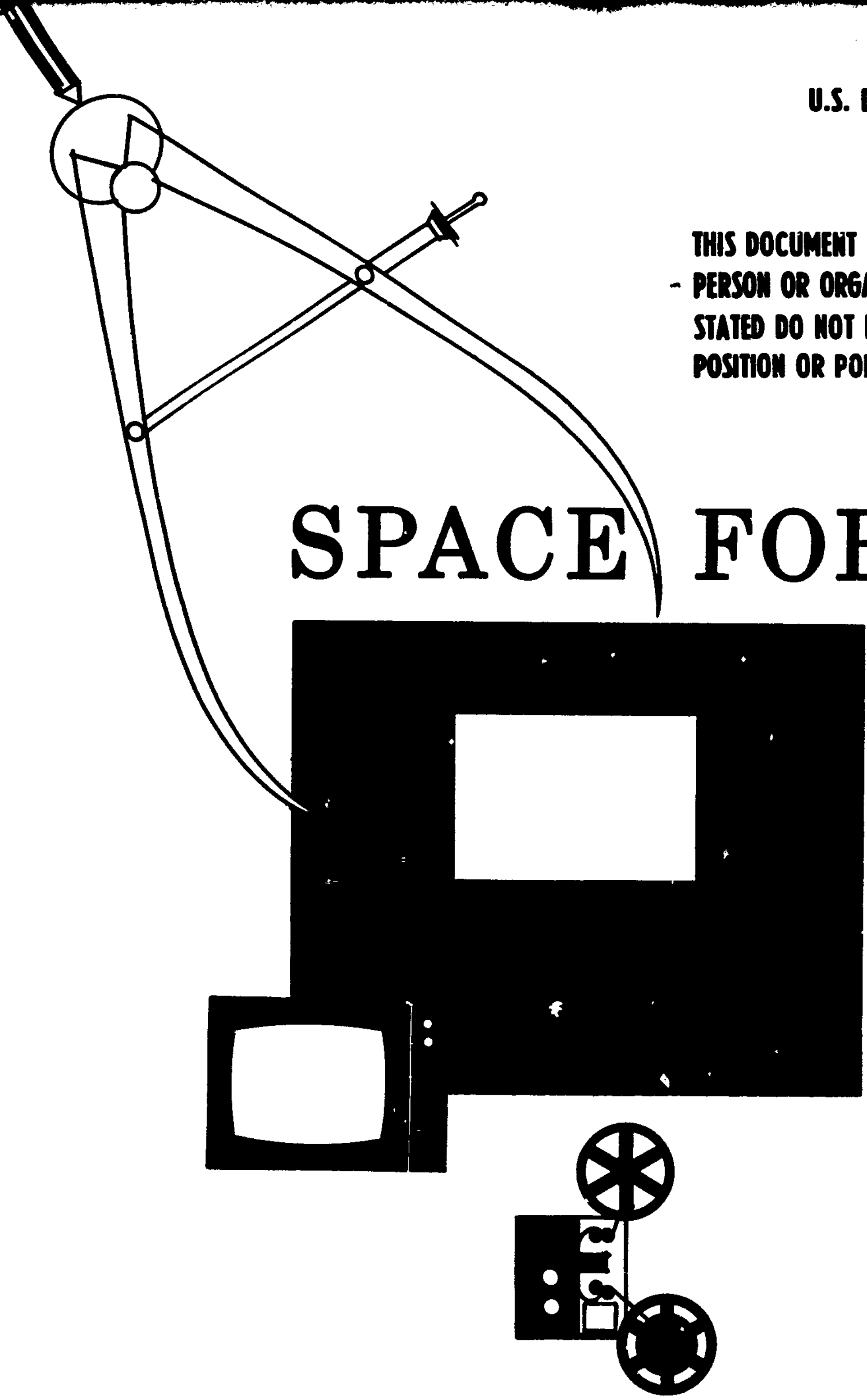
SPACE FOR AUDIO-VISUAL LARGE GROUP INSTRUCTION



UFRC UNIVERSITY FACILITIES RESEARCH CENTER

WITH THE EDUCATIONAL FACILITIES LABORATORIES, INC.

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University Facilities Research Center

The University Facilities Research Center was created in 1966 by a special grant from the Educational Laboratories, Inc., to the Committee on Institutional Cooperation of the Western Conference Universities and the University of Chicago.

The Center, located at the University of Wisconsin, is now expanding those activities aimed at generating information useful to institutions of higher education toward increasing the effectiveness of the planning and utilization of their physical facilities.

The activities of the Research Center are conducted by a small staff, assisted by consultants drawn from either private architectural and engineering firms experienced in college and university facilities design and planning, or from university faculties and staff.

UNIVERSITY FACILITIES RESEARCH CENTER

The University of Wisconsin
Madison, Wisconsin 53706

Educational Facilities Laboratories Inc.

477 Madison Avenue; New York 22, New York

This organization is a nonprofit corporation established in 1958 by the Ford Foundation to help American schools and colleges with their physical problems by the encouragement of research and experimentation and the dissemination of knowledge regarding educational facilities.

UFRC Project Associate in Charge of Study:

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UNIVERSITY FACILITIES RESEARCH CENTER

Monograph Series

- Plumbing Fixture Requirements in University Instructional and Research Buildings
- Horizontal and Vertical Circulation in University Instructional and Research Buildings
- Parking Programs for Universities
- Space for Audio-Visual Large Group Instruction
- University Research Buildings for Short-Term Grant Programs
- High-Rise or Low-Rise? A Study of Decision Factors for Residence Hall Planning
- Central Food Stores Facilities

THE BACKGROUND

Unprecedented enrollment increases in American colleges and universities are with us and ahead of us. These same institutions are greatly expanding their activities in the fields of research and service to the public. All of this adds up to the creation of a need for new building facilities in a magnitude never before experienced.

The University Facilities Research Center has recently completed a building survey while studying immediate needs for instructional, research, operating and housing construction at the large middlewestern universities comprising the Council of Ten and the University of Chicago. This survey covered the period from the end of World War II through the ten year forward planning time adopted by the eleven universities. It indicated that approximately $1.85 billions in construction could be expected between 1946 and 1970. Of this about $1.1 billion in construction, or 60%, is now being planned or built or projected for the near future. On a national scale, this would indicate college and university building programs amounting to something in the order of $15 billion between now and the end of this decade.

Among the objectives of the Research Center is the isolation of planning and design criteria problems, followed by the finding or developing of measures for design—all to the end of permitting the best possible use of the university and college construction dollar. Analysis of statistics and interviews and conferences with interested people in the field have contributed to the selection of several monograph subjects, of which this publication is one.

The material is aimed at aiding university and college administrators and their planning and building committee people. It is also directed at private architect and engineer firms engaged in the design and execution of new facilities.

Space for Audio-Visual Large Group Instruction was selected as a subject for study in response to an expressed need for design standards in this highly specialized field which is becoming increasingly important at the college and university level with the current rapid physical growth and accompanying faculty and staff shortages.

Encouraging progress has been achieved in the development of the educational process of using audio-visuals for undergraduate and graduate instruction, and in the programming and production of instructional material. There have been a number of significant new advances in equipment design for open circuit and closed circuit television, as well as for film or slide viewing.

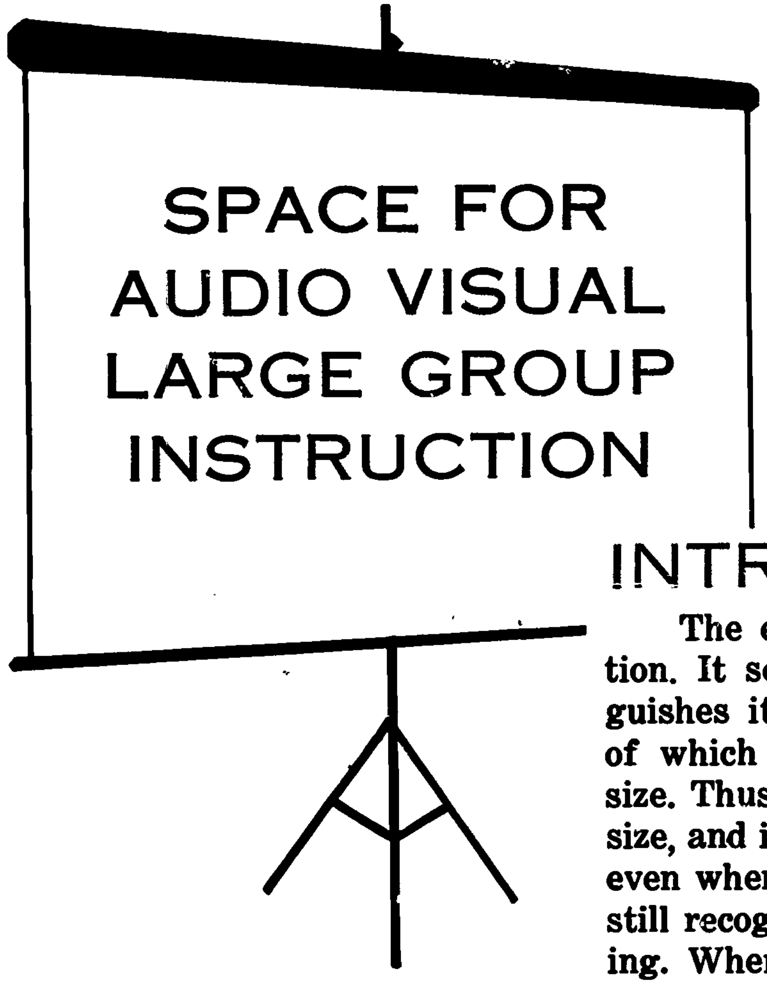
The problem then is how to best provide space for use of these media. Many thousands of new audio-visual classroom seats are to be provided in the near future; many existing facilities will be remodeled or converted for audio-visual use.

This monograph, based quite largely on new source material, suggests design standards for seating patterns, viewing angles, screen characteristics, equipment performance for TV and for film. Carl H. Gausewitz, A.I.A., while a member of the Research Center staff, is responsible for most of the contents of this study and report; he received generous assistance and aid and counsel from numerous sources in education and industry.

W S Kinne Jr.

Consultant, Former Director University Facilities Research Center Madison, Wisconsin

December, 1963



INTRODUCTION

The eye is a mechanism which sees proportion. It sees the whole of an object and distinguishes it from other like objects by the detail of which the object is composed, regardless of size. Thus the eye can read words of almost any size, and in many kinds of script and handwriting, even when distorted to a considerable degree, yet still recognize the letters and thus read the writing. When the eye cannot recognize a letter, it trys to recognize the word by identifying other letters in the word, and then by deduction arrive at the unknown letter.

It recognizes faces, even when the features are exaggerated by cartoonists, distorted by carnival mirrors, or concealed in a maze. It is not an accurate device for measuring except by comparison with objects of known size—and then by proportion. The eye has no memory for size, color, distance, or units of light intensity except by comparison to a known standard within the field of vision; thus the eye is unlike the ear which can commit to memory tunes, tones, and notes. The eye does remember patterns and it stores them. New visions are compared to existing patterns in the memory and thus defined, or stored if a new category is needed.

The eye fails to recognize by proportion when the whole is lost to the parts—i.e. when the entire object cannot be seen and the details themselves do not convey to the eye what the object is. The eye also fails to perceive when details which distinguish it from similar objects are reduced too much in size to be seen.

This latter limitation is called visual acuity and is believed to be limited by the actual spacing of the rods and cones within the eye. Visual acuity is the angle which the limiting detail must subtend at the eye in order for the eye to recognize the object. This angle has been empiracly found to be 2.47 minutes of arc for the average eye in daylight, and because it is an angle, again indicates the proportioning properties of the eye. Objects close to the eye can have smaller limiting details. As objects move away from the eye, the limiting detail must necessarily be proportionately larger in size for the object to be recognized.

Acuity is affected by light intensity. Acuity is reduced at lower light levels.

The ability to recognize colors, too, is affected by light intensity. Color vision is only possible in the photopic area of the eye (the cone area) and then only if the brightness of the object is great enough (.03 lumens per square foot minimum), and provided that the area of color subtends an angle at the eye greater than 5 minutes. Smaller color blotches are too small to be recognized for color, and lesser brightness intensities are only visible to the rods of the eye which do not recognize color.

Even color is recognized on a proportional basis, and the eye is a poor judge of absolute color—except by comparison. Variations of light intensity, light source, background and size of object all affect the eye's ability to judge color, both in hue and chroma.

The eye has a fantastic range of brightness in which it can see; but it accomplishes the full gamut at lower intensities by utilizing the rods (scotopic vision) almost exclusively and at daylight levels the vision is shifted by preference to the cones, with the rods playing a secondary role in the field of vision. In fact, the most intense concentration of vision is centered on the fovea at the center of vision which is a very small area of the retina with an exceedingly high concentration of cones, close to the optic nerve. The fovea is perceptionless at the range of low intensities of light, but in daylight does most of the work.

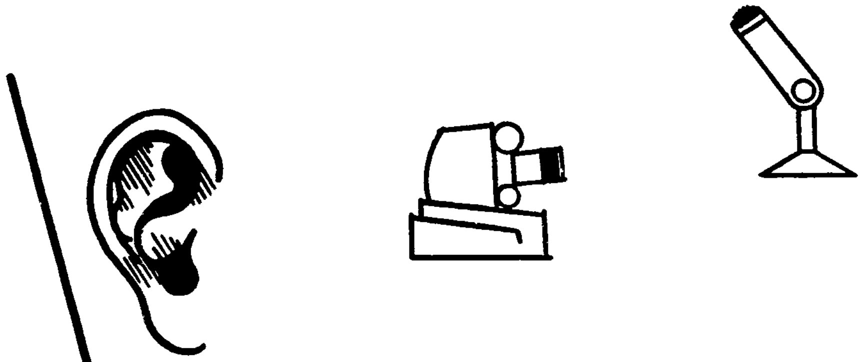
Because the eye is a proportioning mechanism, the object bounds can be best expressed in angles subtended at the eye. Thus an object 20 feet away and 2 feet high appears the same as an object 10 feet away and 1 foot high except for the binocular or stereoscopic effect created by two eyes getting slightly different views of the object.

Relating this to the audio-visual field, one is not concerned with binocular effects as it is assumed that the pictures to be presented are two dimensional. Three dimensional pictures are possible for audio-visuals, but they require special equipment for taking the pictures and projecting them as well as two film tracks to provide left and right eye views. This makes three dimensional presentations more costly and adjustment of perfect alignment of pictures is cumbersome. Since depth can be achieved in two dimensional presentations by means of perspective, color, shade and shadow, object comparison, and by parallax, the extra cost is seldom warrented and, stereoscopic visuals will be ignored in this discussion.

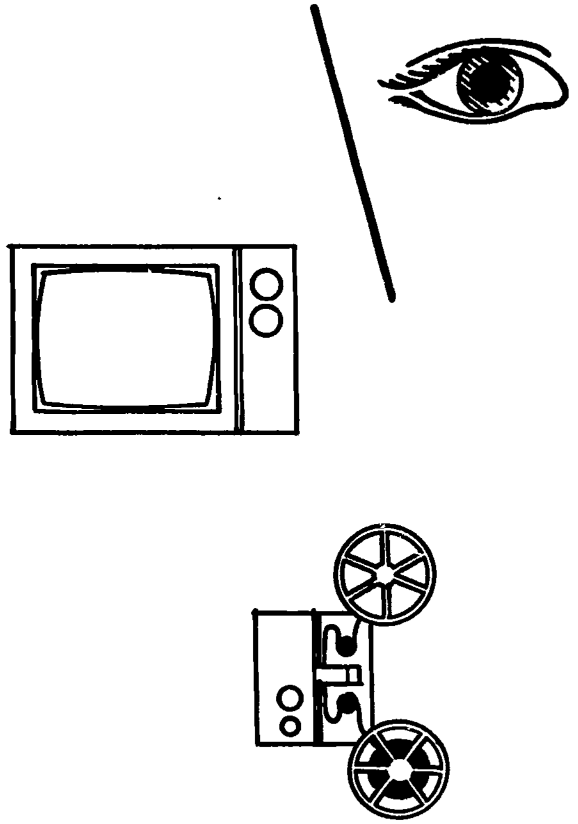
Assuming two dimensional presentations then, and the fact that the field is limited by certain standard sizes of film, one can express this angularity in terms of the viewer's distance from the screen relative to the screen size, i.e. the angle subtended at the eye could be measured as a function of the ratio of the screen width, height, or diagonal, to the distance of the screen from the eye. In audio-visual analysis this is done by expressing the distance of the eye from the screen in terms of multiples of the screen width. Thus an 8W viewing distance infers that the viewing distance is 8 times the screen width. A viewer would see exactly the same image whether the screen were 2 feet wide and he were 16 feet away or if the screen were 10 feet wide and he were 80 feet away. The angle subtended at the eye would be the same in either case.

