DOCUMENT RESUME

ED 025 931 EF 002 605

By-Koppes, Wayne F.; And Others
Design Criteria for Learning Spaces. Seating - Lighting - Acoustics.
Rensselaer Polytechnic Inst., Troy, N.Y. School of Architecture.
Pub Date 62
Note-52p.
EDRS Price MF-$0.25 HC-$2.70
Descriptors-*Acoustics, Audiovisual Aids, Classroom Design, Controlled Environment, Criteria, *Design, Design Needs, Educational Environment, Environmental Criteria, Environmental Influences, Equipment, *Furniture Design, Instructional Design, *Learning, *Lighting

The results of a project undertaken to assist the Office of Facilities of the State University of New York in the development of design and planning criteria for "learning spaces" with particular emphasis on the considerations for seating, lighting and acoustics. The learning spaces referred to are classified as large group instructional facilities developed particularly for the utilization of aids and media in the learning process. Much of the work presented in this study is based on the Rensselaer Experimental Classroom Project. Topics discussed include--(1) introduction - existing research general design considerations, and purpose of study, (2) the experimental classroom, (3) seating - introduction, evaluation, and suggested improvements, (4) lighting - general requirements, evaluation, and suggested improvements, (5) acoustics - introduction, general considerations, and critique, and (6) appendix. (RH)

DESIGN CRITERIA for LEARNING SPACES...

Seating ... Lighting ... Acoustics.

DESIGN CRITERIA FOR LEARNING SPACES

seating – lighting – acoustics

Wayne F. Koppes
Alan C. Green
M. C. Gassman

This is the report of an evaluation and development study undertaken by the Architectural Research Staff of the School of Architecture, Rensselaer Polytechnic Institute, Troy, New York for the Office of Facilities, State University of New York, Albany, New York.

CONTENTS

B. BACKGROUND RESEARCH

Since World War II the use of instructional aids and media has grown rapidly, to keep pace with the demands of contemporary education. Their educational validity and effectiveness has long been recognized, but until recently little consideration had been given to providing the optimum environment for their use. In 1959, however, the Educational Facilities Laboratories, Inc., recognizing the need for guidance in this area, awarded a grant to Rensselaer's School of Architecture to conduct an architectural research study directed at the planning and design of such facilities. This study culminated in the publication of the report **New Spaces for Learning – Designing College Facilities to Utilize Instructional Aids and Media.**

It was found that to properly support an instructional process utilizing the aids and media to their fullest advantage requires a **system** of facilities, comprised of:

a. **The learning space** – where the instructor, students and instructional aids are brought together in an environment conducive to the transfer of knowledge and the process of learning.
b. **The support facilities** – where the instructional materials are prepared, television programs originate and are controlled, and technical assistance is provided for the instructional staff.
c. **The access and review center** – where the instructional materials are made available in a library-type function for student review, reference and self-instruction.

The chief concern of the study, and the principal emphasis in the report **New Spaces,** was the "learning space"; the considerations governing the design of that type of facility are the same as those applying to the design of the instructional rooms with which we are concerned in this study for the State University.

The EFL-sponsored study developed valuable guidelines for the architectural design of contemporary instructional facilities, and the report of this work has received wide attention. The design criteria which were established for the "learning space" are considered to be of special interest and have been included as Appendix A of this report.

Following the study, arrangements were made to construct, for experimental use, a full-scale mockup of a typical learning space, using one of the designs which had been proposed. This "Experimental Classroom" was built on the Rensselaer campus in 1961 and has been in constant use since then. A description of this facility and a summary report of the findings resulting from its use are presented in Chapter II of this report.

C. GENERAL DESIGN CONSIDERATIONS

The previous studies, and the experience with the Experimental Classroom, have established that there are a number of important considerations with which the architect must be concerned in designing instructional rooms of this type. Chief among them are:

1. - the plan shape of the room as determined by viewing facility and acoustic considerations
2. - the sectional shape of the room as influenced by acoustics and lighting
3. - the selection, location, and control of projection equipment
4. - the type and arrangement of seating
5. - the size, type, and location of display surfaces
6. - the intensity, quality and control of lighting
7. - the color, texture, and finish of room surfaces and furnishings
8. - acoustic considerations including reverberation, isolation, and amplification
9. - proper ventilation, cooling, and heating of the room
10. - the provision of necessary auxiliary spaces such as are required for projection equipment and preparation

D. SCOPE AND PURPOSE OF THIS STUDY

All of the considerations listed above are important, but they are not all equally susceptible to meaningful analysis or the development of design criteria useful to the architect. Some of them, in fact, are of more direct concern to the mechanical engineer than to the architect.

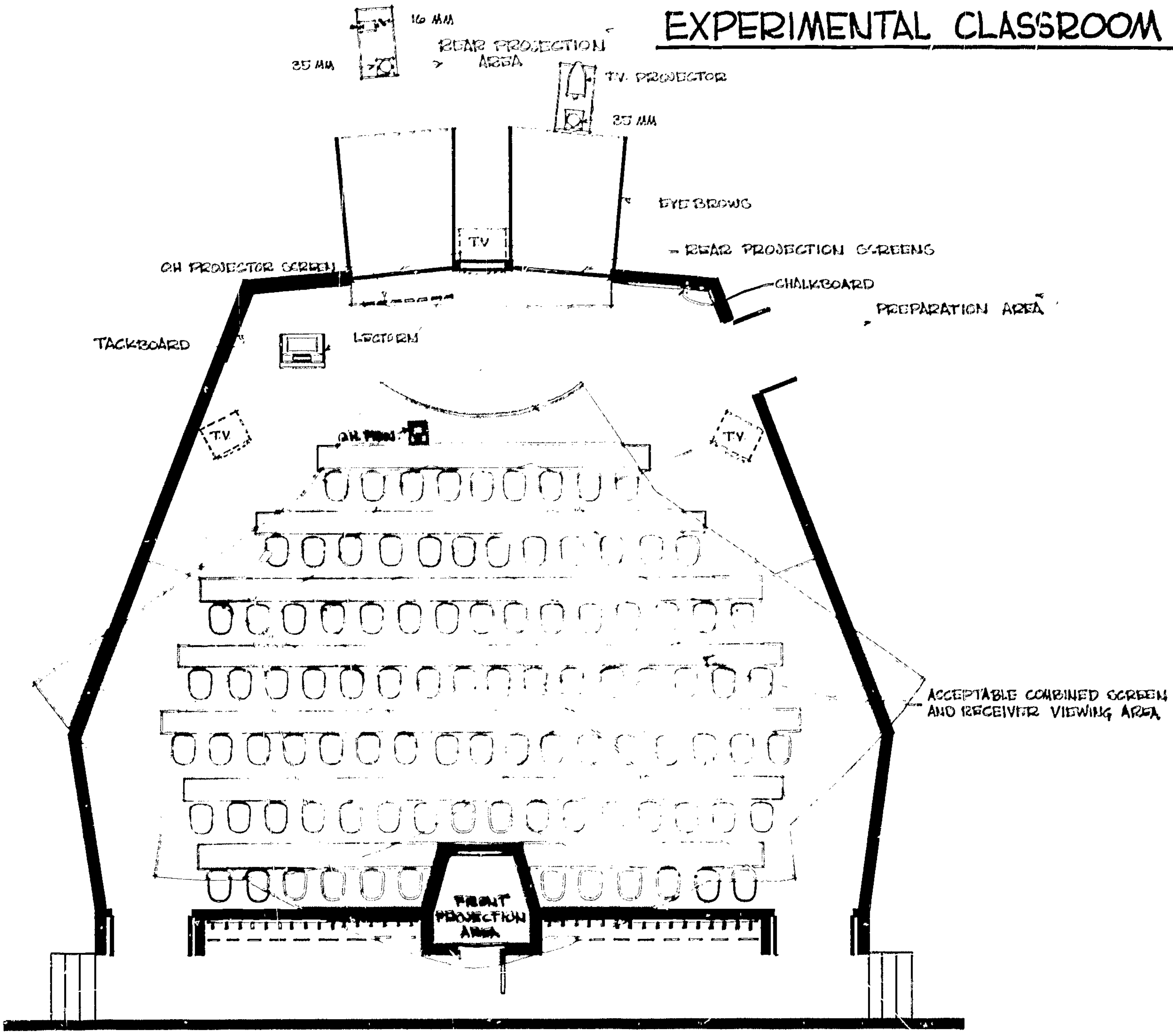
Those of chief interest to the Office of Facilities of the State University at the present time are **the problems related to seating, lighting and acoustics.** The establishment of recommended practices in these areas, based on detailed studies of the basic requirements, is considered essential. The scope of this study has, therefore, been limited to these three topics, and the findings and recommendations in respect to each are presented in Chapters III, IV and V following.

In the study of seating, as reported in Chapter III, a number of commercially available types were examined and compared which involved using a mathematical rating system developed for the purpose. This resulted in the selection of two types which appear to be more potentially suitable, and the further development of one of these units is described in detail. Sketches are also provided showing the preferred arrangements of seating units in rooms of different sizes.

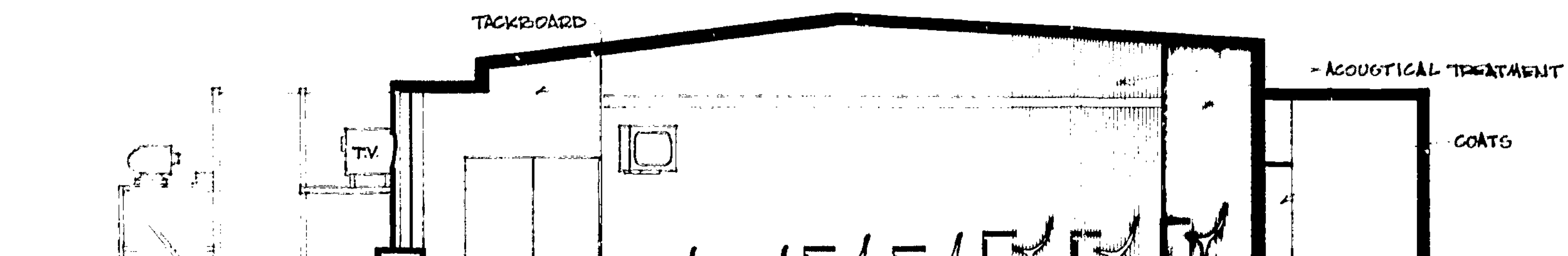
The study of lighting, reported in Chapter IV, began with a critical analysis of the system used in the Experimental Classroom, including the measurement of critical surface brightnesses in the room and critiques by lighting consultants. This was followed by the development of a design of a different and improved system, applicable to all rooms of this type. Both the present and the proposed systems are presented by drawings together with reasonably accurate cost estimates obtained from a reputable electrical contractor.

As explained in Chapter V, the acoustics of the Experimental Classroom were also reviewed in detail by a nationally recognized acoustics consultant, working with the project staff. The information derived from this analysis has been utilized to establish recommended criteria to be observed in achieving optimum acoustical conditions in all such spaces.

EXPERIMENTAL CLASSROOM



PLAN



SECTION

FIGURE 1

Chapter II – THE EXPERIMENTAL CLASSROOM

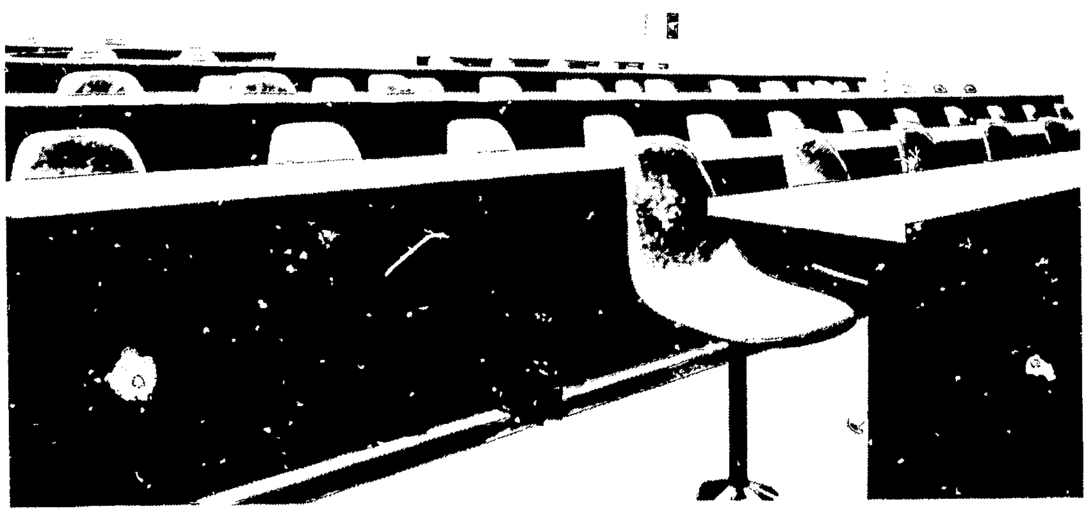
A. BACKGROUND AND DESCRIPTION

As mentioned in Chapter I an important aspect of the background research for this study was the construction and in-use evaluation of Rensselaer's Experimental Classroom. The Classroom was designed and built during the summer and fall of 1961 following the design criteria developed in **New Spaces for Learning**. As a mock-up of a "learning space" it has provided a vital and significant laboratory in which to study and evaluate an educational facility for which no true prototype existed. On the Rensselaer campus it supports three activities: 1) educational research as to the effectiveness of instructional methods and techniques, 2) familiarization by the faculty with the potential of this contemporary type of facility, and 3) architectural research in developing an optimum environment for instruction and learning. It is the latter interest which forms, in part, the basis for this study.

The following points describe the most significant features of the Classroom. It will be helpful when considering each point to refer to the plan, section, photographs, and notes presented as Figures 1 and 2.

1. **Plan shape** – the unusual room shape is dictated by minimum and maximum viewing distances and viewing angles for two centrally located screens, each six by six feet square, and three 27 inch TV monitors.
2. **Sectional shape** – considerations of proper reflective planes for acoustics, angles for ceiling down-lights, and platforms for seating result in the sectional shape shown.
3. **Projection equipment location and controls** – all controls are in a master control console at the instructor's lectern permitting the instructional equipment and lighting to be easily manipulated by the instructor. As an experimental facility, the use of both front and rear projection is possible; enclosures are provided outside the room to house the remotely controlled projectors. In addition, reception of TV by both monitors and large screen projection is possible.
4. **Seating** – molded, plastic, pedestal chairs are arranged in seven rows of varying lengths behind continuous white-surfaced tables. The back-to-back spacing permits passage space behind all the seats. The seats are on three levels and alternate rows of seats are offset to improve viewing.
5. **Display surfaces** – screens, chalkboards, tackboards, and television monitors are arranged across the front of the room to provide continuous, integrated display surfaces. The two screens permit simultaneous showing of two projected images for comparative analysis.
6. **Lighting** – lighting is provided by three specialized, functionally over-lapping systems. The first is a system of dimmer-controlled downlights which illuminate the student writing surfaces. Their intensity is variable and is automatically adjusted to be compatible with the aids being used, but enough light always falls on the desk tops to permit note-taking. The second is a band of dimmer-controlled fixtures near the top of the side and rear walls to wash the walls and ceiling and thus increase the overall room intensity. Finally, accent lights illuminate chalkboards, tackboards, screens, the demonstration area, and the instructor himself. All three systems can be controlled and dimmed individually or in series.
7. **Color and finishes** – the room is designed to provide a basically neutral, glare-free environment so that all attention is directed to the display surfaces and the instructor.

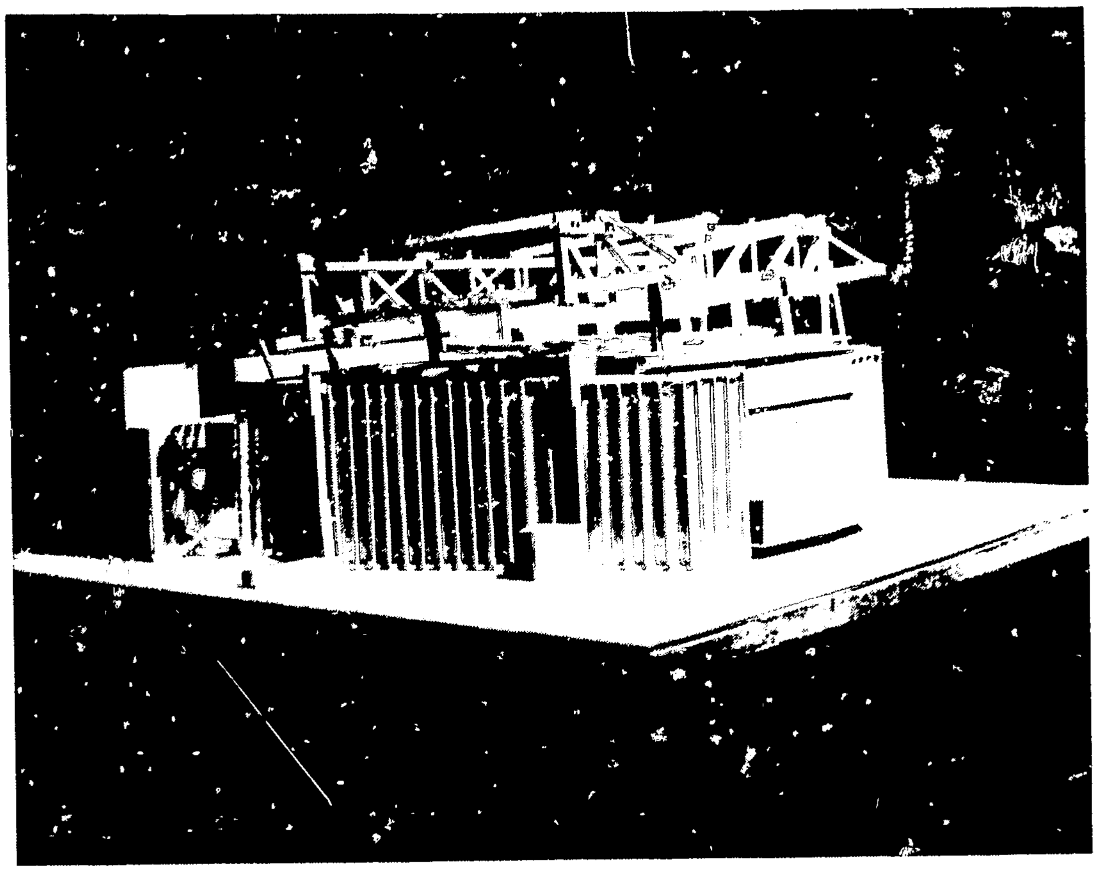
Overall view of the interior of the Classroom looking towards the front and showing the various display surfaces.



