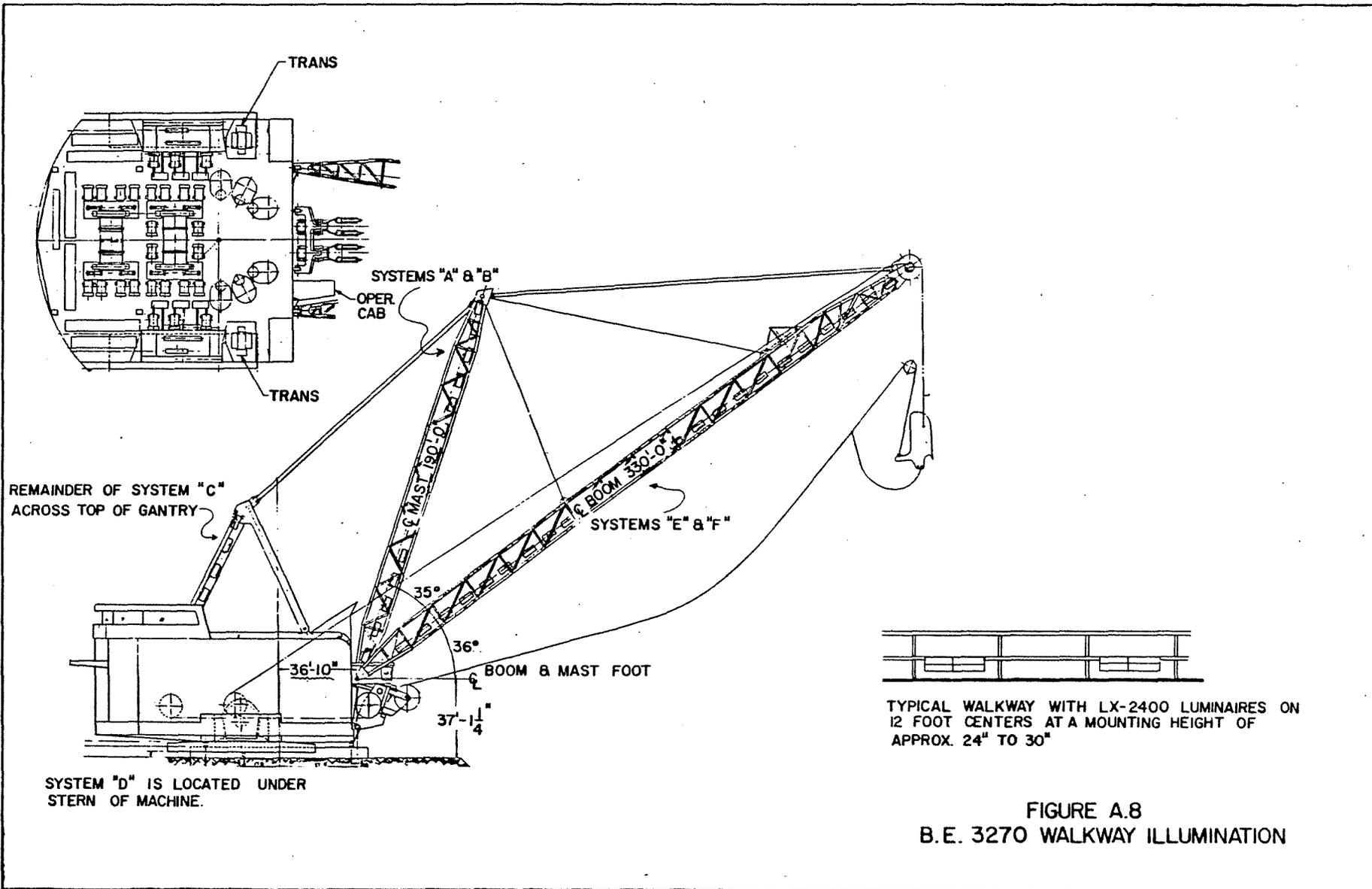
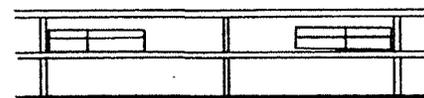
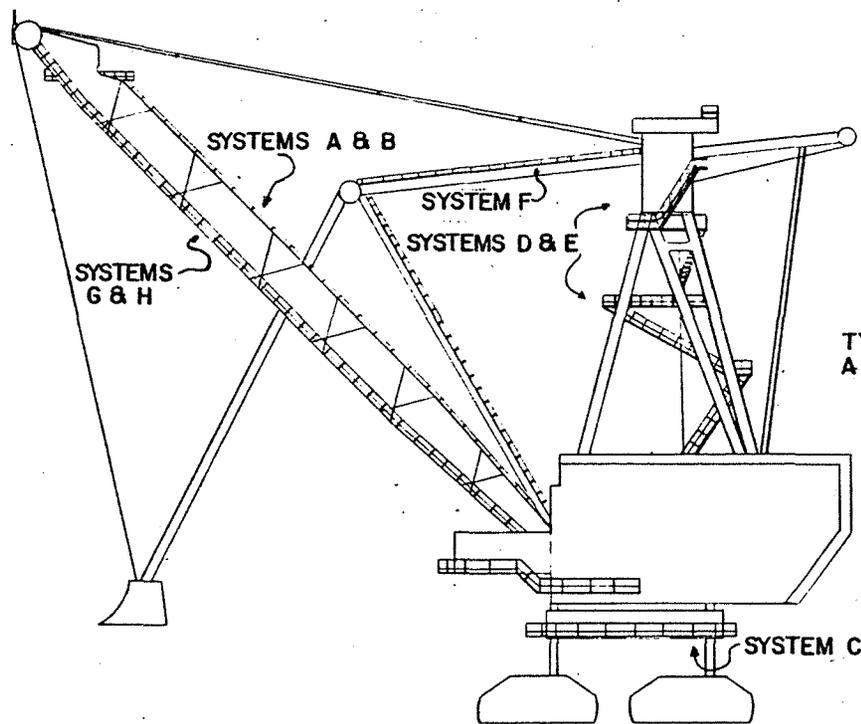
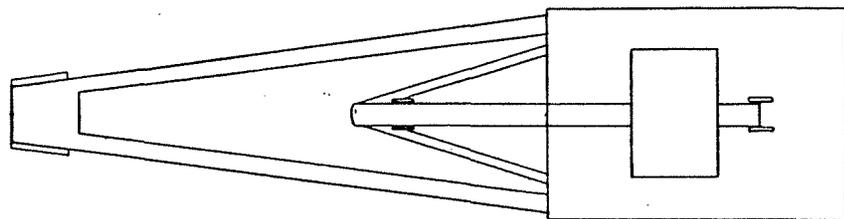


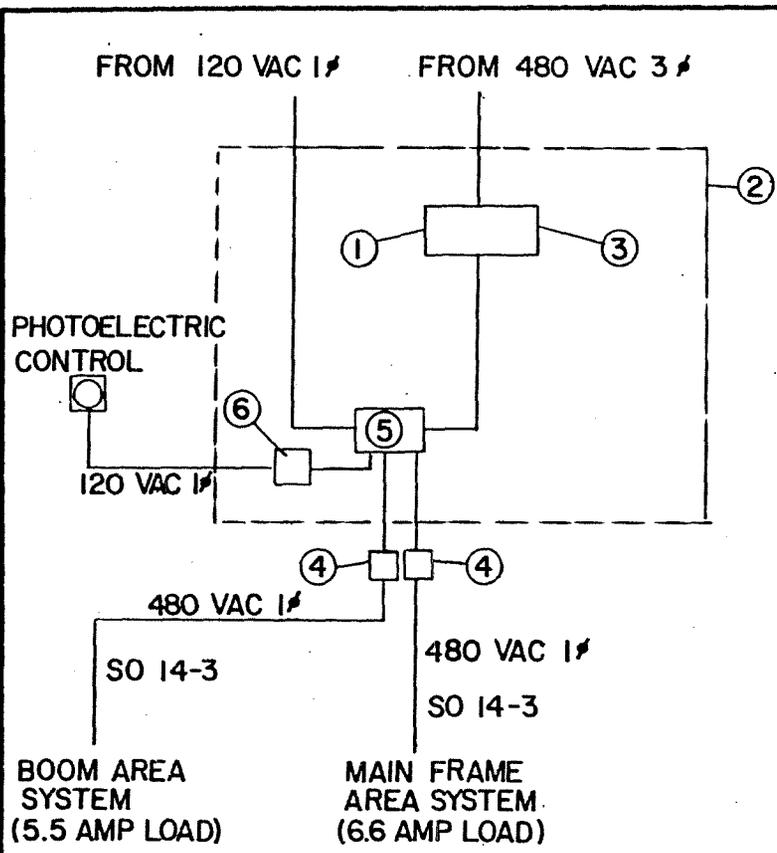
FIGURE A.7
B.E. 1450 WALKWAY ILLUMINATION





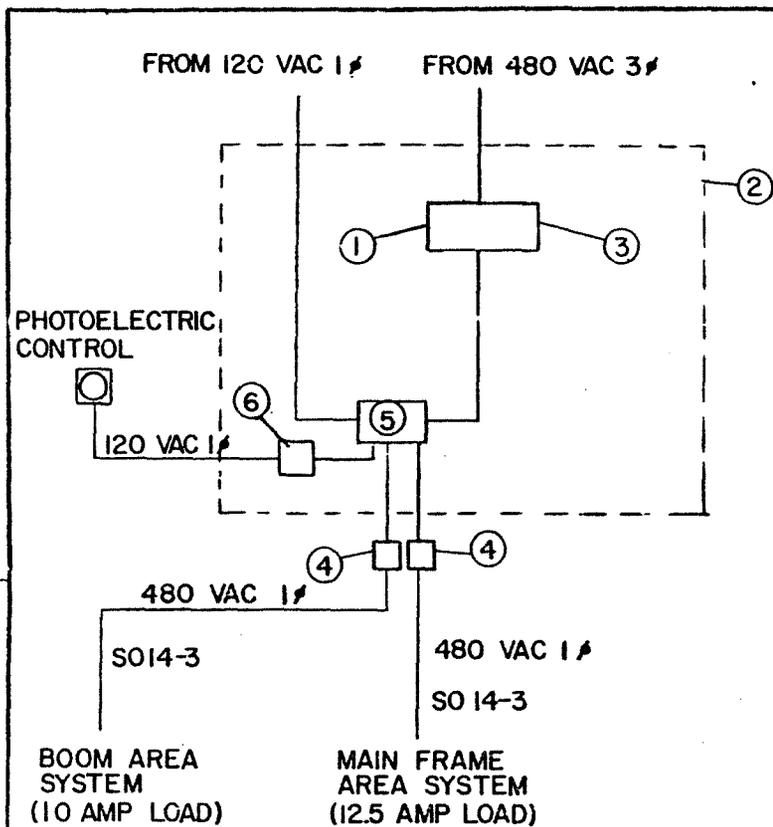
TYPICAL WALKWAY WITH LX-2400'S ON 12' CENTERS AT A MOUNTING HEIGHT OF APPROX. 24" TO 30"

FIGURE A.9
MARION 5900 WALKWAY
ILLUMINATION



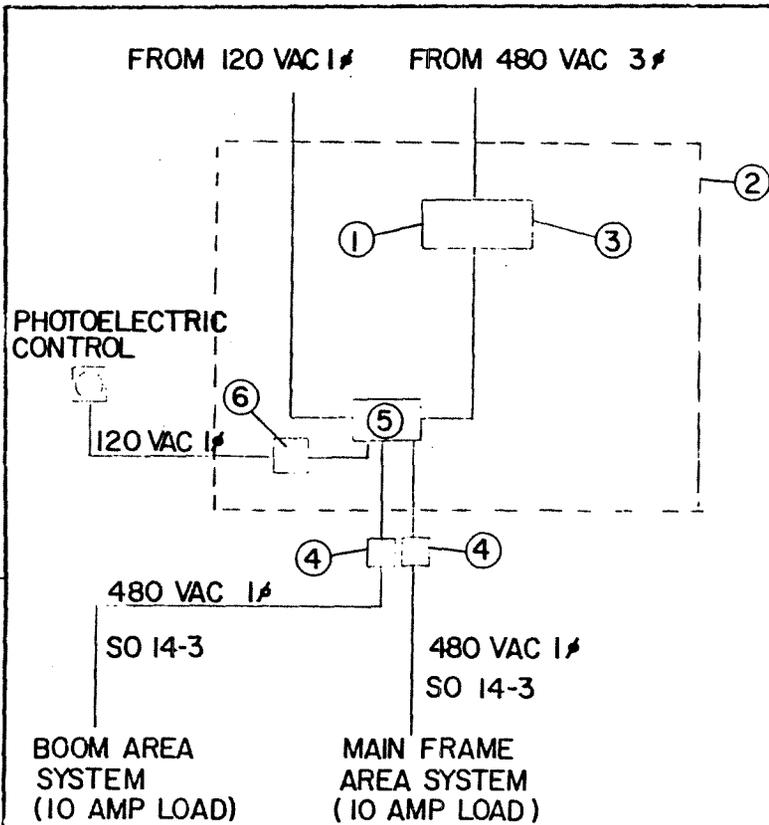
PARTS LIST			
ITEM NO.	PT. NO. DWG. NO.	REQ'D.	DESCRIPTION
1	9422ARC13	1	SQUARE D, 480 VAC 3 ϕ FUSE-ABLE SW. ASSY W/30A LIMITRON
2		1	NEMA I2 ENCL. 35H.x20W.x5 3/4D.
3	KTS 30	3	FUSE, LIMITRON, BUSS 30A.
4	FAE2402ORB	2	20 AMP 2 POLE BREAKER 480 V.
5		1	CLASS 8903 TYPE L040 CONTACTOR WITH 120 VAC COIL
6	KTS438	1	SW. PANEL, "AUTO", "OFF", "HAND"

FIGURE A.10
CIRCUIT LAYOUT B.E. 1450



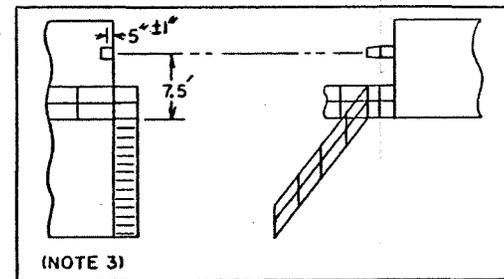
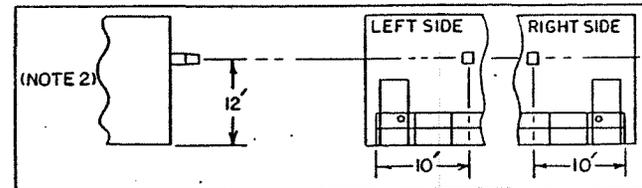
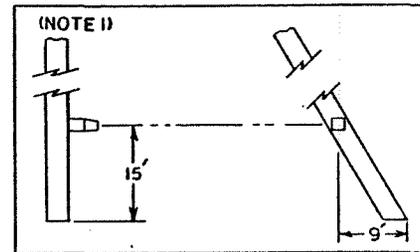
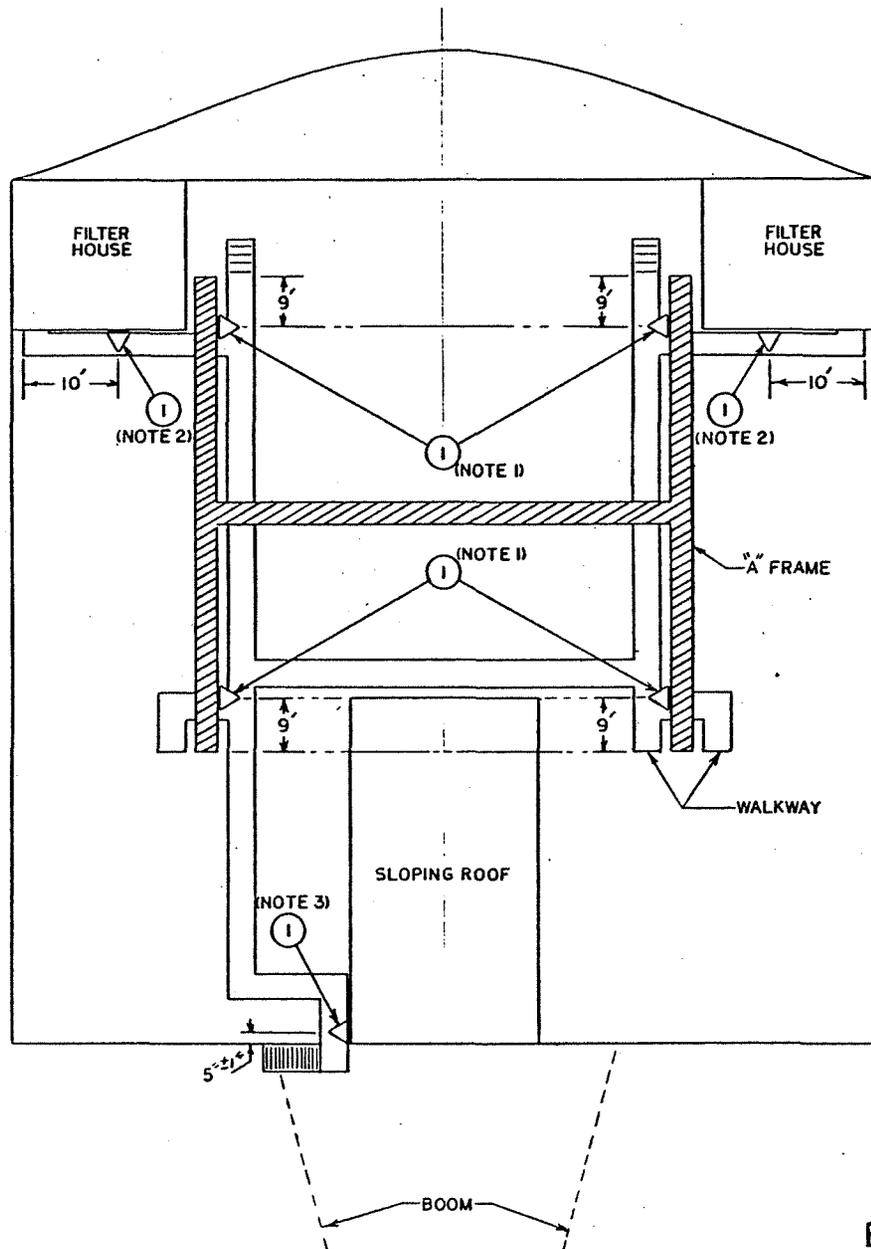
PARTS LIST				REVISIONS
ITEM NO	PT NO DWG. NO	REQD	DESCRIPTION	
1	9422ARC13	1	SQUARE D 480 VAC 3 ϕ FUSEABLE SW. ASSY W/30A LIMITRON	
2		1	NEMA 12 ENCL. 35H x 20W 5 $\frac{3}{4}$ D.	
3	KTS30	3	FUSE LIMITRON BUSS, 30A	
4	FAE24020RB	2	20 AMP 2 POLE BREAKER 480V	
5		1	CLASS 8903 TYPE LO40 CONTACTOR WITH 120 VAC COIL	
6	KTS43B	1	SW. PANEL AUTO "OFF" "HAND"	