In the above discussion, it was assumed that brightness would be the same in each instance. If the light intensity for the 2 foot wide screen was 10 foot candles (lumens per square foot), the 10 foot wide screen would also have to have a brightness of 10 lumens per square foot. However, the area of the larger screen is 25 times as great as the smaller screen, requiring that the projector lamp light output or power input be 25 times as great to produce the same brightness intensity.

The problem of audio-visuals involves understanding these relations and then developing spaces and equipment to present them properly. This monograph suggests graphs for quickly determining occupancy, intensities of light and screen sizes for various spaces based on accepted standards and then presents a tabulation of those standards.



DESIGNING FOR THE MEDIA



To design new spaces or to adapt existing spaces for large group audio-visual instruction requires a rather complete and perceptive understanding of the media involved. This design thinking also requires a thorough sympathy of the conditions necessary for the best possible reception by the human mind, with especial attention to the potentials and the requirements of the eye and of the ear. An understanding of the mechanical equipment and of the techniques used to convey the messages and *the limitations of such equipment*, is essential. Today more improper applications of audio-visual equipment in large group communication and instruction result from a lack of an understanding of the limitations of the equipment than from any other one source.

Figure 1 shows the comfort and design standards which should be met for instructional audio-visual rooms at the college and university level.

The most effective reception by the learning audience is obtained when reasonable standards for temperature, humidity, ventilation, lighting, sound control, comfortable seating, and proper general room atmosphere are met, and when extraneous sources of distraction are eliminated. The human eye is perhaps most important here; its best use requires certain optimum lighting requirements which are outlined in Figure 1. Control and display requirements for this purpose are also covered in Figure 1. Improper control and use of lighting may become a serious source of distraction for ideal viewing.

Figure 2 shows comparative viewing characteristics for film projectors and for TV viewing. Design for this type of equipment is modular as shown on the chart; proper viewing distances are expressed nondimensionally in terms of the screen width as the module. The important point here is that television and film showings have entirely different screen viewing characteristics. To use both on the same screen, in the same scale and size, for the same audience, either by front or back projection, would be ill advised. Similarly, trying to employ film projection in a shadow box of the same size as a TV receiver for the same audience would represent a probable misuse.

If the general lighting is not specially designed for one or another of the above two cases, the lighting will be probably improper for one or the other. Unless the viewing angle is considered, it is likely that only the TV picture will be properly and effectively viewed.

Film projections are today usually made from fine grain films. The practical limit for the closeness at which one can comfortably review the film (measured in screen widths) is determined not by the grain of the film, but by the amount of eye scanning the viewer must do to comfortably enjoy and perceive the field of the film. TV, on the other hand, does not present a fine grain picture, but rather an image composed of very evident lines and not so evident dots. The TV image was developed to have no higher definition as far as grain is concerned than that of an ordinary

FIGURE 1. ROOM DESIGN CHARACTERISTICS

TEMPERATURE	SUMMER	80°-85° F dry bulb	65°-67° F wet bulb	40-50% relative humidity
	WINTER	70°-75° F dry bulb		25-50% relative humidity
VENTILATION	CIRCULATION	6 air changes	Filtered	Consider: 1. Electronic precipitation of fine particles, pollen, dust, smoke. 2. Negative ionization of air for comfort. 3. Sanitizing—air with ultraviolet radiation. 4. Carbon filter for removal of odors from recirculated air.
	FRESH AIR	5-10 CFM/person	Tempered and filtered	
	EXHAUST	5-10 CFM/person	Supply more air than exhausted to create positive pressure and avoid infiltration drafts	
LIGHT	ELECTRIC	Classroom use	30-200 lumen/sq. ft.	Low brightness fixtures, uniform brightness, accent lighting on displays. Avoid bright spots and dark spots, particularly sharp change from one to the other. 1/10 ratio allowed maximum. 1/4 preferred.
		Audio-Visual room Projected image	5 lumens/sq. ft. at writing surface and less than .1 lumen/sq. ft. incident brightness on screen.	
		TV Receiver Use	10 lumens/sq. ft. on surfaces in field of vision around TV screen or 1/10 screen brightness	
	DAYLIGHT	Undesirable for projected images		If supplementary, provide blinding and shielding with automated controls preferably for screening out same.
		Causes undesirable glare effects on glass surface, TV cathode ray tubes		
DECORATION	CEILING	75% minimum reflectance		Pleasant. Use warm colors and materials in modest good taste with variations. Avoid loud or harsh treatments in texture, color pattern, contrast or design.
	WALLS above wainscot	75% minimum if indirect lighted 50% minimum if direct lighted		
	SIDE WALLS below wainscot	50% minimum		
	FLOOR	25% minimum preferably		

ACCOUSTICS		Reverberation time 1 second or less. Transmission reduction should be 40 db min. from all surrounding rooms. Ability to hear depends on lack of interfering and distracting noises.
SOUND		70 db sound delivery in evenly and well distributed system. Ability to concentrate is inversely proportional to the effort required to hear.
SEATING COMFORT		Seating must be comfortable for period of seating. 1 hour seating. May be formed plywood, plastic or hard surface. 2 hour or more seating. Should be cushioned and with arm rests. Discomfort is a distraction.
CONTROLS	AT LECTERN	Room lights (dimming equipment recommended) P. A. system sound level Film projection Slides projector T.V. Daylight shielding Room should be equipped with multi conductor, switches and relays operating low voltage system to various projectors, sound system, low voltage power, etc. Coaxial cable for T.V.
	NEAR LECTERN	Accent lighting controlled at lectern to feature displays. Drapes for dramatic presentation controlled from lectern. Magnetic boards, hook and loop boards, flannel board, pegboard, corkboard and other types.

FIGURE 2. COMPARATIVE CHARACTERISTICS
FILM PROJECTORS AND TV

ITEM	Distances expressed in terms of screen width "W" — FILM	TV	Minimum legibility standard — Height of letter vs height of screen at indicated seating distance — FILM	TV
Picture Composition	High definition Fine grain for close viewing	Lines and dots designed to be of same definition as newspaper photos		
Minimum seating distance	2 W	5 W	1/150	1/70
Minimum ideal seating distance	4 W	8 W	1/75	1/35
Maximum ideal seating distance	6 W	10 W	1/50	1/30
Maximum seating distance	8 W	14 W	1/35	1/20

	FILM	TV	PROJECTED TV
Brightness	10-18 lumens per sq. ft.	100 lumens per sq. ft.	0-20 lumens per sq. ft.
Room requirements	Requires dark room	Satisfactory in normal room light	Requires dark room
Allowable incident room brightness on screen	Color: 1/10 lumen per sq. ft. Black and white: 1 lumen per sq. ft.	Shield light sources to avoid glare (reflections of light) on screen. Requires background lighting around screen of 10 lumens per sq. ft. min. or 1/10 screen brightness.	Any incident screen light undesirable color or black and white.
Limitation of seating area	Screen size or lamp lumens to maintain 10 lumens per sq. ft. Limited by projection lamp output.	Limited by standard picture tubes and manufacturers in small sizes up to 27".	Limited by lumen output of projector tube and screen size.

newspaper pictorial. A newspaper photograph is meant to be viewed from a distance of 14". To study it from a closer distance, or magnify it, does not improve the clarity, and in fact, tends to distort it. So it is with the viewing of a television picture; for the seer to move closer than 5 screen widths from the screen makes the lines of the image quite evident; being closer doesn't improve the clarity on the screen. The ideal viewing distance for normal vision is in the range of 7 or 8W, though satisfactory perception is still obtained from as far away as 14W from the screen.

A room developed to accommodate film projections, then, with 2W minimum and 8W maximum seating distances is not satisfactory for television viewing if the entire screen is used. In fact, a practical answer to the problem (assuming projection of each) is to use the full screen for film projections, and one-half of its length and width dimensions (or one-fourth its area) for TV projections in order to hold the same audience at proper viewing distance. For TV projection then, the audience will be seated between 4W minimum and 16W maximum, which is fairly close to the ideal practical limits.

It might seem that if the same picture is reduced to one-fourth its area a significant amount of detail is lost. However, if the scope of the background of the picture is reduced so that the object remains the same size in both pictures with respect to the screen—with only a loss in background—the result to the eye is the same. This is a significant point, clearly indicating the difference of the media. See Figure 6.

In order to accomplish this, the object must be doubled in size with respect to the TV picture width. If the object occupied the full screen of the motion picture projector, then to maintain the same degree of clarity the TV projection would have to enlarge portions of the object to give an equal picture and to develop all detail.

A TV screen usually has a brightness on the order of 100 lumens* per square foot, while a motion picture screen is of the order of 10 lumens per square foot. Thus the film projection requires a darkened room while the TV screen does not. In fact, supplemental lighting is essential in the TV room because the screen at proper viewing distance occupies the small zone of the eye activated by the cones (photopic vision) while the rod portion of the eye (scotopic vision) which partially controls the size of the iris is receiving no picture signal at all. The eye is readily strained unless the level of the brightness surrounding the screen is held to at least one-tenth the screen brightness.

The two characteristics by which screens are evaluated are its gain and side viewing angle. Gain of a particular screen is defined as the intensity of the light emanating from the screen from a given projection source, as compared to the intensity of light from that same light source reflected from a pure magnesium carbonate screen. For front projection screens this intensity is due to reflectance; and for back projection screens, the intensity is due to transmission.

The side viewing angle is defined as the angle made in a horizontal plane between the viewer and the projector at the center line of the screen.

Logically, the gain of a screen will not be the same for all side viewing angles (decreasing as the side angle increases.) Nor will the gain be the same for all portions of the screen (tending to decrease for the most remote part of the screen.) Fortunately the eyes response to light is logarithmic and variations as great as 3 to 1 are tolerable and not overly noticeable. Light intensity variation is more exactly accounted for by projection engineers in terms of another angle called the bend angle used in point by point analysis across the screen, results being averaged out to arrive at a gain value. Such analysis is beyond the scope of this text.

Gains for screens used in this text will represent the design for the sector involved, the design value being closer to the gain for the sector near the extreme side viewing angle rather than the peak value at the projection axis or the average gain. See figures 3 and 4 for design gain values of various screens, and viewing characteristics.

Film screens in common usage have a narrow angle of effective viewing as compared to TV. TV screens because of their curved surfaces, permit the audience to sit as far as 45° to one side of the projection axis. Matte screens, until recently, permitted the widest viewing angle—30°, with almost uniform brightness throughout the entire viewing sector, with low gain (about one.)

Beaded screens, which have the highest gain, have a practical side angle viewing limitation of 20° with a relative brightness variation in the magnitude of 3 to 1 as one moves through the side viewing angle from the projection axis.

Metallic and non metallic lenticular screens, recently developed, have a gain variation similar

* *This monograph uses the term lumens per square foot for both luminous surfaces and reflective surfaces to avoid the distinction between the correct terms, foot lamberts (due to luminescence) and foot candles (due to reflectance) which are dimensionally expressed in lumens per square foot.*

FIGURE 3. CHARACTERISTICS OF PROJECTOR SCREENS

MEDIA	SCREEN	MIN. VIEWING DISTANCE	MAX. VIEWING DISTANCE	MAX. VIEWING ANGLE EACH SIDE AXIS
FILM	Translucent of high high gain or beaded opaque	2.5 W and not less than 6'	8 W	50°
FILM	Translucent of moderate gain, matte or ordinary lenticular opaque	2.0 W	8 W	30°
TV	Cathode ray tube phosphorescent	5 W	14 W	45°
FILM	Wide angle lenticular opaque	2.0 W	8 W	50°

FIGURE 4. ROOM DESIGN GAIN AND SIDE VIEWING ANGLE CHARACTERISTICS OF VARIOUS FRONT AND BACK PROJECTION SCREENS

SCREEN COMPOSITION	ANGLE	DESIGN GAIN (Reflectance or Transmission)
MATTE OPAQUE	0-30°	1
BEADED OPAQUE	0-5° 0-10° 0-20°	10 4 2
Metal Lenticular Opaque	0-25° 0-30° 0-50°	3 2 1
Non-metallic Lenticular Opaque	0-30° 0-50°	1.5-2.0 1
Translucent moderate gain	0-25°	1
Translucent high gain	0-15° 0-30° 0-35°	3 2 1

to beaded screens, varying with the side angle. But the peak gain is not as great and the variation is not as intense. Satisfactory gains, (greater than one) have been extended to side viewing angles as great as 50°.

It will be noted that due to the directional characteristics of beaded and metal lenticular screens, higher gains are recorded for the lesser viewing angles of the screens; these diminish as the angle increases. It is observed that the gain of certain of these screens represents a higher lumen per square foot emission by the screen than the lumen per square foot input by the projector lamp. This effect is obtained by bunching the light by use of lenticles or beads. Lenticles and beads or texture variations are sized so that the grain they impose on the picture is not apparent at the proper viewing distance, but the effective light intensity of the picture is increased by the degree of bunching that occurs at the various viewing angles.

High gain characteristics are also acquired from rear projection screens made of clear glass or plastic with a roughened diffusing surface acting as the screen. The roughness of the surface causes a diffusing of the light creating a bunching of the light similar to that experienced with lenticular and beaded screen. If the grain of the diffusion particles is small with respect to the viewing distance, the viewer, does not become aware of the bunching. High gain translucent screens are restricted to a narrower viewing angle than metallic or non metallic lenticular screens are. Work is being done to improve translucent screens with the use of Fresnel lenses and other refracting devices.

A comparison of front and rear screen projections for various considerations is given in figure 5. The designer should carefully consider all of them, and depending on his requirements choose accordingly.

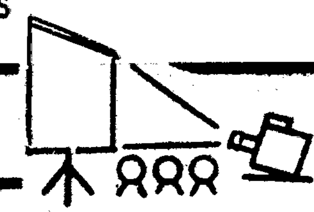
The current trend is to pre-programming and remote control for audio visual presentations. From his lectern, the lecturer should have control of several projectors, all of which were properly threaded with film in proper sequence before the lecture. He should also have control of the room lights and the sound system. Systems have been developed to fulfill this purpose and make the entire procedure of the lecture, light control, sound control, slides, film clips, etc. proceed automatically from a programming computer. In fact, it is possible to put the lecture on tape, tagged so it will operate all the apparatus without the lecturer being present. Remote control of opaque and overhead projectors is not available as of this date.

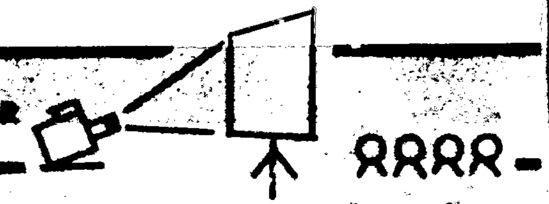
Remote systems are available which have been developed to the extent that more than one picture can be displayed at the same time; in fact, two or three pictures can be shown on several screens simultaneously to allow multiple foci presentations.

