INVESTIGATION OF THE DISTRIBUTION OF LUMINOUS FLUX IN A SCALE MODEL OF THE MOVING PICTURE THEATRE PROPOSED BY BEN SCHLANGER

by

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Submitted in partial fulfillment of the requirements

for the degree of

BACHELOR OF SCIENCE

from the

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Signature of Supervisor

June 1934

19 Wilmot St.
Watertown, Mass.
May 22,1934

Prof. A. L. Merrill
Secretary of the Faculty
Mass. Inst. of Technology
Cambridge, Mass.

Dear Sir:

In partial fulfillment of requirements for the Bachelor of Science in Architectural Engineering from the Massachusetts Institute of Technology, I herewith submit the accompanying thesis and the model investigated. (The model is now in room 10-275)

Hoping that they will meet with your complete approval, I am,

Most sincerely yours,

Warren A. Bjórn
Course IV-A

ACKNOWLEDGEMENTS

The author wishes to acknowledge with deep appreciation the services of those who helped in the completion of this thesis.

Gratitude is expressed to:

Professor P. H. Moon, instructor in charge of the thesis, who, in his supervision of the work, gave many valuable suggestions and criticisms.

Mr. Ben Schlanger for his kindness in providing specifications for the theatrical design and for his permission to use his patented design.

Mr. J. F. Gotimer for his assistance in solving many problems of construction.

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The many persons who, knowingly and unknowingly, contributed valuable information through their works, or who gave valuable criticism behind the author's back.

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INTRODUCTION

The field of Architectural Illumination being of recent origin, there are found within its borders many vaguaries especially in regard to defining the proper amount of illumination for certain purposes. In no other branch of the field is this more noticeable than in the lighting of auditoriums, and more especially the theatre. About the only specifications as to what constitutes good theatre lighting seem to be that the lighting shall be uniform and of a proper intensity, but as to what one may construe by "proper intensity" is more or less left to the descretion of the designer, and thus we find controversy waxing hot over this point.

The subject matter of this paper does not propose to settle this point nor does it offer many arguments in favor of specifying a "proper" level of illumination. This paper will, however, endeavor to present a more or less unique method of auditorium lighting which shall be in keeping with the architectural design of the building considered and which shall provide a uniform distribution of light throughout the entire seating area of the auditorium, and which shall not be of too great a brightness so as to provide a glare source for the observer. Several levels will be investigated to show their effect upon the uniformity of the resultant illumination, aside from this there will be no attempt to specify level of illumination.

It is to be noted that, although the method employed in this problem has been applied to a unique type of theatre, there is no reason for limiting the scope of application solely to this type of auditorium,for the method may be extended and modified to be adaptable to most any type of auditorium. The reasons for adopting this type of theatre were; that it seemed to be the best available type in which the type of illumination proposed could be demonstrated to the exaggerated degree necessary for comprehension of design and effect at the model scale, but which should still have a unity between this exaggeration and the entire architectural treatment of the auditorium; and that, since the theatre had been proposed rather recently and is still in the experimental stage, it was felt that the information obtained would be further enhanced in value by giving some ideas as to the possibilities of this new type of motion picture house.

With the hope that they may be of aid in furthering the cause of illumination, both within the Institute and without, through an increase of interest by the actual showing of the fruits of imagination in scale model which has the further advantage of being a basis for a more accurate prediction as to the final results if carried out at full scale, the model and this paper are submitted as a partial fulfillment of the requirements for the degree of Bachelor of Science at the Massachusetts of Technology,1934.

It is also hoped that the model will show further the feasibility of the use of models in predicting the illumination from designs incorporated in such structures as auditoriums of peculiar shape in which it is almost impossible, without extensive and tedious labor, to predict illumination by the mathematical means resorted to in structures of simpler design.

Warren A. Bjorn
Author

DESCRIPTION OF THEATRE

The theatre chosen for this illumination design is an application of the new design proposed by Ben Schlanger, a New York Architect. The use of this design was suggested by Prof. Hardy who felt that, as a new and practical departure from the old style theatre which has been found more or less impractical when converted to motion picture presentation, it merited consideration and investigation.

The design of the theatre involves the use of what has been called by its inventor the parabolic reversed floor. In principle it is a radical departure from present day design in that the screen is placed at a level well above the first row of the orchestra and the remainder of the orchestra slopes away from the screen so that the succeeding rows are lower than those preceding until one reaches a point, determined by the size of the theatre, at which point the direction of curvature changes. The slope of the floor is determined by projecting sight lines from predetermined points near the bottom of the screen over the head of the person in front and carrying back to the next row, this gives the necessary position of the eye of the observer in order that he might satisfactorily view the picture. Using a standard height, determined by averaging observations of a large number of people, as to the height of the average eye of a seated person above the level of the floor upon which the chair is resting, one can drop down and determine the floor line of the finished floor. This resulting floor line is parabolic in shape and it is from this that the design derives its name. A similar system is followed in the design of the balcony, which is more of less similar to those in the present day theatre. It is to be noted that throughout the design the idea in mind is to provide maximum visibility with a minimum of discomfort and distortion for every seat in the auditorium.

One will notice also in the figure (Fig. 1.) that there are no seats outside of the zone made by the lines at forty-five degrees from the opposite corners of the screen. In this manner Mr Schlanger further insures the the visibility of those who may patronize theatres of his patented design.

The particular theatre selected after written consultation with Mr. Schlanger is one whose seating capacity is about 1200 persons, in an orchestra and balcony level, with a minimum length of auditorium of 104 feet, distance from screen to back of last row in balcony, and an overall width of 80 feet at widest portion, distance between inside of walls. The distance from the screen to the last row of the orchestra level is given as 76 feet. With these dimensions and a few further specifications of design from Mr. Schlanger the floor of the theatre was laid out with the results as shown in the illustrations.

The remainder of the theatre, ceiling, lighting, lobbies, etc., were then developed by the author.

Further reference to the illustrations will show another advantage found in this type of design. This is the compacting of the vertical dimensions of the theatre, the lowering of the balcony level in respect to the screen, bringing the first row almost at a level with the screen center, and the resultant lowering of the projection angle. These make the theatre more economical to construct since there is not the problem of the steep balcony of the old theatre and they reduce the distortion of the image on the screen since the pictureis projected more nearly perpendicular to the screen and the observer is at a more advantageous position from which to view the picture. The peculiar "Horn-shape" of the auditorium also should give a better result acoustically than the present day design.*

*Note: It was the author's intention to also include an acoustical study forthe model, but materials were not available for such a study nor was there time to include it in the present paper, however it is hoped that in the future something may be done along these lines.

LIGHTING SYSTEM DESIGNED

In a building such as this in which the shape of the auditorium is more or less predetermined by fixed conditions it is of course desireable to design a lighting system which is in complete accord with the rest of the design. Having a certain slope for the lower floor it is only natural to expect that a reversal of this slope spplied to the ceiling would give a pleasing appearance and in addition serve to carry the eye toward the screen.

The stepped ceiling resorted to (see Fig. 2) was selected because it served so advantageously the requirements. These were: that the lighting be a note of architectural harmony in the completed structure, how well this is accomplished may perhaps be gathered from the illustrations; that the lighting be more or less uniform, the closer spacing of the steps at the end near the screen not only add to the harmony of the ceiling slope but they serve to give more light over the area where the floor is farthest from the source; and that the lighting shall not detract from the importance of the screen but rather it should focus the attention toward this part of the theatre, this is also accomplished by the more numerous areas of light leading down to the proscenium arch. The proscenium arch was designed to be indirectly lighted to further focus the eye and to add beauty to the auditorium; by carrying the proscenium arch lighting down as a continuation of the ceiling lighting This effect is further enhanced.

Two side wall panels were designed for the sloping wall near the stage. The purpose of these panels is solely for the decorative effect that they offer, and not for any addition to the auditorium lighting, the ceiling units being depended upon to furnish the general lighting.

Under the balcony there are three large glass panel units which serve to give a generous amount of flux to this part of the theatre.

The light would be thrown upon the surfaces of the beams from hidden reflectors (Fig.2). The surfaces of the beams being painted a light color, preferably white, with a diffusing paint, the light would be diffusely reflected back into the auditorium. There would be a maximum desireable brightness for these luminous beams since they would be in almost direct line of vision from the upper part of the balcony, but, since the level of illumination in a theatre is seldom very high, comparatively speaking, and since the length of time when the full intensity would be turned on would be quite short, there is little difficulty to be expected from this quarter. Care must be taken, however, to space the lights close enough so that the resultant illumination upon the beams is uniform.

Under the balcony the panels are best lighted by a number of lamps mounted in a diffuse reflecting pocket and spaced at such a distance that there will be no "spotty" effect. Likewise the side panels are best illuminated in this manner for the general illumination, but beams of light from concentrating "spot" units would give additional decorative effect and would add to the interest of the entire job.