FIGURE A. II
CIRCUIT LAYOUT B.E. 3270



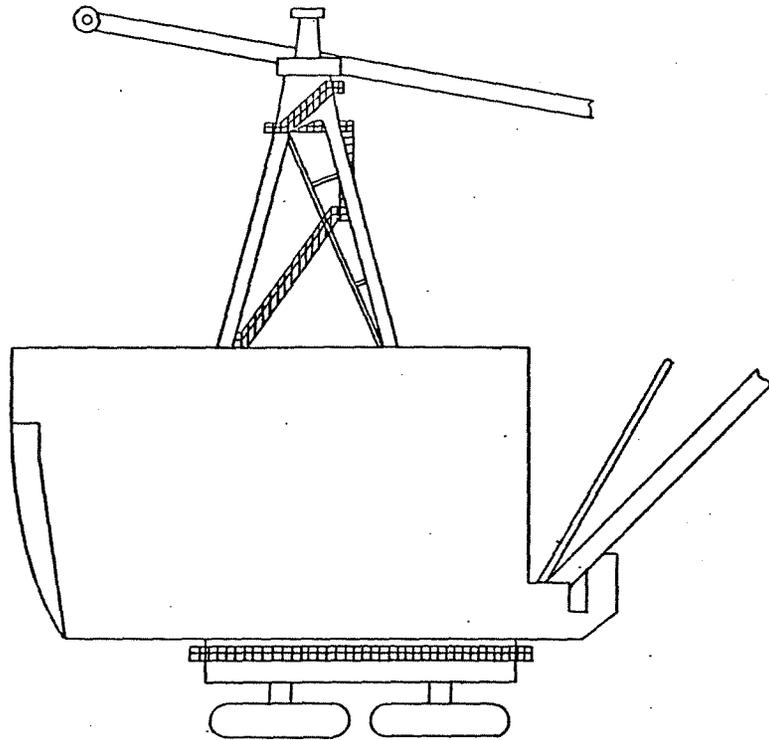
PARTS LIST			
ITEM NO	PT. NO. D.V.G. NO	REQ D	DESCRIPTION
1	9422ARCI3	1	SQUARE D 480 VAC 3φ FUSEABLE SW. ASSY W/30A LIMITRON
2		1	NEMA 12 ENCL. 35Hx20Wx5 3/4D.
3	KTS30	3	FUSE LIMITRON BUSS, 30A
4	FAE2402ORB	2	20 AMP 2 POLE BREAKER 480 V
5		1	CLASS 8903 TYPE L040 CONTACTOR WITH 120 VAC COIL
6	KTS43B	1	SW PANEL "AUTO" "OFF" "HAND"

FIGURE A.12
CIRCUIT LAYOUT MARION 5900

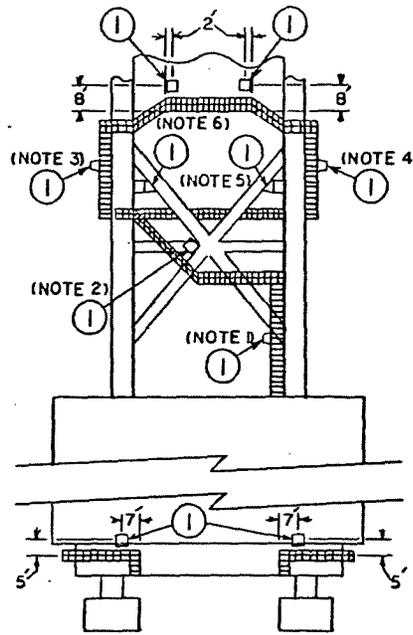


ITEM NO.	REF. DES.	PT. NO. DWG. NO.	REQD.	DESCRIPTION
1		ARC05-10SII	7	70 WATT HPS LUMINAIRE

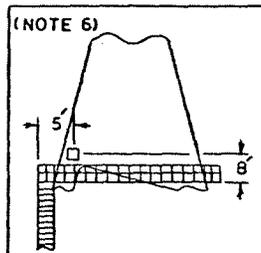
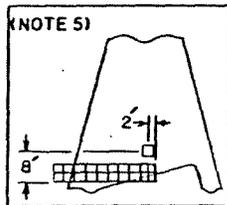
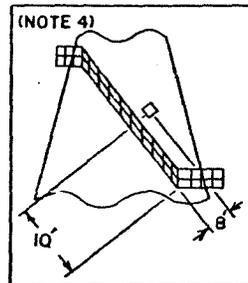
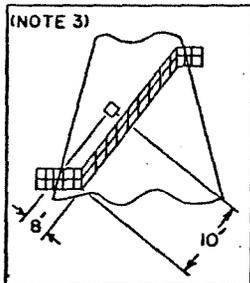
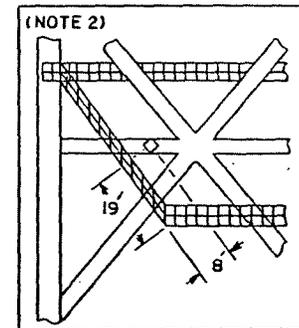
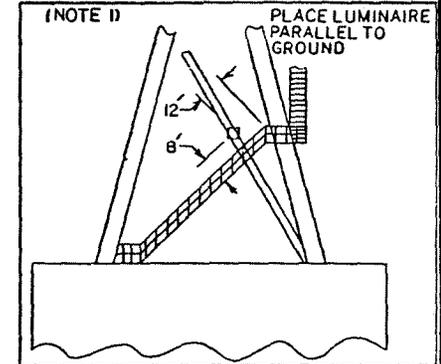
FIGURE A.13
B.E. 3270 ROOF WALKWAY LIGHTING SYSTEM



RIGHT SIDE VIEW



FRONT VIEW



ITEM NO.	REF. DES.	PT. NO. DWG. NO.	REQD.	DESCRIPTION
1		ARCOS-10511	10	70 WATT HPS LUMINAIRE

ALL LUMINAIRES PLACED PARALLEL TO WALKWAYS UNLESS OTHERWISE SPECIFIED.

FIGURE A.14
MARION 5900 WALKWAY LIGHTING SYSTEM

PARTS LIST			
ITEM NO.	PT. NO. DWG. NO.	REQ'D.	DESCRIPTION
1		11	GTE HDF-400-500 RB C LUMINAIRE
2		11	GTE ORB-400-HPS-480-AB BALLAST ENCLOSURE
3			
4		1	PHOTOCONTROL PEC 105-285
5	B971-130A	1	GEDC CONTRACTOR BOX SYS.
6		1	
7		1000'	14-3 SO CABLE

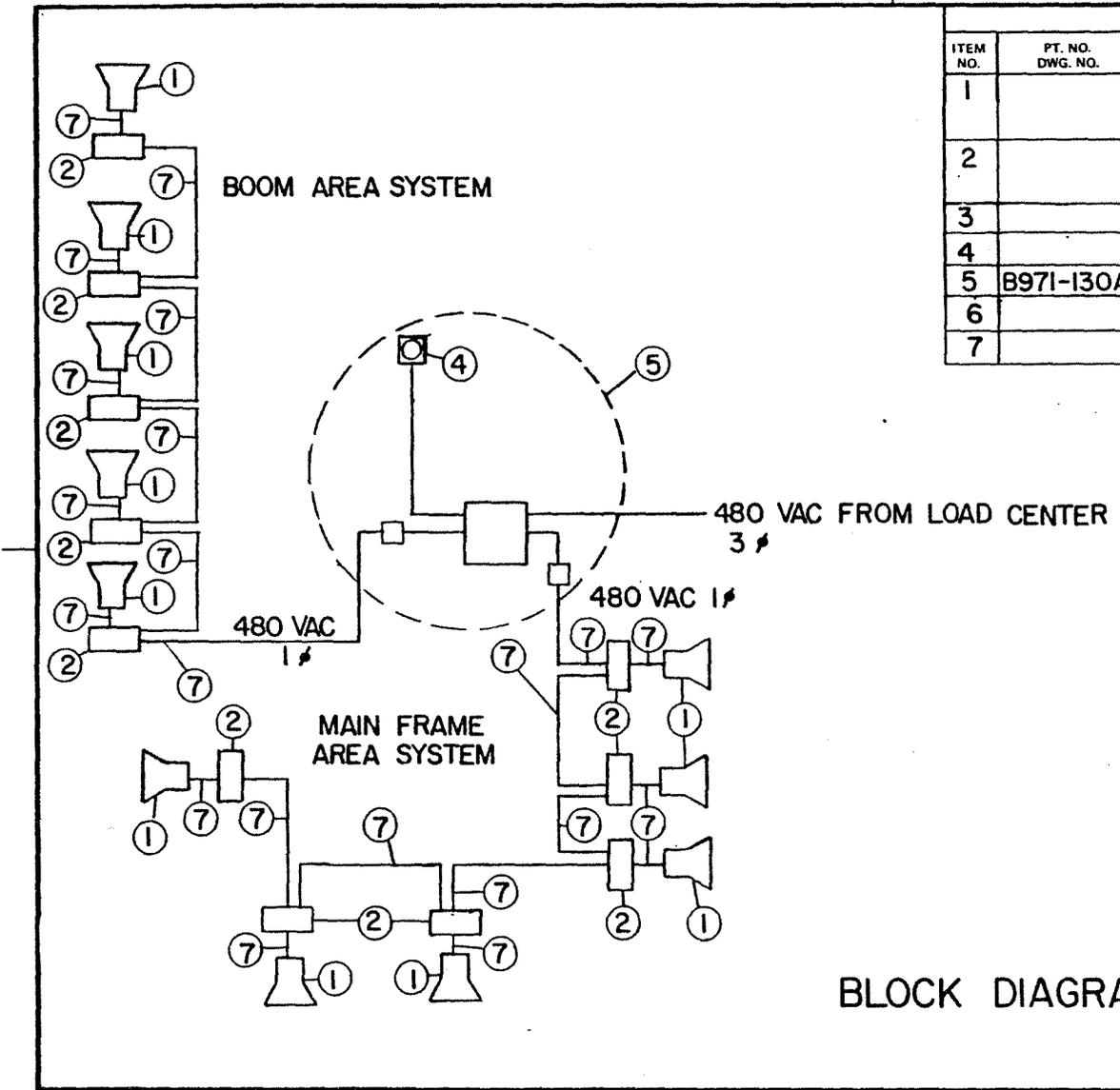


FIGURE A.15
BLOCK DIAGRAM AREA LIGHTING B.E. 1450

PARTS LIST			
ITEM NO.	PT. NO. DWG. NO.	REQ'D	DESCRIPTION
1		9	GTE HDF-1000-500-RB-C LUMINAIRE
2		9	GTE ORB-1000-HPS-480-AB BALLAST ENCLOSURE
3			
4		1	PHOTO CONTROL PEC 105-285
5	B971-131A	1	GEDC CONTACTOR BOX
6			
7		1000	14-3 SO CABLE

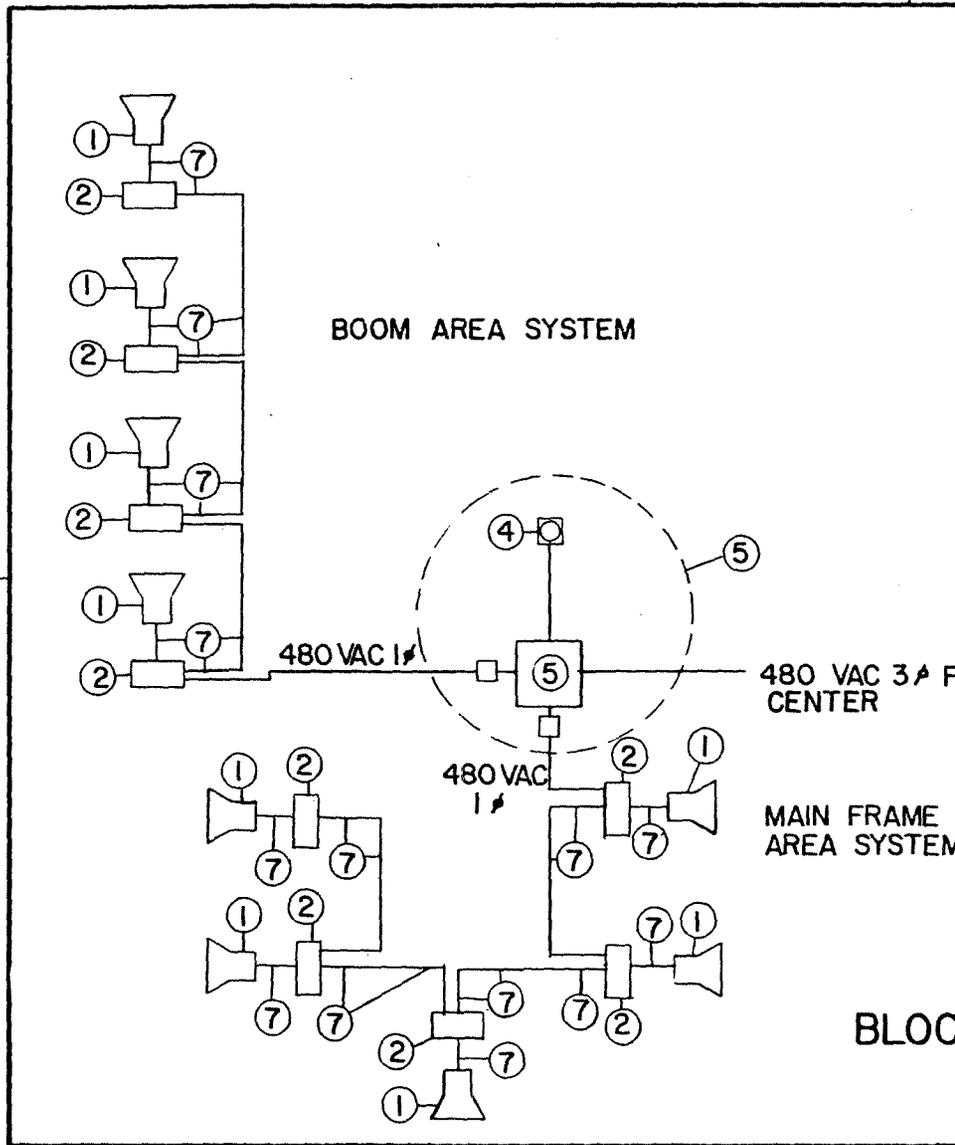


FIGURE A.16
BLOCK DIAGRAM AREA LIGHTING B.E. 3270

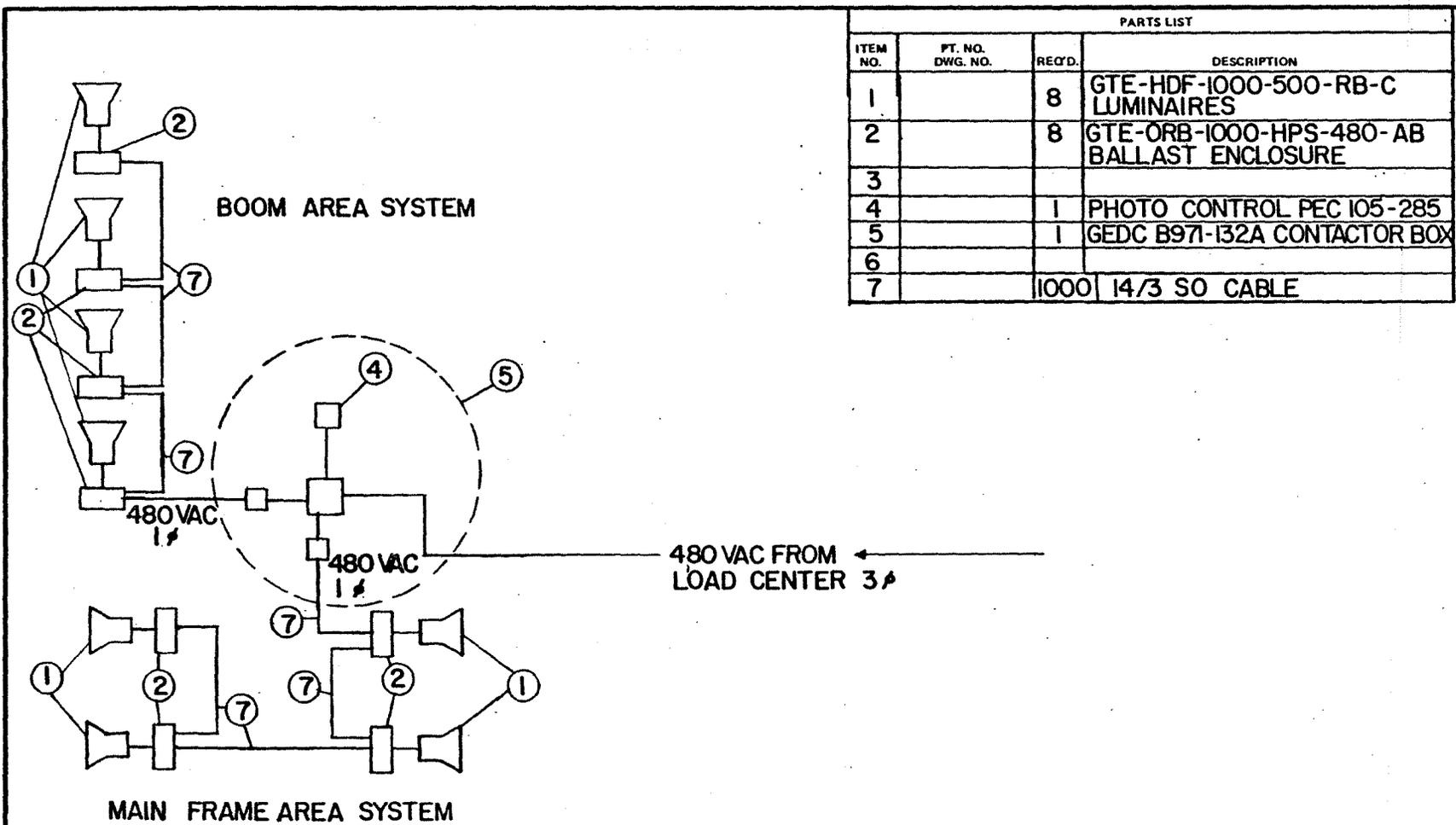
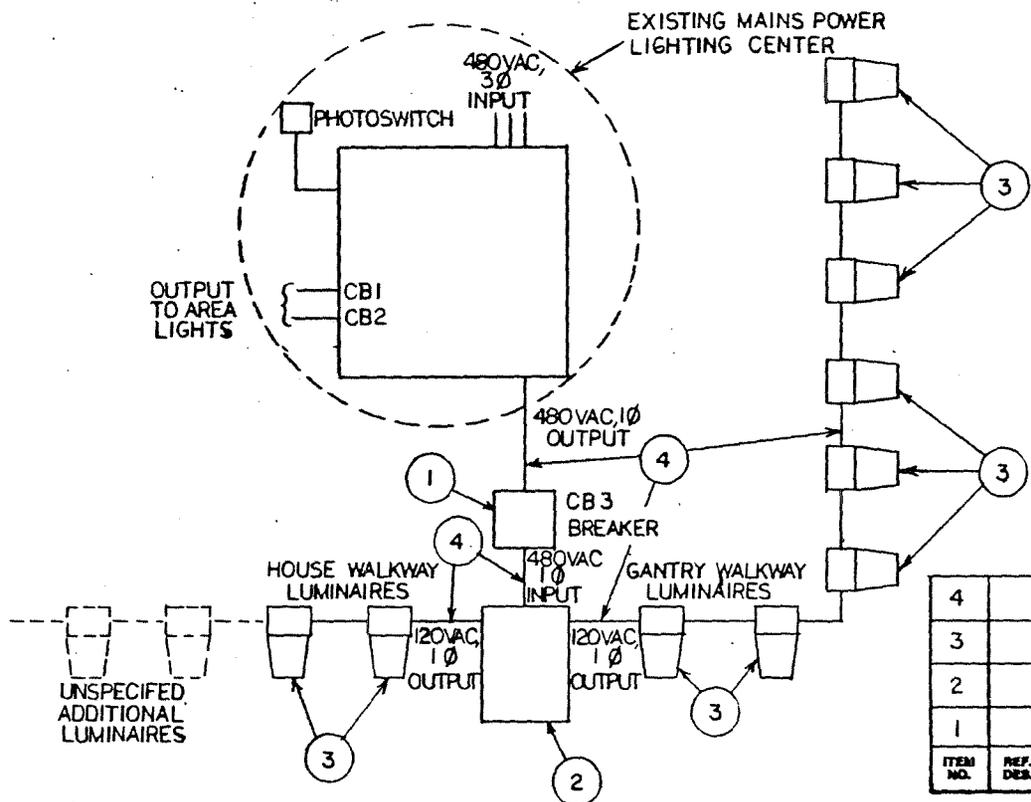