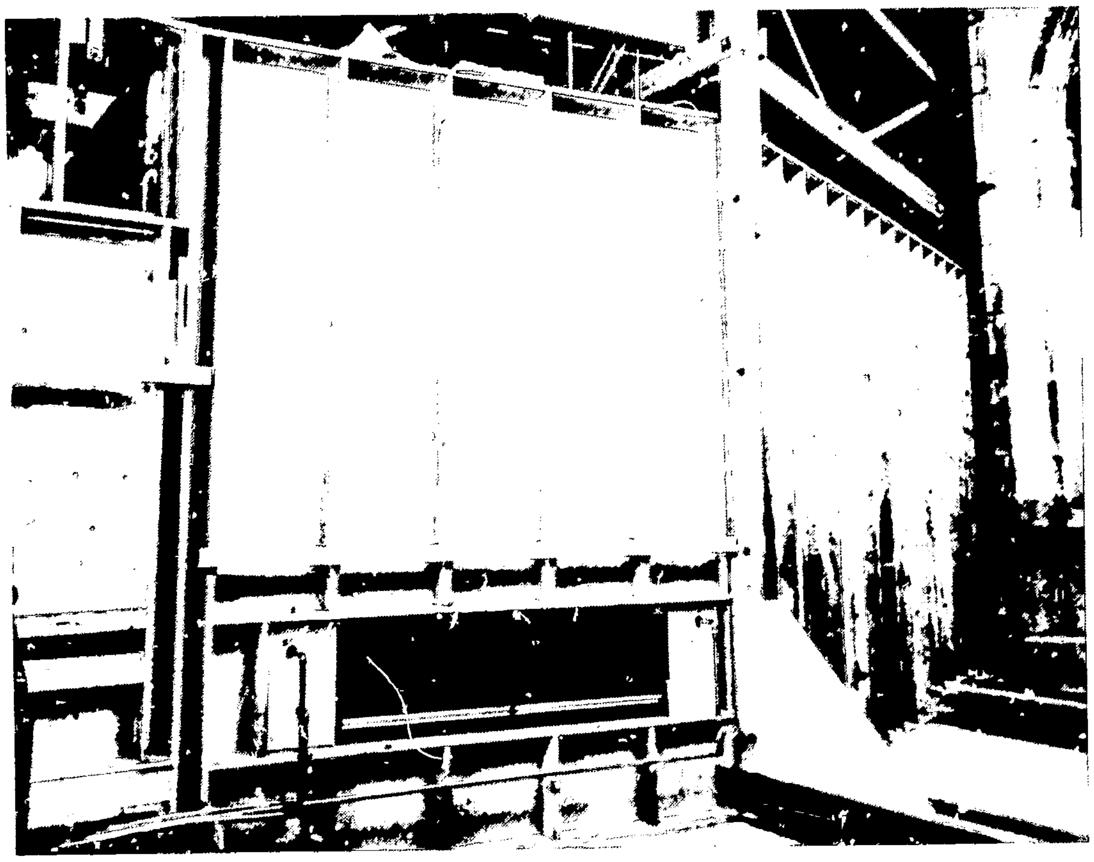
Overall view from the front corner of the Classroom indicating the room shape, seating arrangement, student entrances, and front projection booth.

The arrangement of the front of the Classroom with, from left to right, TV monitor, tackboard, chalkboard, rear projection screen (overhead projection screen above), TV monitor, and second rear projection screen. Note location of the lectern containing controls, and the overhead projector.

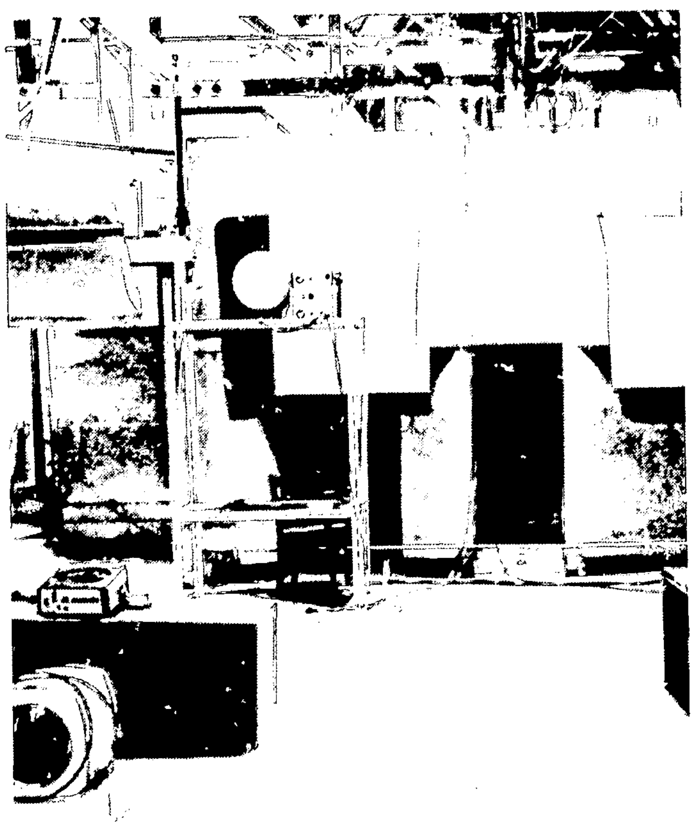
PHOTOGRAPHS OF THE
EXPERIMENTAL CLASSROOM



A model of the Classroom showing the truss system for suspending the ceiling panels.



Exterior view of the Classroom indicating the non-permanent mock-up type of construction which was utilized in its construction and which permits changes and modifications.



Left: The control panel in the lectern for switching projected aids and corresponding lighting.

Right: A part of the rear projection area showing the location of equipment, and the "laboratory-type" environment.

FIGURE 2

8. **Acoustics** -- all amplified sound is distributed over a single, high-level system with the speaker located in the center of the front wall for realism. The acoustical design, typical of lecture rooms of this capacity, permits the instructor to speak unaided by distracting microphones and wiring.
9. **Air conditioning** – the room is completely windowless and is air conditioned to provide a clean, stimulating climate.
10. **Preparation areas** – an adjoining room is provided where demonstrations can be prepared on carts which are then rolled directly onto the front stage of the classroom through double doors. Utilities can be self-contained in the demonstration cart, or are available through a service panel in the floor.

Finally, inherent in the design and construction of the Experimental Classroom is the potential for minor, or extensive revisions and modifications. The ceiling is panelized and suspended on threaded rods from a truss system to permit changes in the configuration of the ceiling if deemed necessary for lighting or acoustic reasons. By virtue of the mock-up type construction, walls can also be relocated, the display surfaces redesigned and relocated, and the platform seating arrangement modified. In addition, new equipment, wiring and controls can be let into ceiling, wall and floor surfaces at any location.

As pointed out previously, both monitor and projected television can be utilized, and by inclusion of the projection booth, both front and rear projection techniques can be compared. The Experimental Classroom thus becomes a true laboratory, capable of experimentation, evaluation, and modification.

B. GENERAL EVALUATION

The Classroom has been used for cross-campus instructional purposes for four semesters during which time courses in anthropology, economics, psychology, biology, physics, architectural history, engineering graphics, and chemical engineering have utilized its potentials. During this period, faculty, students and visitors have discussed the classroom with the projec staff, and an informal evaluation has developed. In addition, a questionnaire evaluation was completed by several classes during the summer of 1962. This has resulted in the following general evaluation of the existing environment and suggestions as to potential improvements:

1. The matte white Formica writing surfaces have been found to be too light and reflective. A light gray would be a better surface from a visual and lighting standpoint.
2. The downlights create multiple shadows from any object placed on the writing surface. When writing, the student's hand and pencil or pen cast a number of distracting shadows on the paper. This is one of the objectionable features of downlights, and could be rectified by an overall luminous, but directional, lighting system.
3. Generally, the seating type and seating arrangement have been satisfactory, although the fixed seat in relationship to a fixed writing surface does not permit any adjustment for the individual. In other words, it is an average relationship for average people, and denies the possibility of adjustment for tall, short, and stout persons. This seating type tends to hold the individual quite erect, and does not permit slouching or relaxed sitting. The students have responded favorably to the continuous counter tops.
4. There has been no adverse criticism or comment on the size and shape of the viewing area as related to screen surfaces. Everyone who has seen the classroom has felt that the screens can be easily viewed from all seats.

5. It has been felt that the chalkboard surfaces are in a poor location, and not very well illuminated. Also, the instructors have found the chalkboards difficult to utilize in a conventional manner. Of course, the room was designed for the use of the overhead projector, and the chalkboards become only a secondary display surface. Most instructors have gone to the use of the overhead projector, and the chalkboards have been used relatively little.
6. Some objection has been raised regarding the center monitor dividing the two screens. This was dictated in the original design because three monitors were necessary to cover the room. With the general acceptance of large screen TV projection, this center monitor can be eliminated and one continuous screen surface can be installed in place of the two separate screens.
7. Several instructors have indicated that they would utilize the room more effectively if the potential for **three** simultaneously projected images could be included. This means that a rear projection screen 6 feet high and 18 feet long should be incorporated at the front of the room. The reflective screen for the overhead projector would be lowered in front of one-third of the large screen when the overhead projector is to be used. This potential for three projected images, resulting in the wider screen surface, would somewhat modify the optimum viewing area.
8. Acoustically, the room has been very satisfactory, and many persons have commented on the ease with which the instructor is heard and the facility with which discussion and question and answer sessions can be conducted. When the classroom was first put into operation and before the air-conditioning was fully adjusted, any small disturbance or whisper in the room was easily heard by the instructor. After the air-conditioning was put into full operation, introducing some background noise into the room, this objection was overcome.
9. When the room was first used for classes, there were a number of mechanical problems with the air-conditioning, often resulting in the room becoming greatly overheated. This, of course, was very objectionable, and was criticized by many persons. Once the air-conditioning was completely operational, no further objections have been raised.
10. There has been some comment on the neutral color scheme of the room. Essentially, these comments have been directed at the selection of the color scheme. In other words, some people prefer blues or greens or something else to the shades of tan which exist in the room now.
11. Several of the instructors have indicated that the black holes in the perforated acoustic treatment on the back walls create a visual disturbance. Actually, the perforated surfaces should have been painted a darker color, to avoid the contrast between the dark holes and the surface of the boards.
12. The controls and projection equipment have worked very well, and there have been no major breakdowns or mechanical difficulties. The instructors and visitors have indicated their ready acceptance of the easy operation of the equipment from the lectern.

C. EDUCATIONAL EVALUATION

The full potential for facilities such as the Experimental Classroom will only be realized when the instructors who use them are completely convinced of their educational validity and make a conscientious effort to utilize them effectively. It was felt that a worthwhile adjunct to this study would be a critical evaluation of the Classroom by a teacher who has taught in it, and is well aware of its concept and purpose. To this end, Professor Walter Eppenstein of Rensselaer's Physics Department was asked to develop a brief statement of educational evaluation. Professor Eppenstein has taught continuously in the Classroom from the beginning of the project and is considered to be an outstanding and highly imaginative teacher. His comments which follow are worthy of careful consideration.

"The Experimental Classroom has been used by me for a number of different physics courses ranging from Freshman physics to graduate courses presented to secondary school teachers. In using the room, all available projection devices were utilized, including slides, 16-mm movies, 8-mm movies, closed circuit televisior overhead projection, live demonstrations and shadow projection.

No major problems were encountered with the use of slides, movies or television. It became obvious, however, that the room was not designed especially for the use of the overhead projector, live demonstrations or shadow projection. Since such demonstrations play an important role in the teaching of the physical sciences, proper facilities should be incorporated into any room that will be used for the teaching of physics and chemistry.

From the instructor's point of view, the seating arrangement is excellent. There is sufficient space to walk among the students if this becomes desirable and students coming in late can get to their seats without disturbing others. Nevertheless, some students and visitors have complained about the seats – their fixed height, fixed distance from the table and their hardness.

With the present location of the overhead projector, the head of the projector interferes with the visibility from some of the seats. It is suggested that this situation be remedied by relocating the overhead projector, rather than changing the seating arrangement.

Some students carry more books than they can comfortably place on the table and still have sufficient space for taking notes. A special place for books, possibly under the writing surface, would be of value.

The general lighting of the room is adequate as long as it is properly adjusted. The maximum level is definitely too bright. In the front of the room two very strong spotlights would be helpful, if their position is not fixed but can be adjusted easily. They would be used when equipment is actually demonstrated. The blackboard lights are poor. To achieve an even illumination of the blackboard, one needs a continuous light above the board. The lighting levels for the various visual aids are pre-set with the exception of the room illumination when the overhead projector is in use. As long as overhead projectors are being usec hey should be included in the scheme of pre-set illumination levels.

While it may be old fashioned to ask for a simple on-off light switch, there are situations during certain demonstrations when the instructor may want to turn off the lights completely. This might also be helpful if there are a few poor slides mixed in with good ones; not all slides need the same amount of room illumination.

The two permanently mounted rear projection screens in front of the room are good. They are just about the right size for the seating capacity of the room. It may be desirable, however, to have one continuous screen instead of two separate ones. This would make it possible, in some instances, to use three pictures simultaneously.

The front projection screen for use with the overhead projector is in a poor location because it blocks one of the rear projection screens. One possible improvement would be a permanently mounted screen above the lectern instead of the present blackboard. If it is desired to keep the present blackboard space, then two vertically moving blackboards on the other side of the room may serve the purpose. It is believed, however, that with a proper installation of overhead projection facilities, the blackboards become unnecessary. The lower parts of the present blackboards are, of course, useless because they cannot be seen by the students. A relocation of the overhead projector screen would also result in a relocation of the projector itself. With proper design, the projector can be placed so that it does not obstruct any viewing space.

In the rear projection area, the 16-mm movie projector and the television projector should be on tracks so that they can be moved from one screen to the other without trouble. The possibility of showing movies should not be restricted to one screen, especially if this screen is unusable when an overhead projector is employed. The instructor should be able, at a moment's notice, to use any projector with any screen.

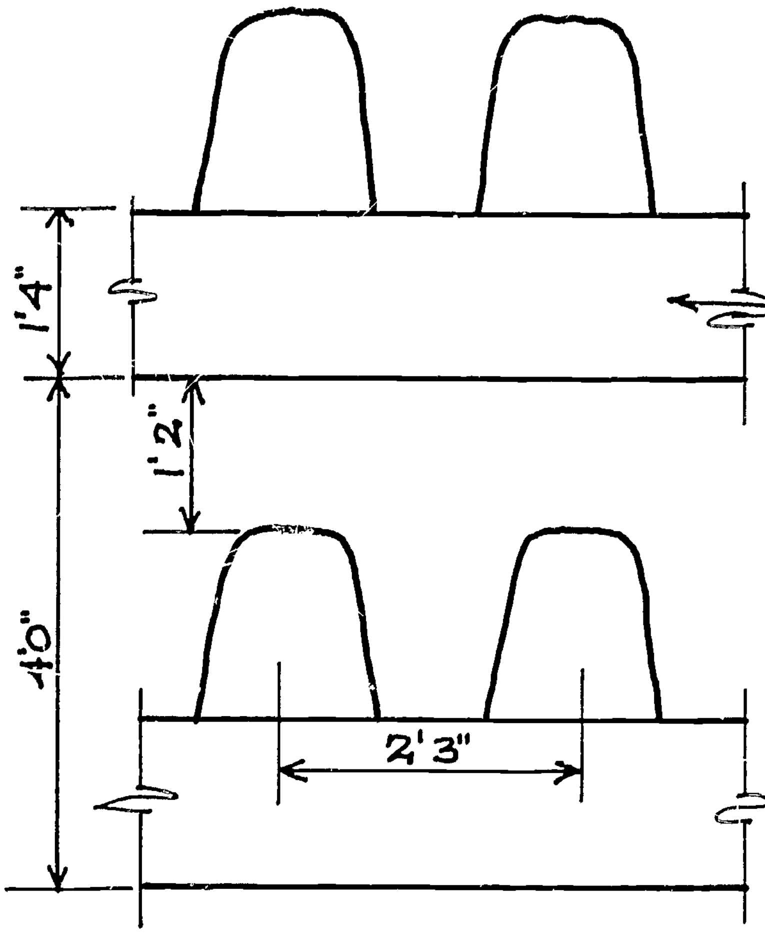
The acoustics were found to be excellent. Students had no trouble in hearing the lecturer, no matter where he was standing. The instructor was able to easily understand any questions or comments from students anywhere in the room. In a class discussion, students were able to understand each other. In all, the instructor found it quite unnecessary to raise his voice while lecturing.

Needless to say, a well functioning air-conditioning system is an absolute necessity when teaching in a closed room without windows. However, more attention should be paid to the direction of the circulating air to avoid cold air blowing directly on some students. The noise of the air handling units does not seem objectionable in this room.