The proscenium arch is lighted by a system similar to that employed in lighting the horizontal beams. To set it apart from the remainder of the auditorium it is advisable to have the arch of a different color from the walls and ceiling, although it is not necessary.

DESCRIPTION OF MODEL

The model constructed for the investigation was a one-thirtysecond scale (three eighths inch equivalent to one foot) model of the interior part of the auditorium. The materials used were wood and galvanized iron.

A sturdy box frame of 1½" square sticks was made first. This was constructed so that the finished model could be built on the inside of the frame. Forms for the main floor were then laid out and cut by bandsaw from 1" boards. These were inserted in the frame and a floor of Masonite Presdwood was put on top of the forms. The Presdwood was used because it was flexible enough to bend to the proper curvature for the floor. The stage part of the auditorium was made of several pieces of 3/8" plyboard cut to the proper shape to give the curved steps, the top pieces were also cut to take a foot-light trough.

Stepped frames of 1" boards were made for the balcony and individual curved steps were cut on the bandsaw from 3/8" plyboard for each row in the balcony. The under part of the balcony was made of plyboard and openings were cut in this board for the panel lighting units. A galvanized sheet iron template was cut to fit under the balcony and in this the openings were cut to the proper size for the light units. The purpose of the metal piece was to prevent the glass from falling through. Ground glass panels were installed to give diffuse lighting under the balcony.

The side walls were made of the plyboard, which, being 3/8" thick, was fortunatly of proper size to represent in scale the one-foot thickness of these walls. The side walls were made in several pieces and three of these pieces were fitted snug but left unfastened so that they could be removed at will to make an easy access to the interior of the model. The slanting side walls abutting aginst the proscenium arch were made of galvanized sheet iron and openings were cut to allow for light to be thrown into the room from side "windows". As an experiment the glass used in these windows was that commercially known as "Magnalite". This glass is composed of a large number of square prismatic "lenses" which gave a unique effect when illuminated by several colered lamps in different places behind the window. Although to get a prismatic window of the proper size in full scale might be a bit expensive, the indications from the small scale unit would make it seem that the resultant lighting panel would be well worth the expense, since a large number of unique effects would be possible with the use of colored spots. The slant wall pieces were also cut at the top to fit the shape of the ceiling.

The ceiling was made of galvanized sheet iron strips bent and fitted to stepped forms cut from plyboard. Each section was made so that there would be an opening between it and the next section of one foot scale to allow for the light to be thrown on the beams which run across the auditouium.

The proscenium arch was made of a number of strips soldered together to form the required six sections and the sections were then bolted together with spacers in between each section to give the proper shape to the arch and to allow light to be thrown unto the exposed parts of the arch so as to give a luminous appearance.

In order to give a finished appearance to the model a complete set of scale seats were made and set in their proper places. These seats were made of cardboard, a whole row being made at a time. The seats were given a coat of shellac to stiffen them and then they were coated with two coats of dark oak varnish stain to give them further stiffness and to make them look more nearly natural. The floors of the model were also varnish stained in dark oak.

The inside of the model was painted cream and white; the walls being cream colored and the ceilings white. The proscenium arch was painted with aluminum bronze which made a decorative addition to the interior. Other than this there was no attempt made to indicate any scheme of decoration, the entire auditorium being kept simple and direct in character with dependence being place upon the lighting to give any desireable decorative additions to the auditorium.

LIGHTING OF THE MODEL

In order to get the proper distribution of light on the ceiling two methods were tried. At first the use of one or two large reflector units placed at the rear end of the model and so tilted as to direct the light toward the front of the model were tried. The light coming at an angle to the ceiling was picked up by the "fins" from the ceiling (see Fig A) and reflected back into the auditorium. This method, although it gave fair results, was abandoned for two reasons; first because the light was not uniform on the successive beams, those near the front of the model being less illuminated than those at the rear, and secondly because it was not possible to get the desired level of illumination using this method.

The second method tried, and that finally adopted, was the use of tubular lamps placed at each of the ceiling openings. (See Fig. A). These lamps were connected in parallel and then a series resistance was put in the circuit so that it was possible to control the illumination from the ceiling.

To light the ground glass panels under the balcony, three tubular lamps were installed. On the three sides of the proscenium arch tubular lamps were placed in specially constructed reflectors made of galvanized metal and designed to throw the light through the spaces between the sections of the arch. Behind the side windows 60 watt white lamps were installed in addition to several colored lamps. The colored lamps were used to give a decorative effect on open-house day, on which day the model was exhibited to the visitors to the Institute. Other than this the colored lamps served no purpose. Also for effect only, a set of footlights were made for the stage. These were made of a set of seventeen miniature sockets sunk into a piece of plyboard and connected in series. Six volt lamps were used in the footlights enabling the unit to be connected across the 110-volt line.

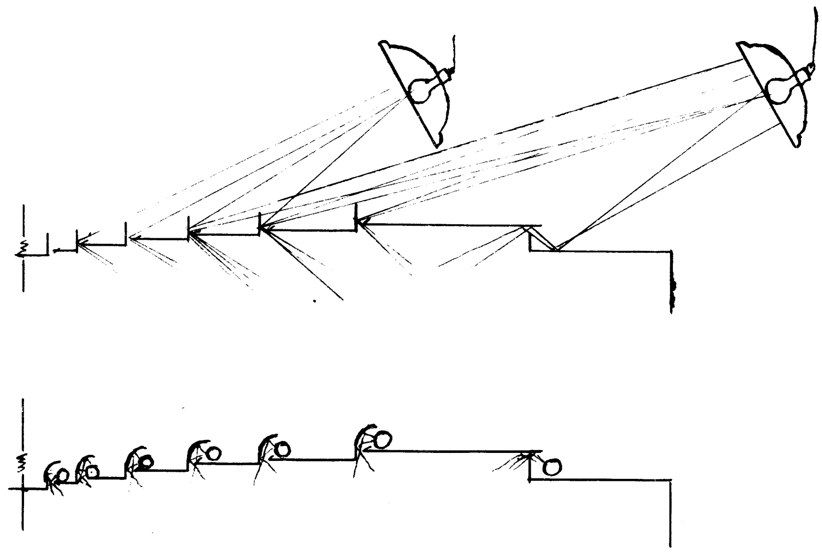


Figure A

Sketch illustrating the initial and final methods employed in the lighting of the model ceiling. (See also Fig.6, appendix.)

MEASUREMENT OF ILLUMINATION

The distribution of illumination in the model was measured by placing a Weston "Photronic" Cell in various positions throughout the model and measuring the current converted by the cell with a milliammeter. The cell was then calibrated using known values of illumination. (See appendix for calibration.) To measure the flux from the ceiling beams, a mask was made for the photronic cell, this mask having an opening the same width as the beams and as long as a diameter of the cell. The cell was also calibrated with the mask.

In measuring the flux from the beams, the cell and mask were affixed to the end of a four foot rule and then the cell was placed close to the beams in such a position that the opening in the mask was parallel to the beam. The reading of the milliammeter was then noted. Readings were made at a number of places on each luminous beam and then the readings were averaged to get the average brightness of the beams. Readings were made at three different levels of luminosity. The four foot rule was used so that it would be possible for one person to hold the cell in position and at the same time make the readings.

In measuring the illumination at the eye level of the auditorium the cell without the mask was fastened to the end of the four foot rule and readings were made with the cell placed in different positions in the model. Readings were taken at the odd numbered rows and at several places in each row measured. These places were, (looking toward the back of the room from the stage) at the far right aisle next to the wall, the center of the right bank of seats, at the aisle between the center and the right banks of seats, at the center of the theatre, at the aisle between the center and left banks of seats, at the center of the left bank of seats, and at the far left aisle along the wall, The reason for taking measurements at only every other row was that the cell was of such a size as to extend over more than one row of the model seats and thus it was felt that readings at every other row would give an accurate indication of the trend of the distribution.

From these readings the illumination in lumens per square foot (foot-candles) was then calculated from the calibration curves. The resultant illumination was then tabulated and plotted as shown in the following tables and plots.

Many of the non-uniformities and most of the major discrepencies were due to an inability to completely control the lighting at the scale of the model. The variations under the balcony were due to the fact that it was impossible to place the tubular lamps used at the exact same positions in each lighting section. The beams were not uniformly illuminated in the model due to the fact that the tubular lamps are not of uniform brightness over their entire length, thus the beams were more brightly illuminated at the central part of each section, with the flux density falling off somewhat near the ends of the sections. The lack of agreement between the far right and far left aisles under the balcony is in part due to the fact that the small right wall panel was left off during measurements to see about how much effect the light colored wall had on the distribution. As may be noted the affect was noticeable and demonstrates that the light colored walls are an advisable inclusion where the decorative scheme permits.