FIGURE A.17
BLOCK DIAGRAM AREA LIGHTING MARION 5900



ITEM NO.	REF. DES.	PT. NO. DWG. NO.	REQD.	DESCRIPTION
4		—	AR	12-3 AWG. CABLE
3		ARC05-10511	10	70WATT HIGH PRESSURE SODIUM WALKWAY LUMINAIRE, 120VAC
2		B971-145	1	WALKWAY LIGHTING TRANSFORMER BOX 4KVA, 480VAC TO 120VAC, 1Ø
1		FAE24020A	1	CIRCUIT BREAKER, 20A, 2POLE, 480VAC, 1Ø

FIGURE A.18
BLOCK DIAGRAM MARION 5900 WALKWAY LIGHTING SYSTEM

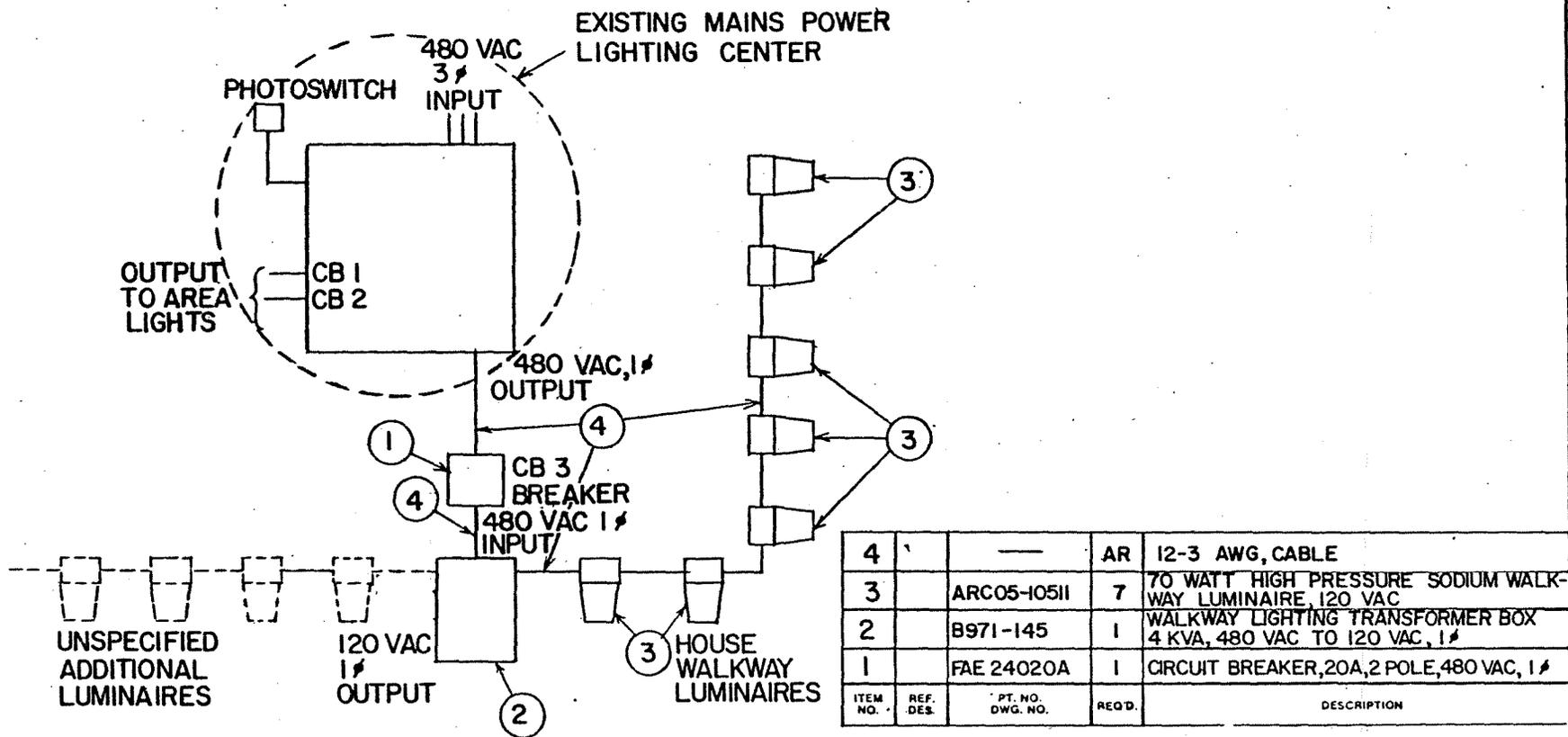


FIGURE A.19
BLOCK DIAGRAM. B.E. 3270 WALKWAY LIGHTING SYSTEM

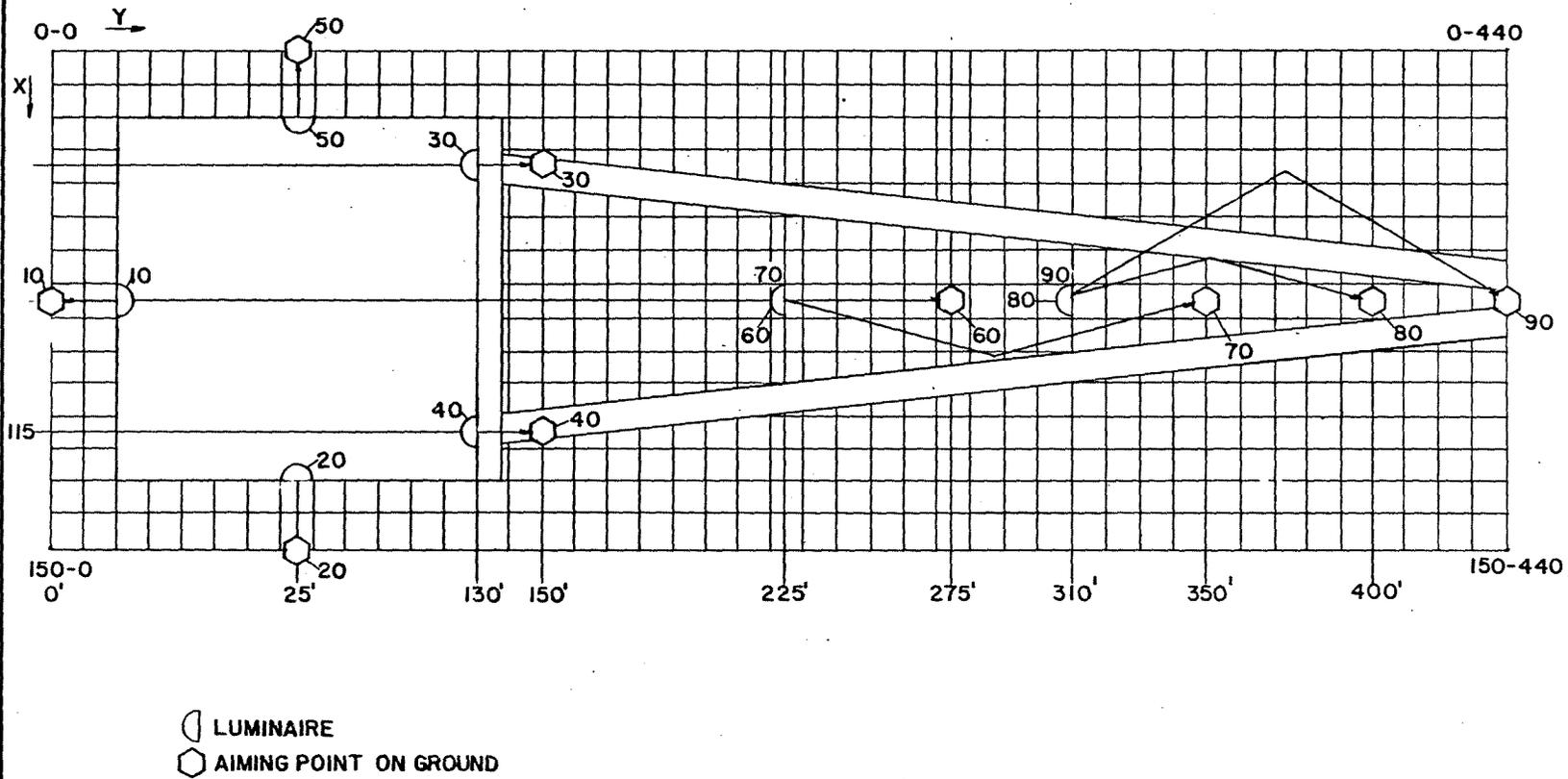
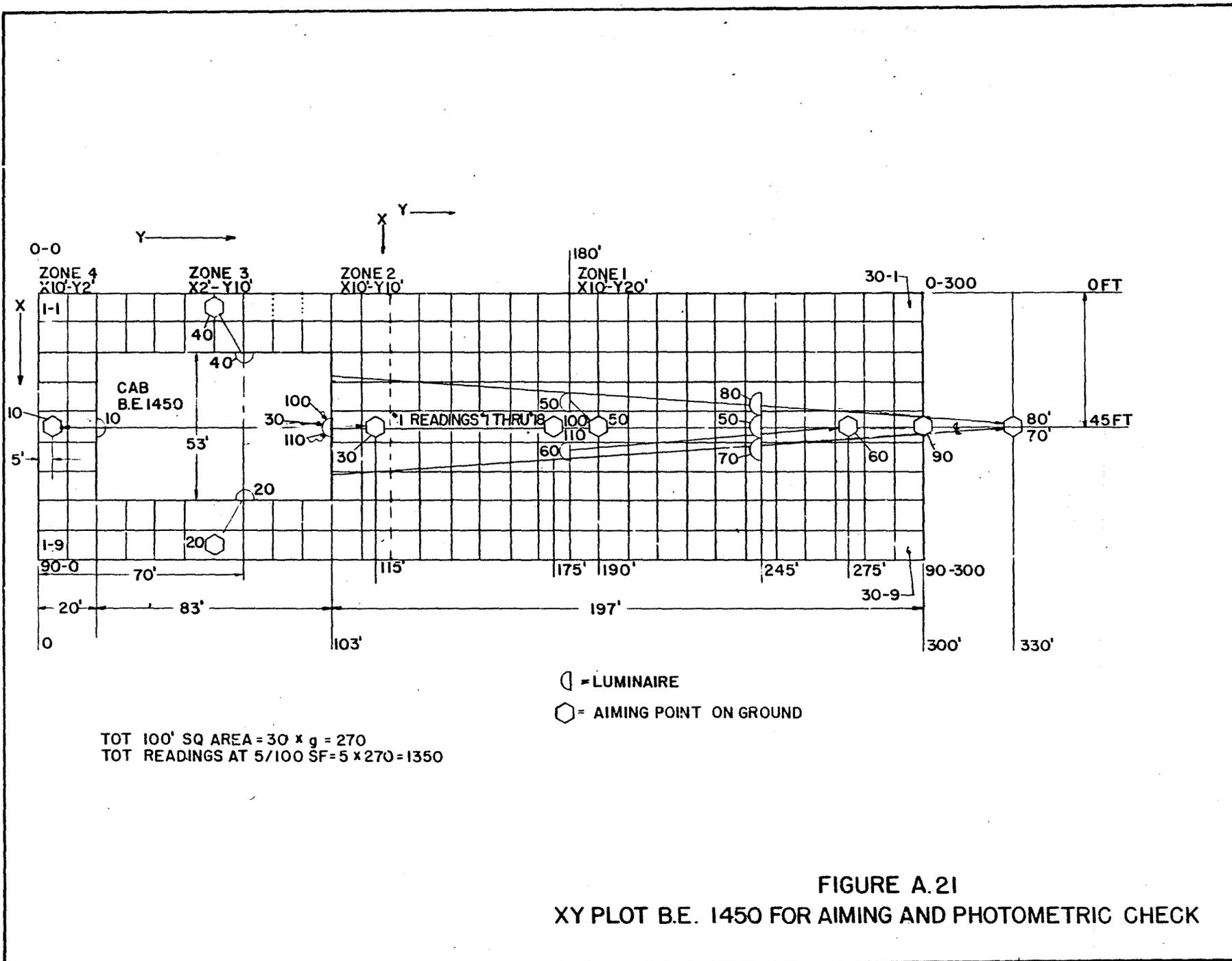


FIGURE A.20
 XY PLOT .B.E. 3270 FOR AIMING AND PHOTOMETRIC CHECK



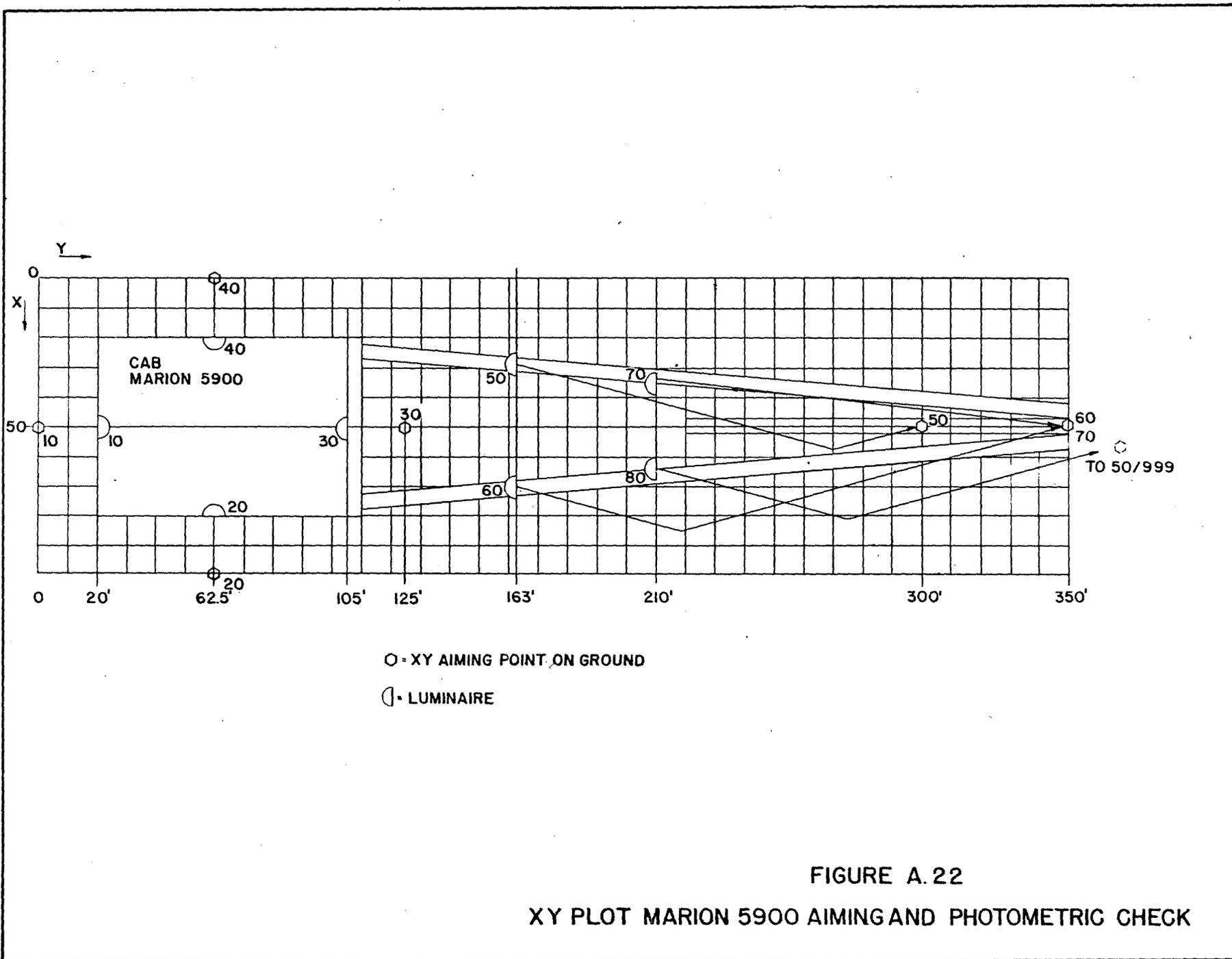
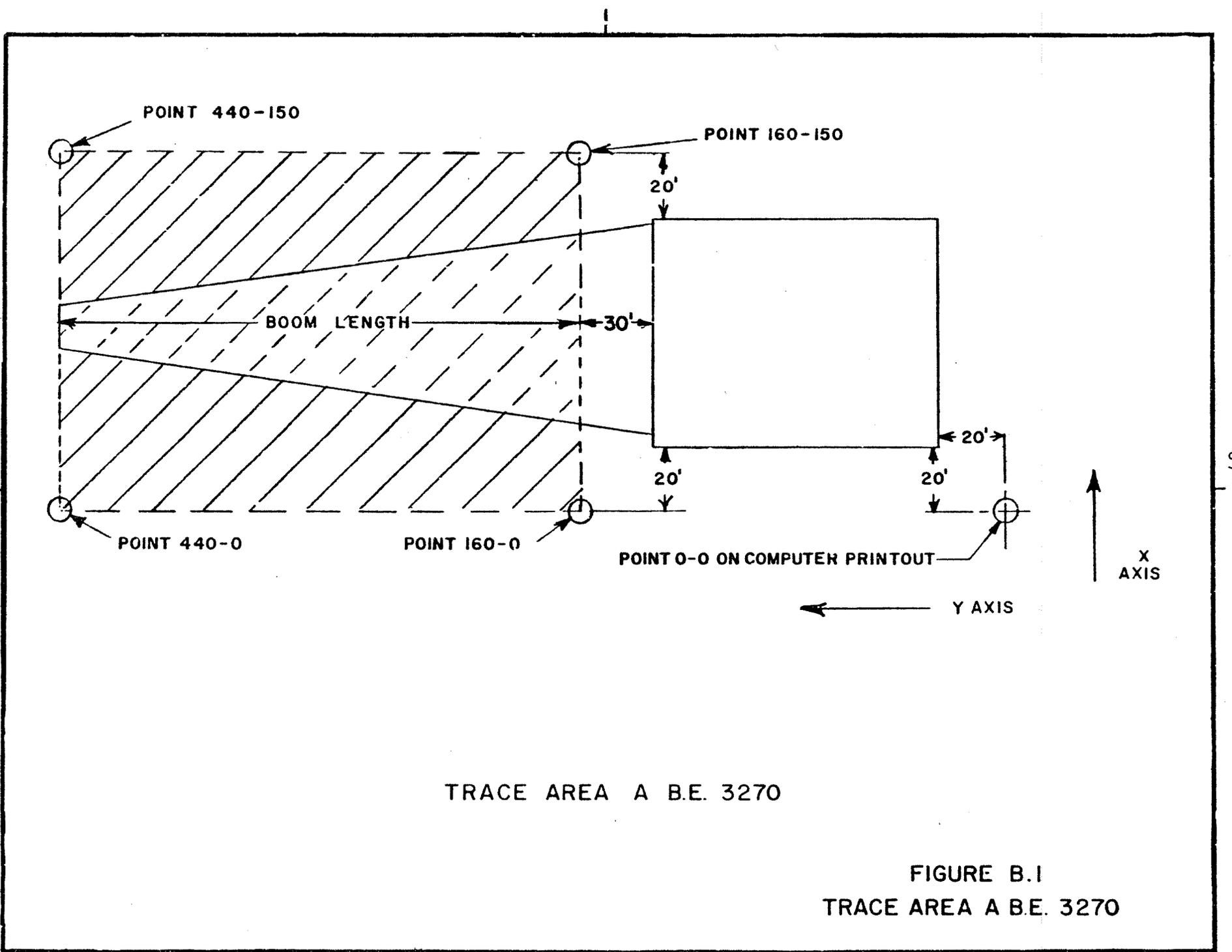