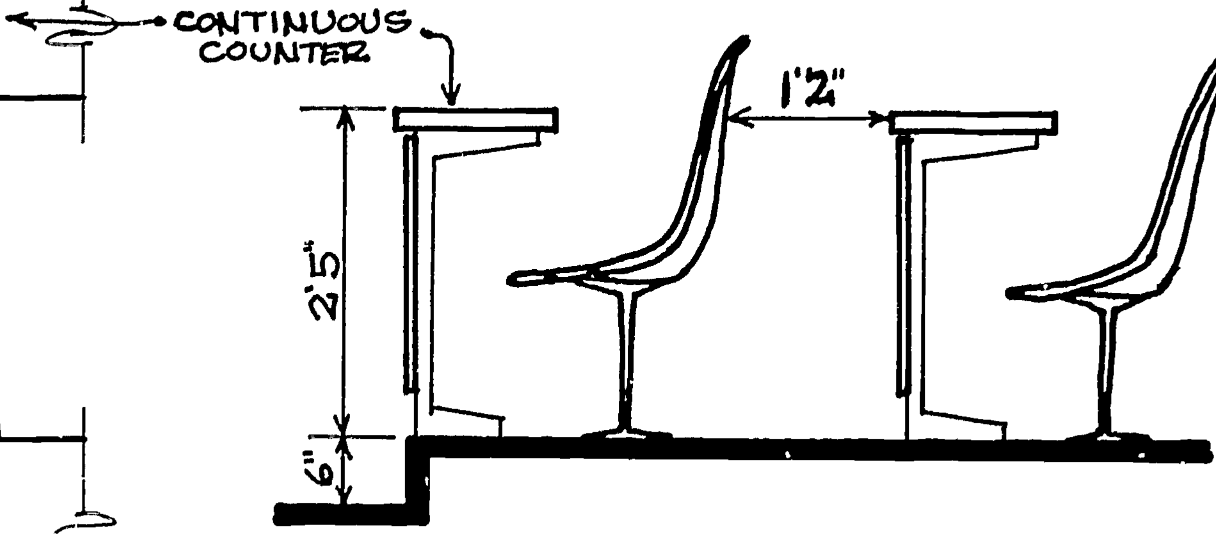
The size of the average class section in the introductory physics courses varies between 20 and 25 students. Over the last few years, a number of experiments with recitation classes of up to 50 students have been conducted. From the point of view of both, students and instructors, the doubling of the section size in a conventional classroom was not successful. Moreover, we have for a number of semesters, taught recitation sections of 40 to 50 students in the Experimental Classroom without encountering any difficulties. The general surroundings, the shape of the room, the excellent acoustics, as well as some of the projection devices, made it possible to double the size of class sections. Although a detailed analysis of the effects of doubling section size has not been made, we can conclude that larger groups of students can be taught successfully in the Experimental Classroom rather than in a conventional classroom.

There is no doubt that the Experimental Classroom is a vast improvement over conventional classrooms. The ease with which the various projectors can be operated opens up an entirely new method of teaching. It must be realized, however, that such a room, with all the latest technological devices, cannot improve instruction without an instructor willing to make full use of its potential. In order to accomplish this, new materials must be prepared. The best projectors are of no use unless necessary films or slides are available. At the present time, the supply of good movies and transparencies and similar devices on a college level is very small, especially in the physical sciences. Such materials must be created, and for this job, the interested faculty members must be supplied with time and funds. After all, a room of this type requires a drastic change in the teaching methods used. The instructor has to be enthusiastic and must be given the resources to reorganize his course material."

EXISTING SEATING



PLAN



SECTION

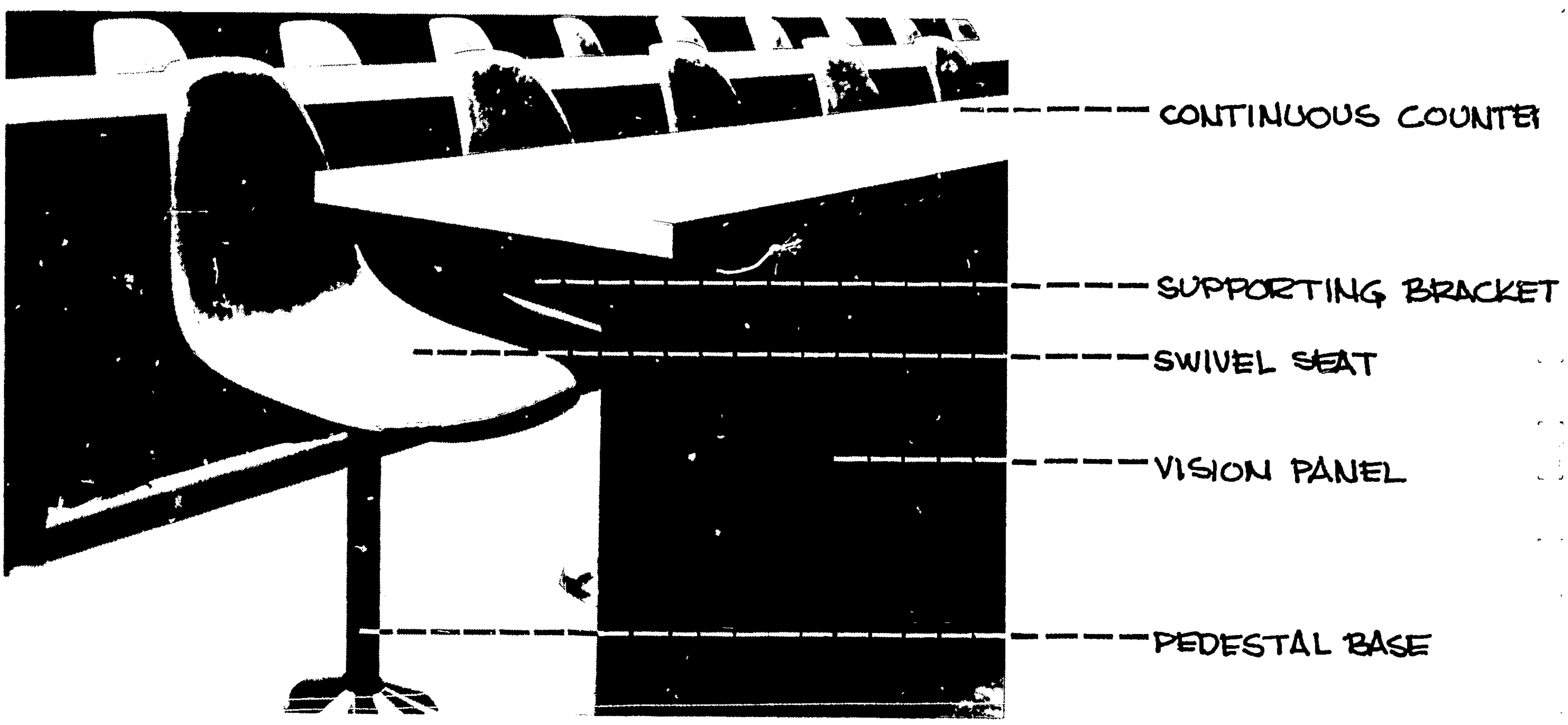


FIGURE 3

Chapter III – SEATING

A. INTRODUCTION

During the preparation of the report **New Spaces for Learning**, and later when the Experimental Classroom was built, many of the currently available types of seating were investigated to find a type that would meet the particular requirements of the "learning spaces." The results were somewhat discouraging; there seemed to be none which were wholly appropriate. As a result, the seating provided in the Experimental Classroom is a combination of a commercially available seat and a custom-made writing surface, as illustrated in the photograph and plan sketch of Figure 3. Fixed, pedestal-mounted, swivel, molded plastic seats are arranged behind continuous writing counters surfaced with white Formica. The back-to-back spacing is 48 inches and the lateral spacing is 27 inches, making a floor area requirement of nine square feet per unit. It is felt that this spacing is over-generous, and for practical reasons could well be reduced.

Recognizing that probably a better type of seating might be found or developed, an objective analytical approach to the problem was adopted. To determine the best possible type of seating for spaces of this type, and to translate this knowledge into improved seating design, the following steps have been taken:

1. The characteristics and requirements of such seating were first objectively defined, and the relative importance of these essentials was determined.
2. All available seating types considered possibly appropriate were reviewed, and data concerning these types were tabulated.
3. A "rating method," or means of comparative evaluation, based on the established essentials, was then devised, and this was applied to the available designs to determine their relative merits and their chief deficiencies.
4. Concepts for improved designs were developed, incorporating essential features found lacking in available standard types.
5. Several leading manufacturers of seating were then contacted and advised of the improvements desired; they cooperated by providing prototype designs incorporating the desired improvements.

These steps are explained more fully throughout the remainder of this chapter.

B. SURVEY QUESTIONNAIRE ON SEATING

Many persons have recently concerned themselves with the problem of improved classroom seating for a variety of instructional situations. To tap this resource of recent experience, it was decided early in the study to conduct a survey of architects, administrators and college teachers to determine their reaction to specific points on seating. Of the 154 inquiries sent out, 97 prompted replies. A summation of the appropriate responses is presented in Figure 4, which also indicates the format of the questionnaire.

The primary result of the survey was the verification of seating problems; inadequacies and limitations that the project staff had experienced were verified by the survey findings, and it was towards solving these problems that attention was directed.

SURVEY QUESTIONNAIRE WITH
SYNOPSIS OF RESULTS

Study of Improved Seating..........School of Architecture..........Rensselaer Polytechnic Institute

1. With what type of seating for lecture halls have you had the most experience? (Please check X)

X	XX	FIXED
6	____	chair only
32	6	chair with tablet arm
29	4	theater-type (folding seat)
56	27	" " with tablet arm
9	3	pedestal type seat
23	7	" " " with tablet arm
41	30	seats behind continuous table tops
4	3	other (please specify): (Includes two fixed seats behind non-continuous counter top)

X	XX	MOVABLE
15	2	chair only
56	16	chair with tablet arm
14	3	chair with folding tablet arm
13	9	combination unit-seat and writing surface
7	2	other (please specify): (Includes loose table and chair).

2. Please double check (XX) the type you prefer in the list above.
Was this seating used with stepped, sloped or flat floors?
Stepped 42 Sloped 16 Flat 29

3. What are the major deficiencies you have experienced in lecture hall seating?

64	writing surface too small
35	seat uncomfortable
9	poor quality construction
21	seat too rigid and unyielding
34	poor aesthetic design
12	non-durable materials
11	mechanical defects
13	lack of range of styles and types
18	problems of maintenance (please specify):
23	improper critical dimensions (please specify):
28	poor spacing and arrangement of units (please specify):
7	other (please specify): Noisy; Lack of adjustment to fit varying body types.

4. Have you experienced a completely satisfactory seat? 21 Yes 58 No
If so, please specify type and manufacturer.
Including a table and chair, typist chair with table, and Experimental Classroom seating.

5. For a fixed seat, what method of fastening to the floor is best?
(No significance to responses)

6. What color and material do you prefer for writing surfaces?
General consensus was matte to semi-gloss, light colored, impervious, maintenance-free materials for surfaces.

7. In developing an improved seating unit and arrangement what do you feel are the primary considerations and needs? (Use back of sheet if necessary)

FIGURE 4

Of particular interest were the responses to the items of the survey which requested comments. A few of the more salient and typical responses follow:

On preferred seating types –

"Currently, we think the fixed table, with movable chairs offers the most varied use. Movable seats permit adjusting the seating to fit the size of the group. The noise of moving chairs on a hard floor has been criticized. We are now solving this by using carpets on the floor."

"My preference would be for continuous table tops which work well with continental seating arrangements and with a swivel chair, upholstered, tilt-back, noiseless, and at least as comfortable as the secretary chair in which I am sitting to write this. There should be room enough between the back of the chair and the table behind for single passage. With a little more space in this location, it might be possible to move in emergency seating for use when lectures other than teaching lectures are given."

On general criteria –

"For most schools, the ideal seat would combine low cost; good design and engineering, as well as good workmanship; easily cleaned . . . . provision for storing books must be considered."

"A completely satisfactory seat may not be possible unless the '**comfort versus alertness**' quality of the seat can be varied at will."

"Harsh details and materials seem out of place in a college lecture room. By 'harsh' I refer to excessively harsh, sharp and glaring surfaces, corners, and edges."

"Manufacturers must recognize the fact that the average student of today is considerably larger than he (or she) was 15-20 years ago."

"The angles of the three main planes (back, seat, and writing surface) with the horizontal are more important than the size of the planes."

"Seating should be designed to provide writing surfaces equally satisfactory to both right and left handed students; units should be affixed to the floor; writing surfaces should be readily adjustable both fore and aft, and up and down; seats should swivel to aid entry and egress; seats should be contoured and cushioned; and seating arrangements should allow the lecture room to be used effectively for testing."

"If we can free the number of legs going to the floor, we feel we can save maintenance money and provide a more aesthetically pleasing classroom."

"In developing improved seating units, I think one of our shortcomings is the ability of people to get up and leave the room without disturbing everyone else in a row."

"I have had an impression . . . that the manufacturers of such seating units are operating with insufficient knowledge of and sympathy with the people who sit in such seats . . . I am aware of the difficulties inherent in a situation where students are so uncomfortable that they are far more aware of their discomfort than they are of what is being taught."

On writing surfaces –

"We say a hard top, not too light in color, with a matte finish to avoid glare. A slightly darker shade than paper avoids contrast problems and discourages doodling."

"Recognize the fact that seating and writing surfaces perform very different functions. A satisfactory writing surface makes a very hard seat."

"The writing surface should permit the flat opening, with full support, of loose leaf binders and tablets."

On cost –
"Initial costs and even maintenance costs cannot be the first consideration for the seating in the very expensive lecture spaces that are provided today. The lecture halls will occupy the most prime spaces on the campus; very expensive equipment will often be provided to aid the teaching process. The seating should also be of the best."

C. CRITERIA FOR APPROPRIATE SEATING

The criteria for optimum seating for the "learning space" involves chiefly the following considerations:

1. **Functional Values** – Obviously the prime requirement of the seating is that it provide the best accommodations possible to encourage and facilitate the learning process; it must function with maximum efficiency and convenience. Specifically, its proper function depends upon these matters:

   a. **Writing Surface**
   The provision of a suitable writing surface is a basic essential, whether this surface be provided as a part of the seat structure itself or as a separate counter unit. **No designs without such provision have been considered.**

   The surface should be of ample size to facilitate note-taking concurrently with the use of reference materials. A surface area approximately 12" deep by 24" wide is considered to be desirable, and very few of the presently available designs were found to meet this standard. The material used for the surface must be hard, durable and easily cleaned, with a reflection value somewhat below that of white paper.

   b. **Book Storage**
   The seating unit should provide a conveniently accessible space off of the floor, in which four or five good-sized books may be stored during the class period. This may be an open wire basket or shelf; storage on the writing surface itself is not acceptable.

   c. **Comfort and Posture**
   It is generally agreed that the seat should be so designed as not to be uncomfortable, but that a degree of comfort encouraging relaxation is detrimental to mental alertness. For this reason, soft cushioning is not desirable.

   The seating should, however, provide such appropriate postural support that the occupant may comfortably view projected materials, watch the instructor, use reference materials or take notes without being required to repeatedly adjust his position. This multiple function becomes particularly critical in the front seats of the larger rooms, where screen surfaces are likely to be above the normal line of vision.

d. **Adjustability**
Dimensions and proportions of the seating unit will necessarily be based on the physical characteristics of the average occupant. It is important, however, that it also accommodate without discomfort those persons who are smaller or larger than the average individual. This applies particularly to the amount of leg and knee room provided, and the clearance dimension between the occupant and the writing surface. Ideally, the latter should be adjustable.

e. **Accessibility**
The seating should be readily accessible without the need to disturb the occupants of adjacent seats. Ideally, the necessity of rotating or lowering the seat or of manipulating the writing surface in order to make use of it, should be avoided.

2. **Structural Values** – Next in importance to the functional values of the seating unit is its ability to stand up well under use, as determined by the following characteristics:

   a. **Durability**
   Satisfactory long-time service obviously requires that the seating unit be of strong, rugged construction requiring a minimum amount of maintenance and repair. Surface materials and finishes should be highly resistant to damage by wear and scratching, and any attachments to the floor should be sturdy enough to meet all normal requirements of use, and even misuse, without loosening or deteriorating.

   b. **Simplicity of Construction**
   The design should involve no intricate or delicate mechanisms, and should have a minimum of moving parts which may be subject to malfunction or require periodic replacement.

3. **Ease of Cleaning** – Maintenance requirements are an increasingly important consideration in all educational facilities, and must, of course, be considered in the design of seating units. This requires that:

   a. Units should be so supported as to cause minimum interference with the cleaning of floors, and
   b. All surfaces of the unit itself should be readily cleanable with a minimum of time and effort.

4. **Economy of Space** – Seating units should be readily adaptable to arrangements which will provide both optimum viewing and easy access and egress, within a minimum of required floor space. The floor space per occupant in standard seating arrangement, and exclusive of normal aisle requirements, should not exceed 6 or 7 square feet.

5. **Appearance** – The esthetic design of the seating unit should, of course, be attractive, clean and uncluttered, and should be compatible in color and textures with the sophisticated, contemporary character typical of the learning spaces themselves.

6. **Cost** – Certainly not least in importance is the consideration of the cost involved. Frequently, the question of economy may carry undue weight in the selection of seating; very rarely can it be ignored. To be compatible with typical budgetary standards, the installed cost per unit should not exceed $30.

D. ANALYSIS OF AVAILABLE TYPES

Drawing upon the literature of the leading manufacturers of seating, as well as upon information gathered concerning recent installations of seating in rooms of this general character, diagrams were prepared illustrating the typical characteristics of seven different applicable types of seating presently available. These diagrams are presented in Figure 5 following.

Several of the design types shown on these data sheets are available from only one source, and for these the dimensions shown are those established for that design by the manufacturer. In many cases, however, the design is available from several different manufacturers, and for these types, typical dimensions are indicated. The standard tablet-arm chair has not been included among the designs tabulated because it is not considered appropriate for use on either stepped or sloping floors.

E. A METHOD FOR RATING SEATING

The essential requirements of appropriate seating having been defined, a method was devised for evaluating design types or specific designs in respect to these criteria. This involved determining the relative importance of the various requirements and assigning to each of them a numerical value proportional to its significance. Thus, a comparative "score" for each type or design being considered could be computed.

Several variations of the system have been used in this study depending on the nature of the designs being evaluated, as will be explained. Basically, however, the rating takes into account those essentials previously discussed, with point values for each, as follows:

FUNCTIONAL VALUES		34 points
Writing Surface	14	
Book Storage	5	
Adjustability	6	
Accessibility	9	
STRUCTURAL VALUES		22 points
Durability	12	
Mechanical Simplicity	10	
EASE OF CLEANING		12 points
Cleaning of Floor	7	
Cleaning of Seating Unit	5	
ECONOMY OF SPACE		10 points
APPEARANCE		10 points
COST		12 points
	Total	100 points

The relative values assigned to these items are, of course, debatable. Those shown here reflect the best judgement of the authors after considerable study of numerous alternatives; within the same general framework, other values may be substituted, if preferred. In any case, such a device for comprehensive comparisons should be useful in evaluating any proposed designs.

Before illustrating the application of the rating method, several matters pertaining to its use should be explained:

a. The method is chiefly useful for comparative ratings, since it is difficult to "score" any one design in respect to the theoretical ideal. In judging a specific design, however, it provides a check list of essential characteristics.

b. It may be illogical in some cases to attempt to establish scores for all of the qualities listed. Hence, certain items may be disregarded and the "perfect score" is reduced accordingly. This procedure might be followed, for instance, in comparing the inherent values of generic design types rather than specific designs, or when the esthetic details of the design have not yet been determined.

c. For some of the qualities listed, it is illogical to assign a minimum score of zero, while for other qualities, a zero rating may be an appropriate minimum. In connection with the following explanation of the "Basis for Rating" the minimum recommended score considered appropriate in each case is indicated.