ROOM DESIGN

Using the principles of design presented in this monograph it is possible to graphically solve problems, achieving good design for varying dimensions, areas, occupancies, screen widths, gain, project distances, lens focal lengths, and lamp sizes required for the several types of film and projectors that may be used. Solutions for these problems can be divided into at least two categories. The first of these relates room dimensions, areas, occupancies and occupied areas to screen

FIGURE 5. COMPARISON OF FRONT AND REAR SCREEN PROJECTION FOR VARIOUS CONSIDERATIONS





CONSIDERATION	FRONT	REAR
	(Projected to opaque screen from viewing side of screen)	(Projected to translucent screen from side of screen away from audience)
Proximity of Lecturer to equipment	REMOTE—without equipment attendance or automation—requires lecturer to go through audience to tend equipment	CLOSE—with or without equipment attendance or automation—lecturer is close to equipment for tending
Method for providing central attendance	Racetrack continuous projection booth over perimeter corridor	Central projection area (requires additional building space)
Programming	Requires careful programming	Simpler programming, less wiring
Emergency tending	Emergency tending difficult unless signal system provided	Emergency tending good. Care must be taken to prevent attendant from crossing other projections
Screen and seating	High gains through wide angles permit greater seating	Viewing side angle not as great for same values of gain
Projection distance	Projection over audience may be slightly distracting	Accomplished at sacrifice of space, and light intensity if mirrors are used
Noise	Noisy if equipment is in room. Absolutely quiet if equipment is in booth.	Some machine noise will penetrate screens
Tending of Equipment	Distracting and noisy if in viewing room. Not noticed or heard if in booth.	Some noise may be heard through screen. Movement behind screen may be distracting.
Projector light as source of incident light on screen	Undesirable in room. Non-existent from projection booth.	Causes some incident screen light. Requires dark-colored, light-absorbing paint and shielding in room area back of screen
Overhead Projector	Conspicuous in room. Lecturer in central position. Attendant optional.	Equipment not conspicuous. Lecturer not in room. No attendant required.
TV Projector Application	Conspicuous	Inconspicuous
Interpositioning	Front screens not usable for rear screen projection	Rear screens may be used for front projection with some sacrifice of transmission and gain

FIGURE 6. TO COMPARE TELEVISION TO FILM PROJECTIONS

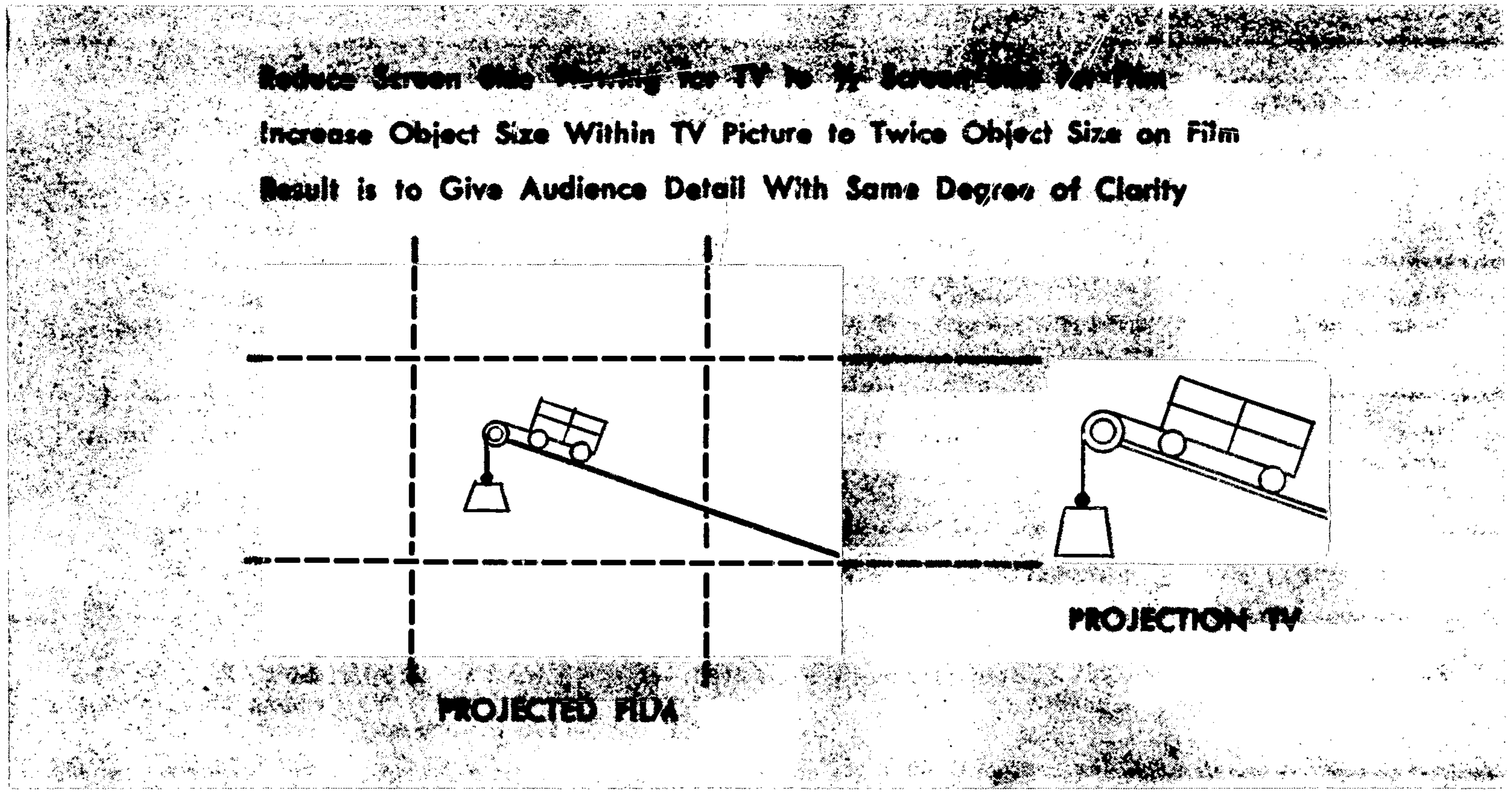


FIGURE 7. SEAT SPACING FOR AUDIO VISUAL PURPOSES

Close seating: auditorium or theatre seating	[illegible]	5 to 8 sq. ft. per person
Conference or seminar seating	[illegible]	[illegible]
Cafeteria seating, library seating, ordinary classroom seating or classroom desk and chair seating, listening lab seating	[illegible]	[illegible]
Office desk seating, loose classroom seating	[illegible]	[illegible]
Laboratory spacing, desk and reference tables, large drafting tables.	[illegible]	[illegible]

width, assuming the characteristic of the type of projection to be used is known. The second category relates screen brightness, projection distances, types of screen, characteristics of gain, and the relations of lamp lumens to screen width, assuming that the desired performance requirements are known. The common denominator for each type of design approach is screen width. The graphs described here can be used to properly determine the best way to a problem solution.

The first type of design graph is useful in the design of rooms for required occupancies, or for adaptation of existing rooms to projector use, or for solving occupancy and area problems; it may be employed for sizing the screen knowing the general room requirements. For usual occupancy seating requirements see Figure 7. The second type of design graph is useful for solving problems in the selecting of equipment for viewing, knowing the projection distances and the screen widths—solving for type of screen to be used, gain, focal length of projector, and brightness of projection lamp, knowing the type of visual material to be projected effectively.

It is as advisable for designers of rooms to check through this second design consideration, to assure themselves of the availability of equipment for the room designed, as it is for the equipment manufacturers to design and manufacture equipment for audio-visual rooms in terms of newly defined needs. Modifications outside the scope of present standard equipment or practices are likely to be a prime need for some time in the immediate future.

In the first category (relating room dimensions occupancies, seating areas, and ratios of occupied areas to screen widths for assumed equipment) graphs are here developed for seating—and viewing situations—for sectors of a circle, for nearly square rectangular rooms, and for long narrow rectangular rooms. The sector graph is usable for fan shaped auditoriums, triangular, hexagonal, and other angularly shaped rooms in which seating is arranged in a circular sector type pattern. One of the rectangular room graphs is developed for use for rooms with the projector axis along the diagonal; this actually allows the most efficient use of the space within the room when the length of the room and the breadth of the room are nearly equal. The other rectangular room graph is developed for long narrow rooms where the projection axis is most economically placed along or close to the center line of the room parallel to the long side of the room. The mathematical formulations for the graphical solutions are contained in an appendix published separately and available on request. The graphical solutions yield results more quickly for variations in parameters than calculated results and they are accurate enough for the purpose (within 1 to 3%).

THE CIRCULAR SECTOR

Figure 8 shows a circular sector for a viewing audience and indicates the dimensions W of the screen, Dx, the maximum seeing distance, and Dn, the minimum seeing distance and Θ, the maximum side viewing angle.

The area factor in a sector expressed in non-dimensional terms is as follows:

$$\frac{A}{W^2} = \left[\left(\frac{Dx}{W}\right)^2 - \left(\frac{Dn}{W}\right)^2\right]\frac{\pi\Theta}{180^\circ}$$

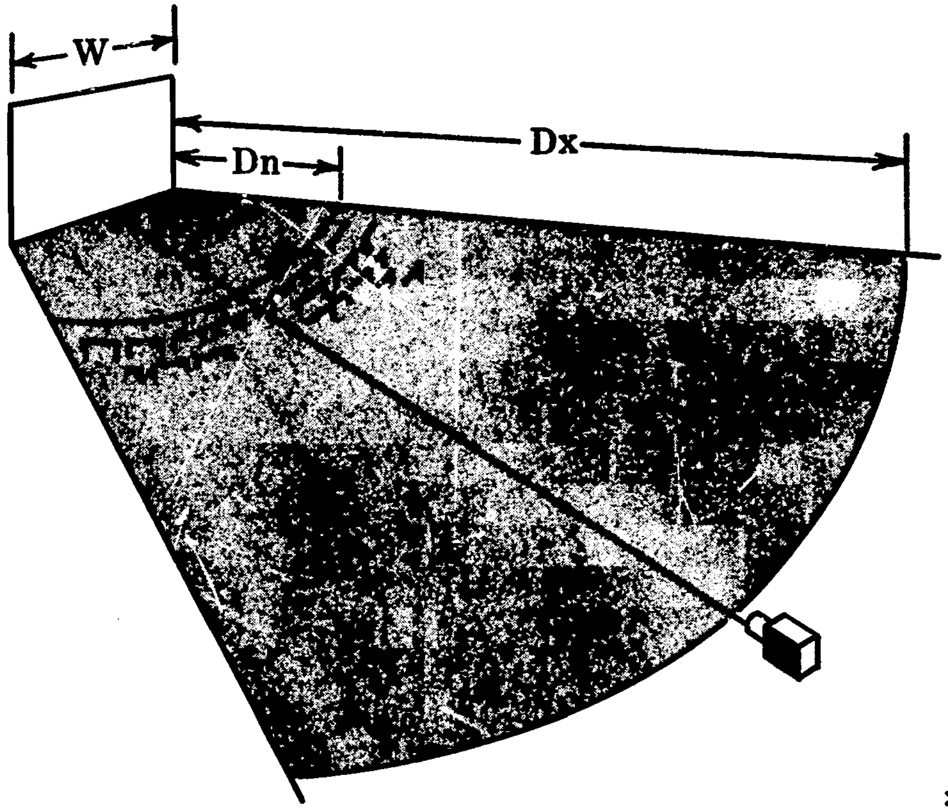


FIGURE 8. CIRCULAR SECTOR ROOM

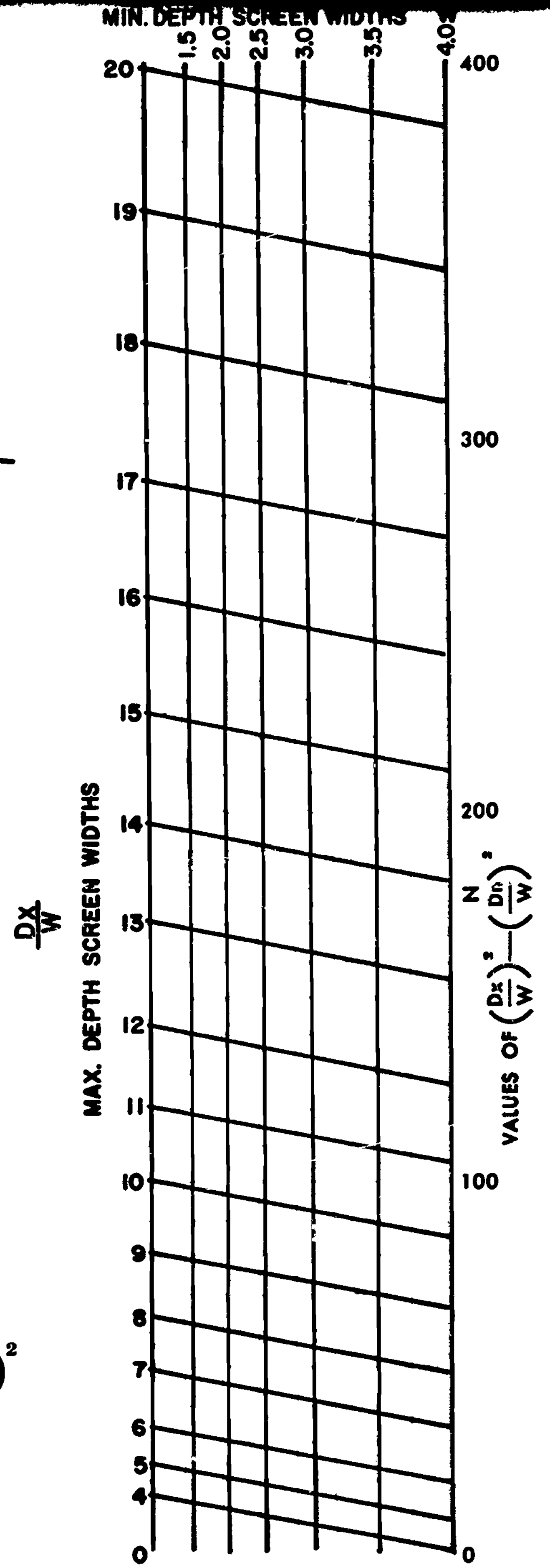


FIGURE 9. Graph for solving $\left(\frac{Dx}{W}\right)^2 - \left(\frac{Dn}{W}\right)^2$ N

11

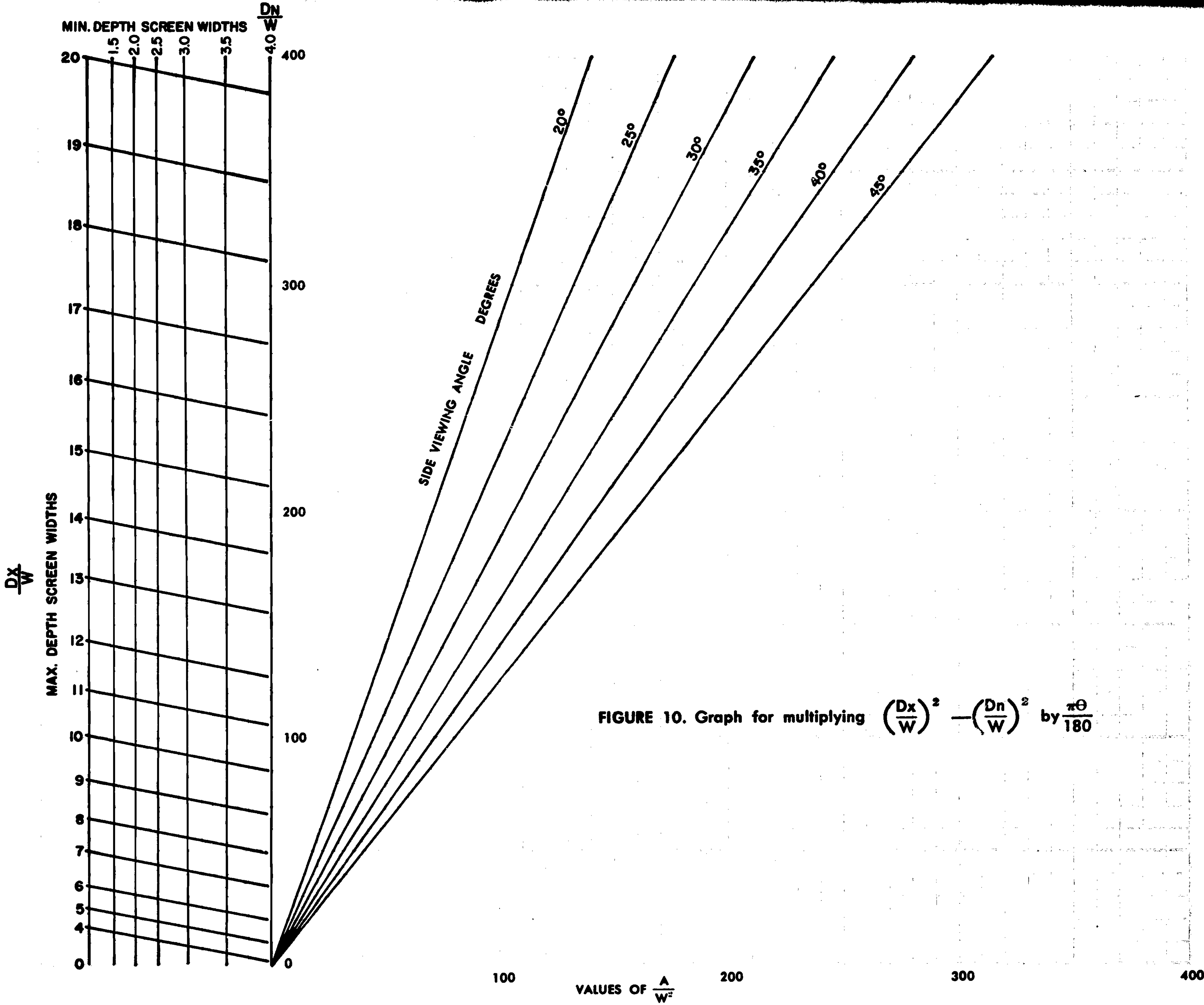


FIGURE 10. Graph for multiplying $\left(\frac{Dx}{W}\right)^2 - \left(\frac{Dn}{W}\right)^2$ by $\frac{\pi\theta}{180}$

For derivation, see appendix supplement furnished on request.

Figure 9 shows how the dimensionless portion within the brackets is solved.

To multiply by $\frac{\pi\Theta}{180^\circ}$, figure 10 was developed.