On the whole, however, it will be noted that the illumination is fairly uniform, quite uniform in fact, when one considers the accuracy of the obtainable data and the accuracy of control for lighting models.

TABLE #1

ILLUMINATION (LUMENS/SQ. FOOT)

Average Luminosity of Beam Panels--75.8 Lumens/sq. foot

Row*	Left Aisle	Left Center	Aisle	Center	Aisle	Right Center	Right Aisle
1	14.4			18.6			16.3
3	11.4		14.1	16.2	14.4		11.8
5	10.7	17.0	13.8	14.8	13.5	17.0	10.3
7	8.1	11.1	11.7	12.4	11.4	10.8	8.4
9	5.4	6.6	8.4	10.0	9.2	6.2	5.4
11	1.4	3.0	2.4	3.4	4.7	3.4	1.3
13	1.2	12.6	5.4	17.1	4.6	10.7	1.0
15	2.1	22.0	5.3	2.3	5.4	10.7	1.0
17	4.5	18.9	4.5	2.7	5.6	7.3	0.8
B1	10.9	12.8	12.8	13.2	13.6	14.3	11.8
B3	11.4	12.2	12.7	12.2	12.4	13.1	11.3
B5	10.9	11.1	11.1	12.0	12.2	12.0	11.3
B7	10.1	10.8	10.8	11.4	11.6	12.4	10.8
B9	10.0	11.3	11.0	11.3	11.8	12.9	11.4
B11	10.0	9.0	8.4	9.0	10.2	12.2	11.4
B13	11.0	8.7	8.7	8.4	9.3	10.2	9.6
B15	13.0	18.9	12.2	13.8	12.5	21.2	10.6
B17	21.6	8.2	1.0	1.0	1.0	2.4	18.9

<u>TABLE #2</u>

ILLUMINATION (LUMENS/SQ. FOOT)

Average Luminosity of Beams--35 Lumens/sq. foot

Row	Left Aisle	Left Center	Aisle	Center	Aisle	Right Center	Right Aisle
1	5.4			7.7			5.9
3	4.5	6.2	6.2	7.4	6.9	6.2	5.1
5	4.7	5.18	6.2	6.9	6.2	5.8	4.7
7	4.7	5.4	5.18	6.3	5.7	5.4	3.9
9	3.2	3.9	4.6	5.0	5.4	4.7	1.0
11	1.0	1.6	1.8	2.2	1.4	2.4	
13							
15		Same as in Table 1					
17		Omitted for averages					
B1	5.6	6.9	6.9	7.2	7.2	7.5	6.2
B3	5.4	6.2	6.2	6.6	6.8	6.9	6.2
B5	5.3	5.9	5.9	6.5	6.3	6.2	5.7
B7	5.3	5.9	5.9	6.3	6.2	6.2	5.7
B9	5.0	5.9	5.6	6.2	6.2	6.6	5.7
B11	5.0	5.2	4.7	4.8	5.2	6.0	6.2
B13	4.2	4.4	4.4	4.6	4.6	4.8	5.4
B15	4.4	4.7	5.3	5.9	5.4	5.9	4.7
B17	8.1	6.6	1.0	0.6	1.2	11.7	10.2

TABLE #3

ILLUMINATION (LUMENS/SQ. FOOT)

Average Luminosity of Beam Panels--7.73 Lumens/sq.foot

Row	Left Aisle	Left Center	Aisle	Center	Aisle	Right Center	Right Aisle
1	0.9			1.2			0.8
3	0.7	0.9	1.0	1.1	1.0	0.9	0.8
5	0.6	0.8	0.9	1.0	0.9	0.8	0.7
7	0.6	0.8	0.9	1.0	0.9	0.7	0.6
9	0.6	0.6	0.6	0.9	0.9	0.8	0.5
11	0.3	0.8	0.9	1.0	0.8	0.8	0.4
13							
15		Same as Table #1					
17		Omitted for Averages					
B1	0.8	1.0	1.0	1.1	1.0	1.0	0.8
B3	0.8	1.0	1.0	1.0	1.0	1.1	0.8
B5	0.8	0.9	1.0	1.0	1.0	1.0	1.0
B7	0.8	1.0	1.0	1.0	1.0	1.0	0.9
B9	0.6	0.9	0.9	1.0	1.0	1.0	1.0
B11	0.6	0.6	0.6	0.6	0.8	0.9	1.0
B13	0.5	0.6	0.6	0.6	0.6	0.6	0.8
B15	0.6	0.7	0.7	0.8	0.7	0.8	0.6
B17	1.2	1.2	0.3	0.2	0.4	1.6	1.4

TABLE #4

ILLUMINATION (LUMENS/SQ. FOOT)

Average Luminosity of Panel same as Table #1

Auditorium Lit By Center Section of Ceiling Only

Row	Left Aisle	Left Center	Aisle	Center	Aisle	Right Center	Right Aisle
1	6.5			10.2			7.4
5	4.7	6.3	7.2	8.7	6.6	5.7	4.8
9	3.0	3.9	4.7	5.6	5.8	3.2	2.6
15	(4.5)	(16.7)	(5.3)	(18.2)	(3.4)	(8.4)	(.4)
B1	3.5	4.3	8.4	9.3	8.1	5.3	3.6
B5	2.1	4.0	6.3	8.0	6.8	4.0	2.4
B9	1.8	2.8	4.2	6.5	5.4	4.7	2.1
B15	1.2	2.5	5.6	6.6	4.1	2.0	1.5

Auditorium Lit by Side Sections of Ceiling Only

Row	Left Aisle	Left Center	Aisle	Center	Aisle	Right Center	Right Aisle
1	2.4			2.4			2.4
5	3.0	3.3	3.2	2.9	3.2	3.3	3.1
9	2.3	2.3	2.3	2.4	2.4	2.4	1.6
15	(3.5)	(1.7)	4.0	(18.2)	(5.0)	(11.4)	(8.4)
B1	5.9	6.2	4.0	2.5	4.2	9.2	6.8
B5	6.8	6.8	3.8	2.4	4.0	8.4	11.2
B9	9.9	5.0	3.0	2.1	[illegible].2	13.6	9.3
B15	5.4	7.6	4.0	1.6	6.3	9.4	6.8

TABLE #5

AVERAGE ILLUMINATION BY ROWS (LUMENS/SQ. FOOT)