Basis for Rating

In accord with the previously discussed qualifications of good seating design, the basis on which scoring was computed for each quality were defined as follows:

Writing Surface – Credit size and convenient location of the surface provided. In comparing **specific** designs, the surfacing material also should be considered

Maximum score: 14 points (consider 12 x 24 inches as an optimum size)
Minimum scores: 6 points if any usuable surface is provided
0 points if no writing space at all

Book Storage – Credit provision for adequate and convenient space in addition to writing surface.

Maximum score: 5 points
Minimum scores: 2 points if any usuable space is provided
0 points if none provided

Adjustability – Credit provision for adjusting distance between writing space and seat, and seat and floor, and adequacy of leg and knee-room.

Maximum score: 6 points
Minimum scores: 3 points if ample leg-and knee-room but no adjustability
0 points if very cramped and no adjustability

FIGURE 5

DIAGRAMS OF AVAILABLE SEATING TYPES . . . . .

1 Fixed Seat: Movable Tablet Arm

2 Theater Seat: Drop Tablet Arm

3 Theater Seat: Drop Counter

4 Continuous Counter: Pivoted Seat

5 Continuous Counter: Loose Chairs

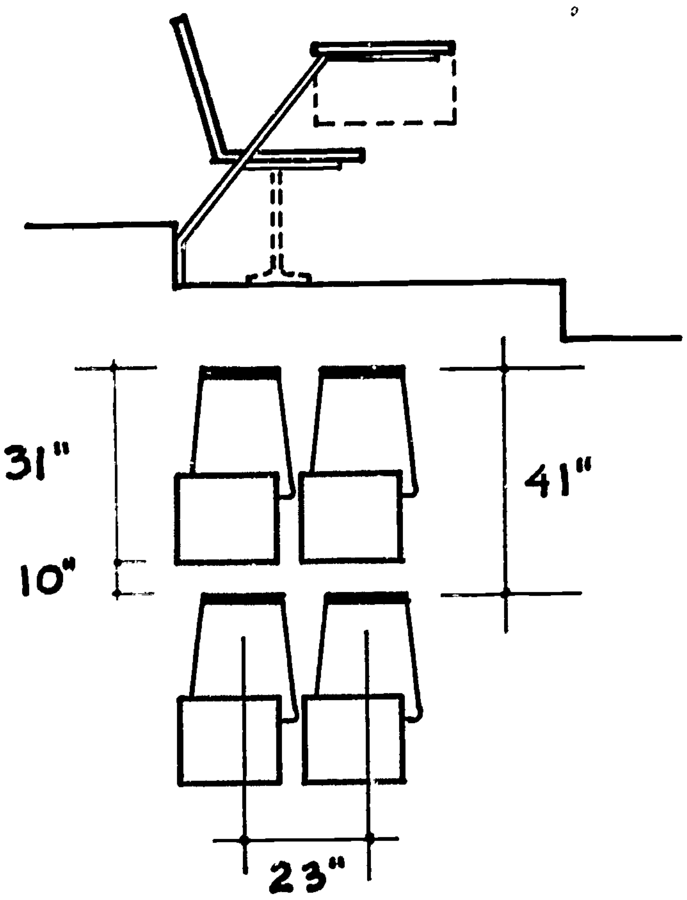
6 Two-Man Counter: Adj. Pivoted Seats

7 Seat-back Counter: Folding Seat

W.S.A. - WRITING SURFACE AREA
F.A - FLOOR AREA

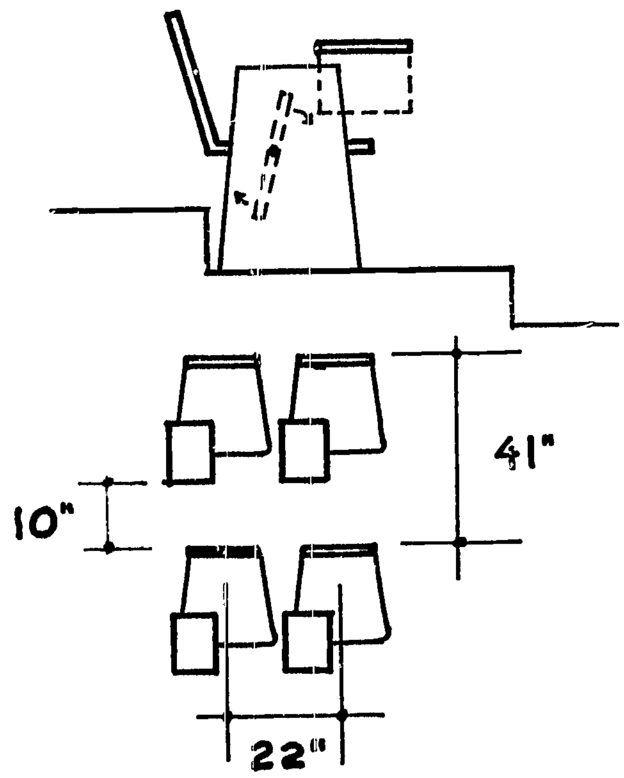
W.S.A.- 259□
F.A. 6.5□

1



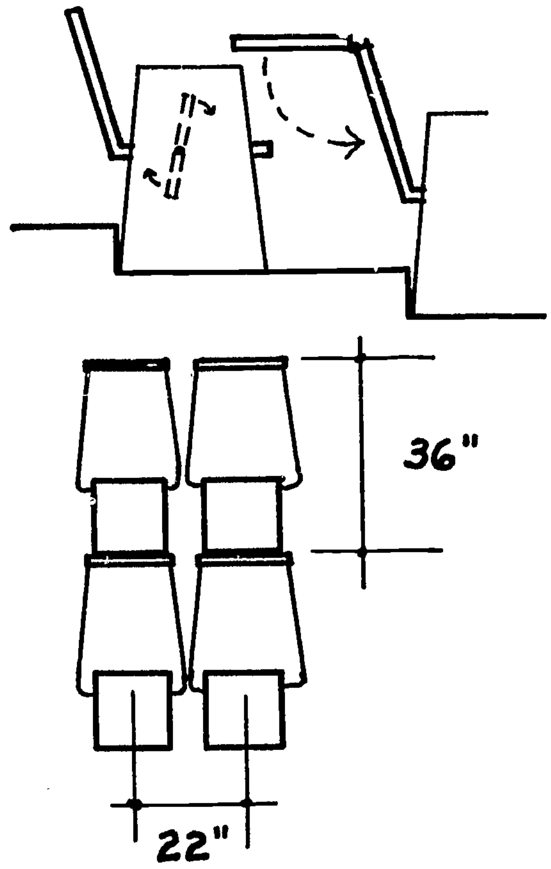
W.S.A. 98□
F.A. 6.3□

2



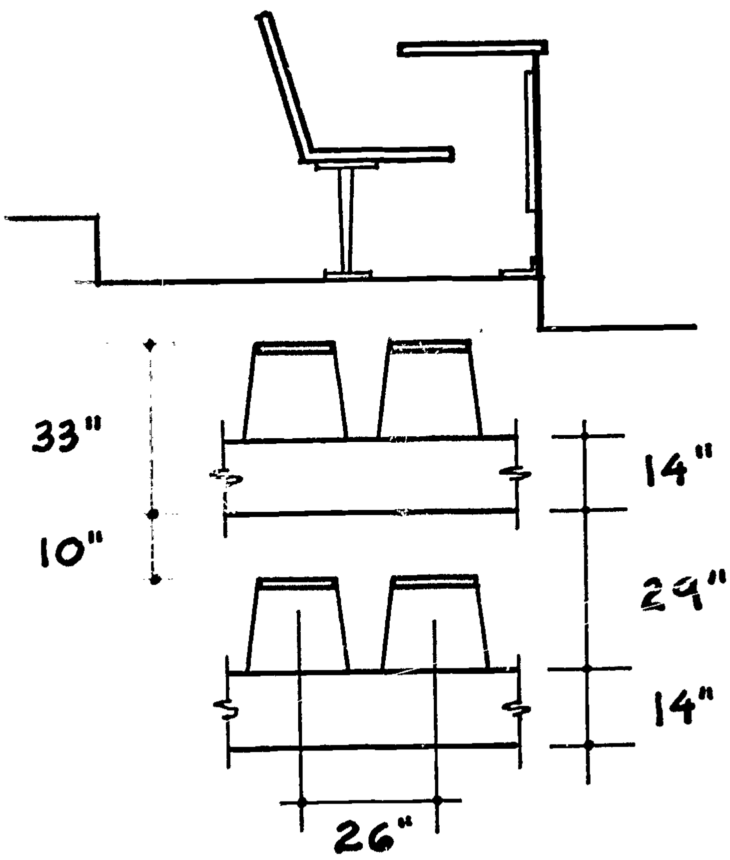
W.S.A. 210□
F.A. 5.5□

3



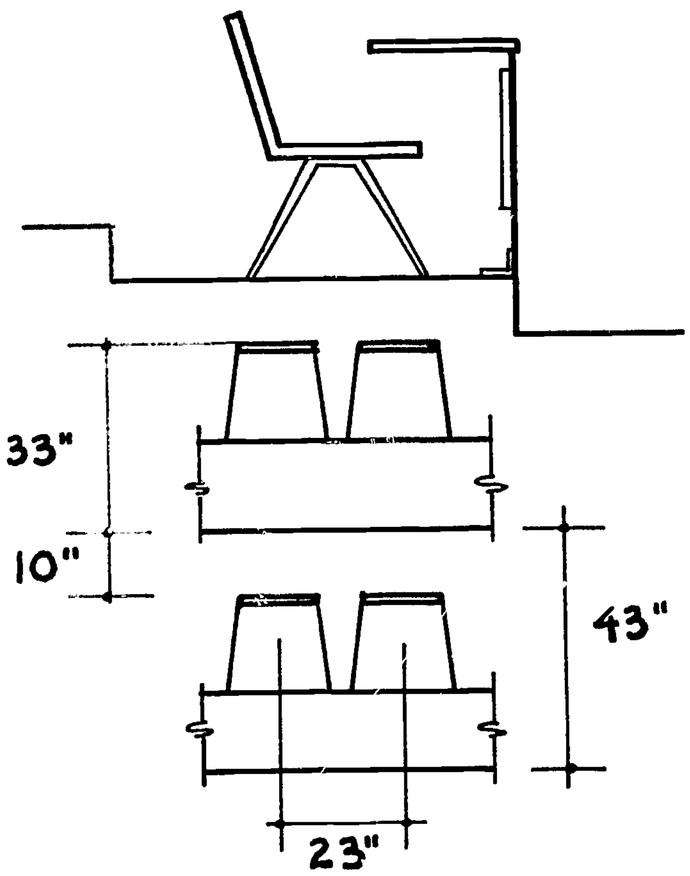
4

W.S.A. 364
F.A. 7.7



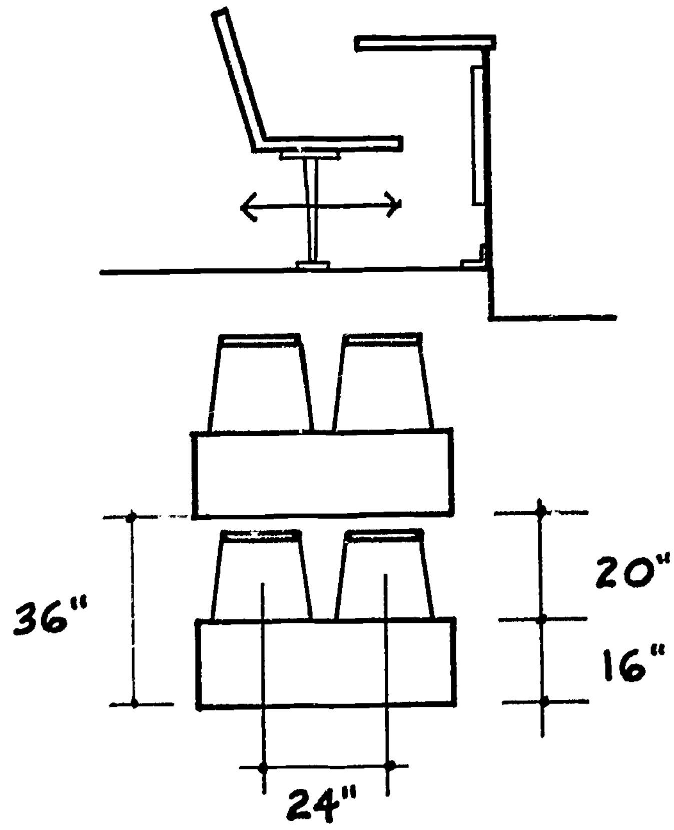
5

W.S.A. 322
F.A. 6.8



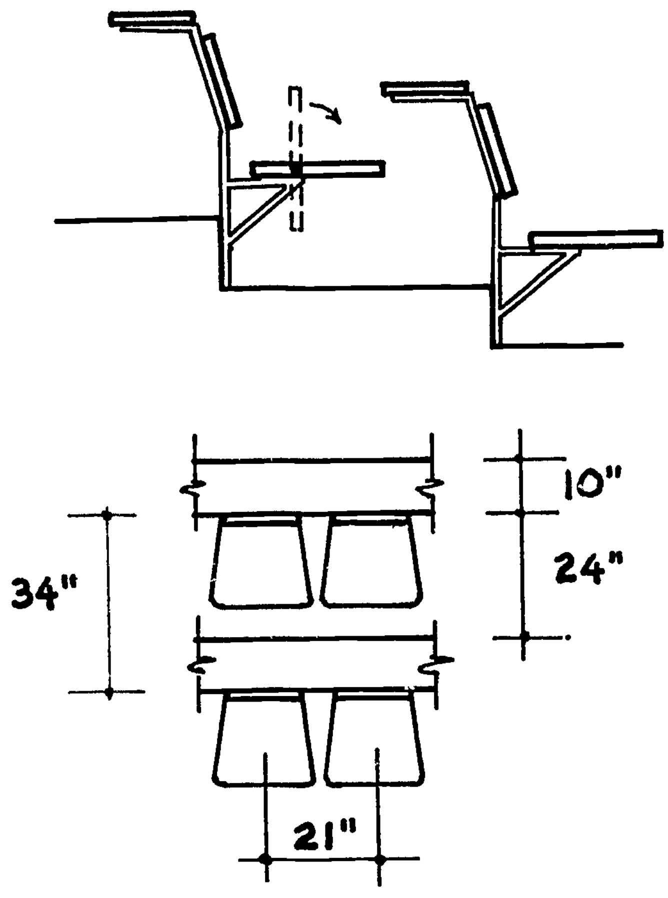
6

W.S.A. 384
F.A. 8.1



7

W.S.A. 210
F.A. 4.95



SEATING

Accessibility – Credit ease with which person can occupy and vacate seat and use writing surface without disturbing neighbors. Since no seat is wholly inaccessible, a zero score is not justifiable.

Maximum score: 9 points
Minimum score: 3 points

Durability – Credit inherent strength and ruggedness of design, and sturdiness of floor attachment(s), if any, as well as invulnerability to physical damage. No design will be considered which is totally lacking in these values.

Maximum score: 12 points
Minimum score: 4 points

Mechanical Simplicity – Credit **lack** of complex mechanisms and/or moving parts which may increase repair and maintenance costs.

Maximum score: 10 points
Minimum score: 3 points

Ease of Cleaning Floor – Credit minimum interference of supports or attachments (of **total** unit) with floor cleaning. Since minimum interference is caused by a single smooth round contact, this type should be given maximum credit .

Maximum score: 7 points
Minimum score: 0 points, for continuous irregular floor contact or insufficient clearance for cleaning.

Ease of Cleaning Total Unit – Credit minimum time and effort required for cleaning seat **and** writing surface.

Maximum score: 5 points
Minimum score: 2 points

Economy of Space – Credit smallness of floor space required per unit, assuming standard seating arrangement, 14 seats per row, and including an allowance for standard aisle space requirements.

Maximum score: 10 points
Minimum score: 4 points

Appearance – Necessarily a matter of opinion, but credit cleanness and attractiveness of design character.

Cost – Credit economy of **installed** cost per unit.

Maximum score: 12 points
Minimum scores: 5 points, if not above normal range
0 points, if exorbitant

Rating of Available Seating Types: Conclusions

The rating method previously described was applied to the seven available seating types in order to determine:

a. which of these types comes closest to satisfying the requirements of good seating, and
b. what are the chief deficiencies of the various types.

It should be noted, that because generic types rather than specific designs were being rated, values could not be assigned to three of the eleven rating factors – durability, appearance and cost – and because it was felt that the provision of book storage space had generally not been considered in their design, but **could** be provided for any of them, this factor, too, was not scored. The maximum possible score was thus reduced from 100 to 61.

The results of this rating are shown in Figure 6. It will be noted that the generic type receiving the highest score is the combination of a continuous writing counter and movable chairs, which provides an ample writing surface, as well as maximum adjustability and mechanical simplicity. It is likely that if cost and durability had also been taken into consideration, this type of seating would still score high.

Next in value, by this rating, are the two-man counter unit with adjustable pivoted seat, the continuous counter with fixed pivoted seat, and the fixed seat with movable tablet area. Examination of the scoring breakdown, however, shows that a principal factor accounting for the good rating of the continuous counter types (Designs 4, 5 and 6) is the high score given because of the size of the writing surface they provide. If Design No. 1 provided a larger surface for writing, it would easily rate second.

F. IMPROVED DESIGNS

To our knowledge, there are no standard continuous counter units currently being offered by manufacturers, present installations of this type having been custom made. It would not be difficult, however, to design a modular unit of this type for production, and if demand warrants, manufacturers should certainly be interested in adding such units to their lines. The chairs to be used in connection with these counters may be any of several standard sturdy types, with the addition of a suitable book storage basket or shelf.

Because of the demonstrated potential merits of the fixed seat with movable tablet arm (Type No. 1), and the fact that currently available designs of this type fail to provide adequate writing space, the representatives of several seating manufacturers were contacted, suggesting that their companies might be interested in developing improved designs. This suggestion met with favor, and the companies have cooperated most effectively. As a result, several new designs of this type have been developed, prototype models have been made, and the manufacturers have become sufficiently convinced of their merit to put these designs into production. A photograph and drawings of one of these prototype models are shown in Figure 7.