This results in the dimensionless area multiplier along the bottom edge of the graph in Figure 10.

To multiply this dimensionless number by W^2 one should add the lines shown in Figure 11.

Then to divide this area by the number of square feet per person one should include the lines shown in Figure 12.

So to use the graph to solve an entire problem one should proceed as follows:

Suppose that the problem is to design a room for audio-visual film presentation using a 5′ wide matte screen. What would be the area of the seating sector and what would be the useful occupancy area, and how many occupants could one place in this room in seminar seating? From previous data it would be known that the furthest seating would have to be within 8W of the screen; the minimum would be beyond 2W of the screen and the seating would require about 10 square feet per occupant. Enter the graph at 8W and then proceed along the diagonal line until it crossed the minimum ratio 2W; then proceed horizontally to Θ equals 30° (the maximum side viewing angle for a matte screen); then vertically to the screen width 60″ (or 5′); then horizontally to the margin where it is seen that the occupied area was about 800 square feet. Turning back on this last horizontal line until the path has crossed the line where the square feet per occupant was 10, one would proceed vertically to the bottom of the chart where it is seen that the number of the occupants would be about 80. This procedure is illustrated in Figure 13.

To determine the entire area within the room, one would then proceed from 8W horizontally to the angle, then vertically to the screen width, then horizontally to the right-hand margin and there one could find the entire area within the sector.

Another way in which this same graph might be used would be for determining the best screen width, knowing the maximum and minimum viewing depth ratios, the side viewing angle, the occupancy desired, and the square foot per occupant required. To do this, one would proceed vertically on the graph from the occupancy notation until reaching the square foot per occupancy chart, thence horizontally to the right-hand margin where one can read the probable occupied area. Knowing where this horizontal line is, one will now proceed over to the left-hand side of the graph, following the maximum and minimum space requirements; then will proceed horizontally until striking the viewing angle required; thence vertically until striking the horizontal line from the occupied area. Where these two lines meet, one can read the screen width required by interpolating between the screen width lines shown on the graph. To find the sector area, start at the maximum ratio, proceed horizontally to the viewing angle and thence vertically to the now found screen width. Proceeding horizontally from this intersection, one will find the sector area of the room. This is illustrated in Figure 14.

THE BROAD RECTANGULAR ROOM

(Length and breadth not too far different from each other dimensionally) and the diagonal is used as a projection axis.

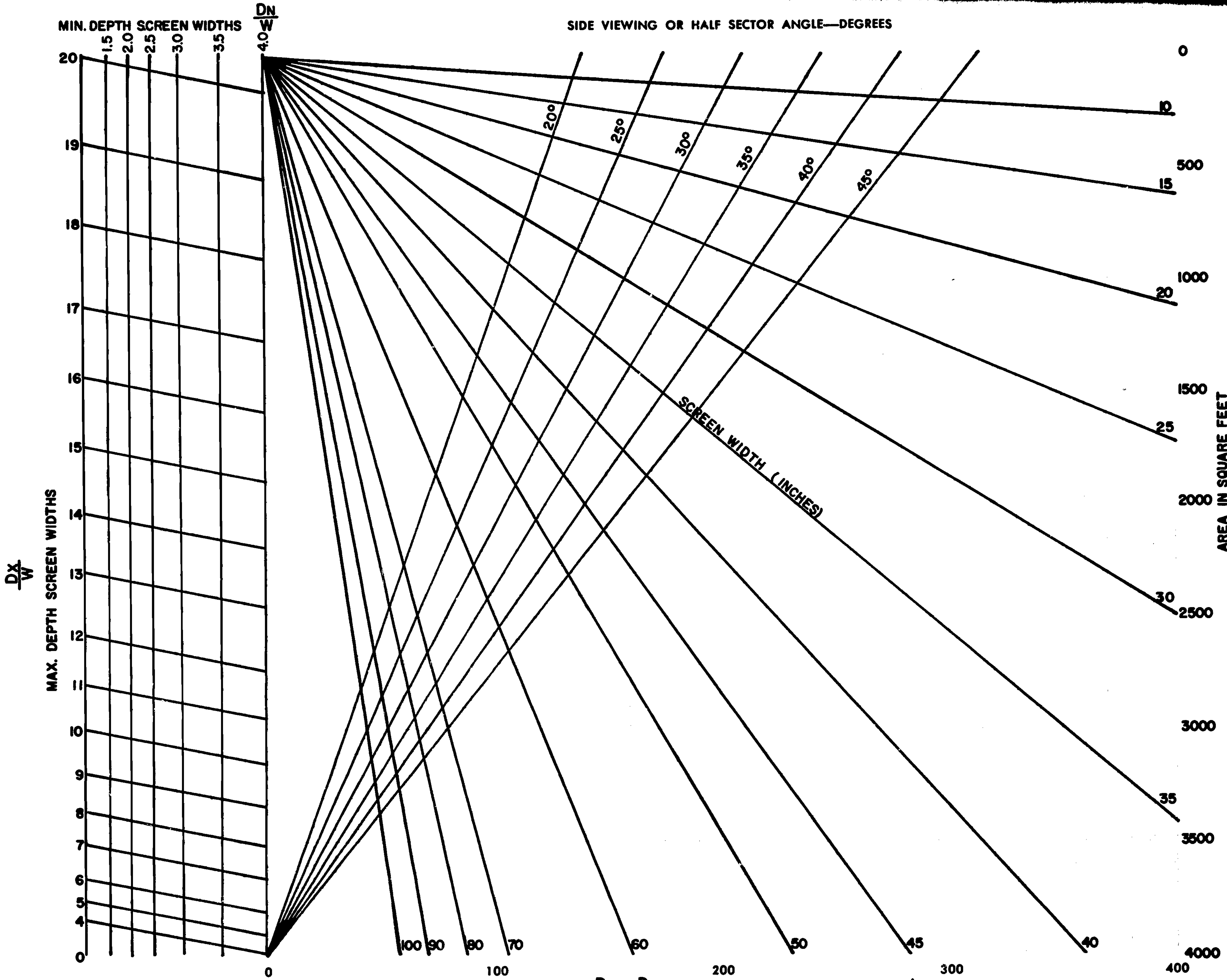


FIGURE 11. Graph for solving sector viewing area from given values $\frac{Dx}{W}$, $\frac{Dn}{W}$, Θ, and W

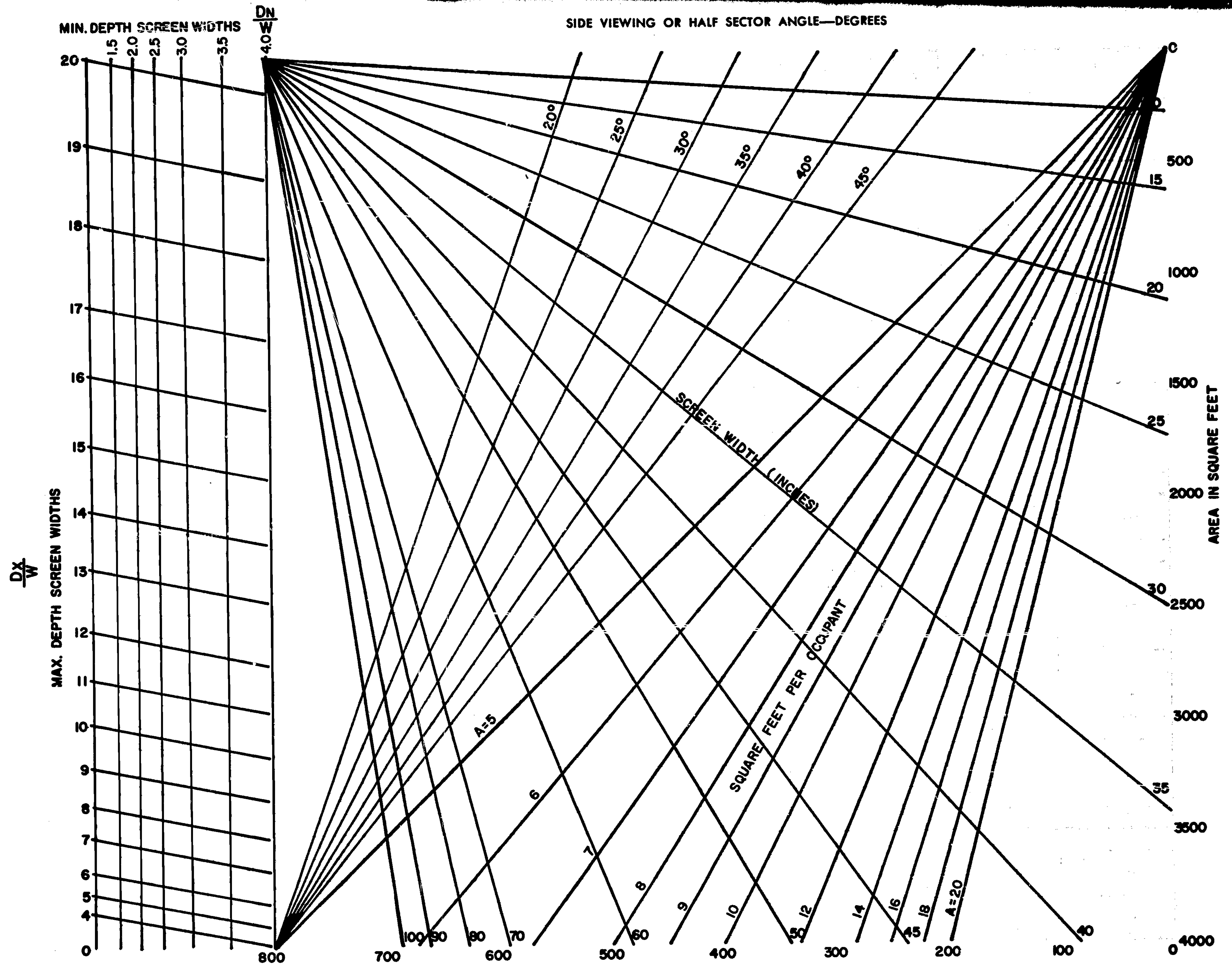


FIGURE 12. Graph for solving number of occupants, knowing area per occupant $\frac{D_x}{W}$, $\frac{D_n}{W}$, Θ, and W

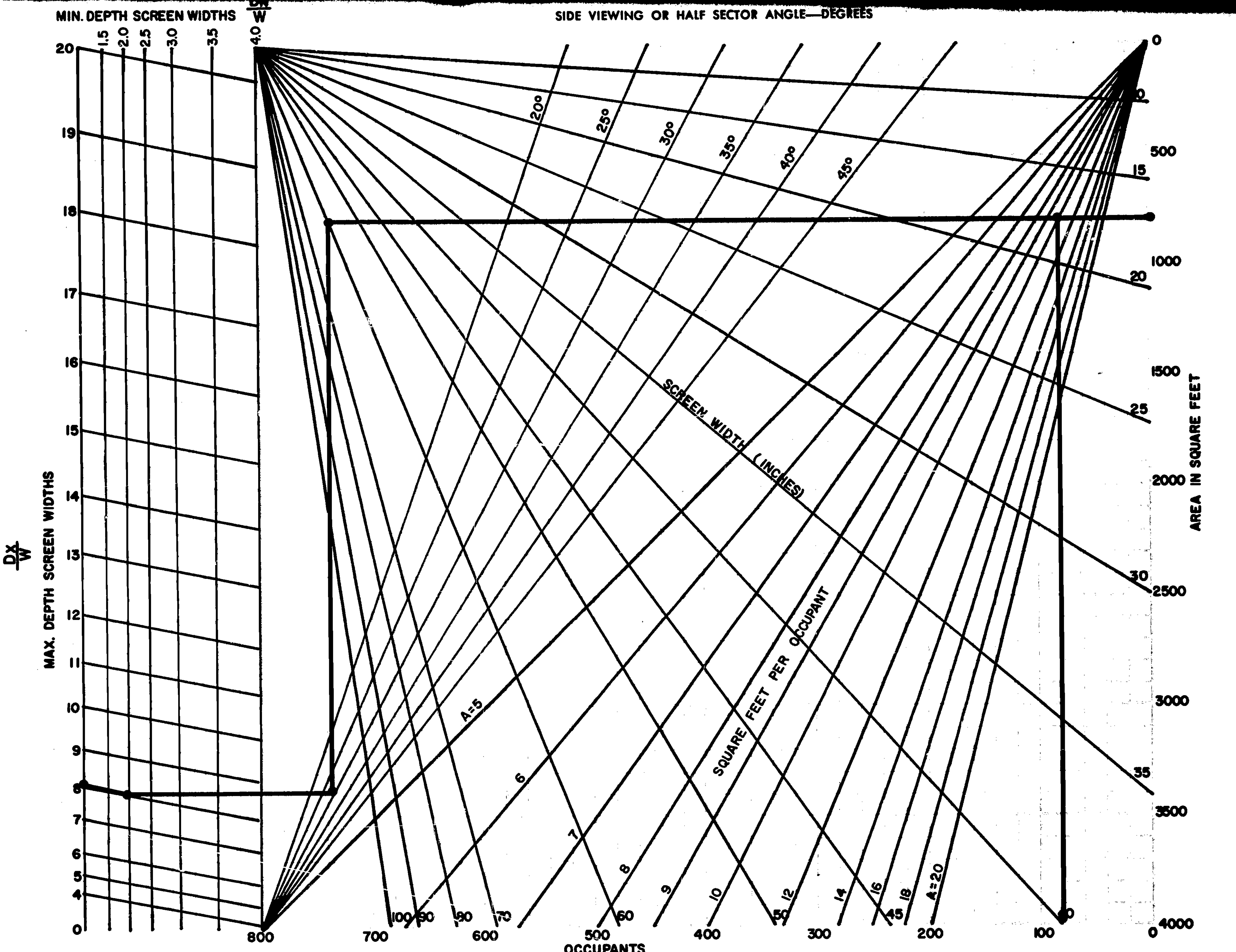


FIGURE 13—Solution to illustrative problem I using Figure 18

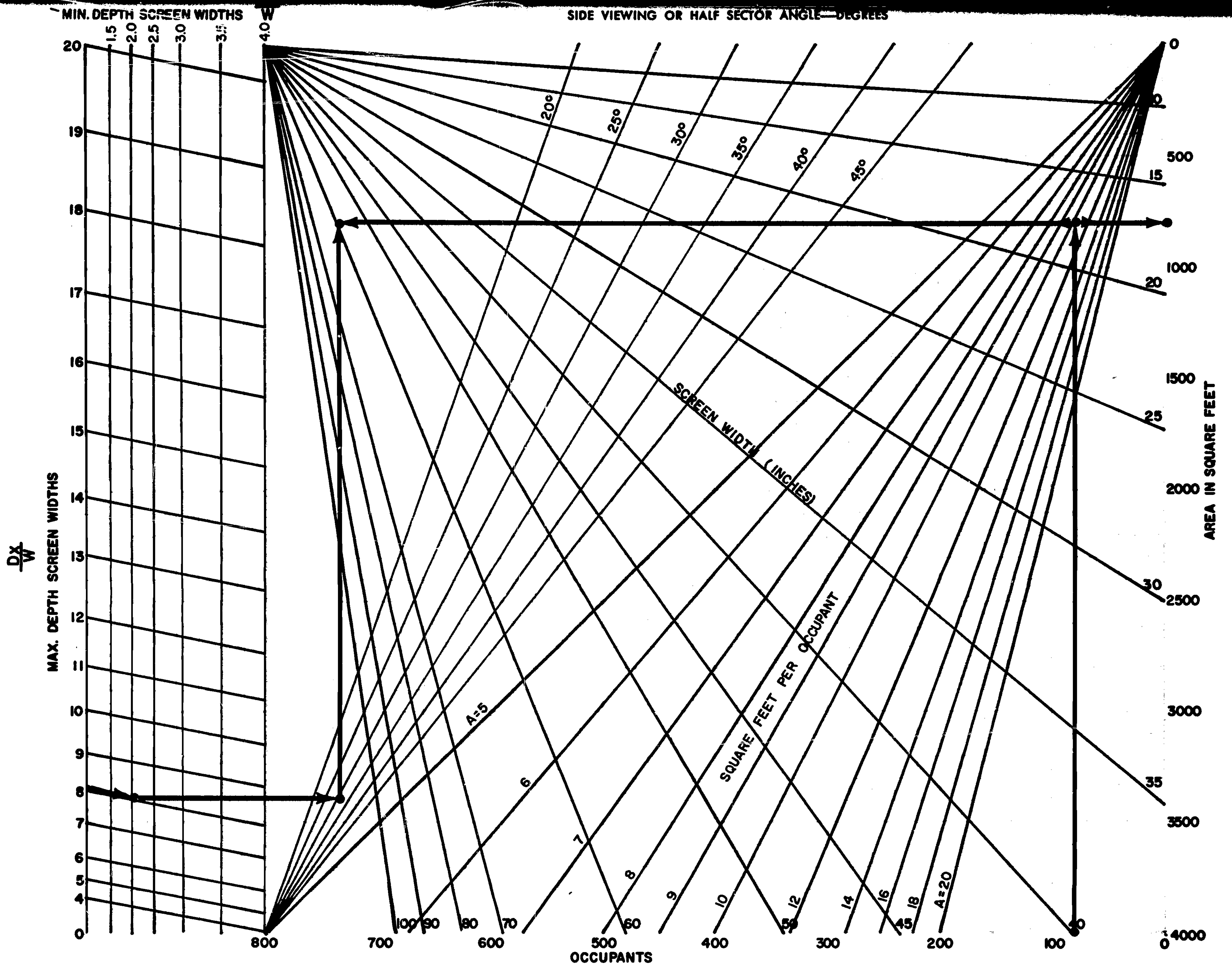


FIGURE 14—Solution to second illustrative problem using Figure 18

These relations are indicated in Figure 15. In addition to Dx, Dn, W and θ already defined, α is defined as the acute angle formed in the horizontal plane between the diagonal and the long side of the room and d is defined as the length of the diagonal of the room.