FIGURE A.22

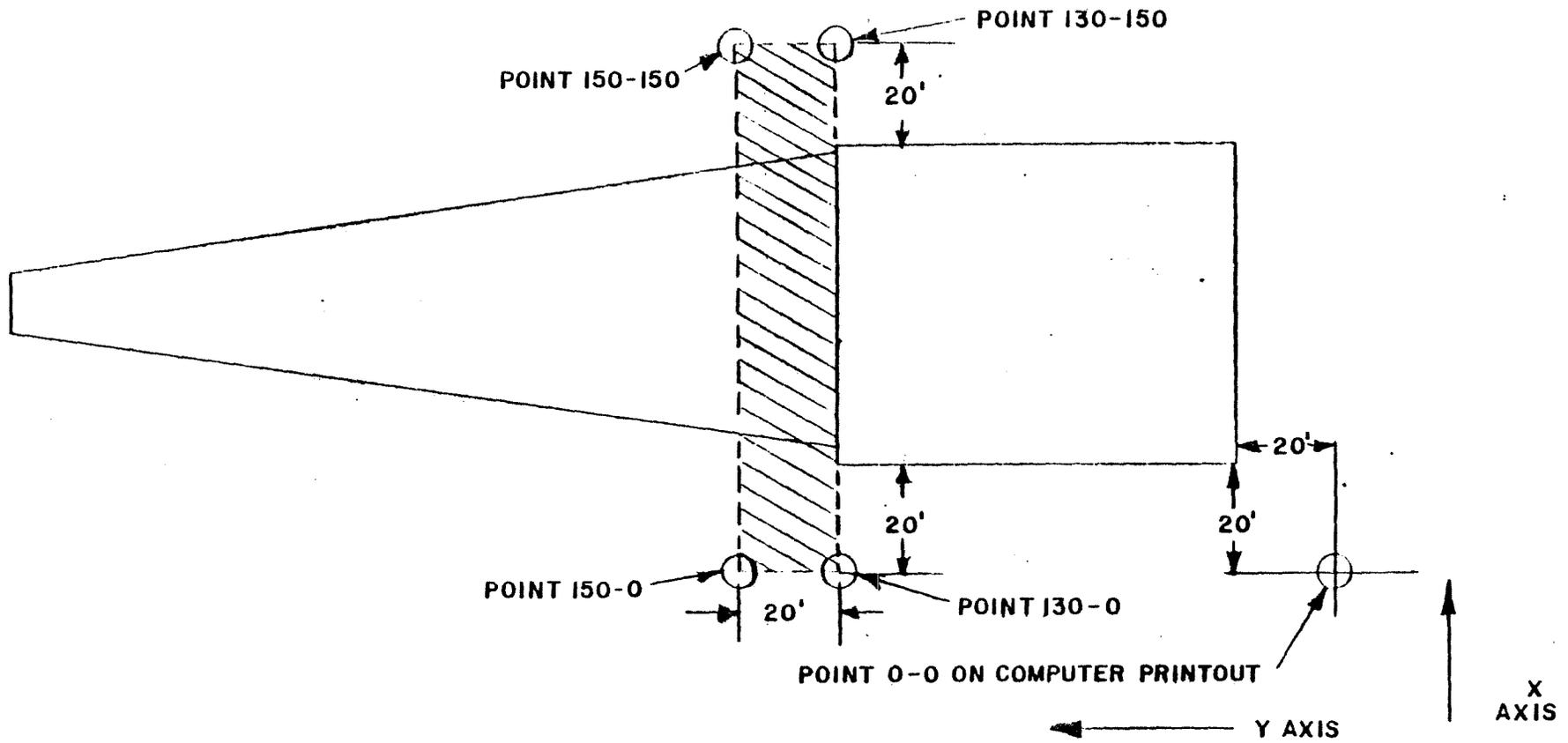
XY PLOT MARION 5900 AIMING AND PHOTOMETRIC CHECK

APPENDIX B - TRACE AREAS/COMPUTER MODEL PRINTOUTS



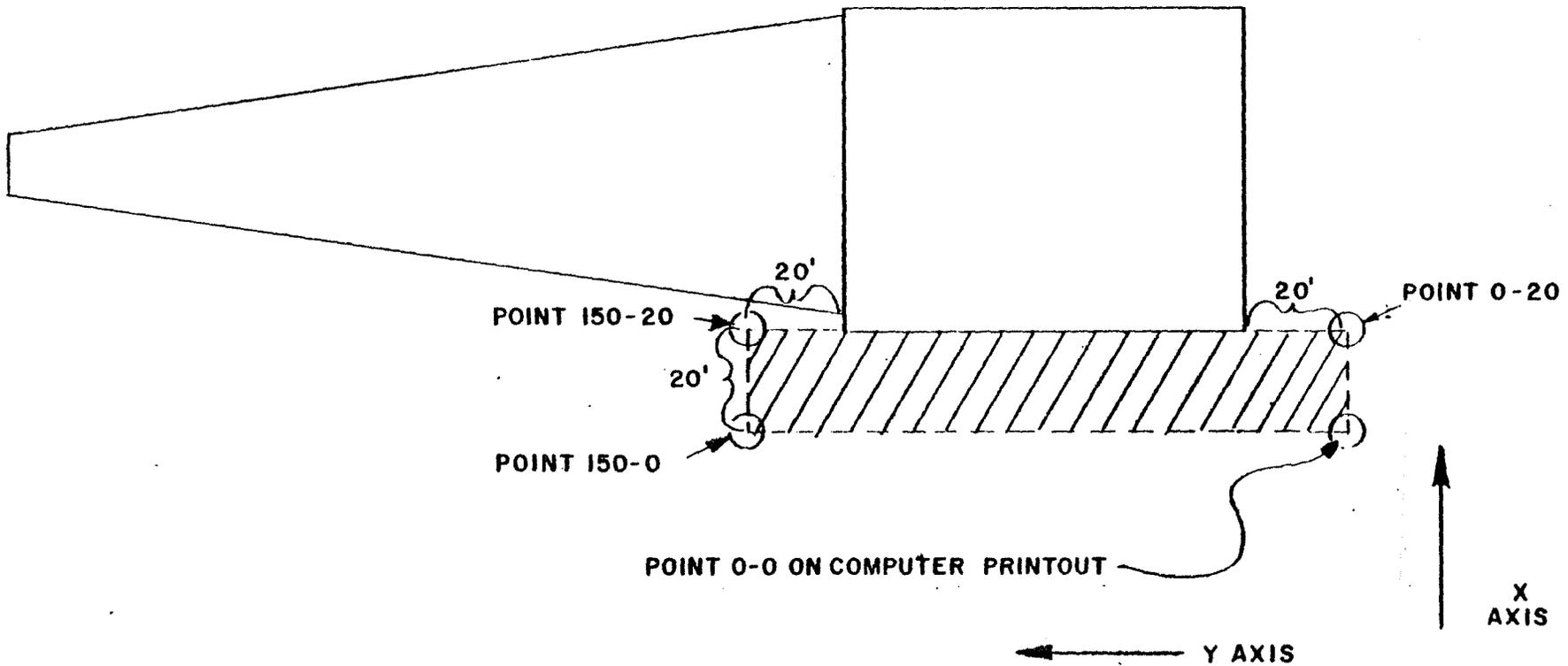
TRACE AREA A B.E. 3270

FIGURE B.1
TRACE AREA A B.E. 3270



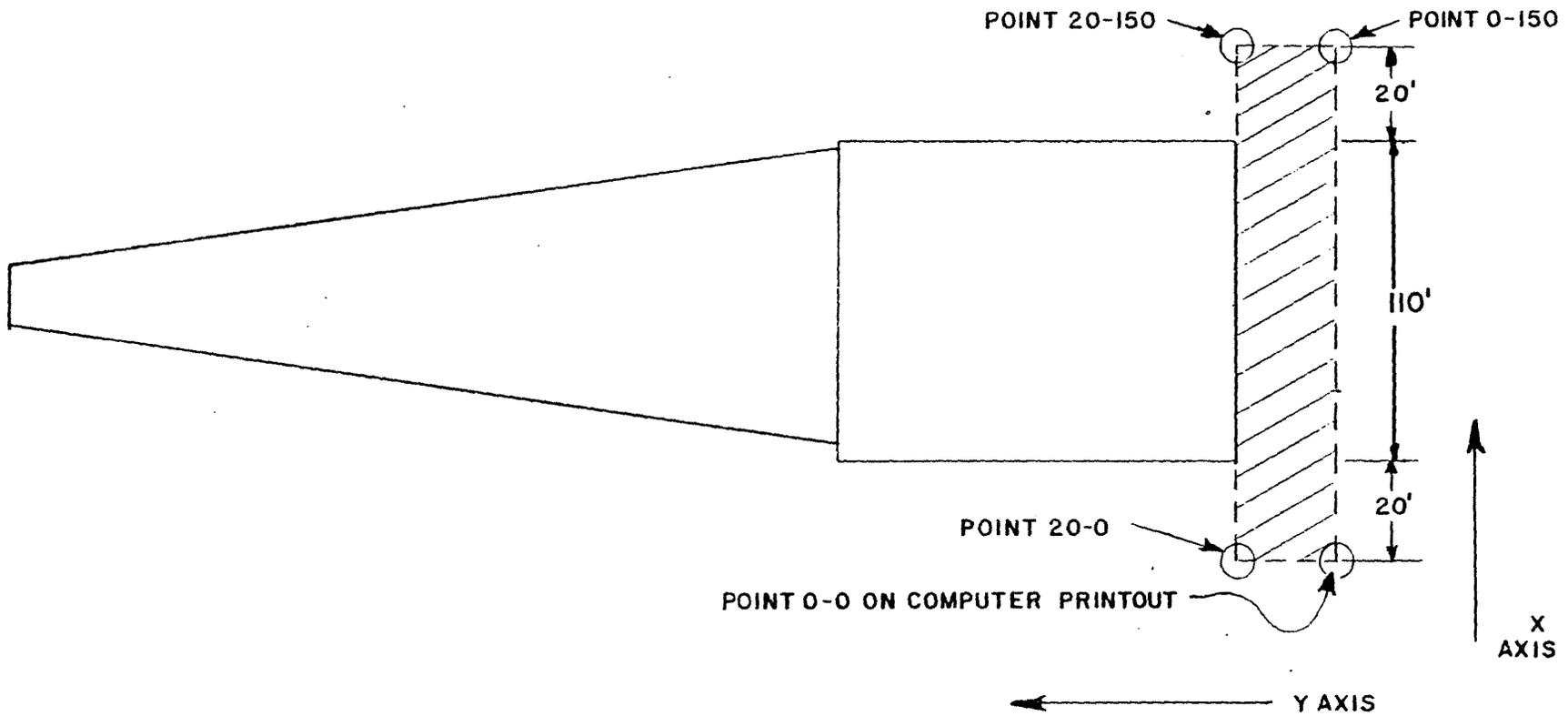
TRACE AREA A I B.E. 3270

FIGURE B.2
TRACE AREA A I B.E. 3270



TRACE AREA A2 B.E.3270

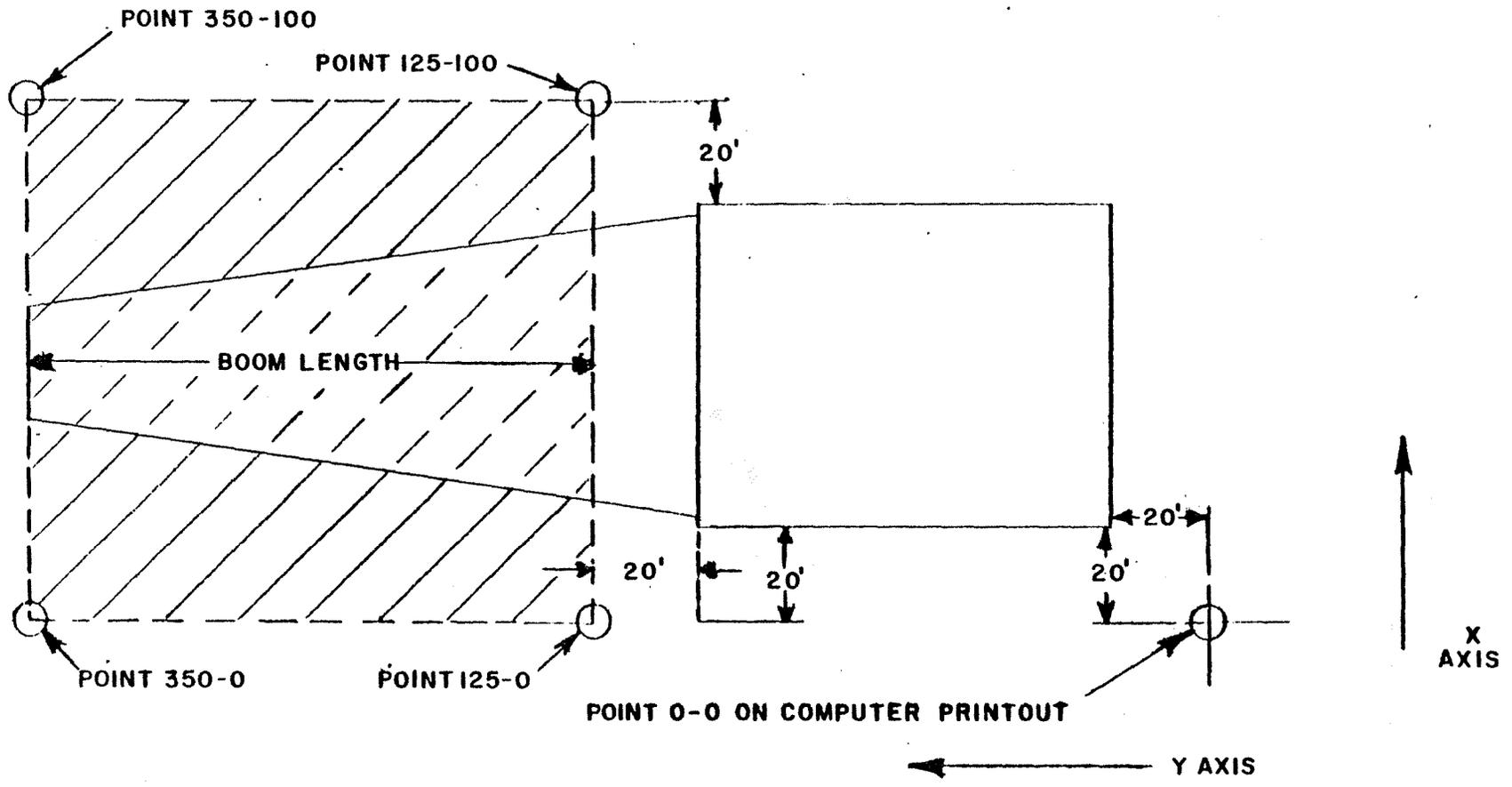
FIGURE B.3
TRACE AREA A2 B.E. 3270



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TRACE AREA A3 B.E. 3270

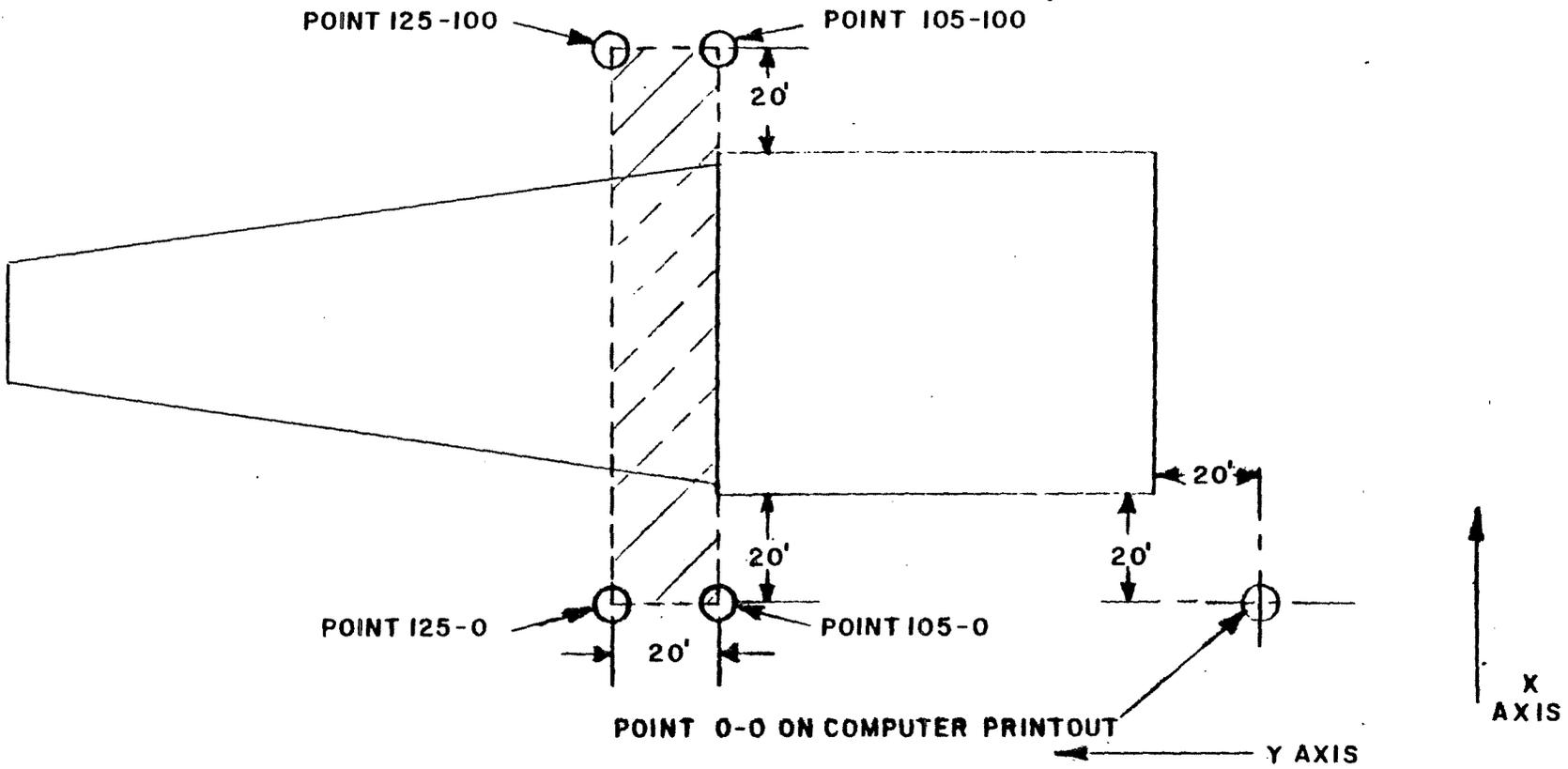
FIGURE B.4
TRACE AREA A3 B.E. 3270



TRACE AREA B MARION 5900

FIGURE B.5

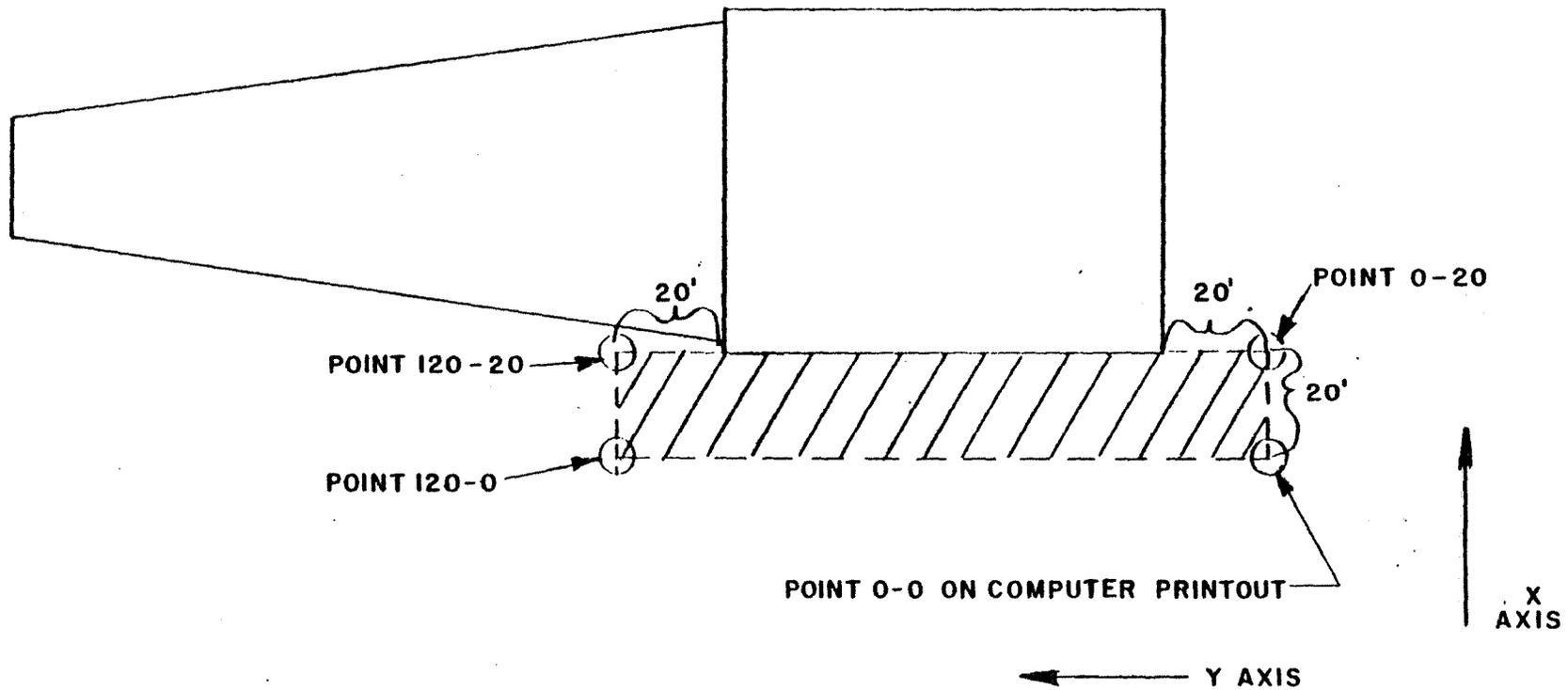
TRACE AREA B MARION 5900



TRACE AREA BI MARION 5900

FIGURE B.6

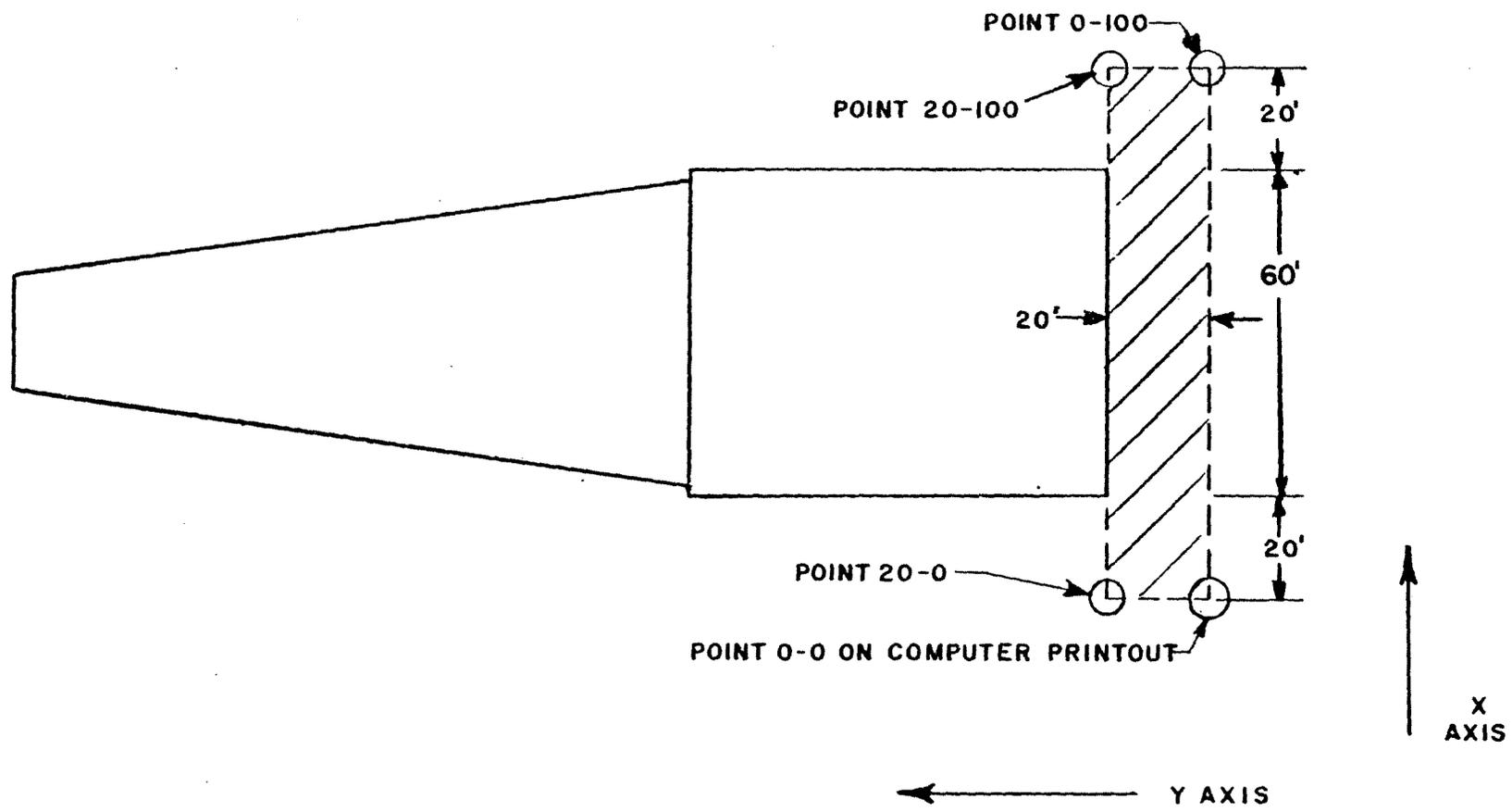
TRACE AREA BI MARION 5900



TRACE AREA B2 MARION 5900

FIGURE B.7

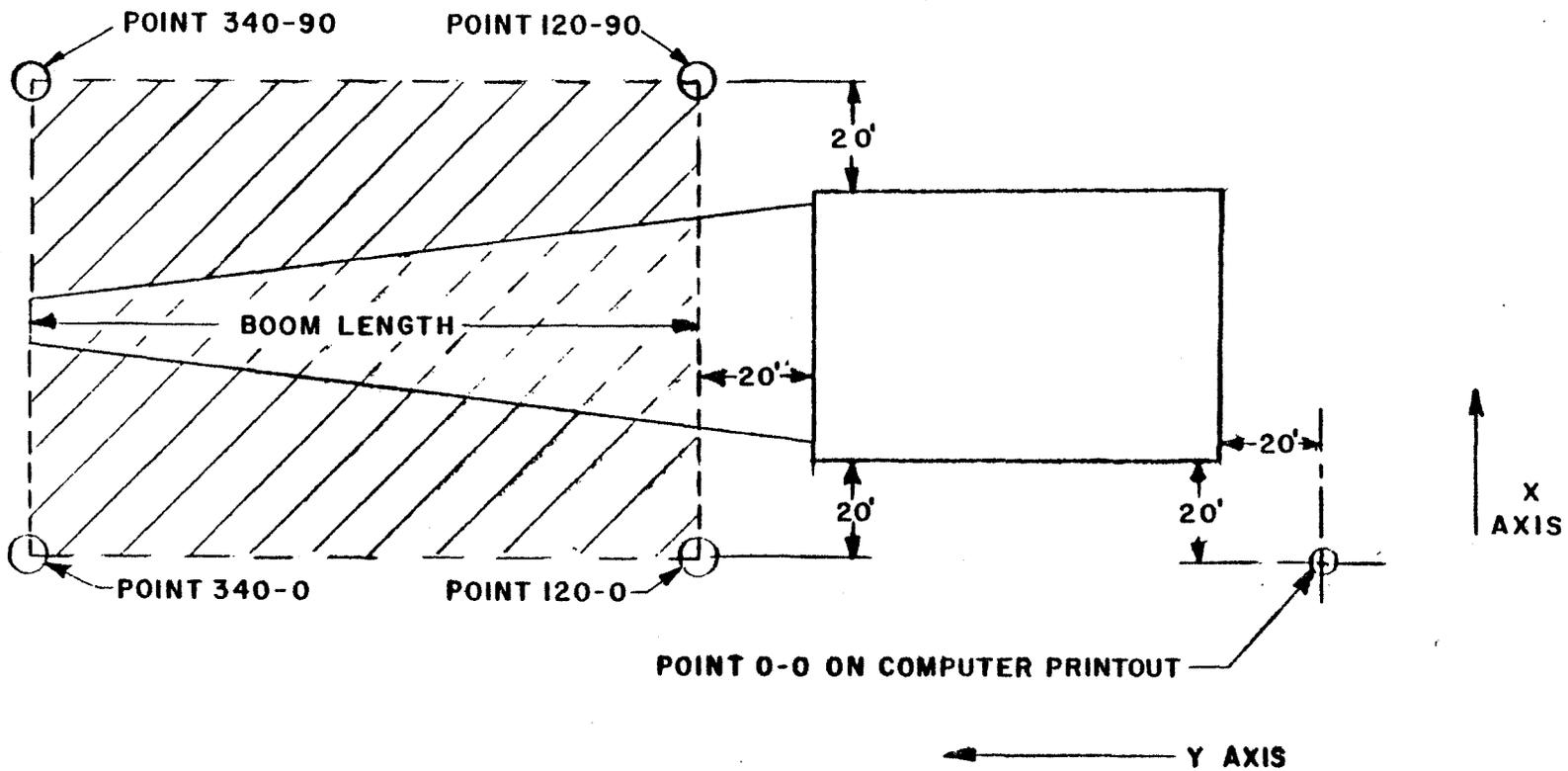
TRACE AREA B2 MARION 5900



TRACE AREA B3 MARION 5900

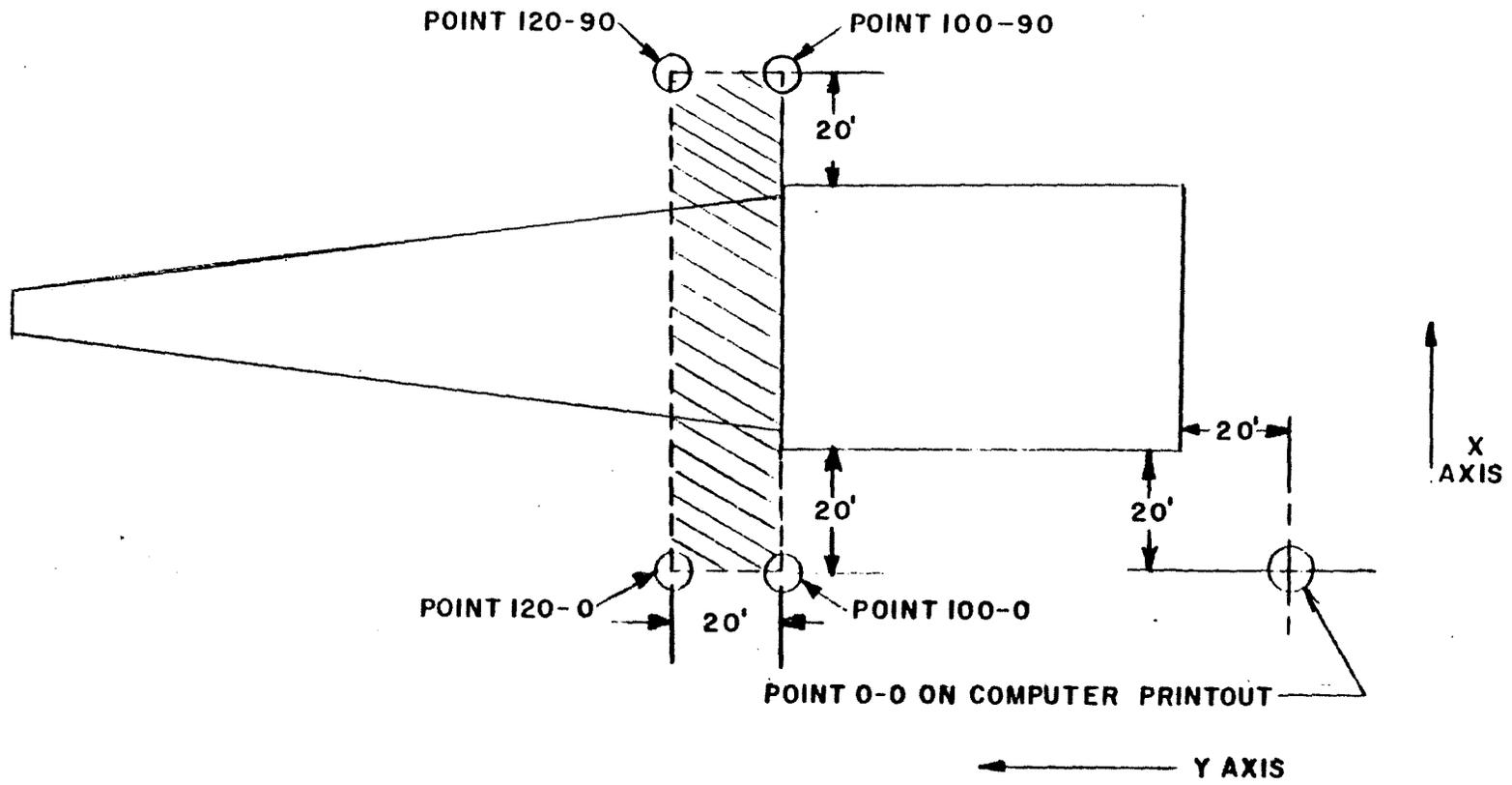
FIGURE B.8

TRACE AREA B3 MARION 5900



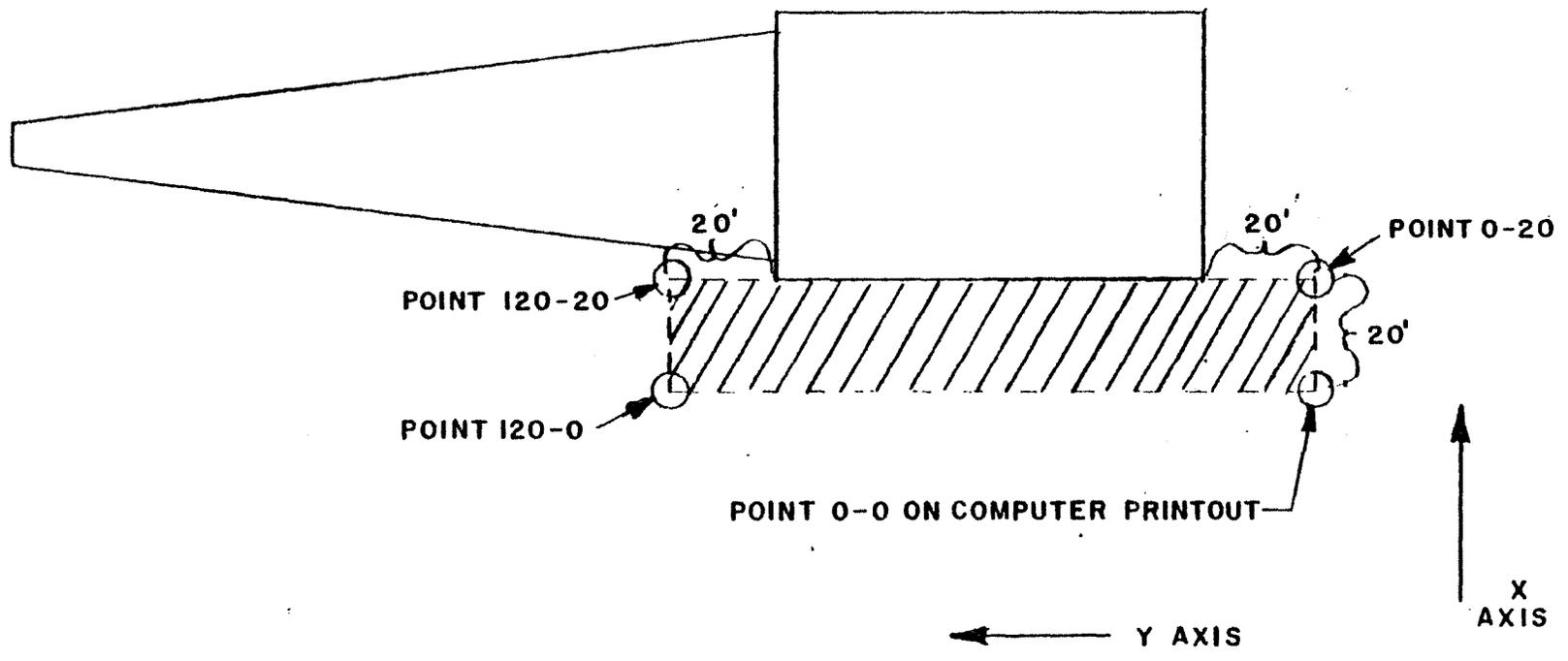
TRACE AREA C B.E. 1450

FIGURE B.9
TRACE AREA C B.E. 1450



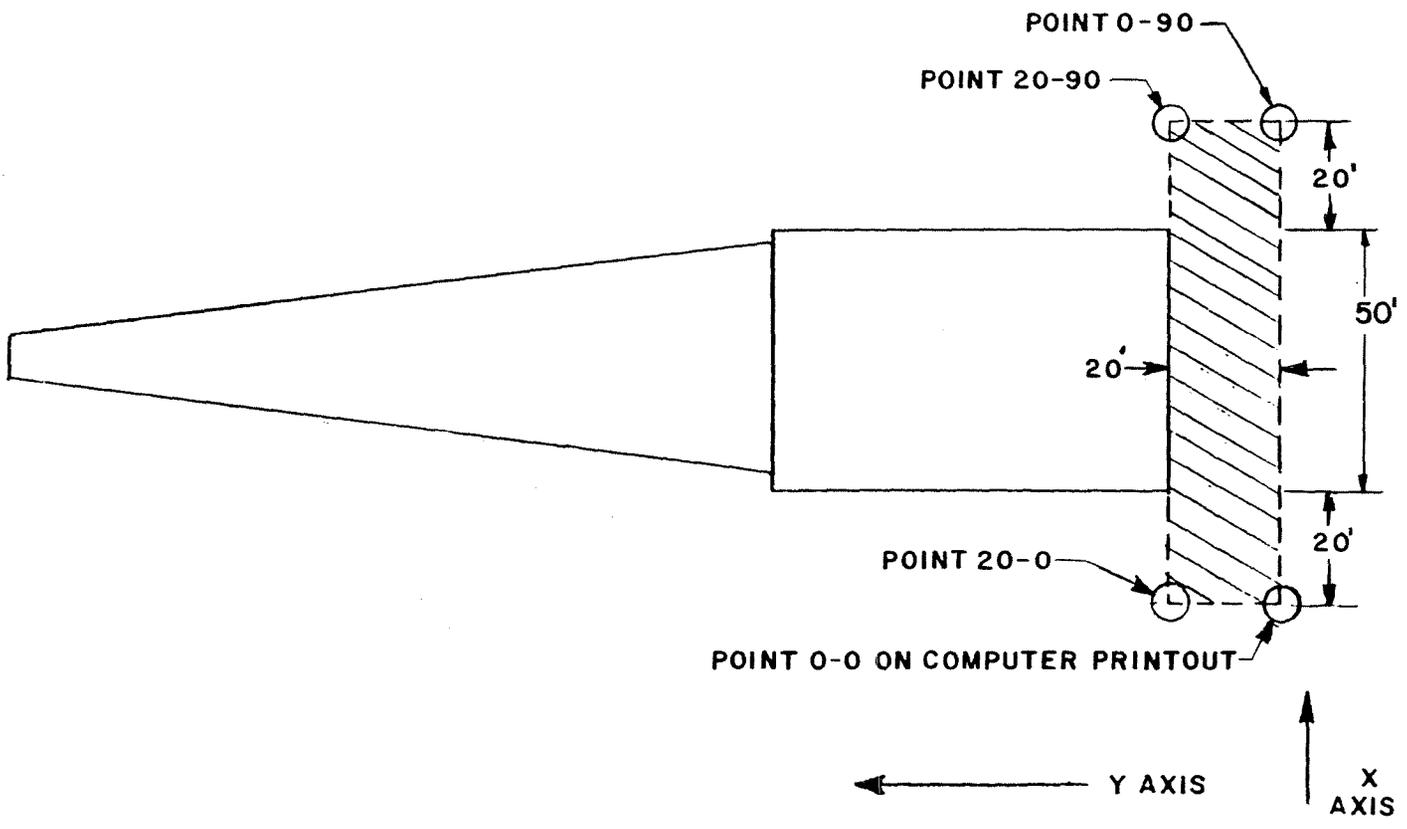
TRACE AREA CI B.E. 1450

FIGURE B.10
TRACE AREA CI B.E. 1450



TRACE AREA C2 B.E. 1450

FIGURE B.II
TRACE AREA C2 B.E. 1450



TRACE AREA C3 B.E.1450

FIGURE B.12
TRACE AREA C3 B.E.1450

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 3270-W

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 165

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING	AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	HEIGHT	XA	YA			
10	PR-4438	0.650	75.00	20.00	55.00	75.00	0.00	340.	0.	270.	
20	PR-4438	0.650	130.00	75.00	55.00	150.00	75.00	340.	0.	0.	
30	PR-4438	0.650	35.00	130.00	32.00	35.00	150.00	328	0.	90.	
40	PR-4438	0.650	115.00	130.00	32.00	115.00	150.00	328.	0.	90.	
50	PR-4438	0.650	20.00	75.00	55.00	0.00	75.00	340.	0.	180.	
60	PR-4438	0.650	75.00	225.00	100.00	75.00	275.00	333.	0.	90.	
70	PR-4438	0.650	75.00	225.00	100.00	75.00	350.00	309.	0.	90.	
80	PR-4438	0.650	75.00	310.00	165.00	75.00	400.00	331.	0.	90.	
90	PR-4438	0.650	75.00	310.00	165.00	75.00	440.00	322.	0.	90.	

BUCYRUS-ERIE NO. 3270-W

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 3.2

440.0	1.1	1.2	1.2	1.3	1.2	1.2	1.2	1.3	1.2	1.2	1.1
420.0	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	1.4
400.0	1.6	1.7	1.8	1.9	1.9	1.8	1.9	1.9	1.8	1.7	1.6
380.0	2.0	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.0
360.0	2.3	2.4	2.5	2.6	2.6	2.6	2.6	2.6	2.5	2.4	2.3
340.0	2.6	2.7	2.8	2.9	3.0	3.0	3.0	2.9	2.8	2.7	2.6
320.0	2.7	2.9	3.1	3.2	3.3	3.3	3.3	3.2	3.1	2.9	2.7
300.0	2.9	3.2	3.4	3.6	3.6	3.6	3.6	3.6	3.4	3.2	2.9
280.0	3.1	3.4	3.7	3.9	4.0	3.9	4.0	3.9	3.7	3.4	3.1
260.0	3.0	3.4	3.7	4.0	4.2	4.2	4.2	4.0	3.7	3.4	3.0
240.0	2.7	3.2	3.5	3.7	3.7	3.7	3.7	3.7	3.5	3.2	2.7
220.0	2.1	2.4	2.8	3.0	3.1	3.2	3.1	3.0	2.8	2.4	2.1
200.0	2.0	2.4	2.8	3.0	3.0	3.0	3.0	3.0	2.8	2.4	2.0
180.0	3.0	3.6	4.4	4.7	4.6	4.6	4.6	4.7	4.4	3.6	3.0
160.0	7.2	9.1	10.5	10.5	9.9	10.2	9.9	10.5	10.5	9.1	7.2
X AXIS	0.	15.	30.	45.	60.	75.	90.	105.	120.	135.	150.

PDS>

TABLE B.1 - COMPUTER MODEL PRINTOUT

TRACE AREA A

TYPE 8113A1.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 3270-W

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO
FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET
AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 121

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING HEIGHT			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA	ZA					
10	PR-4438	0.650	75.00	20.00	55.00	75.00	0.00	340.	0.	270.			
20	PR-4438	0.650	130.00	75.00	55.00	150.00	75.00	340.	0.	0.			