G. SEATING LAYOUTS

Based on the improved seating type (fixed seat, movable tablet arm) which appears to have the most potential and which was illustrated in Figure 7, seating layouts were developed. Since the State University programs "learning space" – type facilities in capacity ranges of 60, 120,

RATING CHART OF AVAILABLE SEATING TYPES

Factor	Points Max.	Points Min.	SEATING TYPES 1	2	3	4	5	6	7
W. S. *			259	98	210	364	322	384	210
F. A. **			615	6.3	5.5	7.7	6.8	8.1	4.95
			Fixed Seat; Movable Tablet Arm	Theater Seat; Drop Tablet Arm	Theater Seat; Drop Counter	Continuous Counter; Pivoted Seat	Continuous Counter; Loose Chairs	Two-man Counter; Adj. Pivoted Seats	Seat Back Counter; Folding Seat
1. WRITING SURFACE	14	6/0	8	6	7	14	14	14	7
2. BOOK STORAGE	5	2/0				not rated			
3. ADJUSTABILITY	6	3/0	3	3	3	3	6	5	3
4. ACCESSIBILITY	9	3	8	4	3	7	7	9	5
5. DURABILITY	12	4				not rated			
6. MECHANICAL SIMPLICITY	10	3	7	3	3	8	10	4	5
7. EASE OF CLEANING FLOOR	7	0	7	3	3	4	6	4	4
8. EASE OF CLEANING UNIT	5	2	4	2	2	5	3	5	3
9. ECONOMY OF SPACE	10	4	7	8	9	5	6	4	10
10. APPEARANCE	10	4				not rated			
11. COST	12	5/0				not rated			
TOTAL SCORE			44	29	30	46	52	45	37

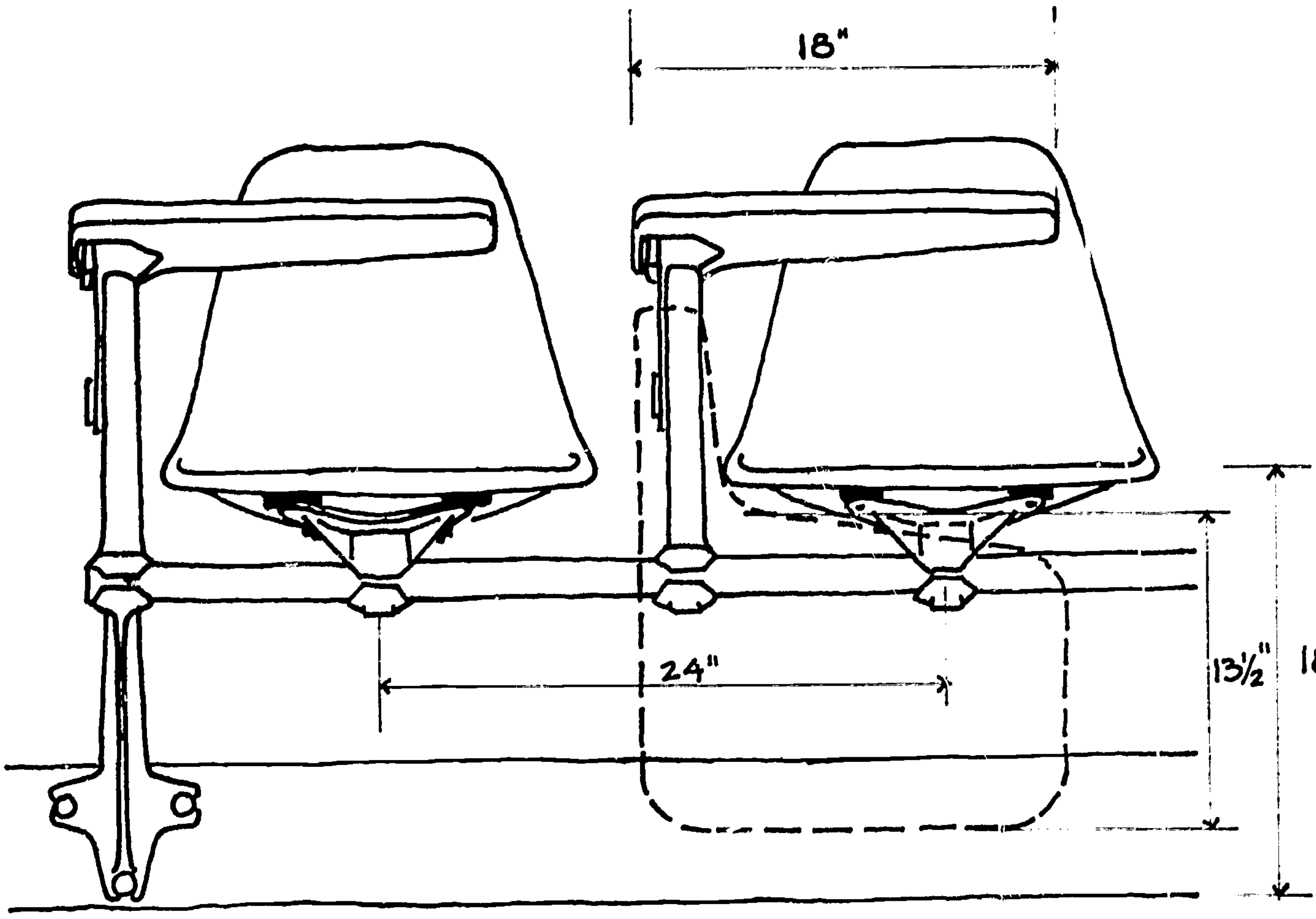
NOTES:

* W. S. – Writing Surface
Area of writing surface in square inches (typical).

** F. A. – Floor Area
Floor area in square feet occupied by each unit (typical).

FIGURE 6

IMPROVED DESIGN



DESIGN DEVELOPED BY
HERMAN MILLER INC.
ZEELAND, MICHIGAN.

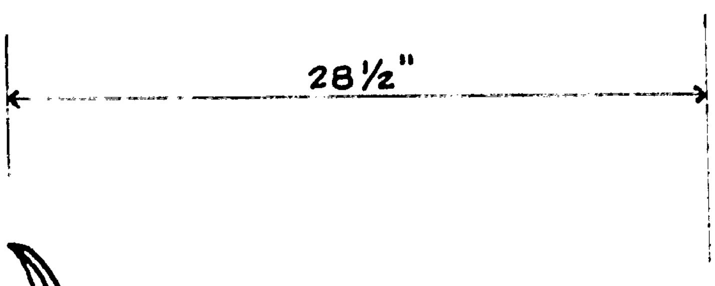
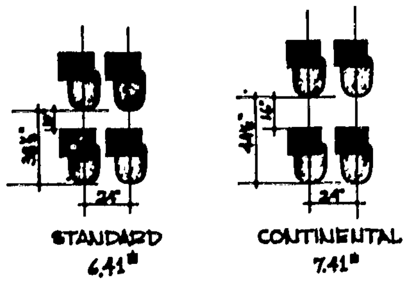
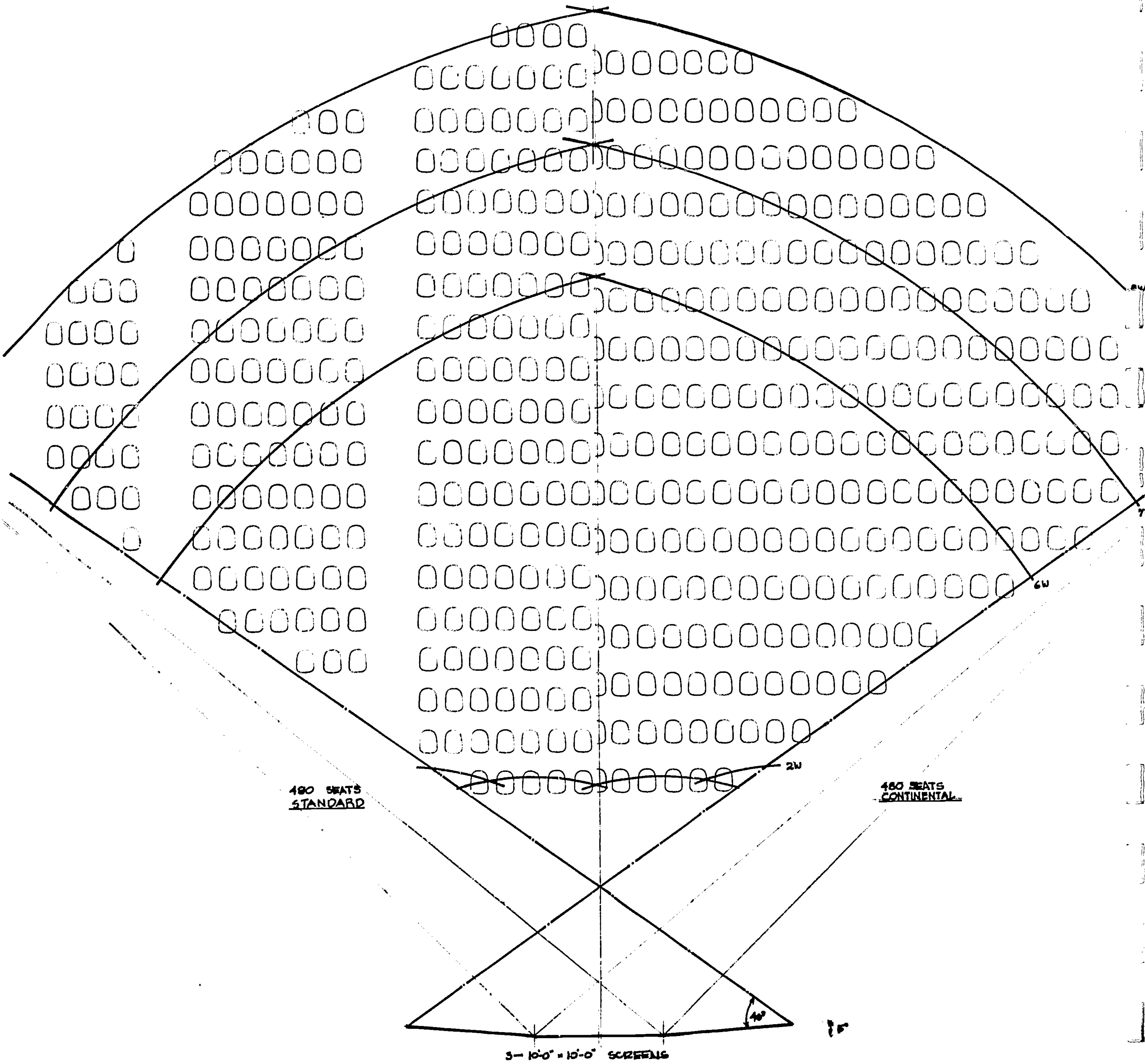


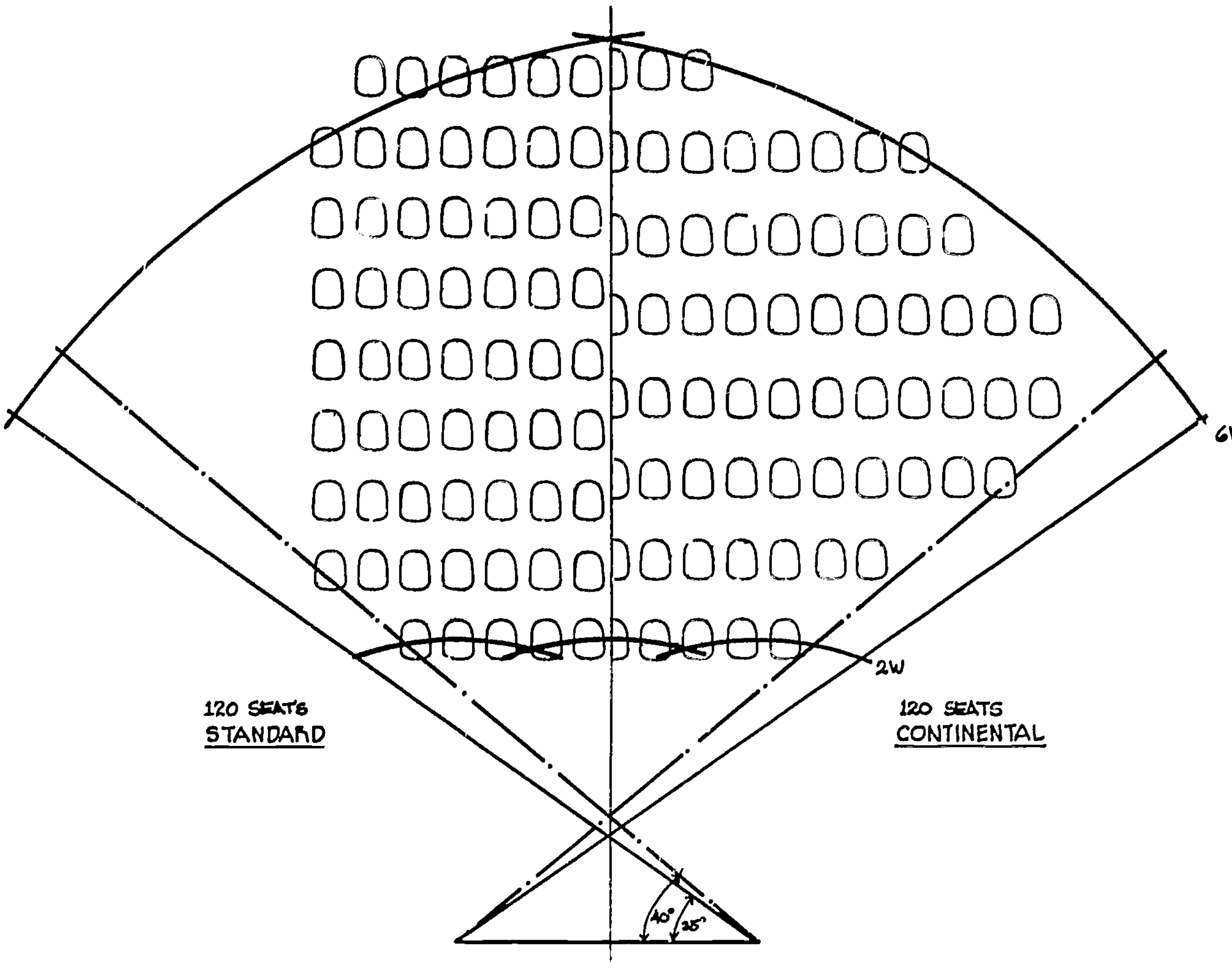
FIGURE 7

FIGURE 8

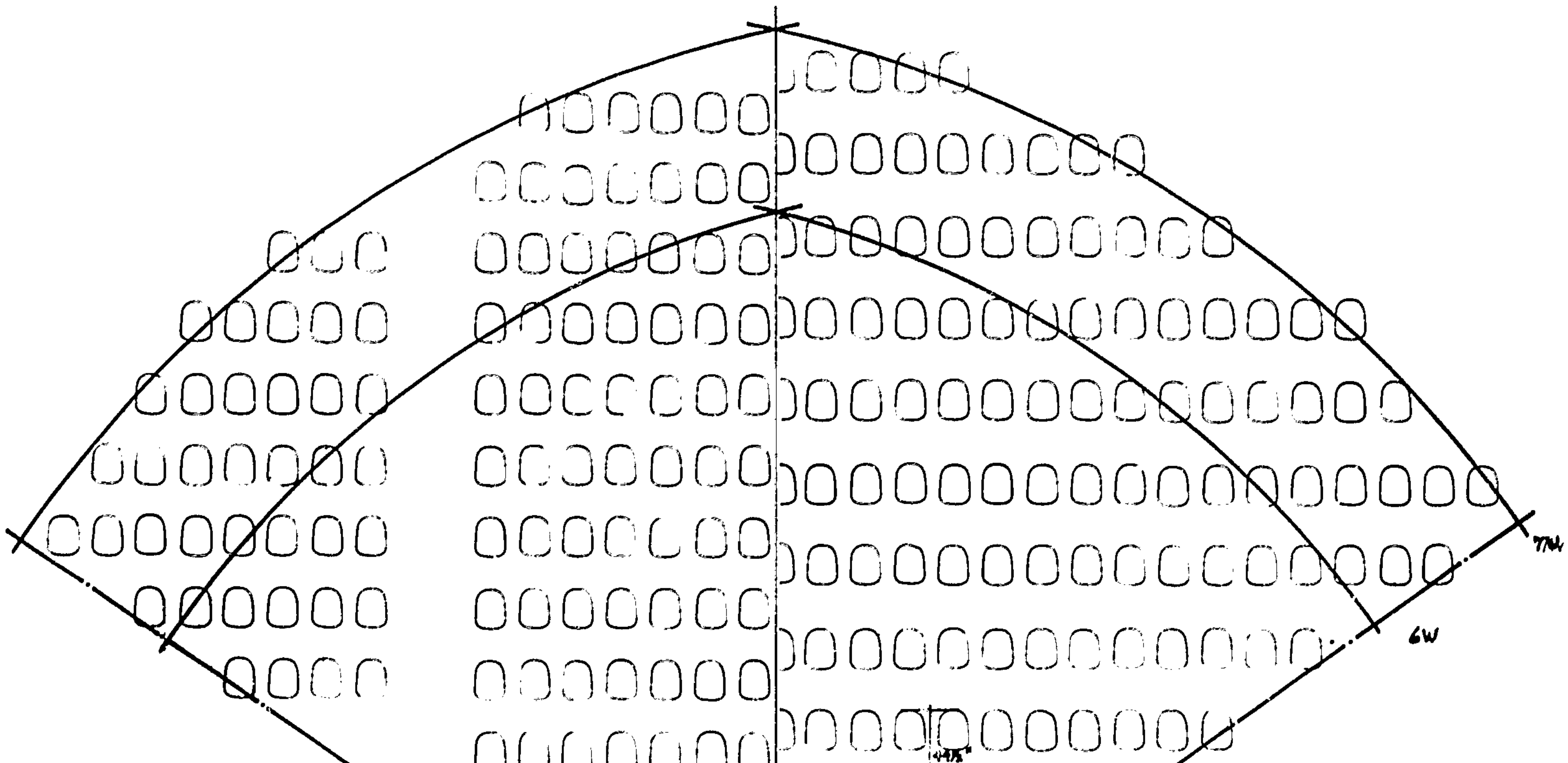


COMPARATIVE SEATING LAYOUTS





2–7'0" × 7'0" SCREENS



3 — 8'0" × 8'0" SCREENS

240, 360 and 480 students, it seemed logical to illustrate the seating layouts using several of the same programmed capacities. Therefore, the seating layouts in Figure 8 include illustrations of:

120 capacity space – fixed seat, movable tablet arm
(standard arrangeme

– fixed seat, movabl arm
(continental arra

240 capacity space – fixed seat, movable tablet arm
(standard arrangement)

– fixed seat, movable tablet arm
(continental arrangement)

480 capacity space – fixed seat, movable tablet arm
(standard arrangement)

– fixed seat, movable tablet arm
(continental arrangement)

The notes accompanying the layouts indicate the spacing dimensions used, and are based on appropriate viewing areas for two screens (120 capacity) and three screens (240 and 480 capacities.) Obviously, at the discretion of the individual designer, the seats can be arranged in curved or slanted rows.