The non-dimensional formula for finding the area of occupancy is as follows:

$$\frac{A}{W^2} = \frac{1}{2}\left(\frac{Dx}{W}\right)^2 \left[\sin 2\alpha - \cos\alpha \sin(\alpha - \theta) - \sin\alpha \cos(\alpha + \theta)\right] - \frac{Dn}{W}\,\frac{\pi\theta}{180°}$$

Derivation of this formula is found in the Appendix.

Figure 16 is a graph for solving α' and d when the length and breadth of the room are known.

Figure 17 is a graph to be used for solving for the required screen width W knowing the $\frac{Dx}{W}$ ratio used as a design criteria, the θ value for the screen assumed, and the α and d values found in Figure 16. The left-hand side of the graph compensates the $\frac{Dx}{W}$ ratio for various α and θ angles by evaluating the complex trigonometric formula $\sin 2\alpha - \cos\alpha \sin(\alpha - \theta) - \sin\alpha \cos(\alpha + \theta)]$ for the various values indicated. The right-hand side of the graph solves for the screen width by interpolation between screen width lines for the depth of the room selected at the bottom of the graph.

Figure 18 is a five pentrant graph which solves for the complex mathematical notation

$$\frac{1}{2}\left(\frac{Dx}{W}\right)^2 \left[\sin 2\alpha - \cos\alpha \sin(\alpha - \theta) - \sin\alpha \cos(\alpha + \theta)\right] - \left(\frac{Dn}{W}\right)^2 \frac{\pi\theta}{180}$$

Entering the upper left-hand pentrant with known values of α and θ, one proceeds horizontally to the value of $\frac{Dx}{W}$ in the right-hand upper pentrant; thence vertically to the bottom of the upper right-hand pentrant to the indicated value of total sector area (not corrected for area lost by non-occupancy inside the Dn limit: $\frac{1}{2}\left(\frac{Dx}{W}\right)^2 [\sin 2\alpha - \cos\alpha \sin(\alpha - \theta) - \sin\alpha \cos(\alpha + \theta)]$

Here the operator pauses momentarily and enters the middle left-hand pentrant with values of $\frac{Dn}{W}$, and θ and makes a horizontal line from the intersection. Now the designer proceeds from the vertical line at the top of the middle right-hand pentrant until the line intersects the horizontal line from the middle left-hand pentrant. At this intersection the designer proceeds vertically to the value of screen width in the bottom pentrant found from the solution of Figure 17; thence horizontally to the area of occupancy at the margin or horizontally to the value of area per occupant indicated in a second series of diagonal lines; and thence vertically to the occupancy at the lower margin.

By not following the curved line imposed by the graphs in the middle section of the graph, but proceeding vertically from the upper-right graph to the lower-right graph to the screen width, the operator can find the total area within the visual sector, instead of the occupied area only.

Illustration

Suppose an existing rectangular room is 40′ x 70′ to be used for audio-visual projections. What should the screen width be, assuming a matte screen, film projection, and an occupancy

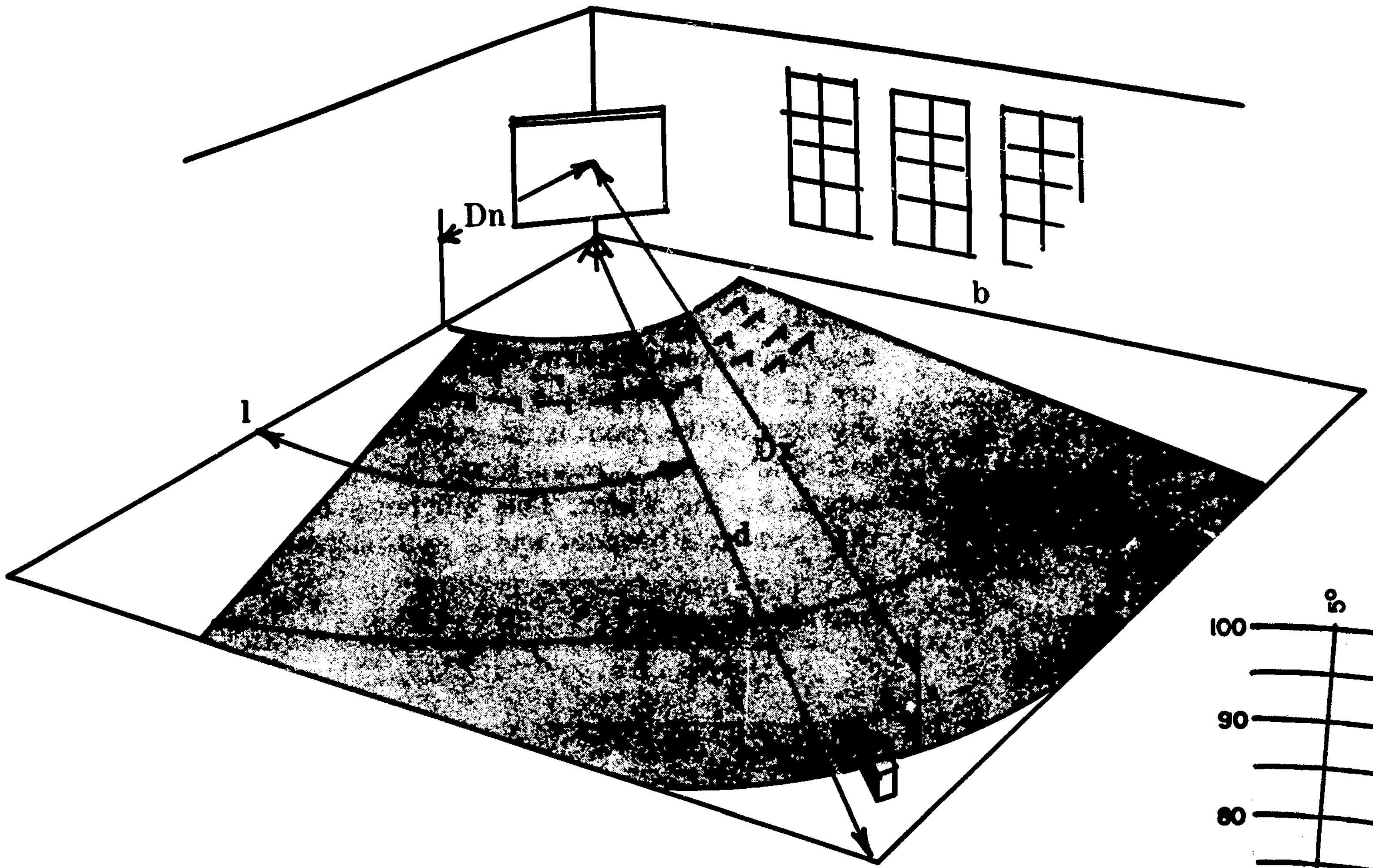


FIGURE 15. THE BROAD RECTANGULAR ROOM

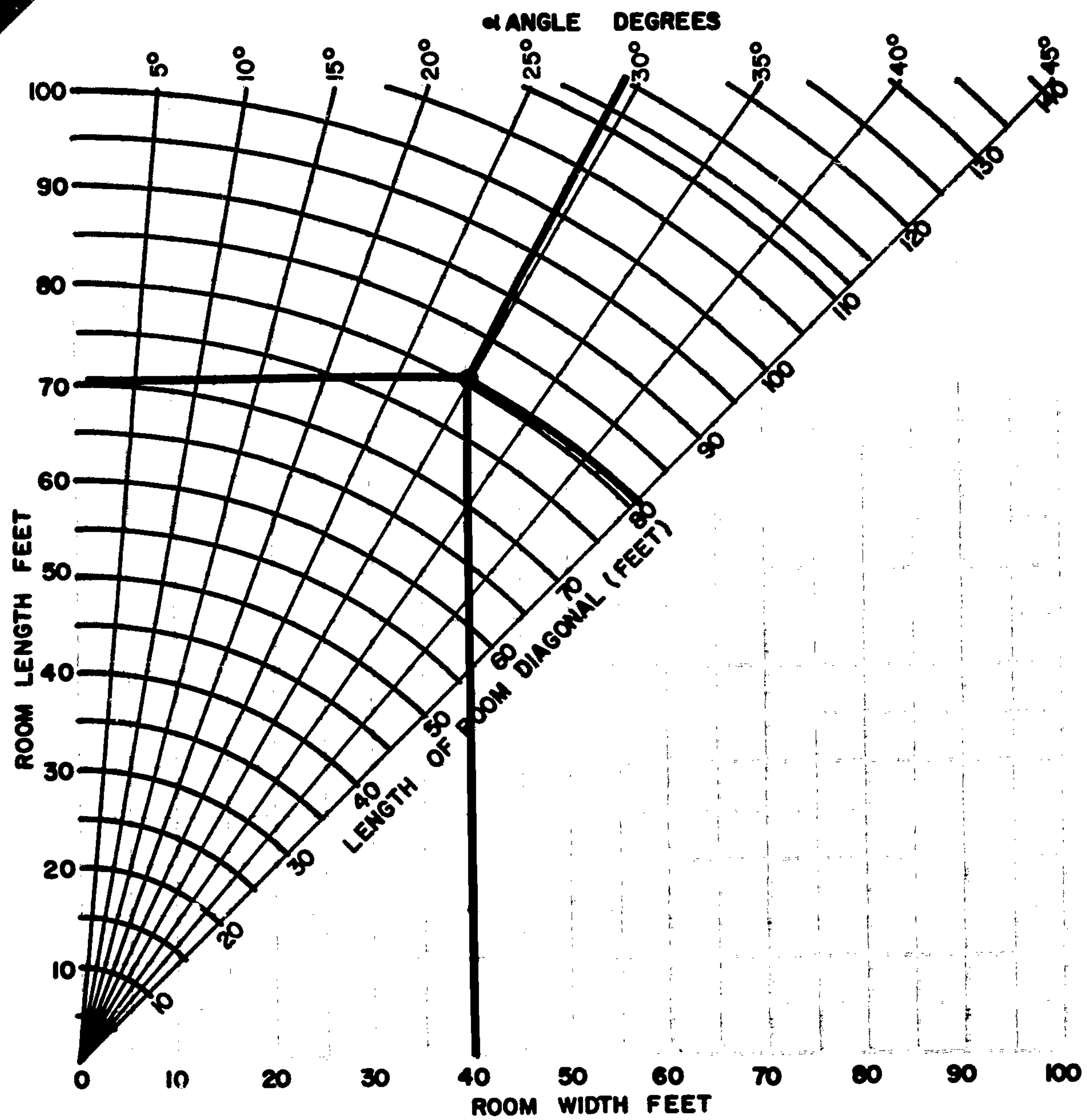


FIGURE 16—Graph for solving d and α knowing b and l.

Relation of room width and length to room diagonal and least acute angle and illustrated solution based on ordinary classroom seating? From Figures 2, 3, and 7 the $\frac{Dx}{W}$ is 8; the $\frac{Dn}{W}$ is 2; Θ equals 30°; and classroom seating is 18 sq. ft. per person. From Figure 16 Θ equals 29°, and d equals 80′. From Figure 17 the screen width is 114″; as required when α equals 38°, Θ equals 30°, and d equals 38′.

Entering Figure 18 at Θ equals 30°, α equals 29°, thence horizontally to $\frac{Dx}{W}$ equals 8; thence vertically downward to the lower margin. Pausing now, one projects a horizontal line from the intersection of Θ equals 30° and $\frac{Dn}{W}$ equals 2.

This horizontal line is extended until it intersects the nearly vertical curved line (drawn parallel to the series of curved lines shown) extended from the abandoned vertical line we paused at. From this intersection the line proceeds vertically downward to W equals 114″ where one finds the area of occupancy to be 1500 sq. ft. Proceeding horizontally from this area of occupancy to the square foot per person and thence vertically to the ocupancy, one finds that the seating area will accommodate approximately 83 students. See Figure 19. It is interesting to note that only half of the area of the room is effectively used, compared to the area of the room found by multiplying the length by the width. This efficiency improves as the room gets broader and Θ approaches 45°.

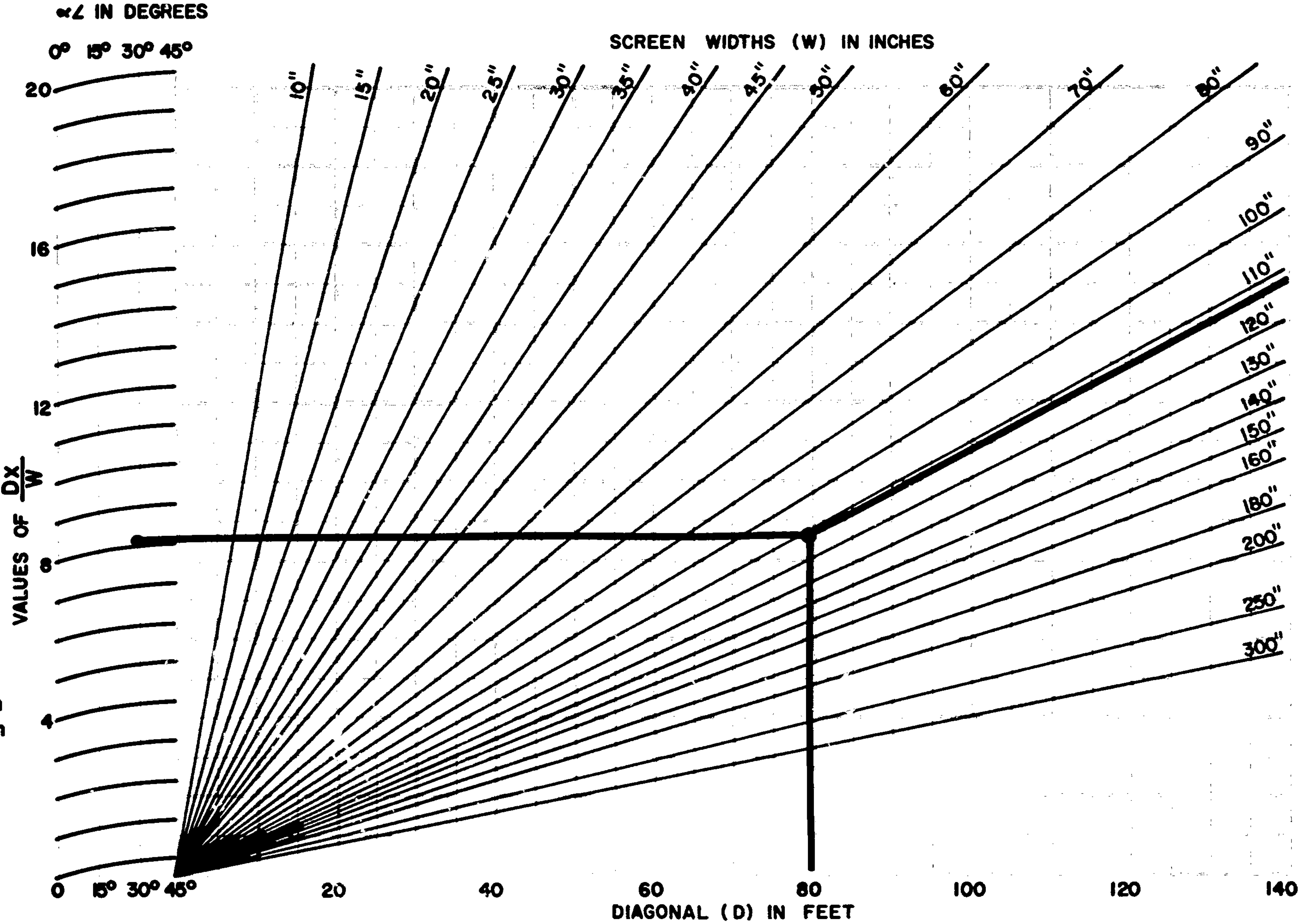


FIGURE 17—Graph relating screen width to room diagonal for known values $\frac{Dx}{W}$ and α (least acute angle of room) and illustrated solution

THE NARROW RECTANGULAR ROOM

(In which the length is considerably greater than the breadth of the room and in which the center line of the room parallel to the long axis is used as a projection axis.)