30	PR-4438	0.650	35.00	130.00	32.00	35.00	150.00	328.	0.	90.			
40	PR-4438	0.650	115.00	130.00	32.00	115.00	150.00	328.	0.	90.			
50	PR-4438	0.650	20.00	75.00	55.00	0.00	75.00	340.	0.	180.			
60	PR-4438	0.650	75.00	225.00	100.00	75.00	275.00	333.	0.	90.			
70	PR-4438	0.650	75.00	225.00	100.00	75.00	350.00	309.	0.	90.			
80	PR-4438	0.650	75.00	310.00	165.00	75.00	400.00	331.	0.	90.			
90	PR-4438	0.650	75.00	310.00	165.00	75.00	440.00	322.	0.	90.			

BUCYRUS-ERIE NO. 3270-W

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 16.3

150.0	10.2	14.1	17.2	16.6	14.0	13.0	14.0	16.6	17.2	14.1	10.2
148.0	10.7	15.3	18.6	17.8	14.9	13.3	14.9	17.8	18.6	15.3	10.7
146.0	11.1	16.6	19.8	19.0	15.8	13.5	15.8	19.0	19.8	16.6	11.1
144.0	11.3	18.0	20.8	20.0	16.5	13.4	16.5	20.0	20.8	18.0	11.3
142.0	11.4	19.3	21.6	21.0	17.0	13.0	17.0	21.0	21.6	19.3	11.4
140.0	11.2	20.3	22.2	21.6	17.2	12.1	17.2	21.6	22.2	20.3	11.2
138.0	11.0	21.1	22.6	22.2	17.3	11.1	17.3	22.2	22.6	21.1	11.0
136.0	10.5	21.0	22.5	21.9	16.6	10.0	16.6	21.9	22.5	21.0	10.5
134.0	9.8	19.5	21.8	20.4	15.0	8.6	15.0	20.4	21.8	19.5	9.8
132.0	9.2	17.7	20.9	18.6	13.2	7.3	13.2	18.6	20.9	17.7	9.2
130.0	8.6	16.0	19.0	16.4	11.3	6.2	11.3	16.4	19.0	16.0	8.6
X AXIS	0.	15.	30.	45.	60.	75.	90.	105.	120.	135.	150.

PDS>

TABLE B.2 - COMPUTER MODEL PRINTOUT
TRACE AREA A1

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 3270-W

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 176

LUMINAIRE	TYPE	FACTOR	FIXTURE MOUNTING LOCATION			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA			
10	PR-4438	0.650	75.00	20.00	55.00	75.00	0.00	340.	0.	270.
20	PR-4438	0.650	130.00	75.00	55.00	150.00	75.00	340.	0.	0.
30	PR-4438	0.650	35.00	130.00	32.00	35.00	150.00	328.	0.	90.
40	PR-4438	0.650	115.00	130.00	32.00	115.00	150.00	328.	0.	90.
50	PR-4438	0.650	20.00	75.00	55.00	0.00	75.00	340.	0.	180.
60	PR-4438	0.650	75.00	225.00	100.00	75.00	275.00	333.	0.	90.
70	PR-4438	0.650	75.00	225.00	100.00	75.00	350.00	309.	0.	90.
80	PR-4438	0.650	75.00	310.00	165.00	75.00	400.00	331.	0.	90.
90	PR-4438	0.650	75.00	310.00	165.00	75.00	440.00	322.	0.	90.

BUCYRUS-ERIE NO. 3270-W

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 8.4

150.0	10.2	11.2	12.0	12.5	12.9	13.2	13.5	13.8	14.3	14.8	15.3
140.0	11.2	12.6	14.1	15.9	17.3	18.2	19.0	19.9	20.6	21.3	21.8
130.0	8.6	9.6	10.8	12.2	13.7	14.5	15.1	15.7	16.2	16.8	17.3
120.0	6.1	6.4	6.7	7.1	7.4	7.6	7.8	7.9	8.0	8.1	8.2
110.0	6.1	6.4	6.7	7.0	7.2	7.4	7.6	7.7	7.8	7.8	7.8
100.0	6.6	6.9	7.1	7.4	7.6	7.8	7.9	8.0	8.0	8.0	8.0
90.0	7.3	7.5	7.8	7.9	8.1	8.1	8.2	8.2	8.1	8.1	8.0
80.0	7.4	7.6	7.9	8.0	8.1	8.2	8.2	8.1	8.1	8.0	7.8
70.0	7.4	7.7	7.9	8.1	8.1	8.2	8.2	8.2	8.1	8.0	7.9
60.0	7.3	7.5	7.7	7.9	8.0	8.2	8.2	8.2	8.2	8.1	8.0
50.0	6.5	6.8	7.0	7.2	7.5	7.7	7.8	7.9	8.0	8.0	8.0
40.0	6.0	6.3	6.5	6.8	7.1	7.3	7.5	7.6	7.7	7.9	7.9
30.0	5.7	5.9	6.2	6.5	6.7	6.9	7.1	7.2	7.4	7.5	7.6
20.0	4.9	5.1	5.3	5.6	5.7	6.0	6.1	6.2	6.4	6.6	6.8
10.0	4.2	4.4	4.6	4.8	5.0	5.2	5.3	5.5	5.6	5.8	6.0
0.0	3.4	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.6	4.7	4.9
X AXIS	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.

PDS>

TABLE B.3 - COMPUTER MODEL PRINTOUT

TRACE AREA A2

TYPE 8113A3.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 3270-W

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO

FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET

AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 121

LUMINAIRE	TYPE	FACTOR	FIXTURE MOUNTING			AIMING		VANGLE	SLOPE	HANGLE
			LOCATION	LOCATION	HEIGHT	LOCATION	LOCATION			
			XF	YF	ZF	XA	YA			
10	PR-4438	0.650	75.00	20.00	55.00	75.00	0.00	340.	0.	270.
20	PR-4438	0.650	130.00	75.00	55.00	150.00	75.00	340.	0.	0.