Chapter IV – LIGHTING

A. GENERAL REQUIREMENTS

Next in importance to optimum viewing conditions, properly designed lighting is probably the most essential requirement in the learning spaces. Working closely with lighting specialists, in this and other related projects, certain specific lighting criteria have been established. These criteria must be given careful consideration in designing the room, if a satisfactory environment for learning is to be provided. The principal considerations involved are the following:

a. Three types of lighting are needed in these "learning spaces" to properly illuminate the three principal visual surfaces –

1. **The students' writing (desk-top) surfaces**
   Regardless of what projection or instructional methods are being used, enough light must fall on the student's writing surface at all times to permit note-taking and reference to printed materials. This can be accomplished with levels as low as 4-8 foot candles. At the same time, the amount of light reflected from notebooks and papers placed on the desk surface (or this surface itself) should be essentially as bright as any other visual task surfaces such as the projection screens, chalkboards or tackboards. Obviously, the brightness of the projection screens will vary due to differences in screen types, lumens output of projectors, type of projected material, reflectance of surfaces, and other factors. Consequently, the source of illumination for these writing surfaces should be capable of varying levels of light output. Probably a minimum of three levels should be provided.

   The light falling on the writing surface should not produce shadows, and the seated student should not be conscious of luminaires within his normal line of vision. Moreover, the light should be so directed that it doesn't illuminate the front of the room where projection surfaces are located. Ambient light falling on projection screens causes serious problems by "washing out" projected images, and lighting located in this part of the room must be prevented from spilling on the screen surfaces.

2. **Non-projected teaching surfaces**
   Chalkboards, tackboards, demonstration areas, and the instructor himself must be illuminated at various times during the instructional process. This lighting should also be capable of varying levels compatible with the simultaneous use of projected materials.

3. **The visual surround**
   The wall surfaces within the student's vision should be so washed with light that they appear neither brighter than the task surfaces nor less than one-third as bright. These surfaces include the tackboards, chalkboards, and even the projection screens when they are not in use. It's very important, also, that no highly reflective or bright colored trim, fixtures or decorative details be used where they will be conspicuous, distractive elements in the area of vision.

b. The lighting system or systems should be readily controlled by the instructor or automatically controlled in conjunction with the projection equipment itself. The instructor should be able to control only the pre-set levels of illumination to be used, and should not be able to adjust or manipulate the lighting during the instruction period, to suit his own preferences.

c. In the interest of economy, the use of elaborate and expensive dimmers, custom fixtures and costly controls should be avoided.

B. EXPERIMENTAL CLASSROOM LIGHTING

As illustrated in Figure 9, the lighting system installed on a trial basis in the Experimental Classroom consisted of 150-watt incandescent recessed ceiling down-lights to illuminate the writing surfaces, a series of recessed accent spots at the front of the room to light the teaching surfaces and instructor, and a band of 60-watt Lumiline lamps high on the sidewalls, behind a fascia, to wash the walls with light. The whole system is controlled by dimmers, with the lighting or levels being pre-set and tied in with the project controls, the master control switches being located on the instructor's lectern. As will be explained, this system has been found to have certain inherent faults.

Brightness levels have been measured on various surfaces in the room during the use of both rear and front projection, and the values recorded are shown in the chart of Figure 10. The differences in tolerable surface brightnesses is particularly noteworthy. For example, when the colored 2 x 2 slide was shown by **rear** projection, the preferred level of illumination in the room produced surface brightnesses of about 8 foot lamberts on the writing surface and 4 foot lamberts on the side walls, with a screen brightness of 4 to 9 foot lamberts. These values are consistent with the criteria noted previously. However, when the same slide was shown by **front** projection, the screen brightness became 3 to 6 foot lamberts, the brightness of the writing surfaces was 4.5 foot lamberts, and the wall brightness was reduced to only .5 foot lamberts. This reduction of wall surface brightness was necessary to prevent washing out of the projected image, since the wall light is nondirectional and spills on the screen at higher levels. This illustrates one of the important advantages of rear projection, and points up one of the chief problems in lighting design.

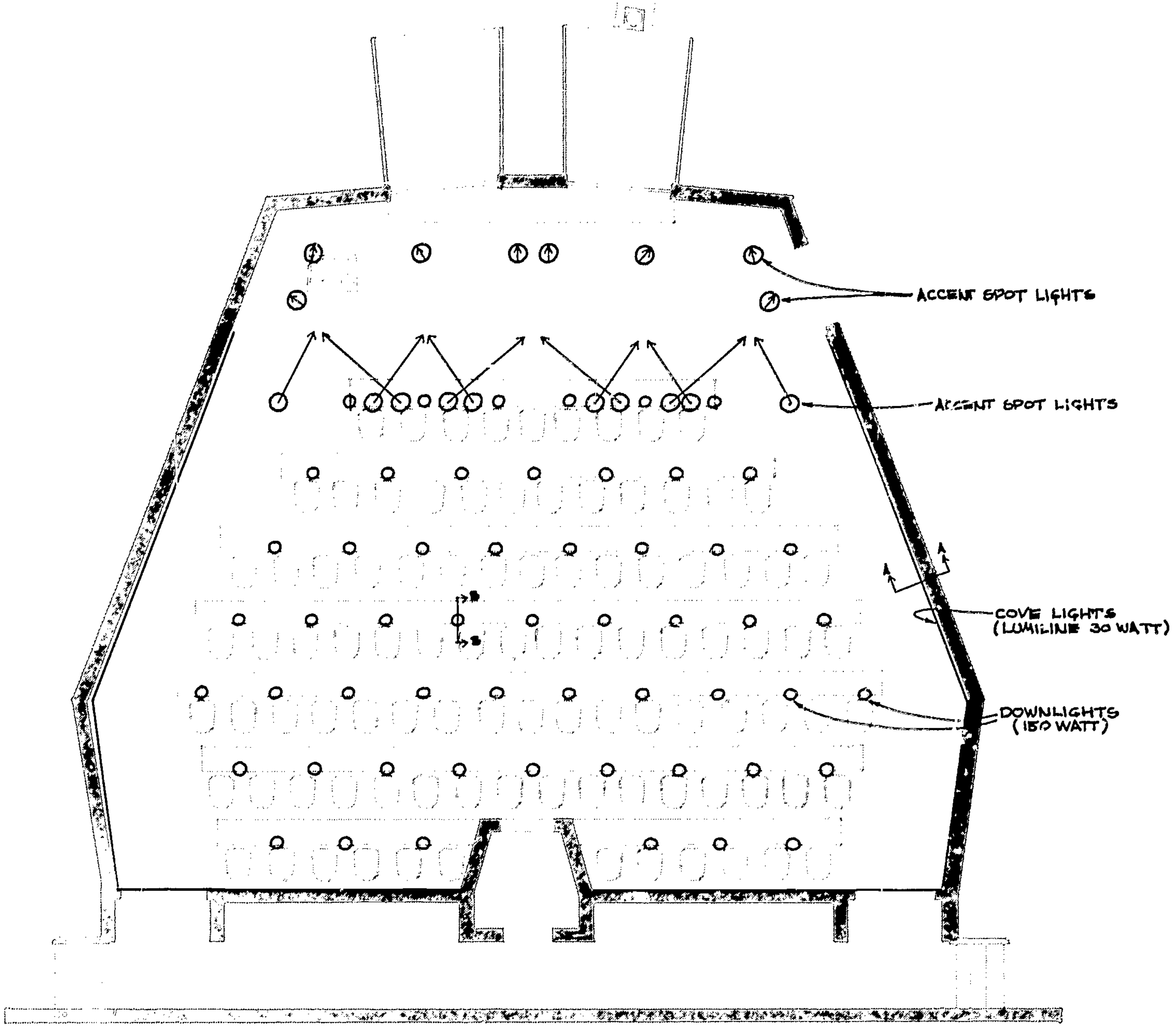
C. CRITIQUE OF THE EXPERIMENTAL CLASSROOM SYSTEM

Although this experimental lighting system has been generally satisfactory, it has been found to have certain objectionable features and, because of the complex dimmer system involved, is thought to be unnecessarily expensive. To substantiate this opinion, a qualified lighting consultant was engaged to review the installation in detail and provide an unbiased objective evaluation. Upon completing his inspection of the existing Experimental Classroom system, E. M. Strong, Professor of Electrical Engineering, Cornell University, submitted the following report:

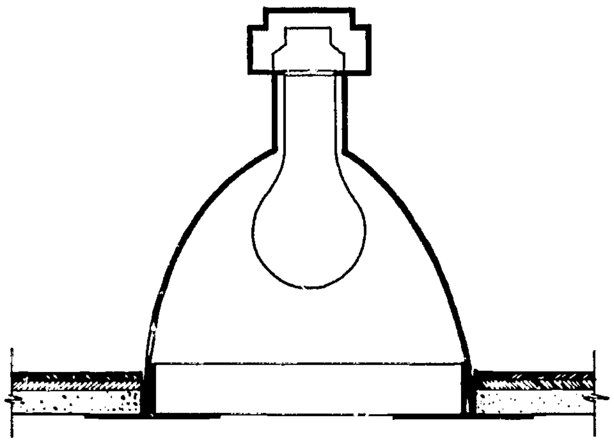
"1. The intent to balance the brightness of the note-taking task at the desk with that of any visual task present at the front of the room (chalkboard, projection screen, etc.) is commendable. Someone noted correctly that the purpose is to avoid a succession of readaptations otherwise required of the eye in looking repeatedly from one task to another.

2. The depolished, high-reflectance, desk tops in the room are more desirable than the quite dark gloss varnish surfaces of earlier practice. It is to be noted, however, that the bright-

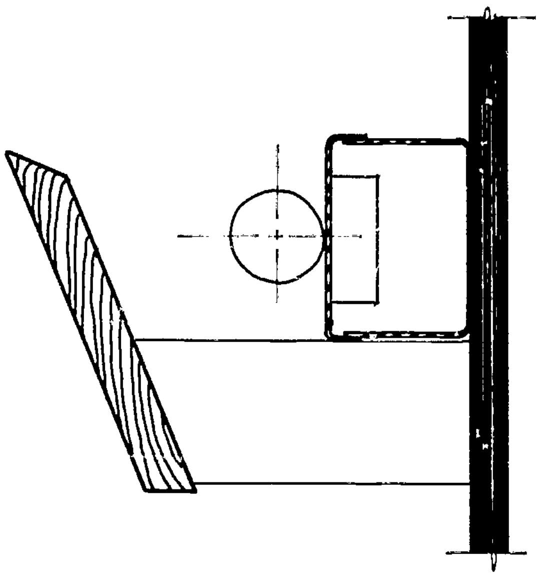
EXISTING LIGHTING SYSTEM



PLAN



DETAIL A-A



DETAIL B-B

FIGURE 9

CHART OF SURFACE BRIGHTNESSES (Foot Lamberts)

Location → / Type of Image ↓	Rear Projection				Front Projection				Monitor TV (Black and White)		
	Left Screen	Right Screen	Table Top (3rd row center)	Side Wall (3 ft. above floor)	Left Screen	Right Screen	Table Top (3rd row center)	Side Wall (3 ft. above floor)	Monitor	Table Top (3rd row center)	Side Wall (3 ft. above floor)
Projected Television (black & white)		.5 to 1.1	1.4	.6	.4 to 1.0		.6	[1]	10 to 20	14.0	7.0
35 mm Slide (colored)	4.0 to 9.0		8.0	4.0	3.0 to 6.0		4.5	[2] .5			
35 mm Slide (black & white)	5.0 to 10.0		8.0	4.0	.3 to 3.0		.8	[1]			
16 mm Film (colored)	2.5 to 8		5.5	2.0	.5 to 5.0		2.0	[2] .2			
Overhead Protector (colored diagram)		Not Applicable			8.0 to 16		15	5.2			

Equipment Types:

Screens: Rear Projection – Glass Polacoat (¼")
Front " – Matte White

Projectors: 35 mm-Kodak Carousel
16 mm-Kodak Pageant
Overhead-Bessler
Television-Telebeam

Notes:

1. Reading too low to be read.
2. Side-wall lighting turned off to prevent ambient light from washing out images.

FIGURE 10

ness of the visual task should **not** be "topped" by any other brightness in the visual field — the eye tends to look toward the brightest area in view. For this reason, I would suggest reducing the reflectance of these surfaces to a value as low as 50%. They now seem even higher than white note paper which seldom exceeds 80 to 85%.

3. The choice of down-lights for the main lighting of the room at first appeals because they —

   a. Have low installed cost.
   b. Are easily dimmed (in principle.)
   c. Easily avoid unwanted light on a projection screen.
   d. Introduce a minimum element of hardware in decor of room.

   For visual tasks of a classroom, however, such lights have serious faults as follows:

   a. Harsh shadows.
   b. Very bad reflected glare.
   c. Low efficiency, especially when operated at the lower (dimmed) voltages.
   d. Heavy air-conditioning load, aggravated by direct radiation heating of seat occupants.
   e. Short life (incandescent) lamps in locations not readily accessible.

   The reflected glare (item b) is known from recent researches to seriously reduce the visibility of reading tasks even for matte instead of gloss surfaced papers. It is not, therefore, a simple annoyance item but has the effect of an **equivalent reduction in light on the task.**

4. It was noted that the supplementary wall lighting produced a double band of objectionably high brightness on the wall close to the light source. This was accentuated by the opaque strip or moulding used to prevent direct view of the luminous lamps. Yet, it was agreed that the room lacked character when tried without this supplement. The need, however, is peculiar to the down-lighting system which, unlike other systems, inherently confines light to the horizontal work surfaces. Other means of providing "Interest" or character to the room were considered such as wall texture, color, etc., that would suffice if another system of general lighting were chosen.

5. The back-projection screen, when unused, was objectionably dark. Correction by providing some light from the back during no-use intervals seemed feasible — also, the possibility of providing a curtain (automatic) for longer no-use periods was noted. Objectionable dark border-bands when the projected image did not fill the screen were observed but means for correction were evident.

6. Other general lighting systems were discussed in terms of the following objectives:

   a. Avoidance of too much light on projection screen, especially if a front-view screen is to be used.
   b. Low reflected glare.
   c. Provision of three fixed levels by switching:
      1. Fixed dimmer settings.
      2. Numbers of lamps (preferably.)
   d. Reasonable installed and operating costs.
   e. Coordination with acoustic requirements.
   f. Coordination with temperature and ventilation requirements.

Equipment using fluorescent instead of incandescent lamps is mandatory to achieve at least items d and f. This stands up even should a choice of dimming equipment (c. 1) prove desirable. It was observed that in striving for a visually comfortable and functional balance of brightness in the room, the bland environment that uniform, unvarying, brightness would create is to be avoided. The principles of good lighting do not properly lead to this extreme in order to achieve a most desirable result.

7. Luminous ceilings were given much attention as potential for meeting objectives in 6 above. They offer advantages in flexibility more favorable to control of light levels by lamp switching (c. 2) than other existing systems provide. All other goals in item 6 seem possible excepting maybe (a), especially if front projection is necessary. It was noted that a great variety of panel materials is now available in louvered and solid forms. Appraisal and selection from these will be needed to obtain the best for meeting the requirements.

8. A new design of lighting fixture was described (in principle) that should provide very low reflected glare. Whether it might prove better than a luminous ceiling in meeting all the requirements here was not pursued at length.

9. Chalkboards were discussed to note that:

   a. low reflectance is necessary to provide acceptable chalk contrast.
   b. high illumination is required to obtain adequate brightness.
   c. precise distribution of light for uniform board coverage is needed.

Apart from lighting, the need for chalkboards at all in the classroom was questioned in favor of projection substitutes. Some of us expressed doubt that chalk would readily obsolesce."

A number of the points of deficiency suggested in Professor Strong's report have become increasingly evident as the Classroom has been used for instruction, and have given impetus to the development of the improved system discussed in D. The photographs in Figure 11 further illustrate several of the problems inherent in the present lighting system, namely the dark band caused by the cove lights, the multiple shadows cast on the writing surfaces by the down-lights, and the scalloped effect created by the accent lights on the chalkboards and tackboards.