These relations are indicated in Figure 20.

In addition to Dx, Dw, W and Θ, as earlier described, α′ is defined as the acute angle formed in the horizontal plane between the half room diagonal and the long side of the room and d′ is defined as the length of the half-room diagonal.

The non-dimensional formula for finding the area of the occupancy is as follows:

$$\frac{A}{W^2} = \left(\frac{Dx}{W}\right)^2 \sin \alpha' \left[2 \cos \alpha' - \sin \alpha' \cot \Theta \right] - \left(\frac{Dn}{W}\right)^2 \frac{\pi \Theta}{180^\circ}$$

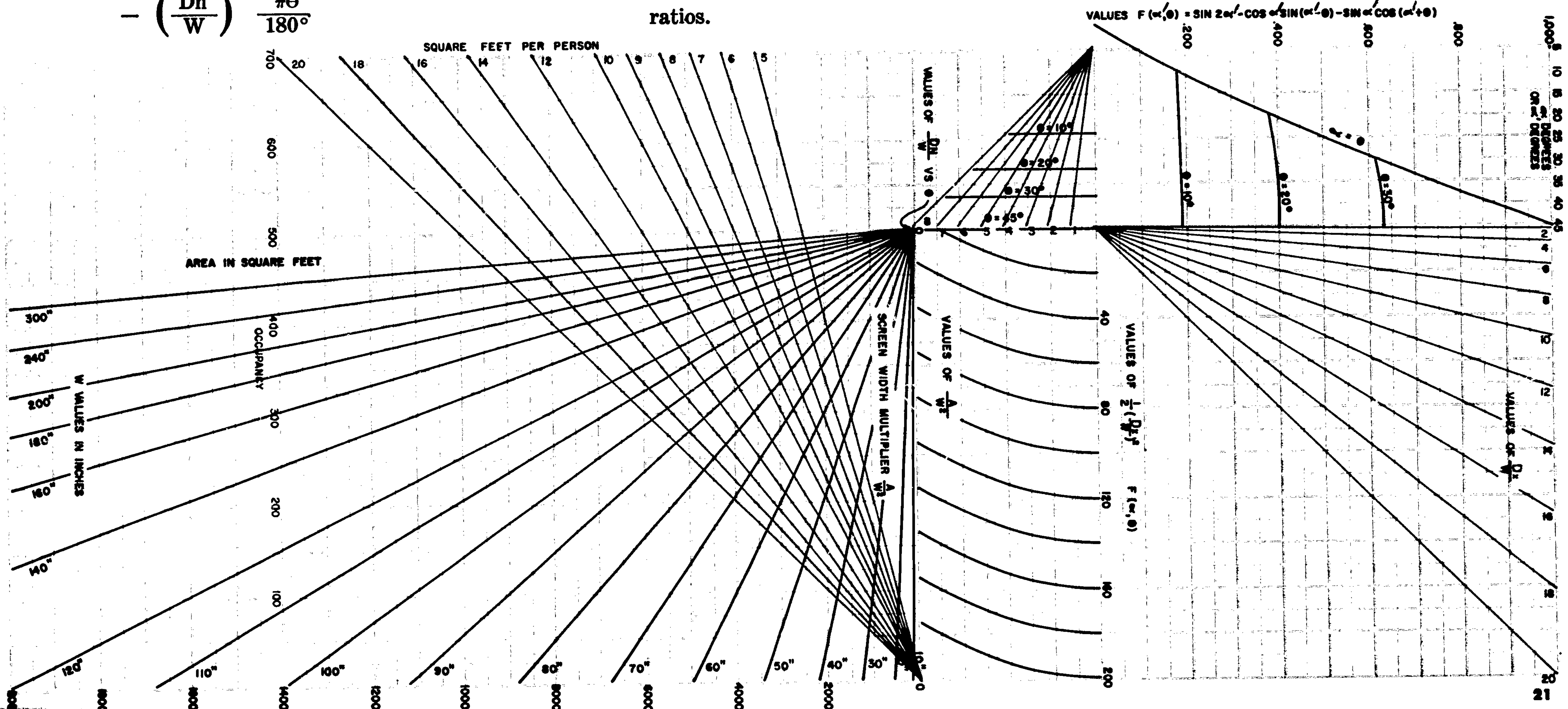
except when $\frac{Dn}{W} > \frac{Dx}{W} \sin \alpha' \cos \Theta$, (in which case the area formed must be compensated for the over-deletion). The compensation area expressed non-dimensionally is

$$\frac{Ac}{W} = \left(\frac{1}{\frac{Dx}{Dn}} - \frac{\sin \alpha'}{\sin \Theta} \right)^2 \left(\frac{Dx}{W} \right)^2$$

Figure 21 is a graph for finding the value of α′ and d′ knowing the length and breadth of the room.

Figure 22 is a graph for solving for the required screen width knowing the d′ and $\frac{Dx}{W}$ ratios.

FIGURE 18—Graph for solving for area of sector and number of occupants knowing $\frac{Dx}{W}$, $\frac{Dn}{W}$, Θ, W, Area Per Occupant



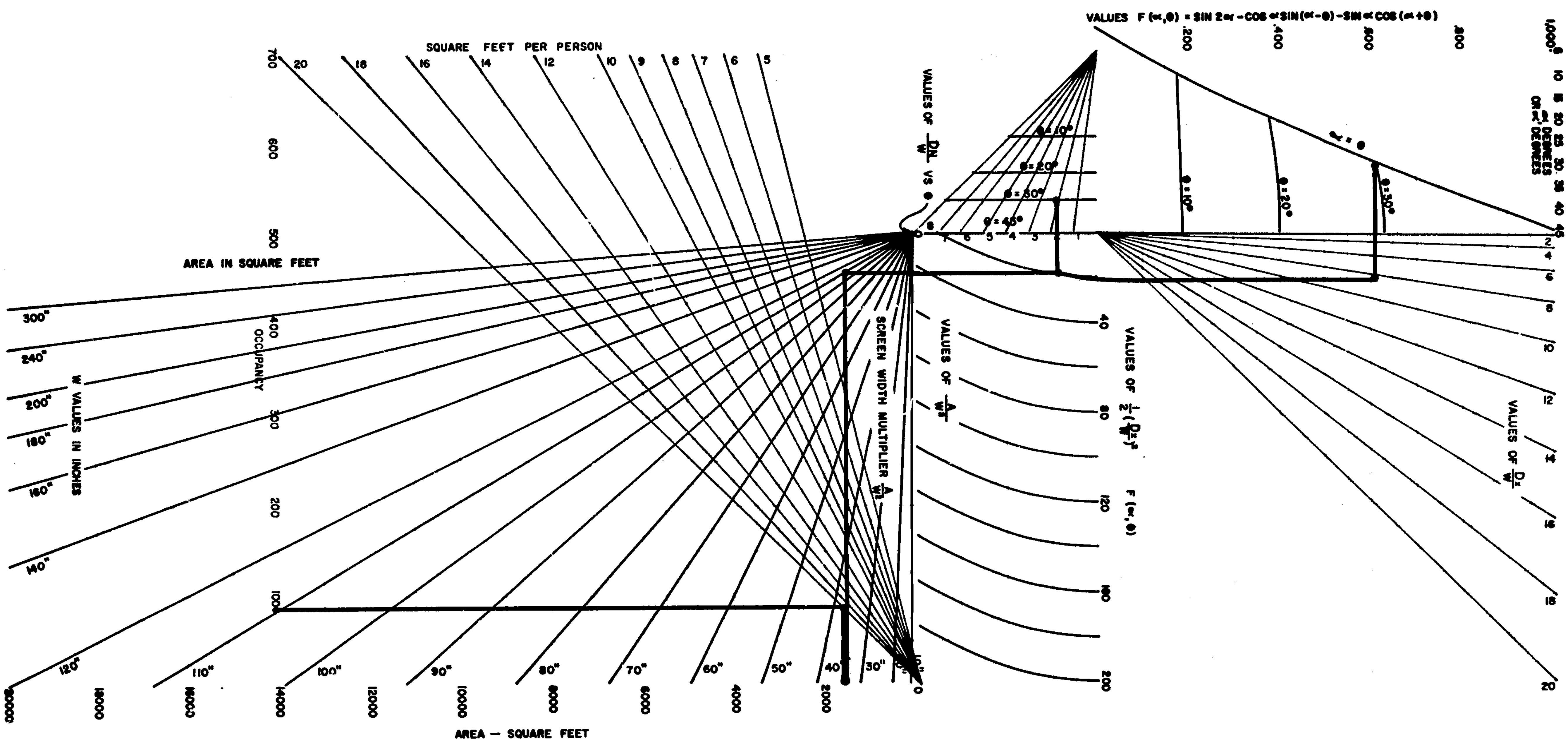


FIGURE 19—Solution to illustrative problem using Figure 18

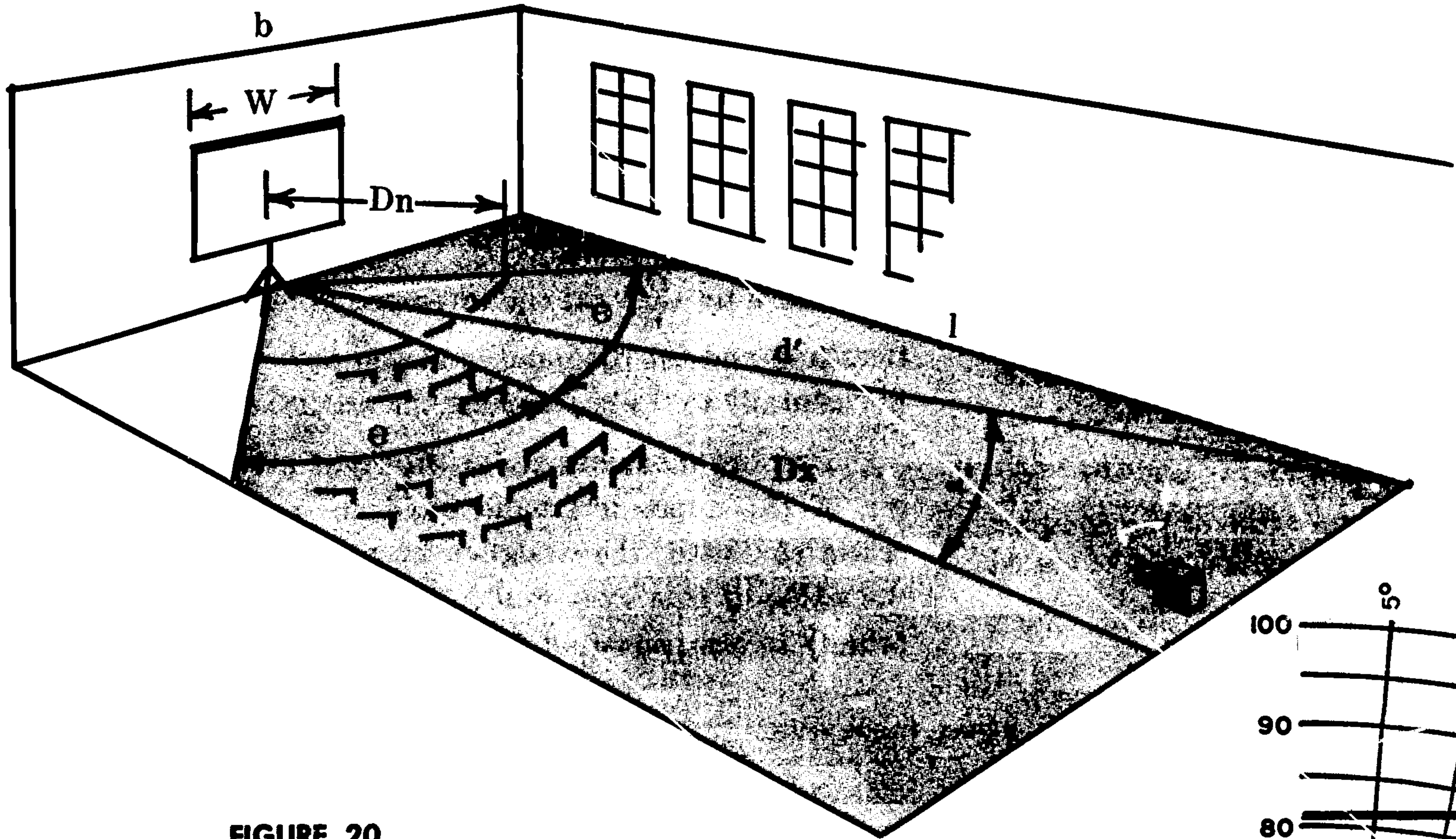


FIGURE 20.

THE NARROW RECTANGULAR ROOM

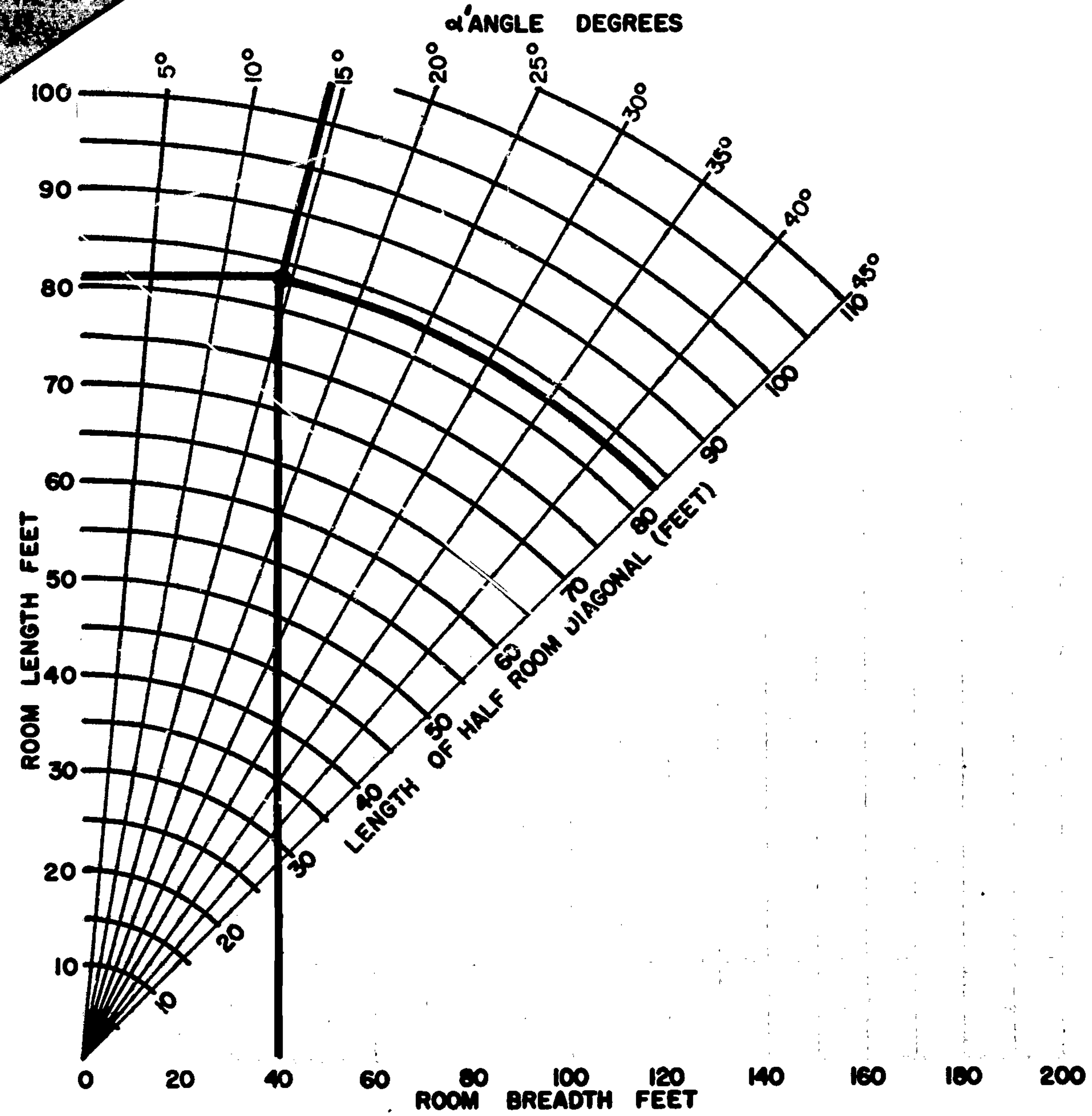


FIGURE 21—Graph for solving d' and α' for rooms of known width (b) and Length (1) Relation of room breadth and length to half room diagonal d' and acute angle α'

Section A in Figure 23 solves for the value of $\frac{Dx}{Dn}$ for various values of $\frac{Dx}{W}$ and $\frac{Dn}{W}$. Figure 23 solves area and occupancy problems for known values of screen width and the various design ratios. With known values of $\frac{Dx}{W}$ and $\frac{Dn}{W}$ calculate the ratio of $\frac{Dx}{Dn}$. This can be done mentally, manually, with a slide rule, or using the small graph to the right of the graphical data in the lower left-hand quadrant of Figure 23.