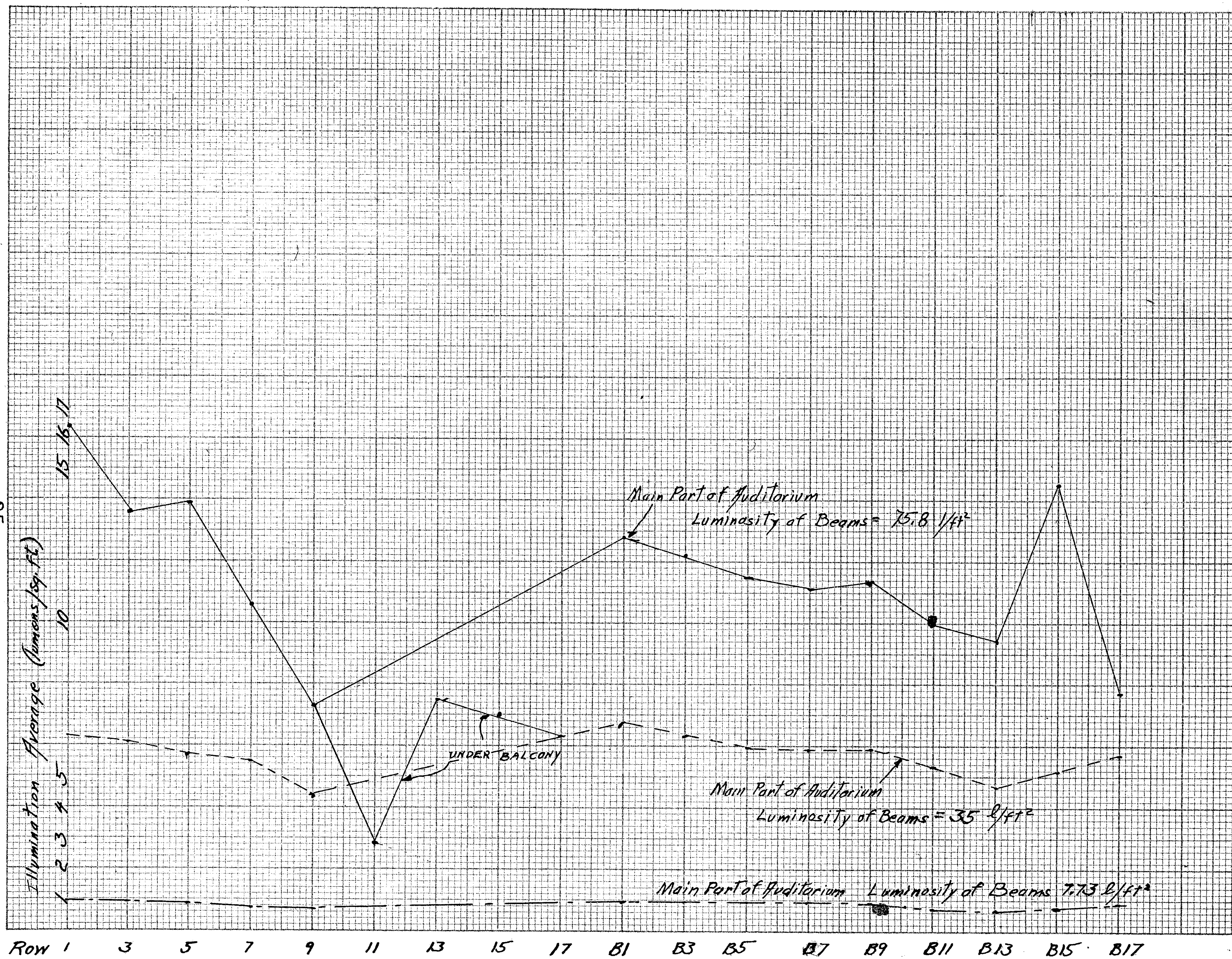
Beam Luminosity 1/ft^2

Row	75.8	35	7.73	75.8 only center lighted	75.8 only sides lighted
1	16.4	6.33	.965	8.03	2.4
3	13.6	6.10	.914		
5	13.9	5.76	.815	6.3	3.12
7	10.6	5.45	.785		
9	7.3	4.4	.700	4.12	2.25
11	2.8	1.64	.715		
13	7.5	-	-		
15	7.0	-	-	8.06	7.46
17	6.3	-	-		
B1	12.8	6.78	.957	6.07	5.55
B3	12.2	6.33	.957		
B5	11.5	5.97	.957	4.8	6.2
B7	11.1	5.93	.957		
B9	11.4	5.88	.915	3.93	6.72
B11	10.0	5.30	.73		
B13	9.4	4.63	.615		
B15	14.5	5.18	.700	3.38	5.9
B17	7.7	5.63	.885		

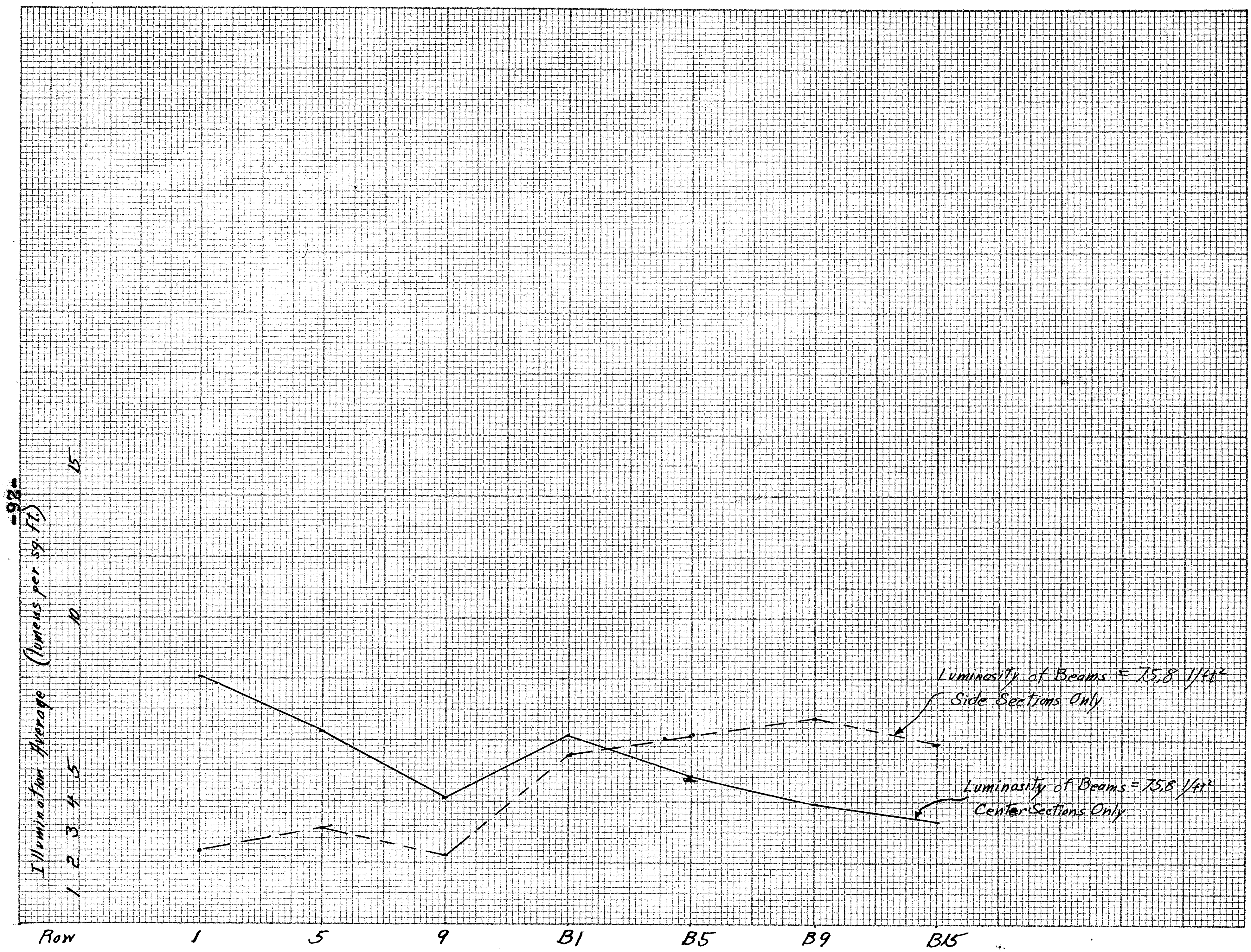
TABLE #6

AVERAGE ILLUMINATION BY AISLES (LUMENS/SQ.FOOT)

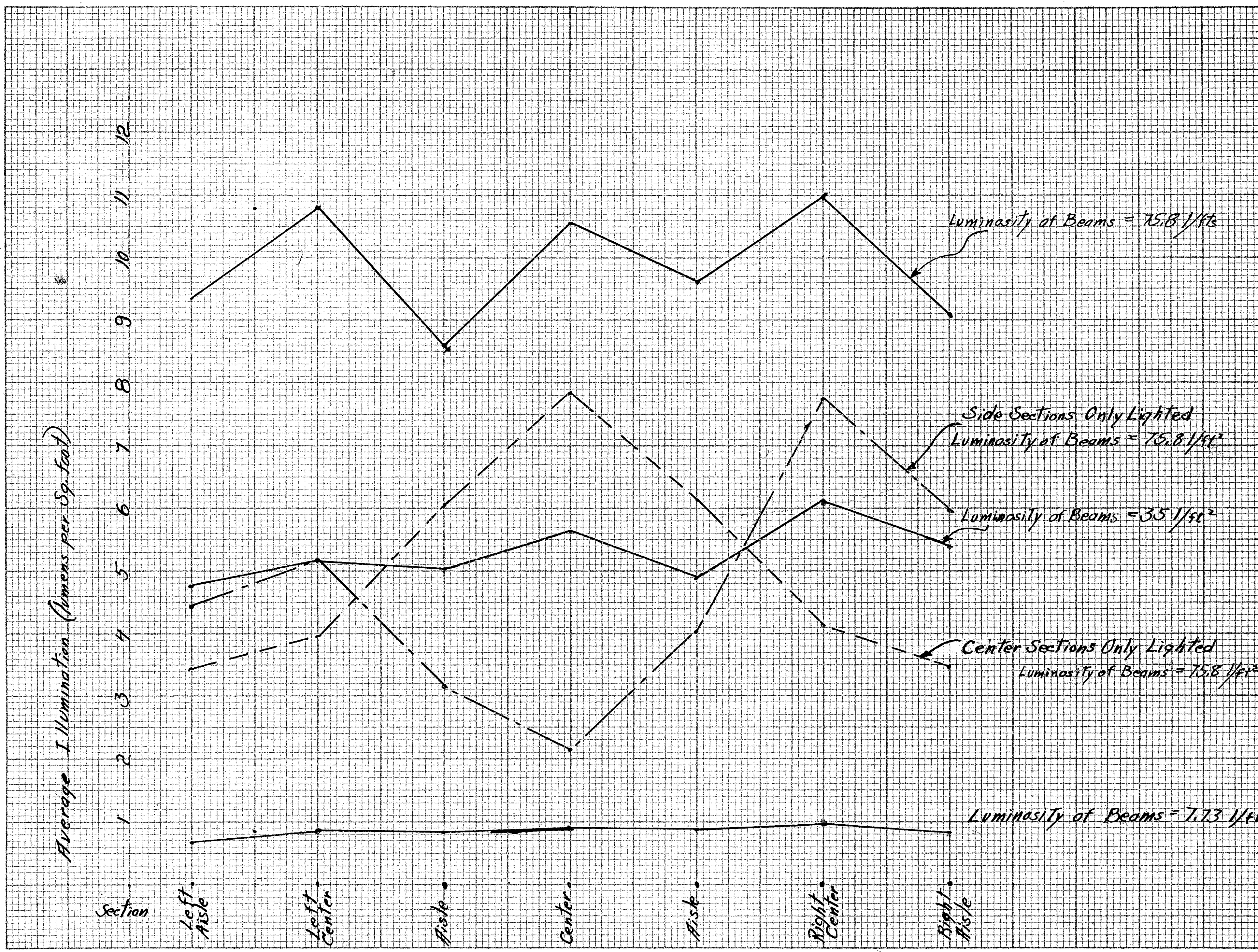
Aisle Designation	Beam Luminosity $1/ft^2$ 75.8	35	7.73	75.8 Center only	75.8 sides only
Left aisle against wall	9.34	4.79	.694	3.41	4.9
Left Center Center left bank of Seats	10.8	5.33	.854	3.97	5.2
Aisle Between banks of Seats	8.6	5.04	.815	6.08	3.38
Center of Theater	10.54	5.61	.900	7.84	2.33
Aisle Between banks of Seats	9.6	4.9	.856	6.14	4.05
Right Center Center right bank of Seats	11.0	6.15	.929	4.15	7.72
Right Aisle against wall	9.1	5.4	.810	3.5	5.9