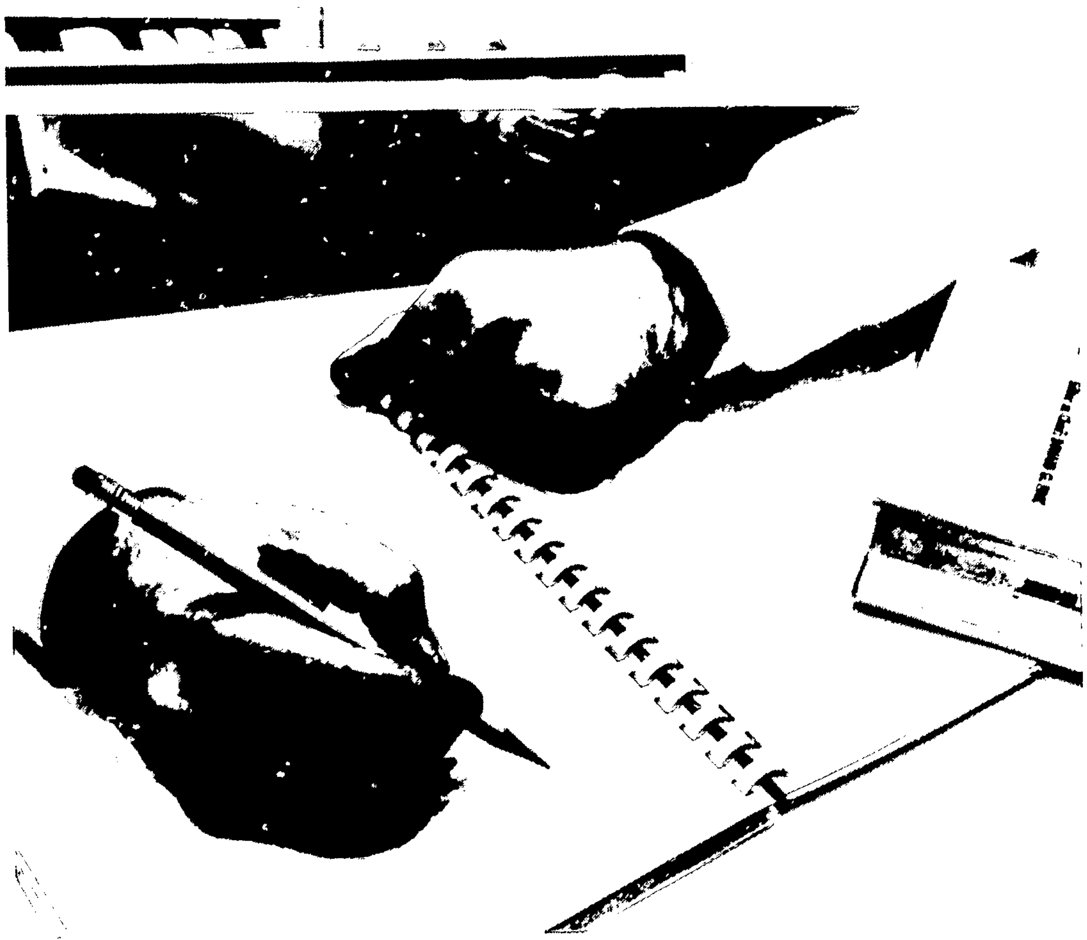
Although the existing system met the lighting criteria established at the time the Experimental Classroom was developed, it is obvious further improvements and refinements are required. The proposed improved system was developed to meet this need.

D. DEVELOPMENT OF IMPROVED LIGHTING SYSTEM

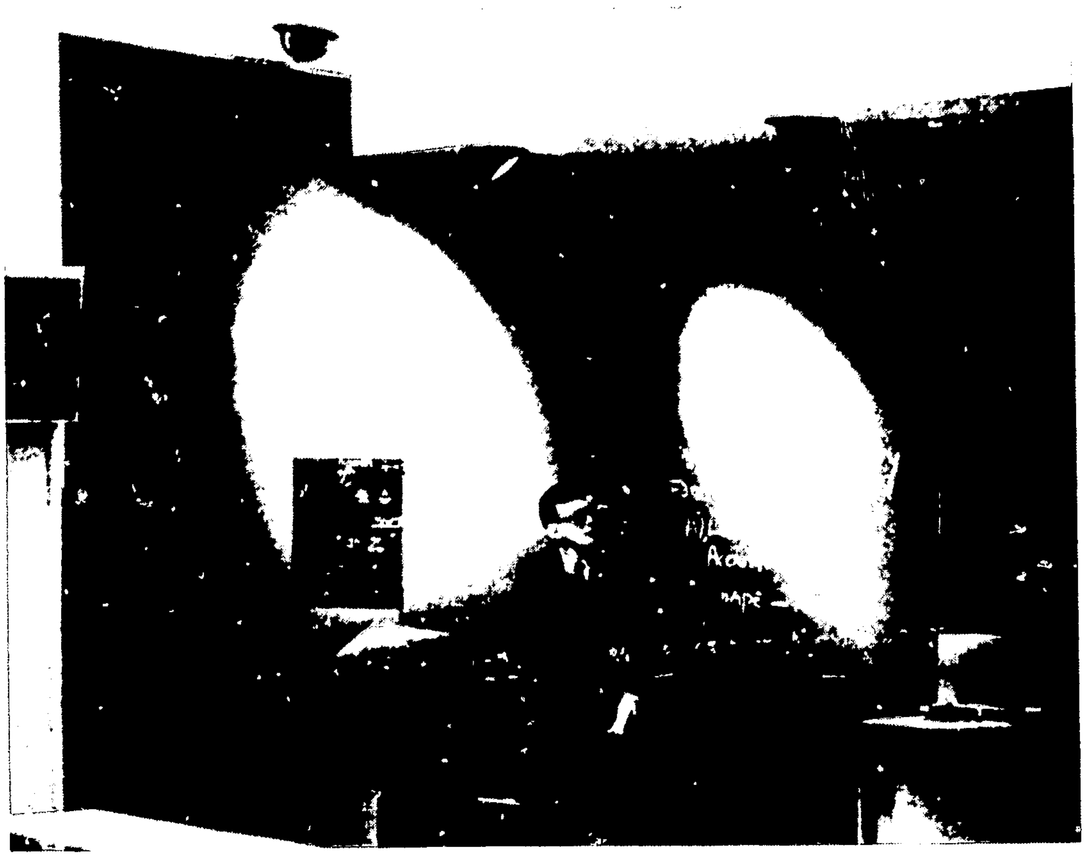
Because of the obvious disadvantages of the dimmer-controlled incandescent system, a proposed new system has been designed, aimed at achieving the required criteria spelled out at the beginning of this chapter. The concept of the system was developed by working with experts in the lighting field, particularly several of the engineers at the General Electric Lighting Institute at Nela Park, Ohio. The basic concept was translated into a design for the Experimental Classroom by J. L. Ottenheimer and Associates, Consulting Engineers of Albany. The plan and sections illustrated in Figure 12 are based on this design.

PHOTOGRAPHS OF CLASSROOM LIGHTING

The cove lighting as installed for washing the walls in light creates a dark band caused by the fascia, with areas of high brightness immediately above and below. This is not a satisfactory means of wall washing.



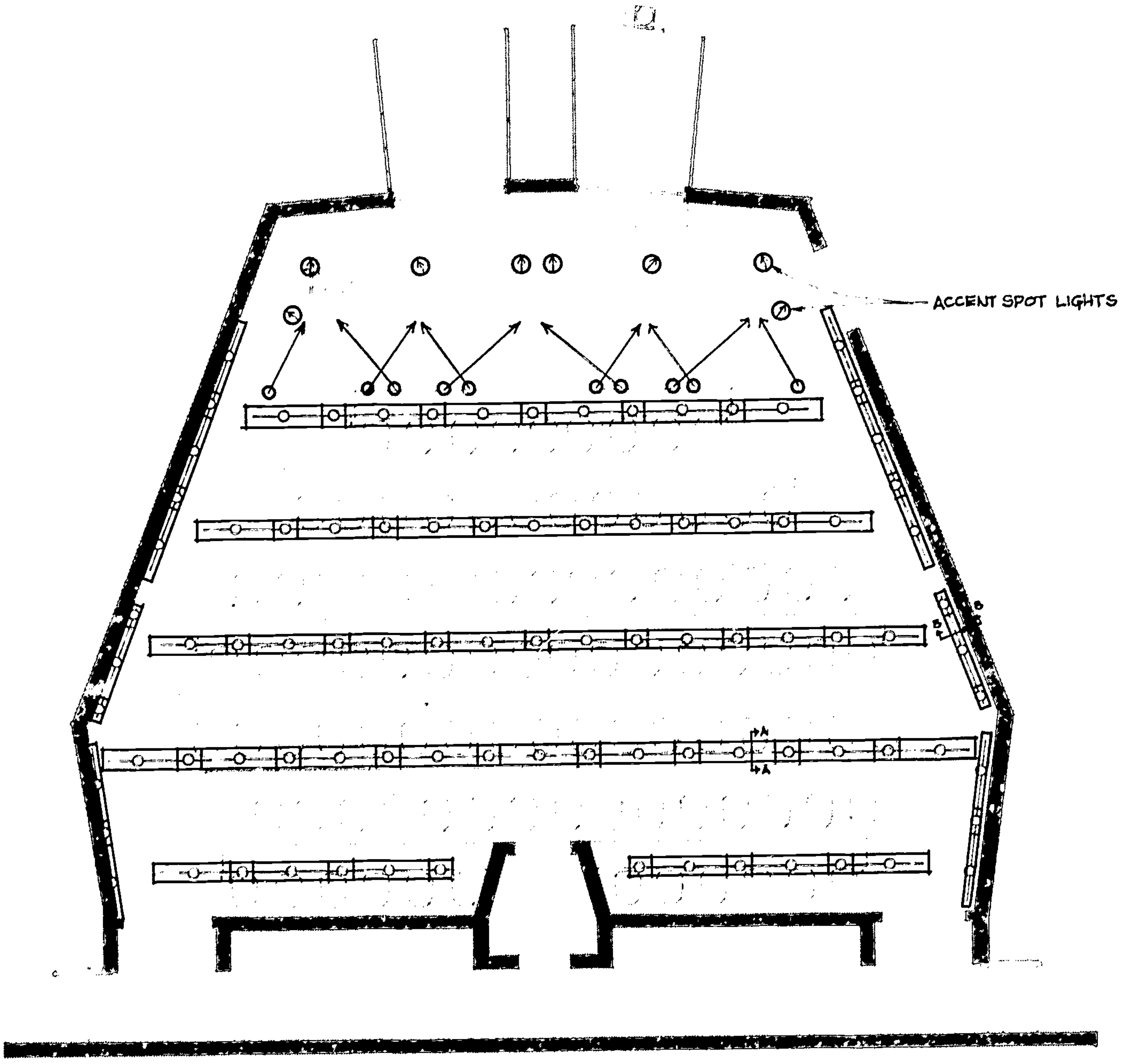
The downlights create multiple shadows on the desk and writing surfaces which are distracting and disturbing.



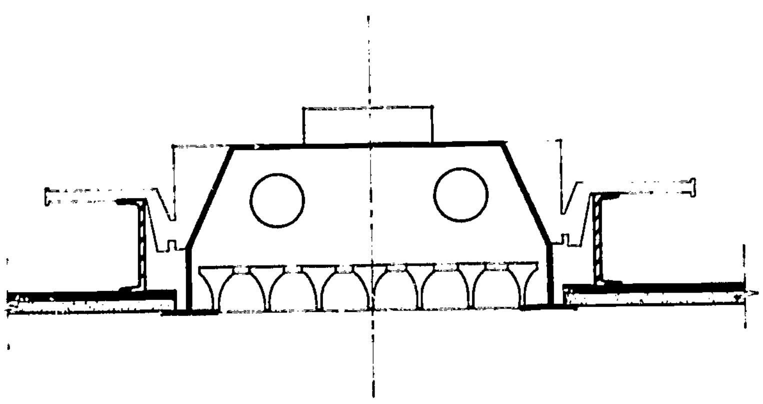
The accent lights at the front create a scalloped effect on the chalkboards and tackboards. This could be improved with relocation of the fixtures and carefully adjusted lenses.

FIGURE 11

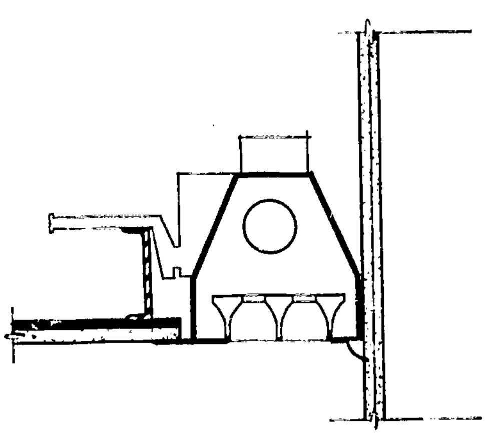
PROPOSED LIGHTING SYSTEM



PLAN



DETAIL A-A



DETAIL B-B

FIGURE 12

The important features of the improved system are as follows:

1. The lighting for the seating area is composed of fluorescent flush recessed troffer units of varying wattages and lengths. (See Appendix B for materials list.) A directional 45° cut-off, plastic grid is located below the luminaires. The individual louvers in the grid are wedge-shaped in section and are surface coated with a reflective material.

2. The fluorescent system is not dimmer controlled; instead, by a system of circuitry and switching, levels of 6, 30 and 60 foot-candles are available for the particular instructional aids used in the Experimental Classroom. (The required levels will vary from room to room depending on the types of equipment, the size of the room, the method of projection, and the size and types of screens.)

3. Lighting to wash the wall surfaces is provided by a perimeter band of fluorescent units, also recessed in the ceiling.

4. Accent lighting for the display surfaces, the instructor, and the demonstration area remains incandescent without dimmers. Each fixture or pairs of fixtures will be individually switched, and the overall effect will be improved by the use of carefully selected and directed lenses and shields.

5. All lighting is controlled from the instructor's lectern and is automatically switched with the projection equipment.

One of the chief objectives of the improved system is a more economical system in terms of initial cost and long term replacement and maintenance. By going to the fluorescent system, longer life luminaires are used, and without dimmers less power is required to operate the system. In addition, the air-conditioning load is greatly reduced by eliminating the high B.T.U. output of the incandescent system. To determine initial comparative costs, a lighting contractor was retained to prepare estimated costs on the two systems – that used in the existing classroom and the proposed improved system. The estimates were based on complete equipment and installation costs for each system from the power sources forward. For realistic comparison, these estimates were based on installation in permanent construction, instead of the mock-up type construction used for the existing Classroom.

The total cost for the existing system was estimated to be $8,020 or $5.43 per square foot of classroom area; while the improved system was found to be $7,460 or $5.05 per square foot. At the time the improved system was developed, it was felt that it represented a substantially less expensive installation. The authors were surprised and disappointed when the estimates were received and the difference in costs was not greatly different. However, the improved system calls for some non-standard, short length units. The cost of these first units include research and development costs, and they are therefore, initially more expensive than they will be when in full production. In other words, actual installations of the improved system should be considerably less expensive than this first quoted price.

Unfortunately, there has been no opportunity as yet to provide a test installation of this system, but based on the consultants' suggestions and the cost comparisons, it would appear that the improved system does have real merit. It would be most advantageous if a test installation could be incorporated in the Experimental Classroom or some similar facility before a permanent installation is used.

Chapter V – ACOUSTICS

A. INTRODUCTION

The acoustic treatment provided in the Experimental Classroom follows very closely the criteria for proper acoustic design spelled out in the report **New Spaces for Learning,** which has been previously referenced. As a result, the room, in our opinion, has been very successful acoustically. As in the case of lighting, however, it was felt that the advice of a professional consultant should be obtained to verify this opinion, and the services of a recognized acoustical authority were engaged for this purpose. The consultant's report which follows in C, points out several minor aspects of the design which might be improved and offers suggestions as to the necessary modifications.

Unfortunately, a mock-up construction does not simulate for acoustical purposes the exact results which would be achieved in the same space if of permanent construction. This is due primarily to the difference in mass and stiffness of materials used in mock-up construction over those used in permanent construction. There are also apt to be small cracks and openings in a mock-up structure which would not occur in a finished building. For these reasons, detailed reverberation time and decibel readings in the Classroom were not considered to be valid for this study. Rather, overall considerations will be reiterated and the consultant's report is presented for further guidance and clarification.

B. GENERAL CONSIDERATIONS

In essence, there are four main points which should be considered in designing an acoustically successful "learning space." These are points which must be considered from the outset of design:

1. **Distribution of Sound Within the Room** – Hard, reflective surfaces distribute sound. The front wall, front sections of side walls, and ceiling should be hard, reflective surfaces, acting as "sounding boards" to distribute the sound to all parts of the room. The "sounding boards" are flat surfaces properly angled to reflect the sound waves originating at the front of the room. Reverse angles in the rear sections of the ceiling and side walls further reflect the sound into the rear-most areas and corners. Reference to the plan and section of the Experimental Classroom (Figure 1) indicates how the "sounding board" surfaces were arranged for a room seating approximately 100. In larger rooms, the same theory applies: the angles of the walls and ceilings must be carefully calculated.

   This principle of sound distribution applies to all sounds originating in the front of the room. Normally, these will consist of the unaided voice of the instructor and recorded sound from films, records and tapes. If properly designed, spaces with capacities of up to 500 or more will allow the voice of the instructor to be heard by all occupants without amplification. Recorded sound can best be distributed through a high-quality, single speaker system, with the speaker located at the upper center of the front wall, relating the sound source realistically to the projection screens.

2. **Prevention of Reverberation** – Once the sound is distributed to all parts of a room, it should be absorbed to prevent reverberation and echoes. Upholstered seats, carpeting and occupant's clothing will absorb some sound, but additional treatment is usually necessary. The treatment consists of highly porous, "wooly" blankets of material located on rear walls, possibly also on the rear sections of side walls, and around the perimeter of ceilings above aisles. The amount and location of absorptive materials will vary from room to room depending on capacity, shape and finish materials.

3. **Sound Isolation** – Points 1 and 2 concern the distribution and quality of sound within a space; of equal importance is the prevention of disturbing and disruptive sound escaping **from** the space or being transmitted **into** the space from adjacent areas. Transmission of sound is best prevented by completely air-tight construction and closures, and by the use of materials with mass for enclosing the space – 6" block is better than ¼" glass, while 8" brick is better yet. In the "learning space" the transmission of sound through screen surfaces is of particular concern to the designer.

4. **Reduction of Ambient Noise from Equipment** – The sound of projectors, air-conditioning or heating units and other apparatus within or adjacent to a room can be annoying and distractive. All such noise producing equipment should be removed from the room or surrounded with sound-absorbing materials to reduce the noise effecting the classroom occupants.

The key to satisfactory acoustical properties in a room is the consideration of acoustics at the outset of design. Acoustic design is not corrective measures applied at the completion of the facility, but rather is inherent in the shape and configuration of the space and the materials with which it is constructed. There are a few unique acoustic considerations imposed by the functional needs of the "learning space" which have been pointed out. Essentially, they are simply rooms designed from the outset for excellent hearing.

C. CRITIQUE OF EXPERIMENTAL CLASSROOM ACOUSTICS

The firm of Bolt, Baranek and Newman of Cambridge, Massachusetts was retained to evaluate the acoustical design of the Classroom and to make recommendations for improvements. Mr. Lloyd J. Williams of that firm spent a day examining the Classroom and talking with the project staff. He later submitted a detailed report, the majority of which follows:

"We understand that this lecture space is a prototype of non-departmentalized teaching spaces which will provide for varying sized groups ranging from 60 to 480 people. The basic idea of accommodating the needed flexibility in the teaching program by providing a number of spaces of different size, leads more easily to the solution of the inherent acoustical problems than single, large subdivisible spaces that attempt to provide good hearing conditions for varying sized groups and activities.