30	PR-4438	0.650	35.00	130.00	32.00	35.00	150.00	328.	0.	90.
40	PR-4438	0.650	115.00	130.00	32.00	115.00	150.00	328.	0.	90.
50	PR-4438	0.650	20.00	75.00	55.00	0.00	75.00	340.	0.	180.
60	PR-4438	0.650	75.00	225.00	100.00	75.00	275.00	333.	0.	90.
70	PR-4438	0.650	75.00	225.00	100.00	75.00	350.00	309.	0.	90.
80	PR-4438	0.650	75.00	310.00	165.00	75.00	400.00	331.	0.	90.
90	PR-4438	0.650	75.00	310.00	165.00	75.00	440.00	322.	0.	90.

BUCYRUS-ERIE NO. 3270-W

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 6.5

20.0	4.9	6.3	7.6	8.1	8.1	7.9	8.1	8.1	7.6	6.3	4.9
18.0	4.7	6.1	7.5	8.0	8.2	8.0	8.2	8.0	7.5	6.1	4.7
16.0	4.6	5.9	7.4	7.9	8.2	8.1	8.2	7.9	7.4	5.9	4.6
14.0	4.4	5.8	7.2	7.8	8.3	8.1	8.3	7.8	7.2	5.8	4.4
12.0	4.3	5.7	7.1	7.7	8.2	8.2	8.2	7.7	7.1	5.7	4.3
10.0	4.2	5.5	6.9	7.5	8.2	8.1	8.2	7.5	6.9	5.5	4.2
8.0	4.0	5.3	6.7	7.3	8.1	8.0	8.1	7.3	6.7	5.3	4.0
6.0	3.9	5.1	6.5	7.0	8.0	7.8	8.0	7.0	6.5	5.1	3.9
4.0	3.8	4.9	6.2	6.8	7.8	7.6	7.8	6.8	6.2	4.9	3.8
2.0	3.6	4.7	5.9	6.5	7.6	7.4	7.6	6.5	5.9	4.7	3.6
0.0	3.4	4.5	5.7	6.3	7.4	7.1	7.4	6.3	5.7	4.5	3.4
X AXIS	0.	15.	30.	45.	60.	75.	90.	105.	120.	135.	150.

PDS>

TABLE B.4 - COMPUTER MODEL PRINTOUT
TRACE AREA A3

TYPE 8113B.OUT

LIGHTING EQUIPMENT PROGRAM

03-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

MARION POWER SHOVEL

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO
FOR HORIZONTAL MEASUREMENT
THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET
AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL
THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 176

Table with columns: LUMINAIRE, TYPE, FACTOR, FIXTURE LOCATION (XF, YF), MOUNTING HEIGHT (ZF), AIMING LOCATION (XA, YA), VANGLE, SLOPE, HANGLE. Rows 10-80.

MARION POWER SHOVEL

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 3.4

Table with columns: X AXIS (0-100) and rows of maintained horizontal footcandle values.

PDS>

TABLE B.5 - COMPUTER MODEL PRINTOUT

TRACE AREA B

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

MARION POWER SHOVEL

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO
FOR HORIZONTAL MEASUREMENT
THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET
AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL
THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 121

LUMINAIRE	TYPE	FACTOR	FIXTURE MOUNTING LOCATION			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA			
10	PR-4438	0.650	50.00	20.00	76.00	50.00	0.00	345.	0.	270.
20	PR-4438	0.650	80.00	62.50	76.00	100.00	62.50	345.	0.	0.
30	PR-4438	0.650	50.00	105.00	44.00	50.00	125.00	336.	0.	90.
40	PR-4438	0.650	20.00	62.50	76.00	0.00	62.50	345.	0.	180.
50	PR-4438	0.650	32.00	163.00	96.00	50.00	300.00	305.	0.	83.
60	PR-4438	0.650	68.00	163.00	96.00	50.00	350.00	297.	0.	95.
70	PR-4438	0.650	38.00	210.00	144.00	50.00	350.00	316.	0.	85.
80	PR-4438	0.650	62.00	210.00	144.00	50.00	999.00	280.	0.	91.

MARION POWER SHOVEL

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 12.1

125.0	7.4	10.0	11.0	12.1	13.3	12.5	13.3	12.1	11.0	10.0	7.4
123.0	7.6	10.3	11.5	12.7	13.8	13.1	13.8	12.7	11.5	10.3	7.6
121.0	7.7	10.6	12.0	13.2	14.3	13.6	14.3	13.2	12.0	10.6	7.7
119.0	7.7	10.7	12.5	13.8	14.6	14.1	14.6	13.8	12.5	10.7	7.7
117.0	7.7	10.8	13.0	14.3	14.9	14.5	14.9	14.3	13.0	10.8	7.7
115.0	7.6	10.9	13.3	14.7	15.1	14.8	15.1	14.7	13.3	10.9	7.6
113.0	7.5	10.8	13.5	15.0	15.2	14.9	15.2	15.0	13.5	10.8	7.5
111.0	7.3	10.7	13.6	15.2	15.2	15.0	15.2	15.2	13.6	10.7	7.3
109.0	7.1	10.6	13.7	15.4	15.2	14.9	15.2	15.4	13.7	10.6	7.1
107.0	6.9	10.2	13.2	14.9	14.8	14.7	14.8	14.9	13.3	10.2	6.9
105.0	6.6	9.8	12.5	14.0	14.2	14.3	14.2	14.0	12.5	9.8	6.6

X AXIS 0. 10. 20. 30. 40. 50. 60. 70. 80. 90. 100.