Plot of Row Averages



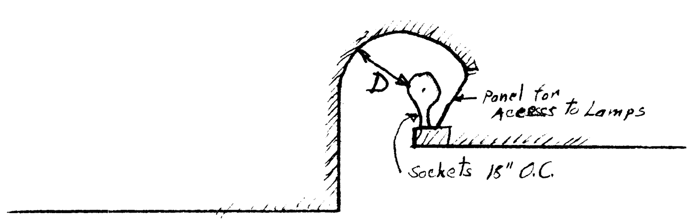
Plot of Row Averages



Plot of Section Averages

CONCLUSIONS AND RECOMMENDATIONS

From the data obtained, considering possible errors, it is concluded that the system employed is one which will give fairly uniform illumination if care is taken in the design. This fact, of course, might be true of most systems, but when simplicity and cost are considered the method employed in this thesis will undoubtedly take a lead over most methods giving a comparative quality of decoration, a similar level of illumination, and the same degree of uniformity over a range of brightnesses. In an actual installation the system would be incorporated in the design of the theatre as are most of the installations of today. The simplicity is noted when one considers that in this method there are no complicated reflectors necessary nor are there any glass panels to install for the general lighting, all the equipment necessary being the curved, diffuse reflecting surface, which might well be a part of the plaster ceiling, and a row of sockets preferably backed by some diffuse reflecting surface. (See figure below.)



The sockets in this installation should be placed 1' 6" on center using 25 watt lamps, for beam illumination of 75.8 lumens per square foot (giving about 11 lumens per square foot at eye level), or 1' 6" on center using 15 watt lamps for beam illumination of 35 lumens per square foot (giving about 5½ lumens per square foot at eye level), the spacings to give uniform distribution over the entire length of the beam. Colored lighting can be provided for by adding more circuits for color-dipped lamps.

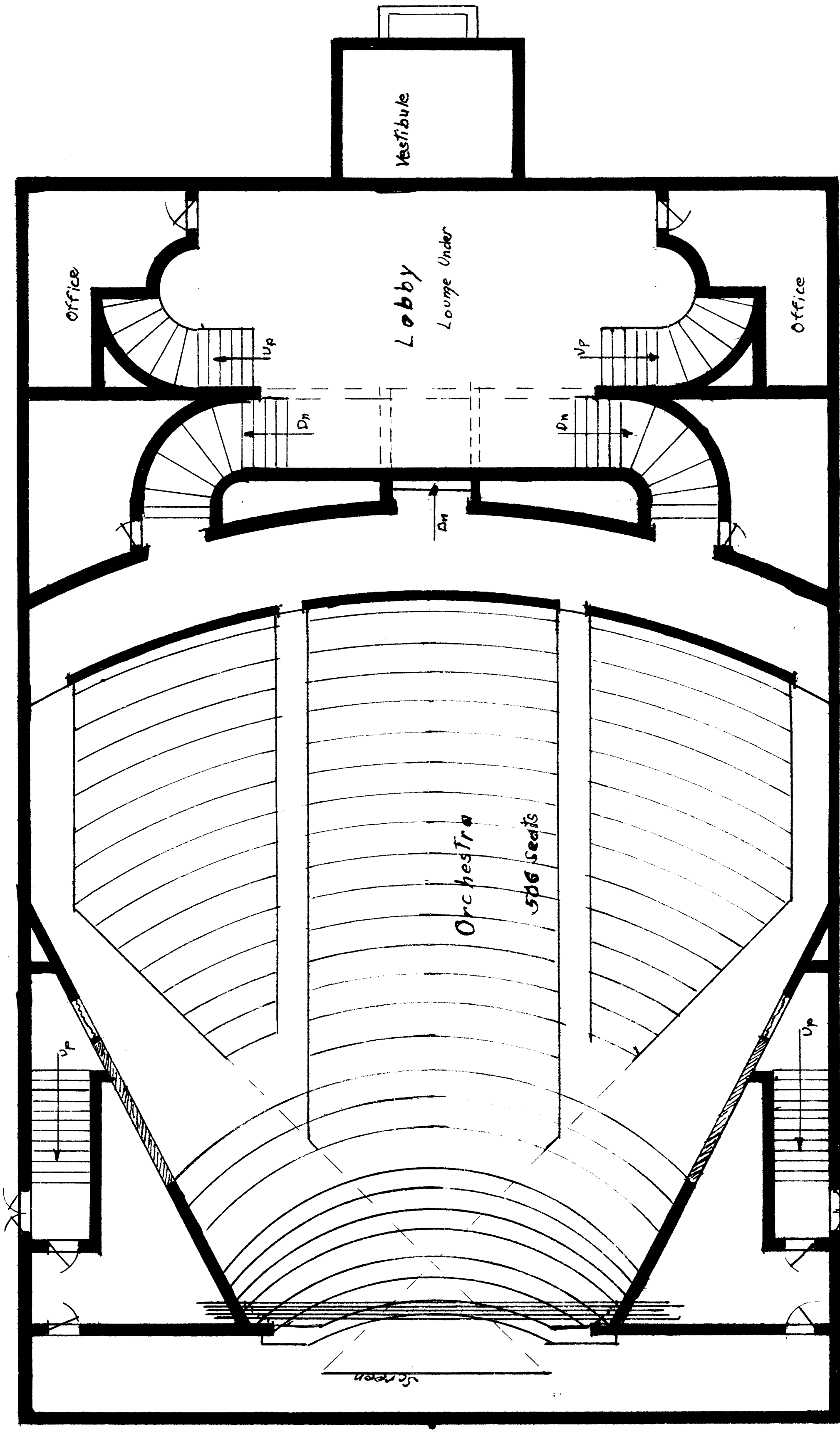
Access for replacement of lamps and for the little cleaning that should be necessary is easy from above the ceiling.

It would be advisable to make a few changes in the lighting of the under part of the balcony so as to make for a more uniform distribution of flux. Such changes would include additional lighting near the front part of the balcony and along the aisles. To get the level of brightness that was obtained in the model, in an actual installation using flashed opal glass one would need lamps of 10 watt size spaced 24 inches on center at a distance of 24 inches from the glass using a diffusing surface in back of the lamps. This recommendation to provide for uniform illumination over panel. (See appendix for derivation of specifications.)

From the unsolicited comments of persons viewing the model not knowing of the presence of the author, one would gather the impression that the model was satisfactory at least from the standpoint of pleasing illumination. From the results of the measurements within the model, one would feel that the method provides a uniformity of illumination comparable to meet installations of the present and without the cost item of most of them. Thus one would gather that the method is most satisfactory.