Knowing the values of α' and Θ, and the $\frac{Dx}{Dn}$ ratio, it is possible to find the value of the complex trigonometric ration $\sin\alpha' [2\cos\alpha' - \sin\alpha' \cot\Theta] + \left[\frac{Dn}{Dx} - \frac{\sin\alpha'}{\sin\Theta}\right]^2 \tan\Theta$ for all positive values of $\left[\frac{Dn}{Dx} - \frac{\sin\alpha'}{\sin\Theta}\right] \tan\Theta$ in the lower left-hand quadrant of the graph in Figure 23.

Proceeding vertically upward from the value thus found to the $\frac{Dx}{W}$ ratio diagonal achieves the multiplication of the complex ratio described heretofore by $\frac{Dx}{W}$ at the intersection of the vertical line and the diagonal, and one now proceeds horizontally to the right along the abscissa.

Pausing momentarily at the right hand margin of the upper left hand quadrant on the abscissa so found, the designer prepares to reduce the value of this area multiplier (the abscissa so found) to compensate it for the area of occupancy

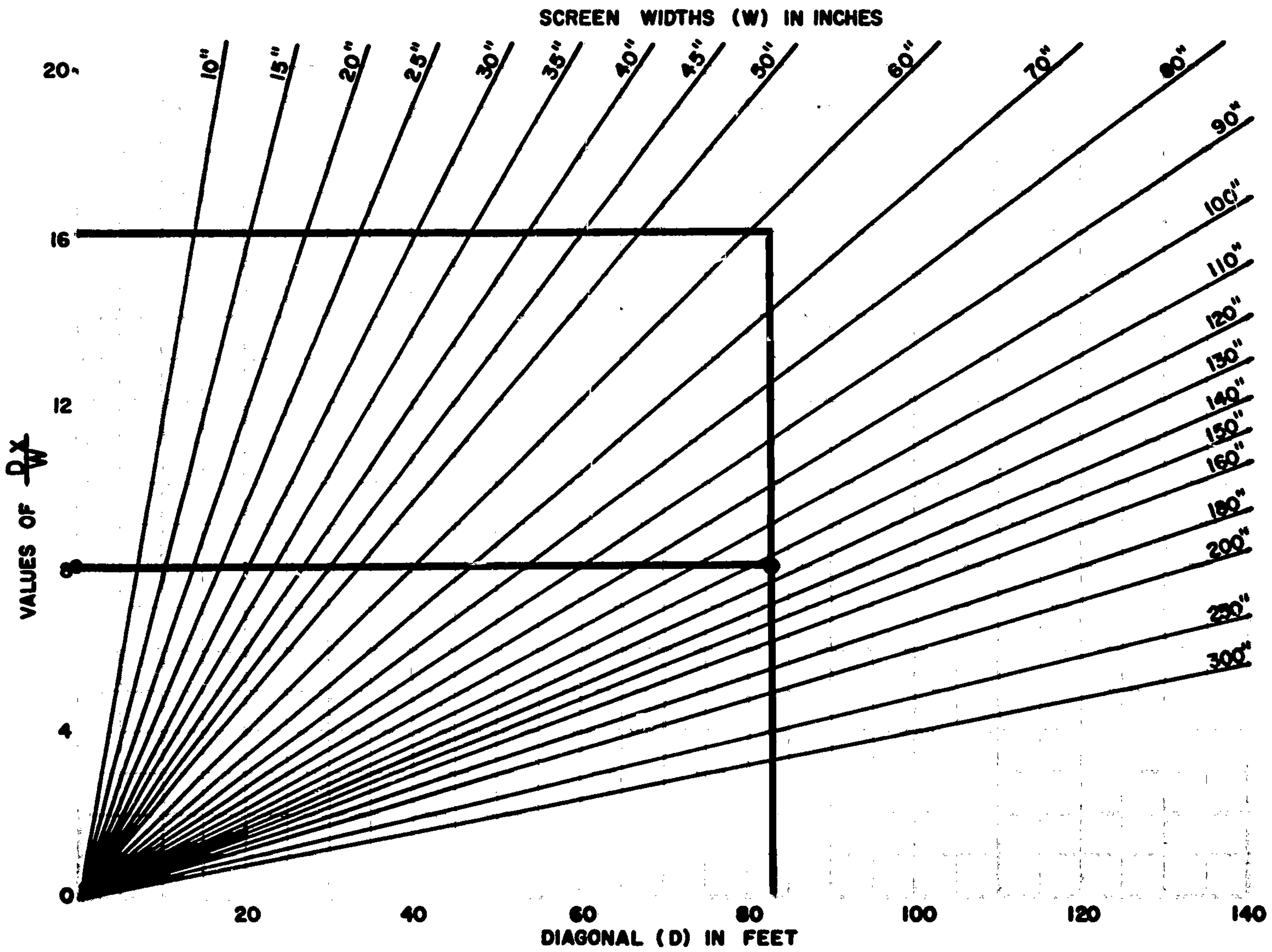
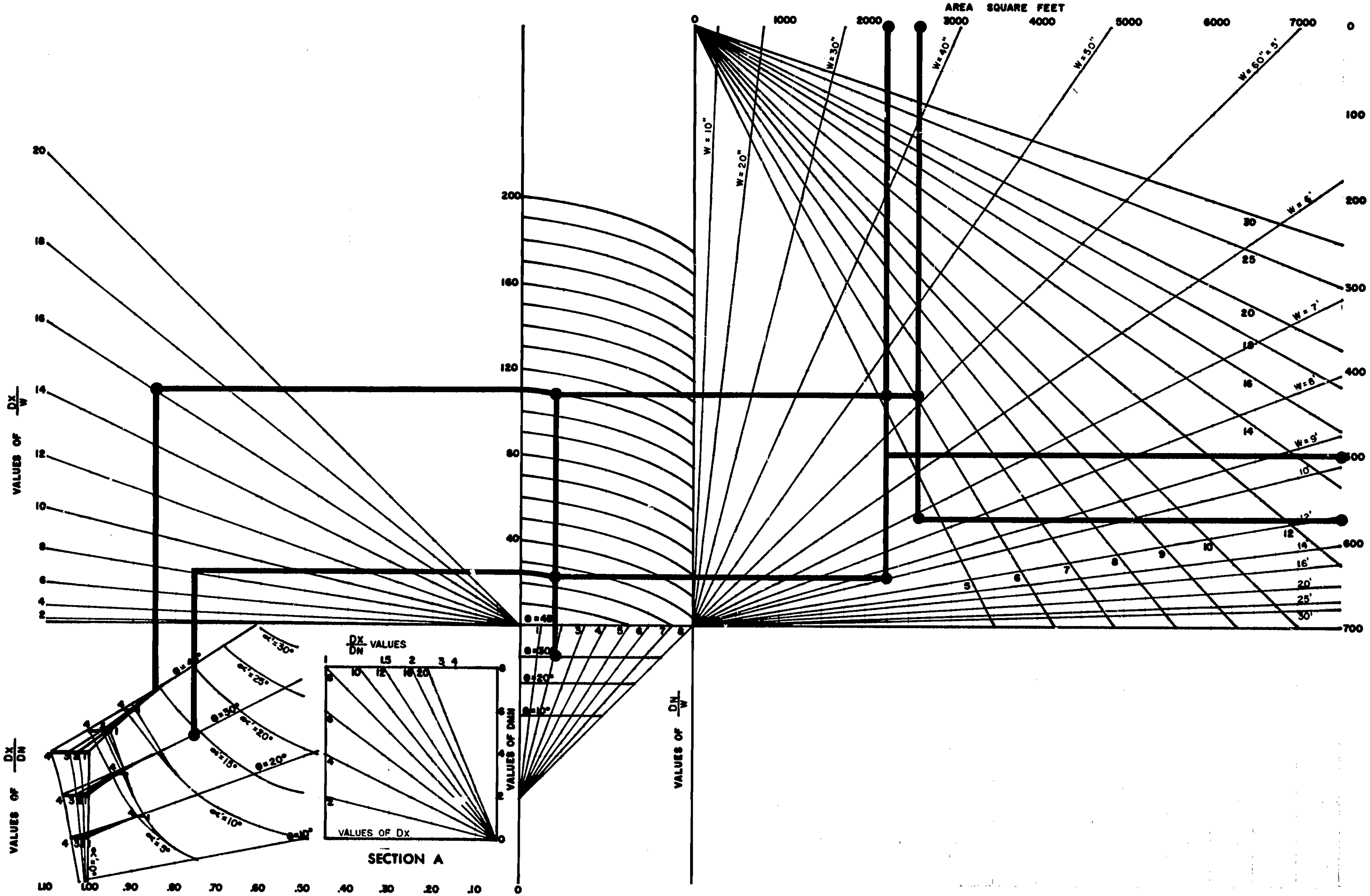


FIGURE 22.



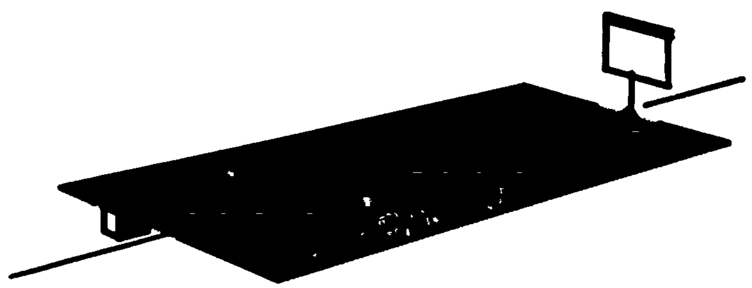


FIGURE 23. THE NARROW RECTANGULAR ROOM
Projection axis on center line

left out by the minimum screen width distance sector. This compensation is accomplished by entering the small graph in the lower center with values of $\frac{Dn}{W}$ and Θ and proceeding vertically upward from the point so found.

The horizontal abscissa previously followed is now "bent" (follows the curve of compensation or proceeds parallel to the curves shown until it strikes the vertical line described in the previous paragraph); thence horizontal again until it strikes the known value of W in the quadrant to the right. From this intersection one can proceed vertically to the area figure in the right hand upper margin, which yields a value representing the area of occupancy. This value can be converted to an occupancy figure by proceeding vertically on the same line until one strikes the diagonal line calibrated to represent the square feet per occupant. By proceeding horizontally from this intersection one finds the number of occupants in the right hand margin of the quadrant. If one had not followed the curved line for $\frac{Dn}{W}$ compensation, the area found would be the entire area within the sector increased by the over compensation for the $\frac{Dx}{Dn}$ ratio. This sector area could be accurately found by following the the procedure again, assuming a $\frac{Dx}{Dn}$ ratio of 1 and ignoring the $\frac{Dn}{W}$ compensation.

Illustration

Assume an existing area is to be converted to audio-visual usage, using lecture room seating, using a matte screen, and using film projection as well as TV projection. The area is 80′ long by 40′ wide.

From data furnished, these are the design criteria:

Lecture room seating—5 sq. ft. per person

Film criteria—$\frac{Dx}{W} = 8$; $\frac{Dn}{W} = 2$; $\Theta = 30°$

Compatible TV criteria—$\frac{Dx}{W} = 16$; $\frac{Dn}{W} = 4$; $\Theta = 45°$

Note the latter is a compromise: If $\frac{Dn}{W}$ for TV work increased to the ideal value, $\frac{Dx}{W}$ would have to be greater than desirable to maintain the same $\frac{Dn}{W}$ ratio as that for film. If $\frac{Dx}{W}$ were decreased to the ideal value, $\frac{Dn}{W}$ would have to be decreased to maintain the same ratio for film, resulting in a very unsatisfactory value of $\frac{Dn}{W}$ for TV.

From Figure 21, the value of α' is 14°, and d′ is 83′.

From Figure 22 the screen width for film is 124″; and for TV is 62″.

In both cases the ratio $\frac{Dx}{Dn}$ equals 4. (from Figure 23)

Considering the film and using Figure 23: $\alpha' = 14°$; $\Theta = 30°$; $\frac{Dx}{Dn} = 4$; $W = 114''$; $\frac{Dx}{W} = 8$; $\frac{Dn}{W} = 2$, one finds that the area of occupancy is 2450 sq. ft.; and at 5 sq. ft. per person, the occupancy would be 490 persons.

Using this same graph for TV criteria and inserting the boundary conditions that: $\alpha' = 14°$; $d' = 83'$; $\frac{Dx}{Dn} = 4$; $\Theta = 45°$; $\frac{Dx}{W} = 16$; $\frac{Dn}{W} =$ and $W = 62''$, one finds that the area of occupancy is 2800 sq. ft. and at 5 sq. ft. per person the occupancy would be 560. See Figure 23.

The figures indicate more viewers can be seated for TV than for film which could be expected since the greater Θ for TV permits a few more at the extreme front sides. The room area is 3200 sq. ft. total; it is interesting to note that a high degree of efficiency is experienced for narrow rooms using the long center line as a projection axis.

SELECTION OF EQUIPMENT

In the previous sections it has been assumed that equipment was available and practical for the criteria chosen. This is not always the case. Quite obviously in the earlier example, where it was found that the TV screen size should be 62″ in width, one could not have used any TV set now on the market (a 62″ wide screen would require a 78″ tube—tubes being measured by their diagonal). This would require a TV projector since there is no tube manufactured of that size. See Figure 30.

One would also have liked to place the projector on the long axis center line of the room at the rear of the area. This would be possible for film, since many various focal length projectors are available to fill the screen for the various types of apertures represented in 35mm, 16mm and 8mm slides, movie clips, etc.

But it might not have been possible for TV projectors, since any projector considered usually has one set of concave mirrors which focus the image at a fixed relationship between screen size and setback, with minor adjustments. And the possible variation in this focus distance among manufacturers at the date of this writing is not broad. Focusing lenses in TV projectors are avoided, as brightness is critical and all light loss devices, such as lenses, are avoided.

Even after it has been found that equipment is available of proper focal length to do the job for the film being considered, a determination must be made to see if the lamp provided has the proper output for brightness required. This hinges on several factors—the brightness and efficiency of the light source and the gain of the screen being used, as well as the incident room light on the screen, viewing angle, etc.

Figures 24 and 25 relate screen width and projector distance to the focal length of lens required for various aperture sizes.

Figure 26 relates screen width, screen brightness, gain, reflectance, and projection efficiency to lamp lumens for films and high light brightnesses for 5″ TV projector tubes (the usual size for TV projectors).

To find projector lamp requirements: Enter Figure 26 with screen width, proceed horizontally to the desired screen brightness, then vertically to the screen reflectance or gain, then horizontally to the projector efficiency, then vertically to the margin where the lamp lumens or highlight brightness required for 5″ TV tubes appears. The process can be reversed to determine screen brightness knowing lamp output or tube brightness assumed.

Usual values of projector efficiency are shown in Figures 27, 28 and 29 for various film and TV projectors. The relation of screen widths to TV picture tube size is also shown in Figure 30.