PDS>

TABLE B.6 - COMPUTER MODEL PRINTOUT
TRACE AREA B1

TYPE 8113B2.OUT

LIGHTING EQUIPMENT PROGRAM

03-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

MARION POWER SHOVEL

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 143

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING	AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	HEIGHT	XA	YA			
10	PR-4438	0.650	50.00	20.00	76.00	50.00	0.00	345.	0.	270.	
20	PR-4438	0.650	80.00	62.50	76.00	100.00	62.50	345.	0.	0.	
30	PR-4438	0.650	50.00	105.00	44.00	50.00	125.00	336.	0.	90.	
40	PR-4438	0.650	20.00	62.50	76.00	0.00	62.50	345.	0.	180.	
50	PR-4438	0.650	32.00	163.00	96.00	50.00	300.00	305.	0.	83.	
60	PR-4438	0.650	68.00	163.00	96.00	50.00	350.00	297.	0.	95.	
70	PR-4438	0.650	38.00	210.00	144.00	50.00	350.00	316.	0.	85.	
80	PR-4438	0.650	62.00	210.00	144.00	50.00	999.00	280.	0.	91.	

MARION POWER SHOVEL

MAINTAINED HORIZONTAL FOOTCANDLES AVERAGE = 7.2

120.0	7.7	8.2	8.7	9.3	10.0	10.7	11.2	11.5	11.8	12.1	12.3
110.0	7.2	7.8	8.4	9.1	9.8	10.7	11.6	12.3	12.7	13.2	13.7
100.0	6.0	6.5	6.9	7.4	8.0	8.6	9.3	9.8	10.1	10.3	10.6
90.0	5.2	5.4	5.7	5.9	6.2	6.5	6.7	6.9	7.0	7.1	7.2
80.0	5.0	5.1	5.1	5.2	5.3	5.4	5.4	5.4	5.5	5.5	5.5
70.0	5.0	5.1	5.2	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4
60.0	5.2	5.3	5.4	5.5	5.5	5.6	5.7	5.7	5.7	5.7	5.7
50.0	5.9	6.0	6.1	6.2	6.3	6.3	6.3	6.3	6.3	6.3	6.3
40.0	6.3	6.5	6.6	6.7	6.8	6.9	7.0	7.0	7.1	7.1	7.1
30.0	6.8	7.0	7.2	7.3	7.5	7.6	7.7	7.8	7.9	7.9	7.9
20.0	6.8	7.0	7.2	7.3	7.5	7.6	7.7	7.9	7.9	8.0	8.0
10.0	6.5	6.7	6.8	6.9	7.0	7.2	7.3	7.4	7.5	7.5	7.6
0.0	5.9	6.0	6.1	6.2	6.4	6.5	6.5	6.6	6.7	6.7	6.8

X AXIS	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.
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PDS>

TABLE B.7 - COMPUTER MODEL PRINTOUT TRACE AREA B2

TYPE 8113B3.OUT

LIGHTING EQUIPMENT PROGRAM

03-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

MARION POWER SHOVEL

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO

FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET

AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 121

LUMINAIRE	TYPE	FACTOR	FIXTURE MOUNTING LOCATION			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA			
10	PR-4438	0.650	50.00	20.00	76.00	50.00	0.00	345.	0.	270.
20	PR-4438	0.650	80.00	62.50	76.00	100.00	62.50	345.	0.	0.
30	PR-4438	0.650	50.00	105.00	44.00	50.00	125.00	336.	0.	90.
40	PR-4438	0.650	20.00	62.50	76.00	0.00	62.50	345.	0.	180.
50	PR-4438	0.650	32.00	163.00	96.00	50.00	300.00	305.	0.	83.
60	PR-4438	0.650	68.00	163.00	96.00	50.00	350.00	297.	0.	95.
70	PR-4438	0.650	38.00	210.00	144.00	50.00	350.00	316.	0.	85.
80	PR-4438	0.650	62.00	210.00	144.00	50.00	999.00	280.	0.	91.

MARION POWER SHOVEL

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 7.2

20.0	6.8	7.6	8.0	8.0	7.5	7.2	7.5	8.0	8.0	7.6	6.6
18.0	6.8	7.5	8.0	8.0	7.4	7.2	7.4	8.0	8.0	7.5	6.8
16.0	6.7	7.5	7.9	7.9	7.4	7.2	7.4	7.9	7.9	7.5	6.7
14.0	6.7	7.4	7.8	7.8	7.4	7.2	7.4	7.8	7.8	7.4	6.7
12.0	6.6	7.3	7.7	7.7	7.4	7.1	7.4	7.7	7.7	7.3	6.6
10.0	6.5	7.2	7.6	7.6	7.3	7.0	7.3	7.6	7.6	7.2	6.5
8.0	6.4	7.0	7.4	7.5	7.3	6.9	7.3	7.5	7.4	7.0	6.4
6.0	6.3	6.9	7.3	7.4	7.2	6.8	7.2	7.4	7.3	6.9	6.3
4.0	6.2	6.8	7.1	7.3	7.1	6.7	7.1	7.3	7.1	6.8	6.2
2.0	6.1	6.6	6.9	7.1	6.9	6.5	6.9	7.1	6.9	6.6	6.1
0.0	5.9	6.5	6.8	7.0	6.8	6.4	6.8	7.0	6.8	6.5	5.9

X AXIS 0. 10. 20. 30. 40. 50. 60. 70. 80. 90. 100.

PDS>

TABLE B.8 - COMPUTER MODEL PRINTOUT

TRACE AREA B3

TYPE 8113C.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO

FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET

AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 120

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING HEIGHT			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA	ZF	XA	YA			
10	PR-4440	0.650	45.00	20.00	32.00	45.00	5.00	335.	0.	270.			
20	PR-4440	0.650	70.00	60.00	32.00	85.00	60.00	335.	0.	0.			
30	PR-4440	0.650	45.00	100.00	27.00	45.00	115.00	331.	0.	90.			
40	PR-4440	0.650	20.00	60.00	32.00	5.00	60.00	335.	0.	180.			
50	PR-4440	0.650	45.00	180.00	70.00	45.00	190.00	352.	0.	90.			
60	PR-4440	0.650	45.00	180.00	70.00	45.00	275.00	306.	0.	90.			
70	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
80	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
90	PR-4440	0.650	45.00	245.00	115.00	45.00	300.00	334.	0.	90.			
100	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			
110	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 3.0

340.0	1.1	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.1	1.1
320.0	1.5	1.6	1.6	1.6	1.7	1.7	1.6	1.6	1.6	1.5
300.0	1.9	2.1	2.2	2.1	2.2	2.2	2.1	2.2	2.1	1.9
280.0	2.0	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.0
260.0	1.8	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.0	1.8
240.0	1.8	1.9	2.1	2.1	2.1	2.1	2.1	2.1	1.9	1.8
220.0	1.8	1.8	2.0	2.1	2.1	2.1	2.1	2.0	1.8	1.8
200.0	2.4	2.4	2.8	3.0	3.1	3.1	3.0	2.8	2.4	2.4
180.0	3.1	2.9	3.3	3.6	3.6	3.6	3.6	3.3	2.9	3.1
160.0	3.0	2.8	3.0	3.4	3.3	3.3	3.4	3.0	2.8	3.0
140.0	4.7	5.7	5.2	5.8	6.1	6.1	5.8	5.2	5.7	4.7
120.0	5.3	7.6	9.1	9.4	11.6	11.6	9.4	9.1	7.6	5.3

X AXIS 0. 10. 20. 30. 40. 50. 60. 70. 80. 90.

PDS>

TABLE B.9 - COMPUTER MODEL PRINTOUT

TRACE AREA C

TYPE 8113C1.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO 1450-W WITH 34 DEGREE BOOM

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO

FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET

AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 110

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING HEIGHT			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA						
10	PR-4440	0.650	45.00	20.00	32.00	45.00	5.00	335.	0.	270.			
20	PR-4440	0.650	70.00	60.00	32.00	85.00	60.00	335	0.	0.			
30	PR-4440	0.650	45.00	100.00	27.00	45.00	115.00	331.	0.	90.			
40	PR-4440	0.650	20.00	60.00	32.00	5.00	60.00	335.	0.	180.			
50	PR-4440	0.650	45.00	180.00	70.00	45.00	190.00	352.	0.	90.			
60	PR-4440	0.650	45.00	180.00	70.00	45.00	275.00	306.	0.	90.			
70	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
80	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
90	PR-4440	0.650	45.00	245.00	115.00	45.00	300.00	334.	0.	90.			
100	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			
110	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 9.8

120.0	5.3	7.6	9.1	9.4	11.6	11.6	9.4	9.1	7.6	5.3
118.0	5.6	8.2	10.2	10.4	13.0	13.0	10.4	10.2	8.2	5.6
116.0	5.9	8.9	11.3	11.5	14.3	14.3	11.5	11.3	8.9	5.9
114.0	5.8	9.4	12.3	12.6	15.5	15.5	12.6	12.3	9.4	5.8
112.0	5.7	9.7	13.2	13.4	16.3	16.3	13.4	13.2	9.7	5.7
110.0	5.4	9.7	13.5	13.6	16.1	16.1	13.6	13.5	9.7	5.4
108.0	5.2	9.7	13.7	13.5	15.6	15.6	13.5	13.7	9.7	5.2
106.0	5.1	9.4	13.0	12.6	14.1	14.1	12.6	13.0	9.4	5.1
104.0	4.8	8.7	10.8	9.9	10.8	10.8	9.9	10.8	8.7	4.8
102.0	4.6	8.1	8.5	6.8	7.2	7.2	6.8	8.5	8.1	4.6
100.0	4.5	7.6	7.1	5.7	6.2	6.2	5.7	7.1	7.6	4.5

X AXIS 0. 10. 20. 30. 40. 50. 60. 70. 80. 90.

PDS>

TABLE B.10 - COMPUTER MODEL PRINTOUT

TRACE AREA C1

TYPE 8113C2.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO
FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET
AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 143

LUMINAIRE	TYPE	FACTOR	FIXTURE LOCATION			MOUNTING HEIGHT			AIMING LOCATION		VANGLE	SLOPE	HANGLE
			XF	YF	ZF	XA	YA	ZF	XA	YA			
10	PR-4440	0.650	45.00	20.00	32.00	45.00	5.00	335.	0.	270.			
20	PR-4440	0.650	70.00	60.00	32.00	85.00	60.00	335.	0.	0.			
30	PR-4440	0.650	45.00	100.00	27.00	45.00	115.00	331.	0.	90.			
40	PR-4440	0.650	20.00	60.00	32.00	5.00	60.00	335.	0.	180.			
50	PR-4440	0.650	45.00	180.00	70.00	45.00	190.00	352.	0.	90.			
60	PR-4440	0.650	45.00	180.00	70.00	45.00	275.00	306.	0.	90.			
70	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
80	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.			
90	PR-4440	0.650	45.00	245.00	115.00	45.00	300.00	334.	0.	90.			
100	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			
110	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.			

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 7.3

120.0	5.3	5.8	6.2	6.7	7.1	7.6	8.0	8.4	8.6	8.9	9.1
110.0	5.4	6.4	7.4	8.2	9.0	9.7	10.6	11.6	12.6	13.1	13.5
100.0	4.5	5.4	6.1	6.9	7.3	7.6	7.9	8.1	7.9	7.6	7.1
90.0	4.7	5.6	6.2	6.9	7.5	7.8	8.0	8.2	7.4	6.2	5.0
80.0	4.7	5.6	6.3	6.9	7.6	8.1	8.5	8.8	7.6	5.9	4.1
70.0	5.7	6.7	7.4	8.1	8.7	8.9	8.9	8.9	7.7	6.1	4.4
60.0	6.3	7.3	7.8	8.3	8.8	9.1	9.2	9.3	7.9	6.1	4.3
50.0	5.7	6.7	7.4	8.1	8.7	8.9	8.9	8.9	7.7	6.1	4.4
40.0	4.7	5.7	6.4	7.1	7.8	8.3	8.7	9.0	7.8	6.2	4.4
30.0	5.0	5.9	6.6	7.2	7.8	8.1	8.3	8.5	7.6	6.4	5.2
20.0	5.6	6.3	6.9	7.4	7.8	8.1	8.3	8.5	8.0	7.5	6.9
10.0	5.6	6.3	7.0	7.6	8.2	8.7	9.2	9.5	9.6	9.6	9.6
0.0	3.7	4.0	4.3	4.7	4.9	5.1	5.2	5.4	5.4	5.5	5.4
X AXIS	0.	2.	4.	6.	8.	10.	12.	14.	16.	18.	20.

PDS>

TABLE B.11 - COMPUTER MODEL PRINTOUT

TRACE AREA C2

TYPE 8113C3.OUT

LIGHTING EQUIPMENT PROGRAM

04-JAN-79

HORIZONTAL AND VERTICAL LIGHT CALCULATIONS

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

A PRECISION OF 1 DIGITS IS USED IN PRINTING THE VALUE OF FOOTCANDLES

THE MEASUREMENT POINT IS ASSUMED TO BE 0.00 FEET ABOVE ZERO FOR HORIZONTAL MEASUREMENT

THE VERTICAL MEASUREMENT HEIGHT IS 0.00 FEET AT AN ANGLE OF 0.00 DEGREES FROM THE VERTICAL

THE TOTAL NUMBER OF POINTS BEING COMPUTED IS 110

LUMINAIRE	TYPE	FACTOR	FIXTURE MOUNTING			AIMING		VANGLE	SLOPE	HANGLE
			LOCATION	HEIGHT	LOCATION	LOCATION				
			XF	YF	ZF	XA	YA			
10	PR-4440	0.650	45.00	20.00	32.00	45.00	5.00	335.	0.	270.
20	PR-4440	0.650	70.00	60.00	32.00	85.00	60.00	335.	0.	0.
30	PR-4440	0.650	45.00	100.00	27.00	45.00	115.00	331.	0.	90.
40	PR-4440	0.650	20.00	60.00	32.00	5.00	60.00	335.	0.	180.
50	PR-4440	0.650	45.00	180.00	70.00	45.00	190.00	352.	0.	90.
60	PR-4440	0.650	45.00	180.00	70.00	45.00	275.00	306.	0.	90.
70	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.
80	PR-4440	0.650	45.00	245.00	115.00	45.00	330.00	324.	0.	90.
90	PR-4440	0.650	45.00	245.00	115.00	45.00	300.00	334.	0.	90.
100	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.
110	PR-4440	0.650	45.00	100.00	27.00	45.00	175.00	290.	0.	90.

BUCYRUS-ERIE NO. 1450-W WITH 34 DEGREE BOOM

MAINTAINED HORIZONTAL FOOTCANDLES

AVERAGE = 7.2

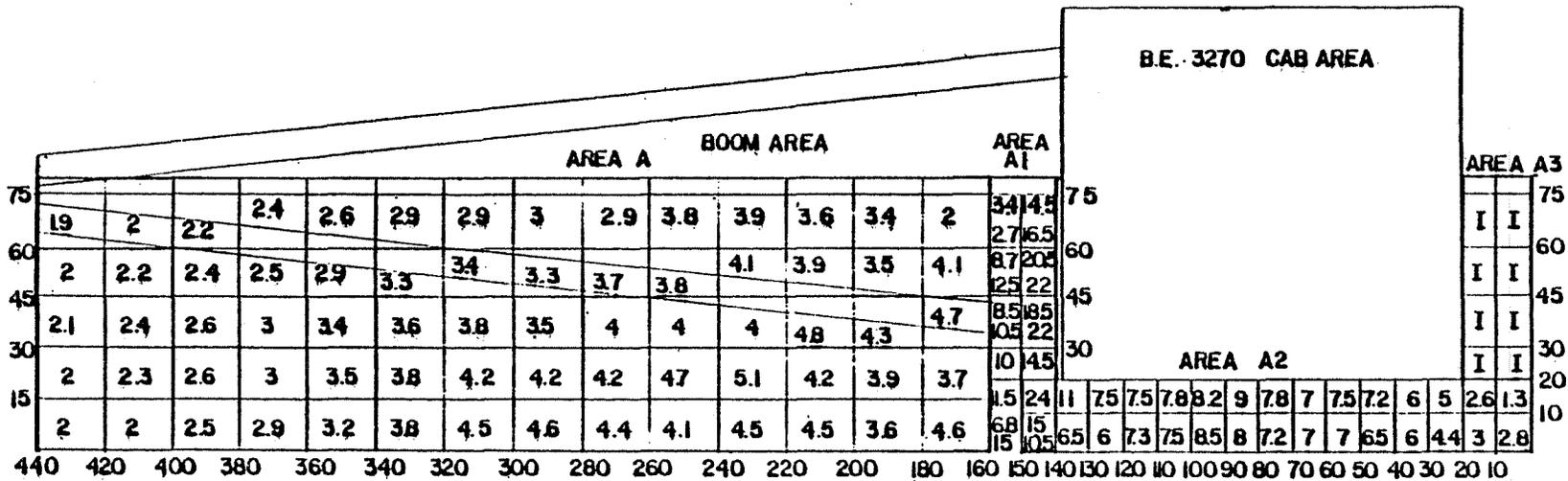
20.0	5.6	8.1	6.9	4.6	4.7	4.7	4.6	6.9	8.1	5.6
18.0	5.7	8.5	8.4	5.8	6.5	6.5	5.8	8.4	8.5	5.7
16.0	5.9	9.0	9.8	6.9	8.2	8.2	6.9	9.8	9.0	5.9
14.0	6.0	9.4	10.8	7.8	9.6	9.6	7.8	10.8	9.4	6.0
12.0	5.8	9.1	10.2	7.8	9.5	9.5	7.8	10.2	9.1	5.8
10.0	5.6	8.7	9.6	7.6	9.3	9.3	7.6	9.6	8.7	5.6
8.0	5.4	8.3	8.9	7.4	9.0	9.0	7.4	8.9	8.3	5.4
6.0	5.1	7.7	8.1	7.0	8.3	8.3	7.0	8.1	7.7	5.1
4.0	4.7	6.9	7.2	6.4	7.6	7.6	6.4	7.2	6.9	4.7
2.0	4.2	6.1	6.5	5.8	6.9	6.9	5.8	6.5	6.1	4.2
0.0	3.7	5.1	5.4	5.0	5.9	5.9	5.0	5.4	5.1	3.7
X AXIS	0.	10.	20.	30.	40.	50.	60.	70.	80.	90.