We wish to reiterate the observations contained in **New Spaces for Learning**—that good conditions for hearing are just as important in learning as is proper and adequate lighting. As with lighting, the acoustical properties should be designed in, rather than being pasted on as an after-thought. Good hearing conditions can be provided in the average teaching space for small, if any, additional cost if the basic principles are considered early in the design process. There will, of course, be extra and sometimes prohibitively high costs if acoustics are forgotten and left for later "fix-up" after the room is occupied.

The two basic objectives in providing good hearing conditions in lecture spaces are well stated in your project report but might be rephrased here. The first objective is concerned with controlling the transmission of unwanted sounds (noise) whether made within or without the space in question. This involves the isolation of sounds by planning, by barriers, by absorptive materials or by combinations of all three measures. The second objective is concerned with the control of the desired sounds and involves the room shape, the choice and use of materials and occasionally the proper integration of electronic amplification equipment.

The provision of good hearing conditions may be achieved in a small room in a fairly simple, straightforward manner. The Experimental Classroom, as it presently stands, is well-shaped, having hard, sound-reflecting wall and ceiling surfaces which are shaped to distribute useful, reflected sound energy to all of the seats in the room. The rear wall is treated with sound-absorbing material to help control delayed reflections from this surface and to provide additional absorption for reverberation control.

In the model classroom there are problems which have not been completely solved, although some are due to the temporary nature of this experimental facility. There are several sources of intruding noise which should have further treatment and consideration in the design of future facilities. These include sound transmission through the many leaks between the rear projection area and the classroom. These are, for example, at the edges of the screens, at the cabinetry, and at the wall-ceiling intersection. In a more permanent facility all of these leaks should be sealed airtight and a minimum of a ¼'' plate glass screen should be used for rear projection. This screen should be set in glazing compound to reduce intruding noise from the projector area.

The existing facility has no gasketed doors as they are not presently required. However, in almost every building design incorporating a lecture hall, it is important to note that corridor noise may be a serious problem. For this reason, we generally recommend that all doors leading to lecture spaces be either 1¾'' thick, solid wood core, full gasketed doors, or fully gasketed, independent face, hollow metal doors. This measure, along with absorptive treatment on the ceilings of the corridors, can provide adequate control of intruding noise from the surrounding spaces which may be used simultaneously with the lecture rooms.

Another source of intruding noise is structure-borne impact noise from occupied spaces overhead. This problem, of course, does not exist in the model classroom. Carpeting or special resilient flooring materials are generally required to adequately control this problem. Needless to say, lightweight wood or even thin concrete constructions are the worst offenders and need the most attention.

Adjacent mechanical equipment rooms are often severe sources of intruding noise in lecture rooms. The noise transmission from these equipment rooms may be transmitted via structure-borne paths, via airborne paths through common walls into the lecture room, or directly from the equipment itself by the duct work. In the model classroom there is structure-borne noise from the adjacent air-handling units as well as airborne noise intruding into the lecture room from the air-handling units at the front of the space. Not only is airborne noise transmitted to the surrounding space and through the lightweight temporary walls of the lecture room, but it is also transmitted directly via the duct work. An NC-30* criterion is recommended for continuous background fan noise in lecture rooms, and it is also important to note that diffuser noise may be a serious disturbing factor in lecture halls even if fan equipment is remotely located and properly treated. The noise generated by airflow at the diffuser should also not exceed NC-30 to 32. As

*NC criteria are described in detail in "Noise Reduction" edited by L. L. Beranek, McGraw Hill 1960.

noted in **New Spaces for Learning,** a certain lower limit of continuous background noise from the mechanical system is desirable as a sort of acoustical perfume to hide minor intrusions. However, the noise in the classroom at present is excessive, as it approximates NC-40 to 45.

We understand that the addition of noise in the lecture room was deliberate because some lecturers complained that they could hear students in the back row whispering, turning pages, etc. It is important to realize that the measures provided to distribute sound from the front of the room to the back are reciprocal. If students are to hear well, so will the lecturer. We expect that most lecturers will be able to control a class better and get better "feedback" if they can hear and "feel" the class.

Another source of intruding noise can be hum from the ballasts when fluorescent lighting systems are used. In general, a high quality, quiet ballast is preferable to one which will hum. It is sometimes possible to use low quality ballasts located outside the lecture space but usually at some cost increase.

The existing lecture space has a projection booth at the rear of the room. At the present time, the lightweight construction of this booth permits some airborne sounds from projectors with their blowers, etc., to be transmitted to the rear seating area. This also occurs through some leaks in the port glazing which is set dry. Generally, these ports should be provided with ¼" glass set in airtight glazing compound or soft extruded gaskets. In addition, the projection area itself should be liberally treated with sound-absorbing material. If a full projection room cannot be provided for reasons of economy, codes, etc., an acoustically lined booth or semi-booth which encloses the projection machinery as completely as possible can affect considerable control. Such measures can reduce the projector noise, particularly for the most disturbed listeners in surrounding seats. Another operational point to remember in arranging projection booths at the rear of the lecture halls is that one of the ¼" glass ports at the rear should be enlarged and arranged to open so that an operator can set up the system at the proper sound level so that it does not blast the people in the front out of their chairs. In general, sound systems are run much too loud because the "enclosed" operator often cannot really hear the sound he is controlling.

One of the conditions for good hearing and good intelligibility of the wanted sound in a lecture room is a loud enough signal from the lecturer or the recorded material being presented to the student. The most effective way to provide for a loud enough signal is to orient hard sound-reflecting ceiling and front wall surfaces so that they will reinforce the direct sound energy from the source to the students. Shaping for even distribution may be effected by geometric means using the principle that the incident sound wave will reflect from a large (4' to 10' or more) plane surface, as light from a mirror. Precise cut-offs and dead spots are not accurately predictable by this method, however, as sound is a spherical wave and will not reflect in a specular fashion from edges, small bumps, etc. The model classroom is well shaped to distribute sound from the front or lecturer's position to all seats. Again, one should note that sound travels as well from the lecturer to the student, or from the student to the lecturer. Therefore, if teachers are to be heard well by the students, they will also hear the students well.

Another problem of providing a loud-enough, high quality signal is that encountered in loudspeaker systems. As noted in **New Space for Learning,** the central, above screen location is recommended for maximum realism of presentation of recorded material. The highest quality loudspeaker and amplification equipment available is recommended for maximum freedom from maintenance and "down time," as well as freedom from distortion.

ACOUSTICS

The present classroom is remarkably poorly equipped in this respect; in fact, during our visit the loudspeaker system was set at an extremely high level with concommitant distortion and lack of realism. We recommended that the present loudspeaker be replaced with a small but high-quality, full-range system, such as the KLH Model 6 or the AR-3. As noted before, the best location for this equipment would be on the longitudinal center line of the room above the rear projection screens. We should point out at this time that in a well-designed lecture room of up to 500-people capacity, a well-trained speaker should have no need for electronic speech reinforcement. We usually recommend in the spaces under consideration that no provision be made for electronic speech reinforcement unless weak-voiced or untrained speakers are expected to use the space.

We are pleased to note that even in the 100-seat lecture hall you have provided a stepped floor. This helps to insure good sound for all students – good sight lines give good hearing lines.

Long delayed reflections (echoes) can affect the intelligibility of signal from a lecturer or from amplified speech. We should note that the echo need not be of the "Alpine" type but may be simply a reflection from a remote surface delayed enough to interfere with intelligibility. Differences in path length between the direct sound from the source and the sound reflected from a remote surface of the order of fifty feet and over, can be troublesome. In general, sound-absorbing material should be located on these remote surfaces, or they should be reshaped to control echo. Note that absorptive materials used for echo control also provide reverberation control. In the model room the sound-absorbing material is covered with a perforated hard-board with small holes spaced about ½" o.c. Unless this material is painted quite dark, the pattern of holes has the tendency to "dance" in front of the eyes of the lecturer and others who must look at it. It also "cuts off" the absorbing material from high frequency sound waves – one hears a distinct hiss or "spit" from the rear wall of the model room. More open transparent materials provide more effective absorption as well as less visual problems. Such treatments would include expanded metal, flattened metal lath, highly perforated metal, insect screen, loosely woven cloth, etc., located over sound-absorbing materials, such as glass fiber blankets or spun asbestos, etc. Sound-absorbing materials perform best with no protective facings; however, almost all sound-absorbing materials are vulnerable to damage because they are either very soft or brittle. As a consequence, protective facings **are** required, particularly where these materials are located within reach. Note also that the openings in the acoustically transparent protective facings must be pencil-proof to prevent damage by curious students.

There is another problem which often appears in rooms with hard parallel surfaces. This is a rapid, repetitive reflection of sound between these hard parallel surfaces, known as "flutter" and often heard as a "ping." This is usually a high frequency phenomenon and is often excited by impulsive sound sources. In general, parallel surfaces should be avoided in lecture halls. Slopes of as little as one-in-ten in walls and ceilings are sufficient to prevent flutter.

Reconcentration of sound energy (or "hot spots") may occur from reflections of sound from concave rear, side and ceiling surfaces. Concave surfaces should be avoided in lecture halls to reduce this possibility of reconcentration and of "creep" – the problem reflection of sound along a curved wall surface.

The sound-absorbing material located on remote surfaces for echo control may also be used for reverberation control. In general, most of the required sound absorption in a fully occupied lecture hall is provided by the audience. Since the audience size can vary, however, fully upholstered seating is the only really effective way to stabilize the room response so that it is reasonably independent of audience size. Carpeting the floor will also provide absorption which is covered up when an audience is in the room and is more or less open when smaller groups are using this space. The carpet will also reduce foot shuffling noise in the room and impact noise in the spaces below the lecture room.

The model room is somewhat live for small occupancy and might well have a carpeted floor. Assuming that lecture spaces under consideration are all for speech use only and that they will never be used for music, we suggest that the calculated reverberation time range from one-half second for the small 60-person rooms to one second or less for the 480-seat rooms. We should also note that, if possible, the rear seats should be separated from the sound-absorbing material by a cross-aisle so that no student is required to sit against the "dead" absorbing material. We pointed out the two seats adjacent to the projection booth in the model hall with sound-absorption behind and to one side, are really rather uncomfortable.

A refinement which may be helpful on very steeply raked amphitheater-type lecture demonstration rooms with concentric seating layout is to provide an acoustically transparent or absorptive desk front if a great deal of the desk front is exposed with the audience in place. This measure is intended to reduce the potential reconcentration of sound-reflected from these regularly stepped and concentric desk front areas. This reconcentration is usually only heard by the lecturer but is extremely annoying and makes it very difficult to lecture.

We wish to emphasize again the value of the statements in **New Spaces for Learning** – Part III, particularly numbers 6 and 8. It should also be pointed out under 14 that if a number of small monitor television sets are scattered around larger spaces that only the single central loud-speaker system should be used to avoid the cacophony which otherwise results from distributing a number of TV sets around the room, each of which may be turned up too loud. We also discussed the possibility of revising the model lecture hall with a new lighting system and reviewed the problem of directional open louvers, such as Parawedge and Parahex louvers. Large areas of these louvers may cause some problems in uniform reflection of sound as the acoustical transparency of the grid will vary with angle and frequency. We agreed that up to 1/6th of the class-room ceiling could be louvered without ill effects if the light fixtures were close behind the louvers and not much over one foot in width."

Appendix:

A. Design criteria for "learning spaces" taken from **New Spaces for Learning.**

B. Improved lighting design – materials list.

APPENDIX A

Design criteria for "learning spaces"

as taken from

New Spaces for Learning

1. **An optimum viewing area, as defined by the various images to be viewed, will determine the most effective room shape.** The optimum area is not a fixed function of the screen or monitor size, but will vary with the type of material being viewed, the duration of the presentation, the quality of the equipment, and factors of environment.

2. **Stepped or sloped floors will provide the best viewing conditions in all rooms; in the smaller rooms they may not be feasible.** In the large rooms sloped floors are essential for good sight-lines; steep gradients in spaces designed for lecture-demonstrations do not appear justified as they are wasteful of space and reduce the effectiveness of the space for other functions. Magnification of critical aspects of a demonstration can be accomplished by projection techniques or television. In the smaller spaces, the desire for possible rearrangements of the seating may render stepped floors objectionable.

3. **The actual capacity of a space, as defined by a viewing area, is a function of the seating type and arrangement, and applicable building codes.** Adequate writing surfaces and stepped floors tend to imply fixed seats and continuous tables for the larger spaces. Building codes usually limit to 14 the length of a row of seats, although wider row spacing (continental seating) will permit longer rows. Center aisles are to be avoided, as they occupy the best viewing area. In the smaller spaces a seminar arrangement of seats as opposed to a focused arrangement, will probably reduce the capacity.

4. **Windows in the learning spaces, whether the spaces be large or small, are a liability rather than an asset.** Two of the major functions of windows are to introduce daylight and provide visual contact with the out-of-doors. Both detract from the most effective use of aids and media.

5. **All learning spaces should be air-conditioned.** With the absence of windows, mechanical ventilation becomes a necessity. Cooling will generally be required, even in cold weather, not only to remove the heat generated by occupants and equipment, but also to provide a stimulating environment.

6. **Proper acoustic treatment in all rooms, and sound isolation between rooms is essential.** These involve no unique problems as far as treatment of surfaces and use of materials are concerned, but several important details require particular attention. A means must be employed to isolate the noise of all projection equipment, and careful attention must be paid to preventing sound transmission through ductwork systems. In addition, a single high-quality, carefully designed sound system should be provided for distributing the audio element of any of the aids and media.

7. **Carefully planned, special lighting is a prime essential to the proper functioning of these spaces.** Lighting levels for both the writing and surrounding surfaces should be carefully related to image brightnesses, and variable intensities appropriate to each instructional device should be provided. In addition, ample illumination for conventional lecture and discussion purposes is necessary. All controls should be pre-set and coordinated with the devices, and located for ready operation by the instructor in charge.

8. **From initial stages of design the mechanical, structural, acoustical and lighting elements must be considered together as coordinated systems.** Design of one system without regard for the others may seriously impair their later accommodation. For instance, location of mechanical ductwork in a ceiling, without regard for the location of the lighting, may result in the lighting fixtures being placed in less than desirable locations.

9. **A conscious effort toward carefully designed color schemes in the rooms, and between rooms is desirable.** Color, as a function of lighting, is critical in these rooms as there are no windows for visual relief and because lighting and surface reflectance has to be carefully planned for optimum viewing. In addition, as students move from room to room, the color schemes should change to provide a variation, and thus avoid monotony of environments.

10. **In designing the spaces, aids and media should be considered with instructional methods as integrated systems, rather than simply pieces of equipment to be included in the spaces.** As an example, a projector and its required screen are not independent items to be accommodated, but are closely related and inter-dependent component parts of an instructional system.

11. **The concept of a coordinated "display surface" or "teaching wall" should be encouraged.** The aim of this concept is to integrate and coordinate as far as possible all instructional materials within an appropriate area, rather than to provide a collection of separate and distinctly defined exhibits.

12. **Whenever feasible, projection equipment should be centrally located in a "projection center" or "area" and should be remotely controlled by the instructor.** (The possible exceptions are the overhead, opaque, and shadow projectors.) In this way, the instructor remains at the front of the room, continuously in control of the presentation. Such an arrangement also permits technicians to ready equipment during a class period.

13. **There are no overriding advantages of either front or rear projection to the exclusion of the other.** Particularly in the larger spaces, either one may be appropriate depending on the functions of the space, personal preferences, and the nature and amount of space provided. Some of the disadvantages of either may be overcome by indirect projection (using mirrors).

14. **Particularly in larger spaces, there are definite advantages to a single, large, projected television image over a number of small monitor images scattered about the spaces.** At the present time, economic and functional limitations of the equipment will not always permit realization of this goal, and instead a number of monitors will be provided. In the smaller spaces, where no more than 2 or 3 monitors are required for adequate viewing, projected television may not be practicable.

15. **The adjunct service spaces which support the functioning of a learning space require careful consideration.** These include preparation and storage areas. As a rule, they become more extensive, and their planning more critical, as the learning spaces become larger and support more functions.

16. **Flexibility, a term with multiple meanings and implications for design, should be carefully analyzed and evaluated for each situation.** Flexibility of functions within a space may be achieved by designing for the use of a variety of instructional aids and media. In the large spaces flexibility of function may be increased by use of multiple platforms, either slide-on or rotating. Flexibility between spaces by use of "flexible partitions" is possible, but not always feasible. By providing a variety of spaces representing a range of capacities and functions, flexibility may be achieved by scheduling of the spaces.

APPENDIX B

Lighting Design

Experimental Teaching Facility

Rensselaer Polytechnic Institute

MATERIALS LIST NO. 1926

1. **Type FA Lighting Units,** flush recessed troffer units, 2 - 40 watt rapid-start, 12" wide, "Para-Wedge" louver in hinger door frame, interior removable reflector, reflecting surfaces finished in high temperature baked-on white enamel, No. 20 Ga. "bonderized" steel housing, plaster frame and fittings as required, Kent Lighting Corp., Type "H" Series.

2. **Type FB Lighting Units,** similar to Type FA Units except 2 - 14 watt standard start, Kent Lighting Corp., Type "H" Series.

3. **Type FC Lighting Units,** similar to Type FA Units except 1 - 40 watt rapid-start, 8" wide, Kent Lighting Corp., "H" Series.

4. **Type FD Lighting Units,** similar to Type FA Units except 1 - 14 watt standard start, 8" wide, Kent Lighting Corp., "H" Series.

5. **Ballasts** shall be rapid-start (40 watt) and preheat start (14 watt), two lamps where possible, sound rating "A", General Electric Co., "Bonus Line."

6. **Lamps** shall be standard warm white, T-12 bulb, General Electric Co.

7. **24 Volt Power Unit,** heavy duty, energy limiting transformer, 120 volt, 60 cycle primary, 24 volt secondary, 35 volt-amp capacity, 4" outlet box mounting with selenium rectifier, General Electric Co., Cat. No. RT-1 with rectifier Cat. No. RA-9.

8. **Remote Control Relay,** standard type 20 ampere, 125 volt, 60 cycle contacts, 24 volt coil, General Electric Co., Cat. No. RR-3.

9. **Remote Control Switch,** standard type, momentary contact, flush mounting, General Electric Co., Cat. No. RFS-6.

J. L. Ottenheimer & Associates
Consulting Engineers
Albany, New York