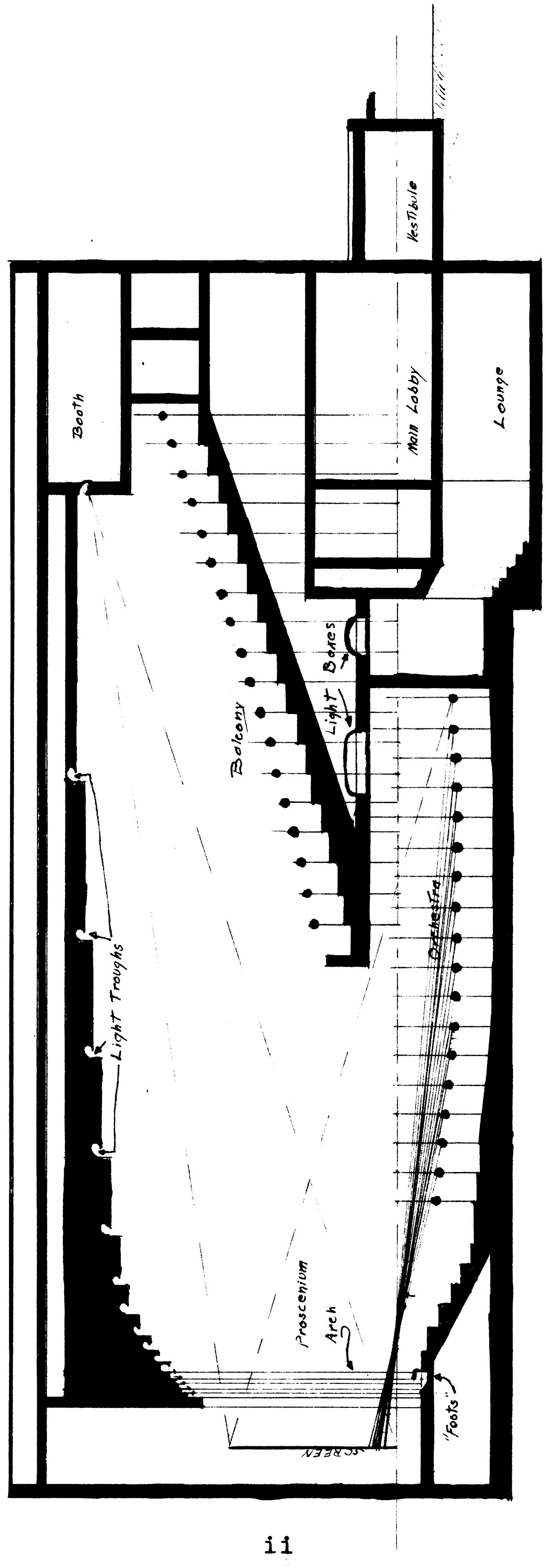
In recommending an actual installation the author would say that for all ordinary motion picture theatres it would be proper and advisable to use the beam brightness through which the illumination of the theatre can be controlled. If desireable the beam brightness could be somewhat lower and still give satisfactory results.

APPENDIX

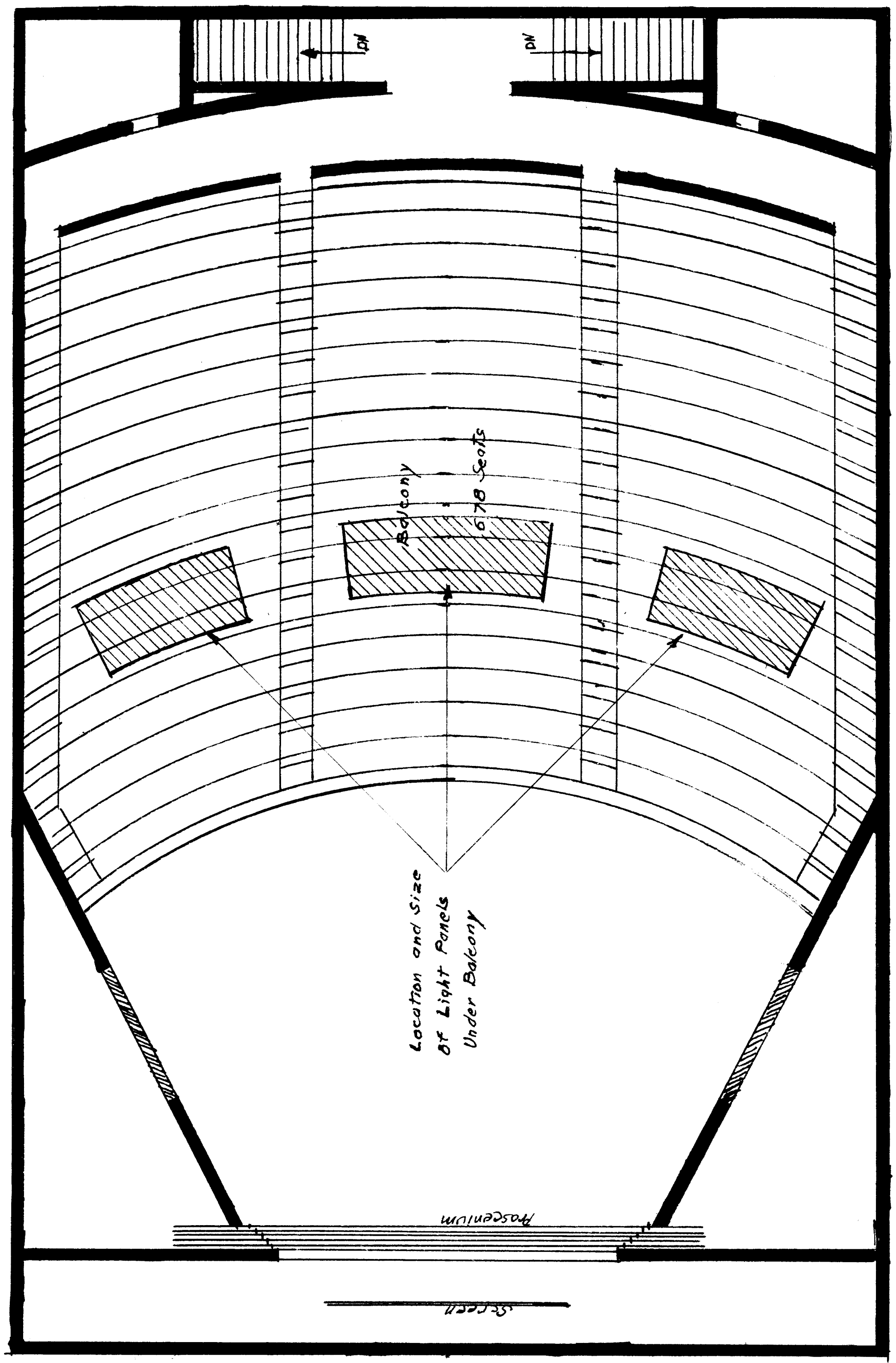


SCALE : 1/16" = 1'

Orchestra Level -
Figure 1.



Cross Section Through Center
Fig 2.



Balcony Level
Fig 3.

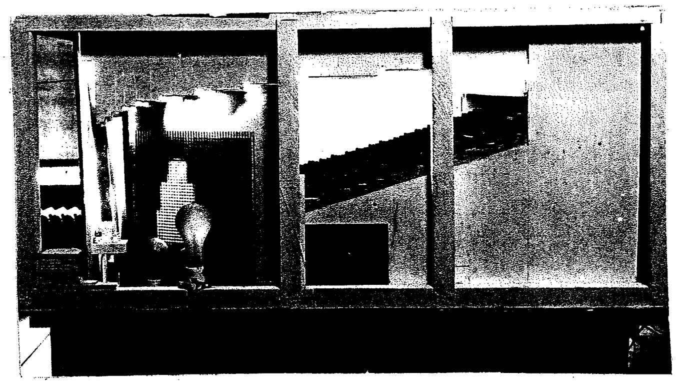
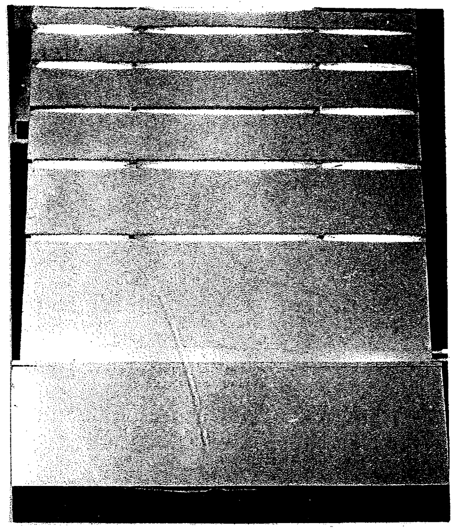
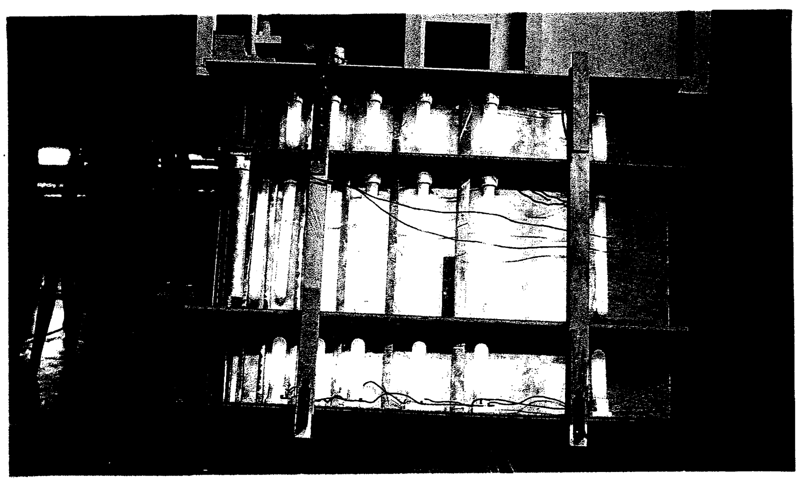


Figure 4

General view of model with two of the side panels removed. This view shows clearly the method of construction, the general slope of the balcony, the stepped form of the ceiling, and the method of lighting the side windows. One can also get somewhat of an idea as to the character of the glass employed in the windows.