PDS>

TABLE B.12 - COMPUTER MODEL PRINTOUT

TRACE AREA C3

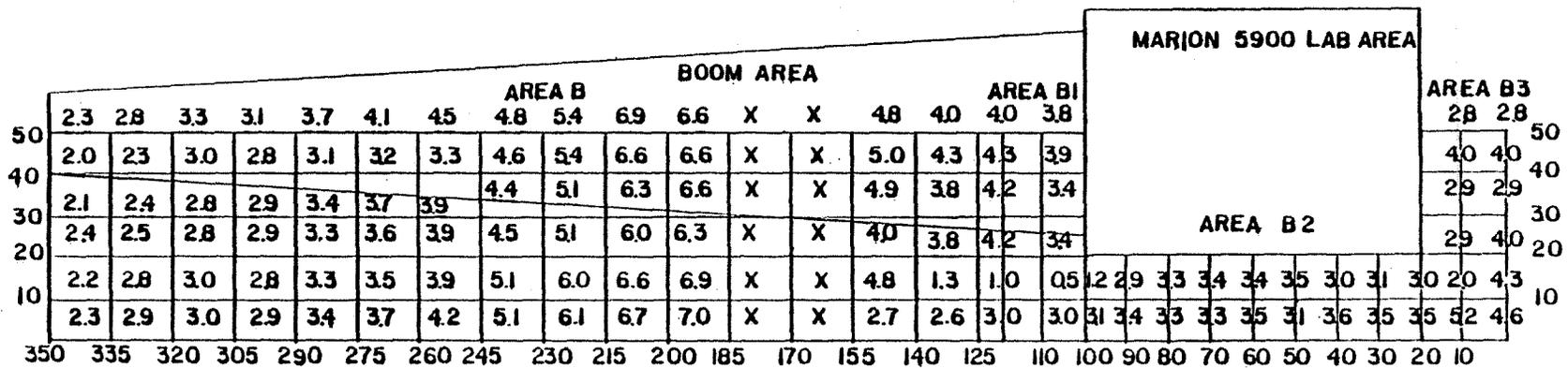
APPENDIX C - PHOTOMETRIC SURVEYS



I- LUMINAIRE AT REAR OF FRAME HOUSE INOPERATIVE

158 POINTS TOTAL
READINGS IN FC

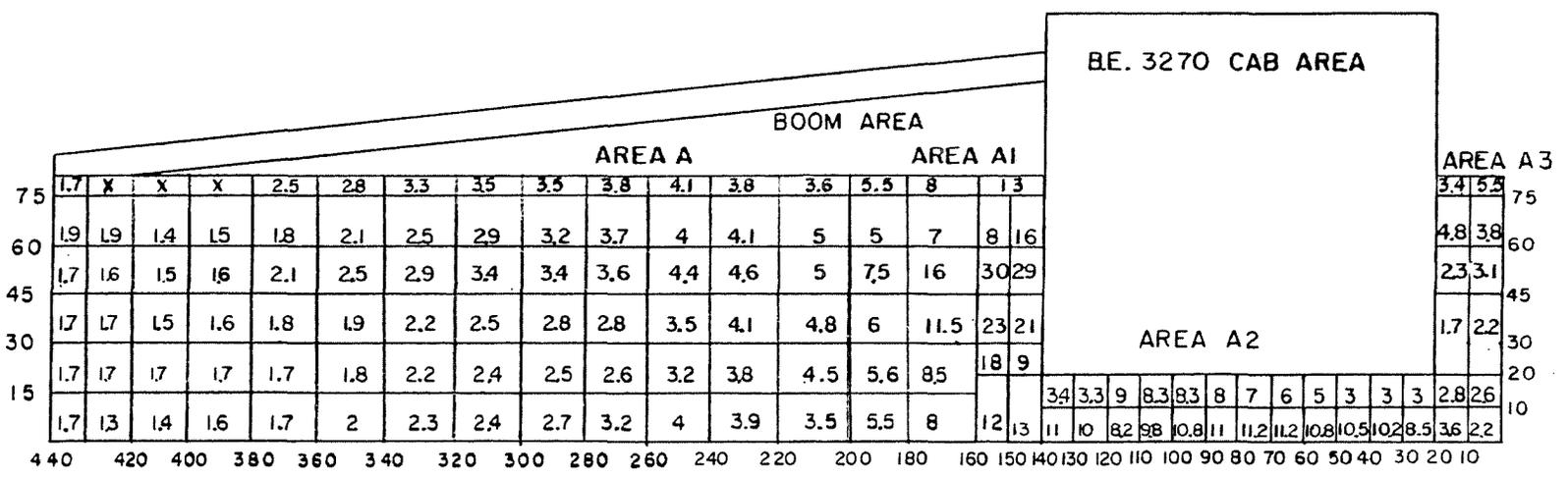
FIGURE C.1
LIGHT LEVELS-B.E. 3270 PHOTOMETRIC SURVEY*1



X- MOUNDS OF DIRT PREVENT READINGS IN THIS AREA

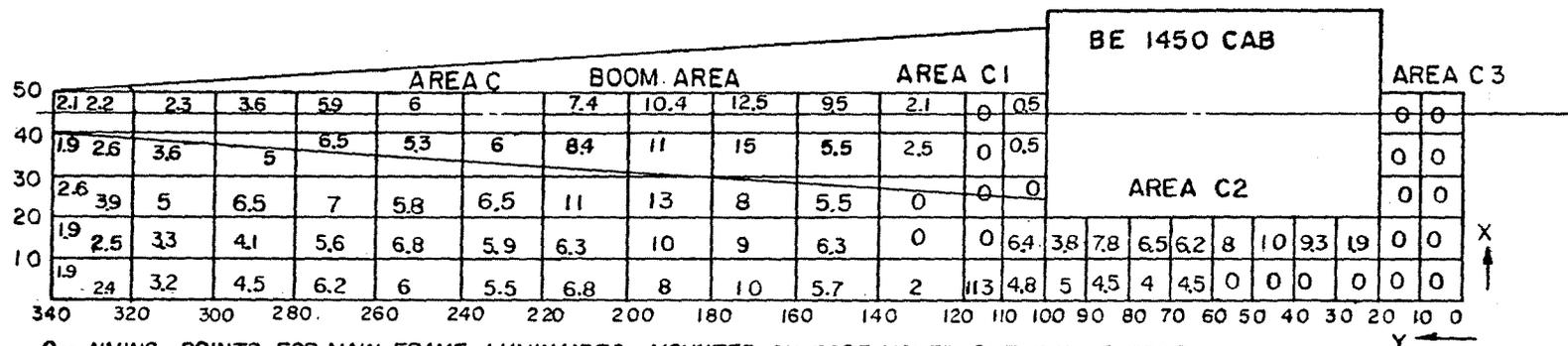
147 POINTS TOTAL
READINGS IN FC

FIGURE C.3
LIGHT LEVELS-MARION 5900 PHOTOMETRIC SURVEY^{#1}



158 POINTS TOTAL
READING IN FC

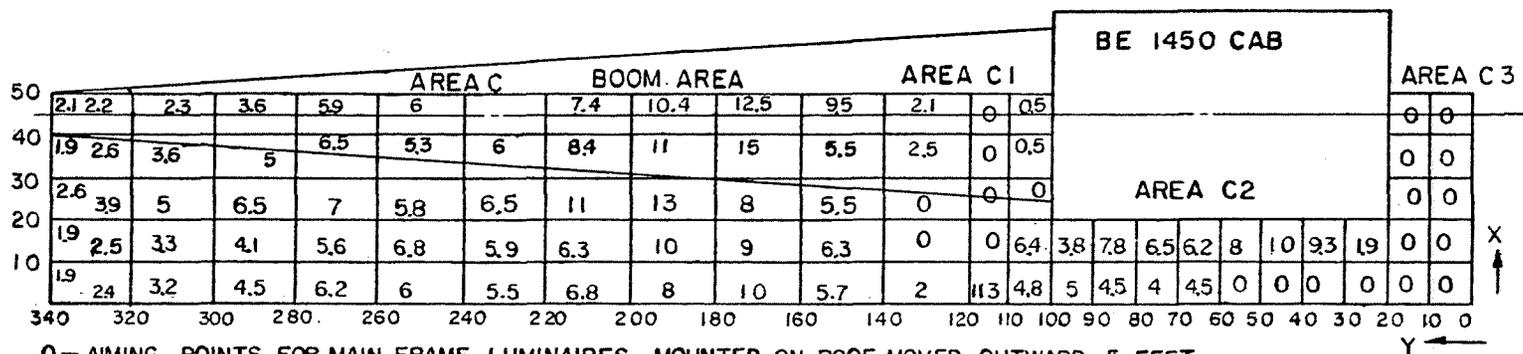
FIGURE C.4
LIGHT LEVEL B E 3270 PHOTOMETRIC SURVEY#2



0—AIMING POINTS FOR MAIN FRAME LUMINAIRES MOUNTED ON ROOF MOVED OUTWARD 5 FEET TO AVOID SHADOWING BY RAIN GUTTERS ON CAB.

123 POINTS TOTAL
 READINGS IN FC

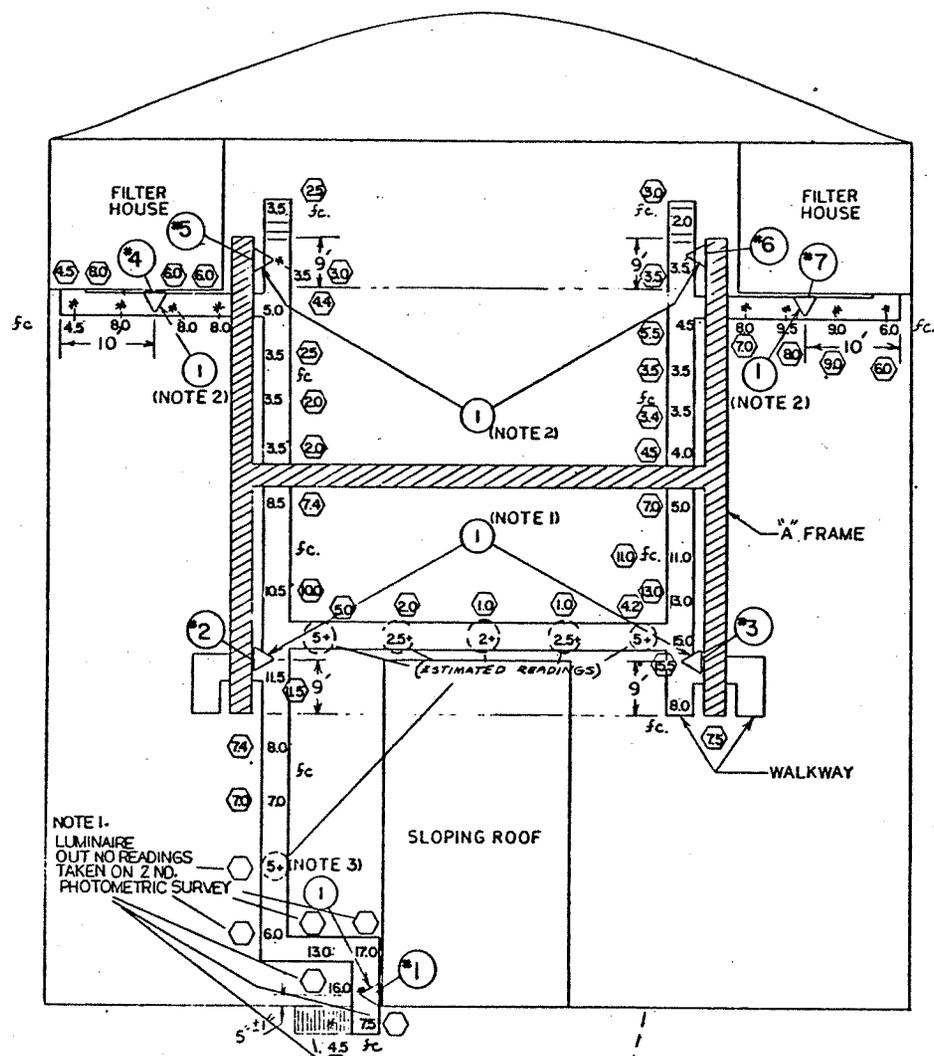
FIGURE C.5
 LIGHT LEVELS-BE. 1450 PHOTOMETRIC SURVEY # 2



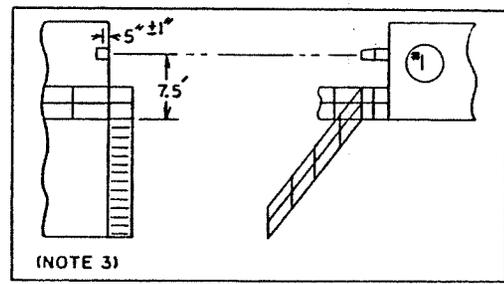
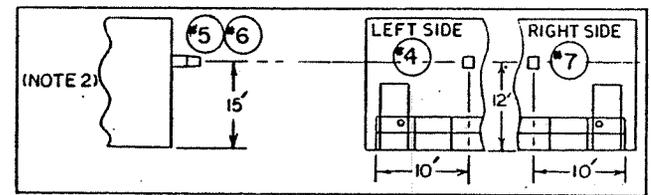
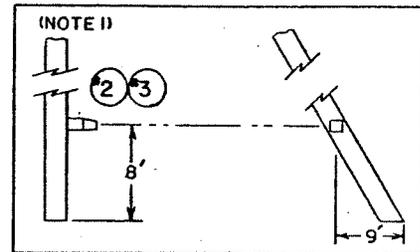
0 - AIMING POINTS FOR MAIN FRAME LUMINAIRES MOUNTED ON ROOF MOVED OUTWARD 5 FEET TO AVOID SHADOWING BY RAIN GUTTERS ON CAB.

123 POINTS TOTAL
READINGS IN FC

FIGURE C.5
LIGHT LEVELS-BE. 1450 PHOTOMETRIC SURVEY # 2



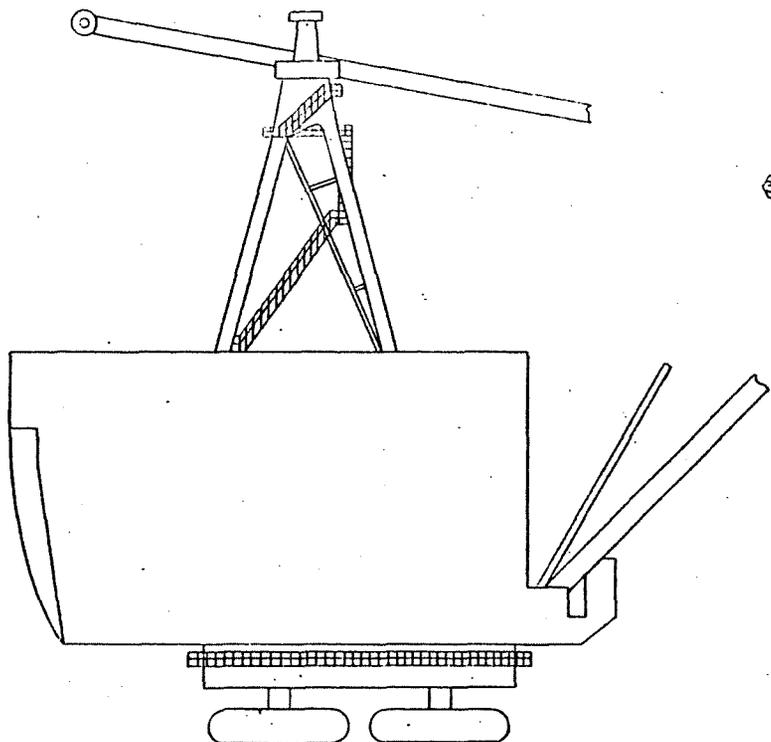
NOTE 1 -
LUMINAIRE
OUT NO READINGS
TAKEN ON 2ND
PHOTOMETRIC SURVEY



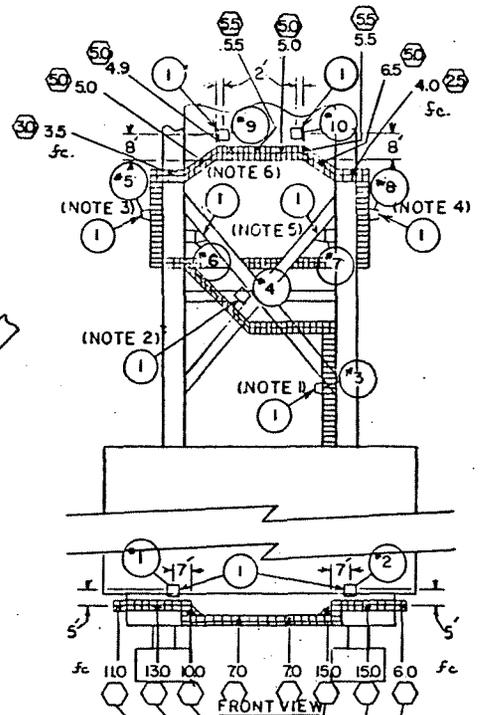
◻ READINGS IN FC.

ITEM NO.	REF. DES.	PT. NO. DWG. NO.	REQ'D.	DESCRIPTION
1		ARCOS-105II	7	70 WATT HPS LUMINAIRE

FIGURE C.7
B.E. 3270 ROOF WALKWAY PHOTOMETRIC SURVEYS NOS. 1 & 2

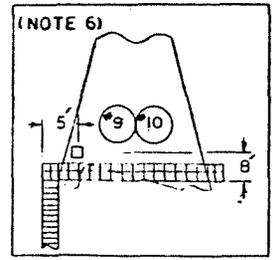
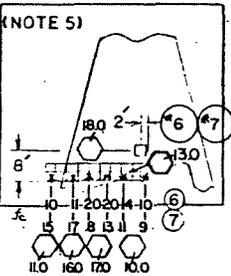
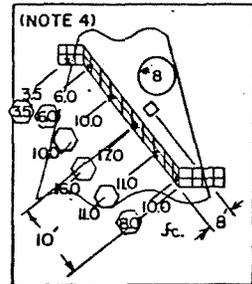
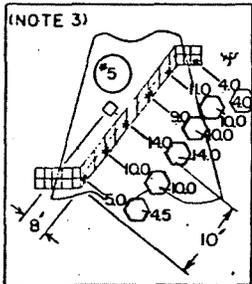
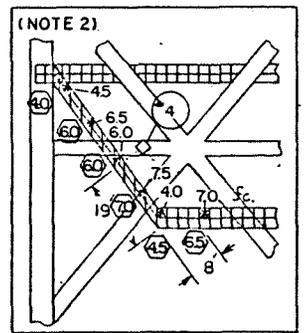
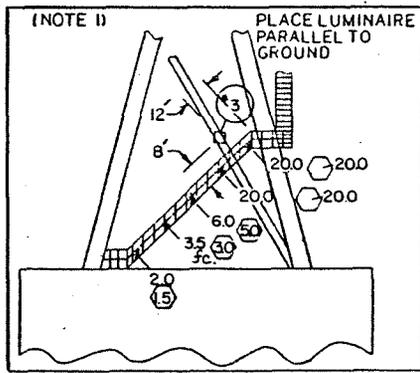


RIGHT SIDE VIEW



FRONT VIEW

NOTE: NO. 14-2 LUMINAIR OUT OF ELECTRICAL CIRCUIT MAINTENANCE IN PROGRESS DURING SECOND PHOTOMETRIC SURVEY



⊖ READINGS IN FC

ITEM NO.	REF DES.	PT. NO. DWG. NO.	REQD.	DESCRIPTION
1		ARCOS-10S11	10	70 WATT HPS LUMINAIRE

ALL LUMINAIRES PLACED PARALLEL TO WALKWAYS UNLESS OTHERWISE SPECIFIED.

FIGURE C.8
MARION 5900 PHOTOMETRIC SURVEYS NOS. 1 & 2