Figures 5 & 6

Showing two views of the ceiling. Figure 5 shows a view looking up toward the illuminated ceiling. Figure 6 shows a view looking at the upper side of the ceiling. This view gives a very clear conception as to the method of construction and the method of lighting adopted using the tubular lamps.

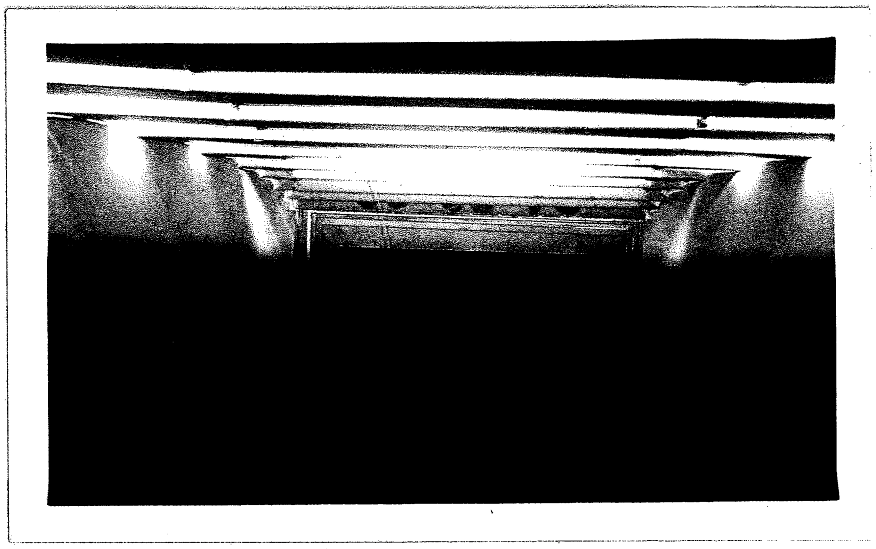


Figure 7

This picture is a view looking along the ceiling toward the stage from the upper row of the balcony. One gets a good idea as to the pleasing quality of this method of illuminating an auditorium, and also the focusing quality of the method is demonstrated as one notices how the eye is carried down to the proscenium arch.

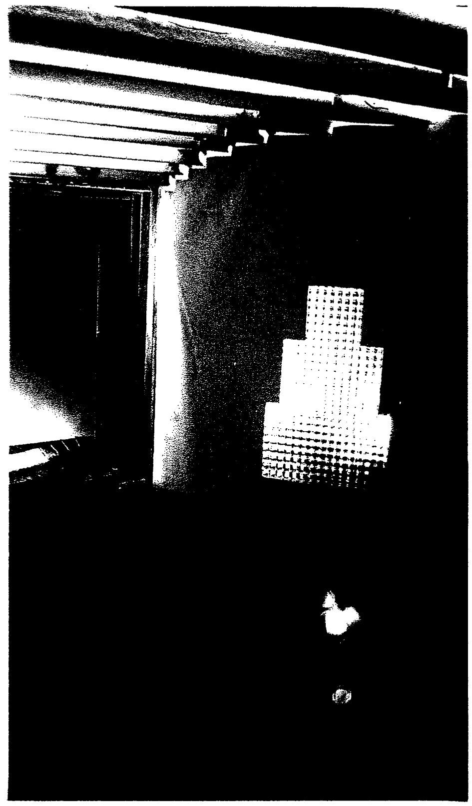


Figure 8

This view is taken through the upper panel which is shown removed in Figure 4. We are looking across the balcony toward the window on the far side. This gives one a conception as to the interesting quality of the windows and also a further conception of the general lighting.

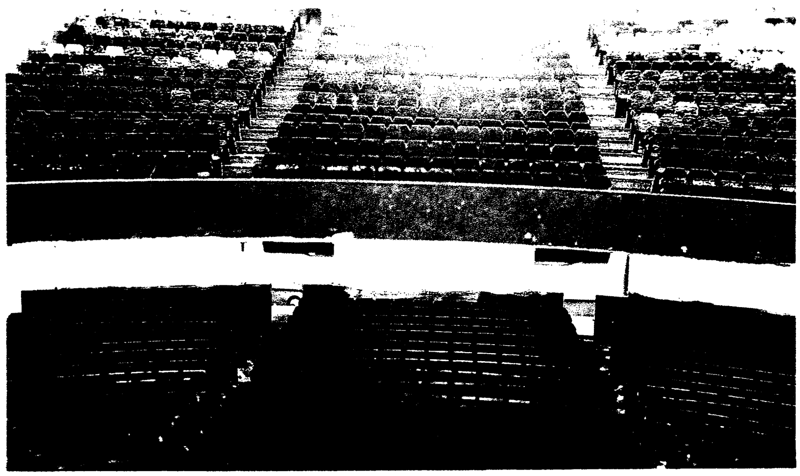


Figure 9

This is a view taken through the proscenium arch. The camera was placed approximately at a level corresponding to the screen center. Note the reversed slope of the orchestra section, the general seating arrangement, and the level of the balcony, with the first row directly on a line with the screen center.

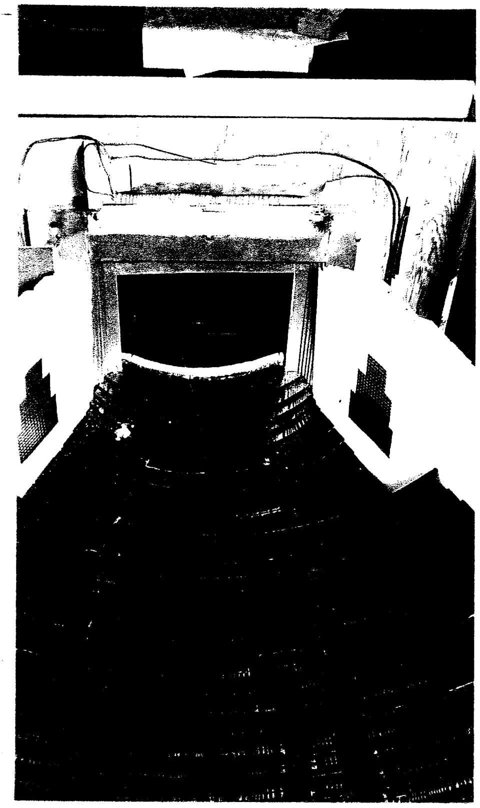


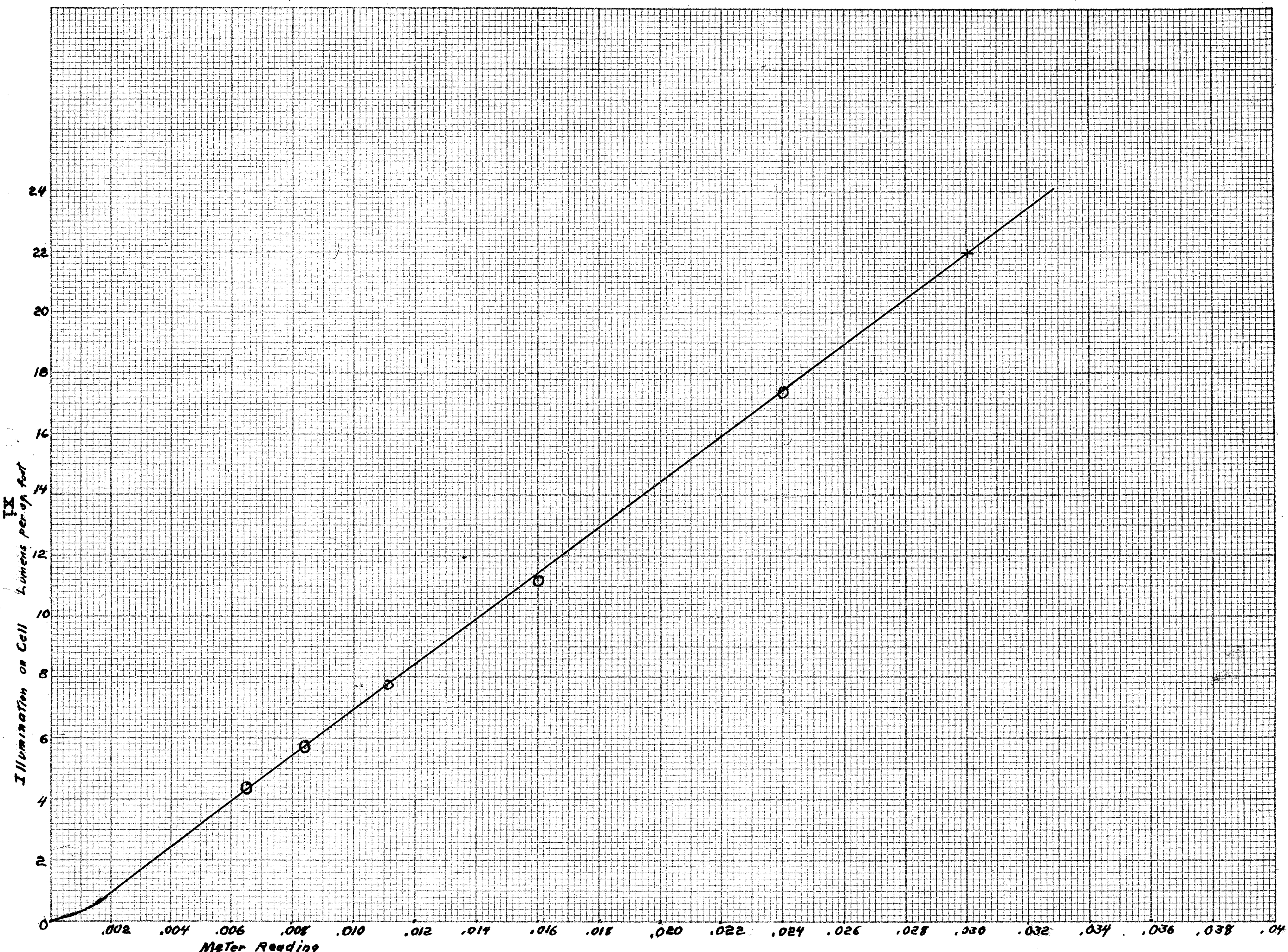
Figure 10

This view is one looking down on the model with the ceiling removed. One gets here a better conception as to the method of construction for the side walls and the proscenium arch. The method of lighting the proscenium arch with the tubular lamps in their special housings is also illustrated. Note also the arrangement of seating, the stepped front to the stage, and the footlight trough.

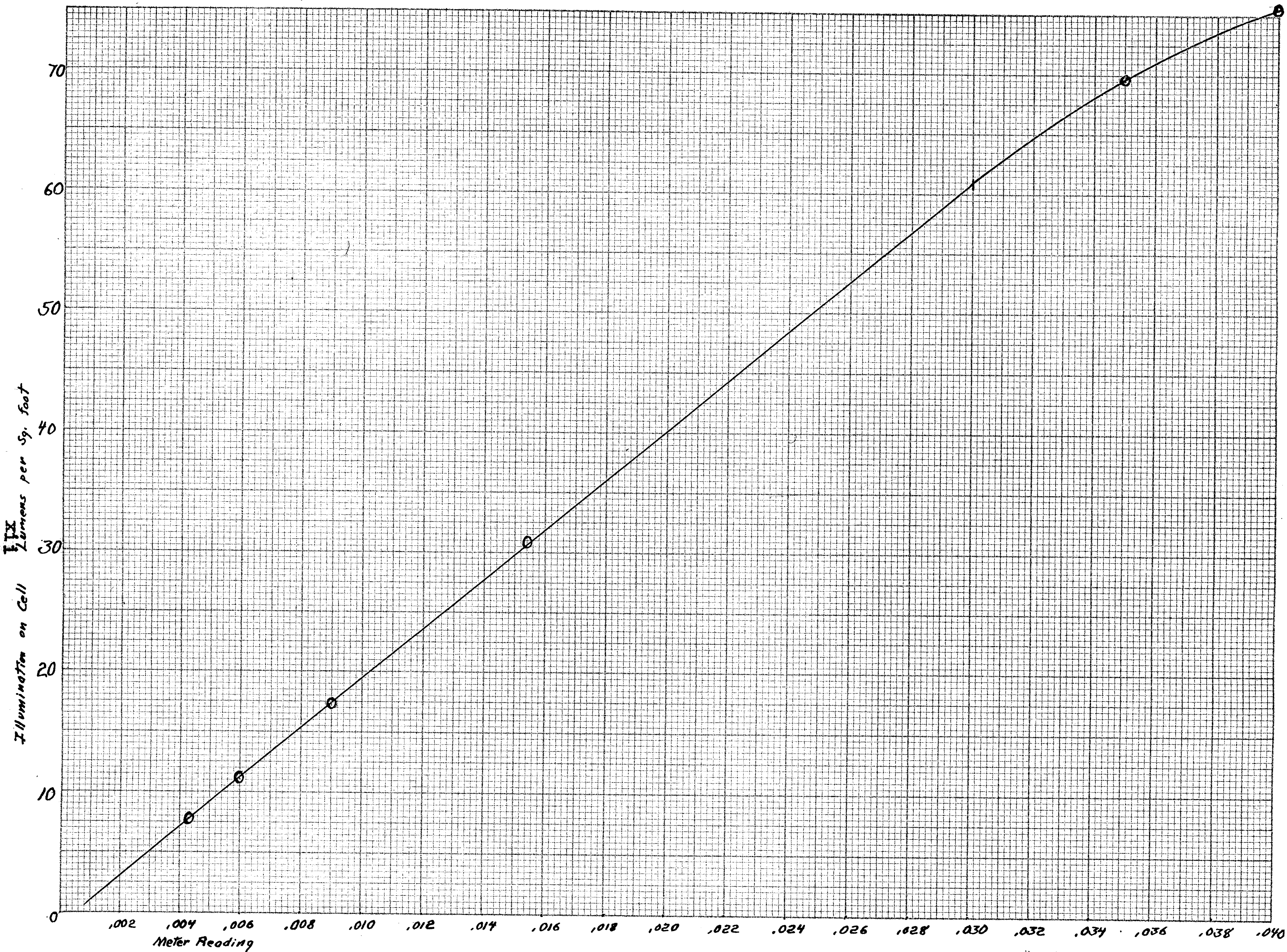
CALIBRATION OF PHOTRONIC CELL AND METER

Calibration made by exposing cell to several known values of illumination and getting reading of meter at these values. Values of illumination obtained by using a lamp of 69.55 candlepower, as checked against standard, operating at a constant voltage and placed at varying distances from the cell. The cell was calibrated both with and without the mask. The results of this calibration are showm in the following table and on the following plots from which the values of illumination and flux were interpolated in calculating the illumination in the model.

Distance Lamp to Cell Feet	Illumination on Cell Lumens/Sq. Foot	Meter Reading Milliamps
	Cell without Mask	
2.0	17.4	.024
2.5	11.12	.016
3.0	7.728	.0111
3.5	5.67	.0084
4.0	4.35	.0065
	Cell with Mask	
0.958	75.8	.040
1.0	69.55	.035
1.5	30.91	.0154
2.0	17.4	.0090
2.5	11.12	.0060
3.0	7.728	.0043



Calibration of Cell Without Mask



Calibration of Cell With Mask

DERIVATION OF SPECIFICATIONS

BEAMS

Luminosity required

1. 75.8 l/sq. ft.
2. 35 l/sq. ft.

Distance from lamp to curved surface is, say one foot. (D)

The allowable spacing of lamps for uniform illumination is about 1.8D (see G. E. Bulletin--Luminous Architectural Elements)

Lamps can be spaced 1.8 feet. Use spacing of 1 ft.-6ins o.c.

Approximate efficiency of panel--43%

Required lumens output of lamps

1.	75.8 x 1.5 x 1.57	178.5 lumens
2.	35 x 1.5 x 1.57	82.5 lumens

Use 25 watt lamps giving 250 lumens for 1

15 watt lamps giving 137 lumens for 2

PANELS UNDER BALCONY

Luminosity required 7.25 lumens per sq. foot

Say depth of box is 2 ft.

Spacing is 1.2D --is 2.4 ft. Use 2 ft. o.c.

Panel about 49% efficient

Lumens required per lamp

7.25 x 4 x 1.51 44 lumens per lamp

Use 10 watt lamps giving 76 lumens

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