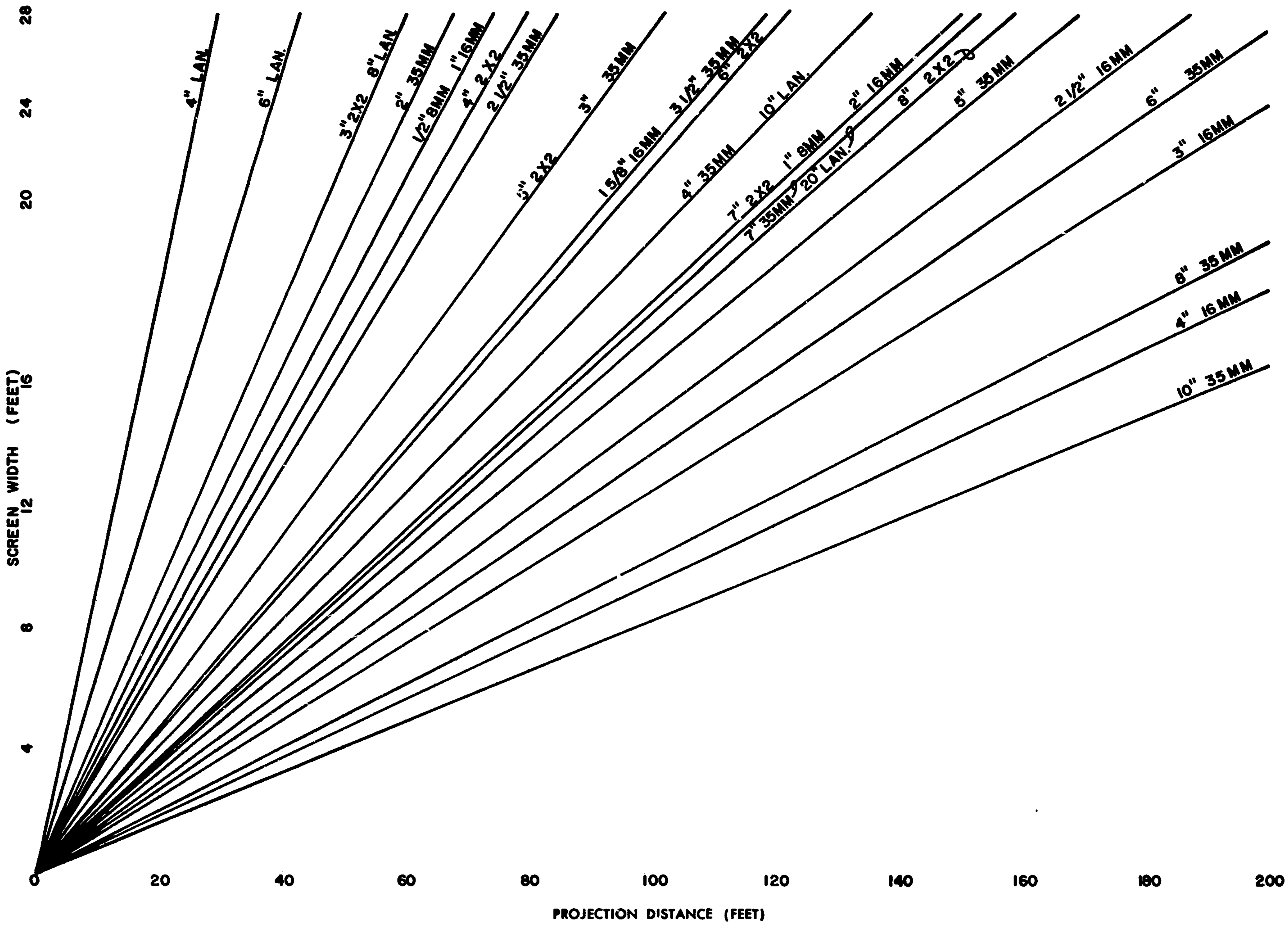


FIGURE 24—Relation of screen widths, projector distances—to focal length of lenses, aperture sizes

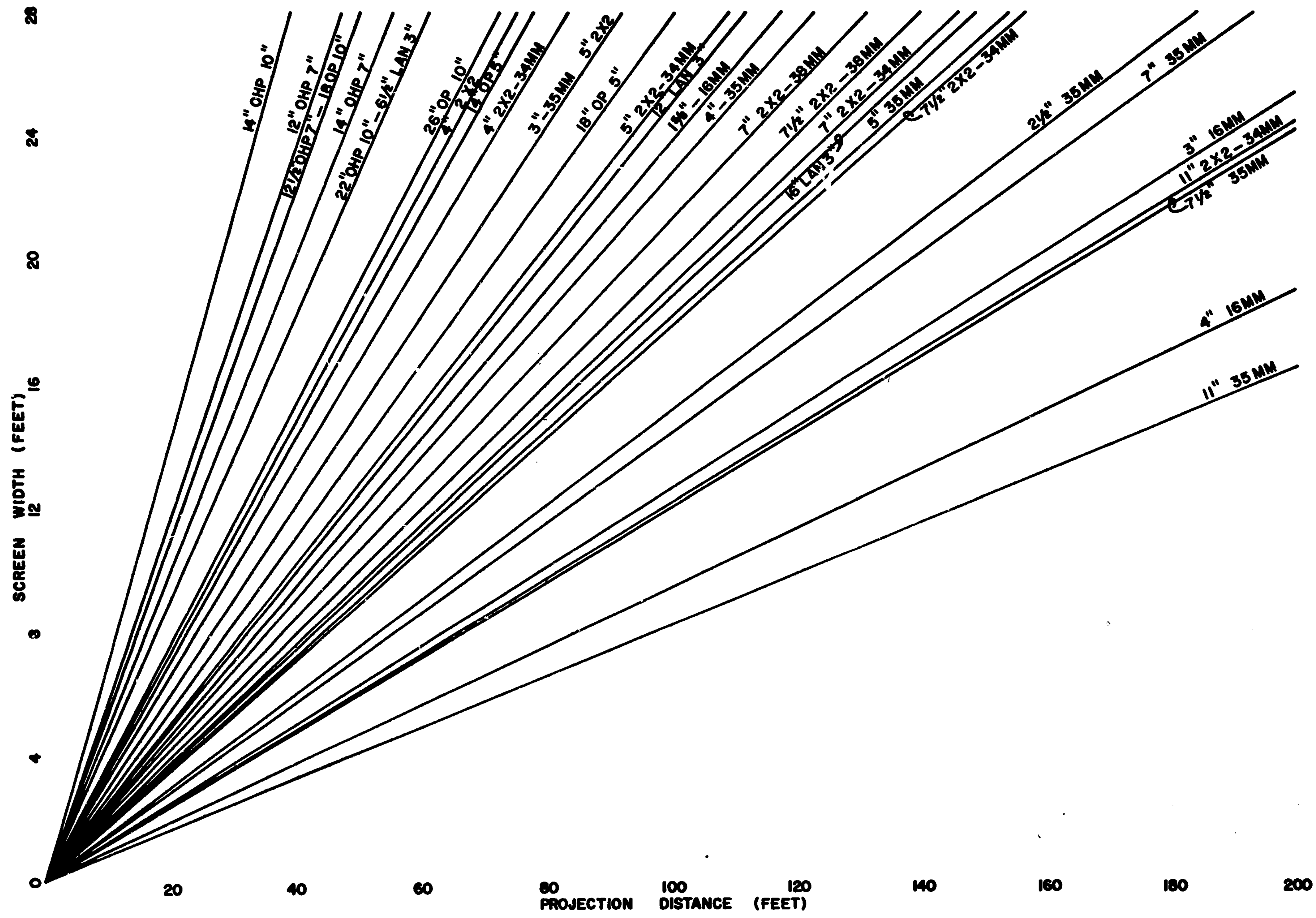


FIGURE 25—Relation of screen widths, projector distances—to focal length of lenses, aperture sizes

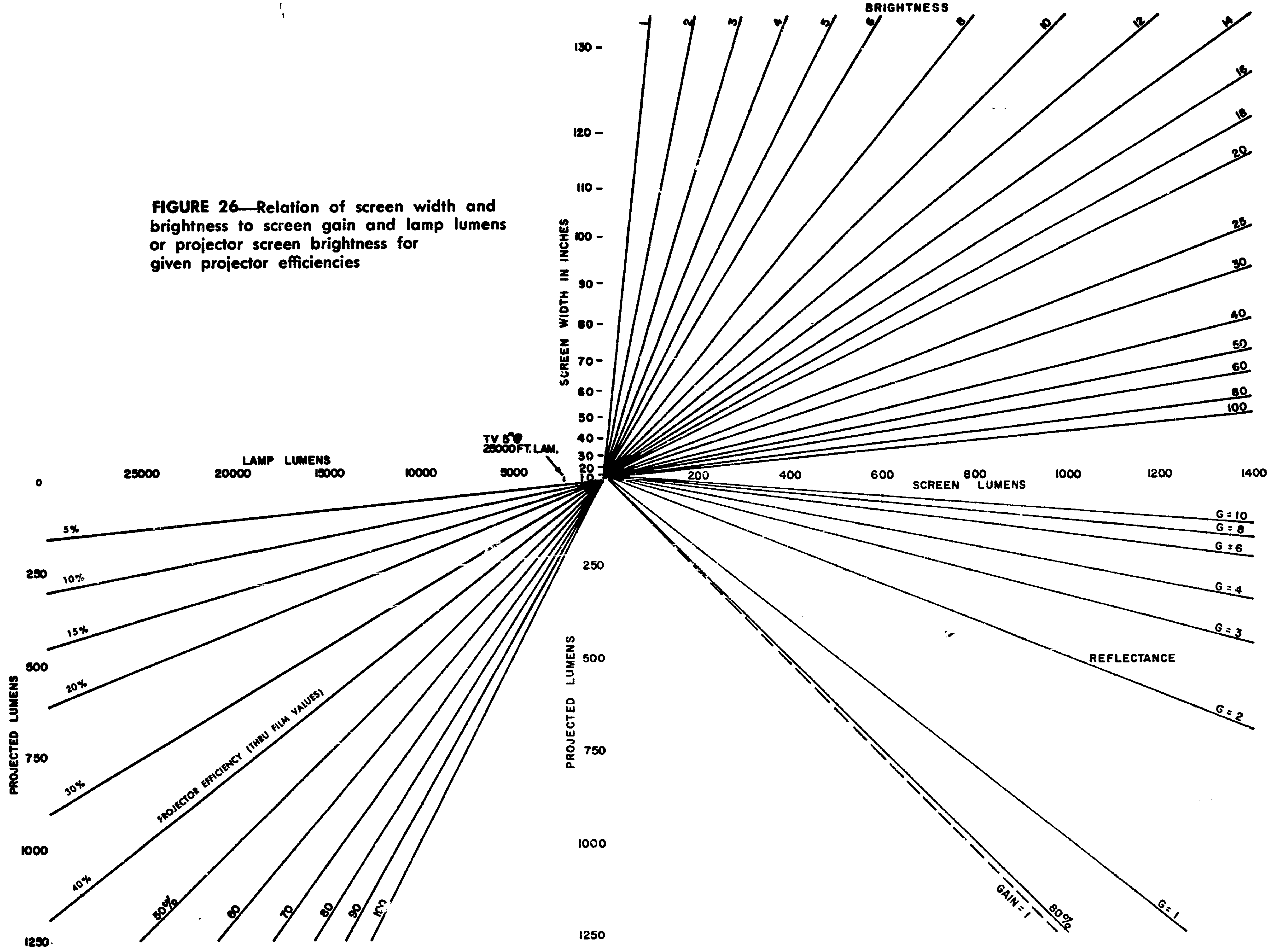


FIGURE 26—Relation of screen width and brightness to screen gain and lamp lumens or projector screen brightness for given projector efficiencies

Projector lamps and wattages are shown in Figure 27 for various required lumen outputs. Outputs are also shown for carbon arc lamps which are required for outputs beyond the range of tungsten filament lamps (Figure 28) and TV Projection (Figure 29).

Illustrative problem:

Assume a long room, 20′ x 40′ is to be converted to audio-visual use for film and TV using lecture room seating and a matte screen possibly. Assumptions:

$$\frac{Dx}{W} = 8, \quad \frac{Dn}{W} = 2, \Theta = 30° \text{ for film.}$$

$$\frac{Dx}{W} = 16, \quad \frac{Dn}{W} = 4; \Theta = 45° \text{ for TV.}$$

Findings:

$\alpha = 14°$.
$d = 42′$.
$W = 64″$ for film.
$W = 32″$ for TV.

Determine the focal length of the lens needed to keep the projector for 35 mm, 16 mm and 8 mm films at the rear of the room; and if not possible, how close to the screen must the projector be placed? Determine the lamp required to develop 10 lumens per sq. ft. minimum on the screen. If this is not possible, determine what the screen brightness will be, employing the largest practical tungsten filament bulb in use by manufacturers of equipment and considering the gain of the screen most practical for the job. What will the screen brightness be for TV, using the highest gain screen practical for the job?

In the design considered, there has been a projection distance of 40′ and screen width of 64″. For this one would choose a 3″ (75mm) focal length lens for 16mm projection and a 6″ (150mm) focal length lens for 35mm projection; these could be used at the rear of the room for projection according to the findings of Figure 24. For 8mm films, however, one would have to move the projector closer to the screen. Using a 1″ (25mm) focal length lens, which is the shortest length available from manufacturers, one would have to place the projector 28′ back from the screen to obtain a 5′–4″ screen width, as determined from Figure 24. In a similar manner, from Figure 25 one finds that in order to use a 10″ opaque projector, one would choose equipment with a 25″ focal length, and one would have to place the equipment 13′ away from the screen.

It has already been indicated that an ideal TV tube for this situation was not available, and hence projection methods would be needed. The screen size would still be as determined since the grain or clarity of the TV picture has not been improved. In fact, it is made worse both by projection and by the superimposed grain added to the picture by the screen lenticles or beads assumed for a high gain screen (but this increased amount of lack of clarity is assumed to be negligible). The Θ value assumed for TV tube screen viewing (45°) has been reduced to the now assumed screen Θ maximum value of 30°. It may be found that in order to increase the brightness, one will have to use a higher gain screen, further reducing this data value to 20° or less.

Trial at Θ equals 30°: The screen used for TV will probably yield the lowest value of screen brightness, with the opaque projection and 8mm film projections running close in value.

For TV projection, Θ equals 30°, $\frac{Dx}{W}$ equals 16, $\frac{Dn}{W}$ equals 4, W equals 32″, one finds that the

FIGURE 27. INCANDESCENT PROJECTOR LAMPS AND LIGHT OUTPUT FOR INDICATED APERTURE CONDITIONS AND ASSUMED LENS IN PARTICULAR EQUIPMENT

BULB	WATTS	INITIAL LAMP LUMENS	LIFE (hrs)	WHEN IN USE FOR	THRU FILM SCREEN LUMENS	THRU FILM EFFICIENCY %
T-8	50	800	50			
T-8	75	1,300	50			
T-8	100	1,750	50			
T-8	150	3,400	25			
T-8	200	4,675	25			
T-8½	300	7,600	25			
T-8½	300	7,100	25			
T-10	500	13,500	25	2x2 Slide	415	3.1
T-20	500	13,200	50			
T-12	750	21,000	25	2x2 Slide 16 MM	830 200	4.0 1.0
T-12	1,000	31,000	10			
T-12	1,000	31,500	10	2x2 Slide 16 MM	1,150 265	3.3 .8
T-20	1,000	28,000	50			
T-20	1,000	28,000	25			
T-12	1,200	37,800	10			
	2,000	64,000				
	5,000	165,000		**2x2 Slide	5,200	3.1
				** 35 MM	4,000	2.4

**Data selected for value indicated was only half as much, but after transmission thru translucent screen of .5 coefficient.

"Thru film Screen Lumens" for 2x2 slide projectors assume certain equipment with film in use and using 5" F 3.5 lens, for 16 MM projector, film in place, using a 2" f. 1.6 lens. Film assumed is of 0.3 density which transmits about 50% of light through aperture. Data is indicative for lamps involved and equipment assumed. Complete data should be secured from projector manufacturer.

area of occupancy is 650 sq. ft. and the number of occupants is 130. This is as expected, based on the findings for film projection.

From Figure 26, entering with the TV highlight brightness of 2,500 foot candles, and assuming 80% efficiency, one finds that the brightness for a matte screen with gain of 1 is about 30 lumens per sq. ft., which would be very satisfactory. Using a lenticular screen of gain 2, one could bring this brightness up to 60 lumens per sq. ft. without sacrifice of a lesser side angle viewing. This would reduce the lamp lumens required for the consideration of film projection which follows.

At screen width 64", and using projector efficiency of 80% with an assumed screen brightness of 10 lumens per sq. ft. and a screen gain of 2, one finds a need for 140 lumens which can be accomplished with a 300 watt projector lamp.

Reducing the limits might yield better appreciated results at some sacrifice in seating capacity. If TV limits were 14W and 7W, the TV screen size could be increased to 37". Comparable film limits might be 6W and 3W respectively, permitting an 84" screen. When θ equals 30°, and $\frac{Dx}{Dw}$ equals 2, and α' equals 14°, one finds that the area of occupancy for film would be 500 sq. ft., reducing the seating capacity to 100 occupants. Considering the TV aspects of a screen 37" wide, one finds an area of occupancy of 600 sq. ft. and a seating capacity of 120. The two vary from each other because the screen width ratio of TV to film is no longer 1 to 2.

Assuming the same efficiencies and other conditions as for the projection equipment already determined, one finds that the opaque projector and the 8mm projector will also be served best by 300 watt lamps.

'URE 28. CARBON ARC PROJECTOR LAMPS AND LIGHT OUTPUT: FOR INDICATED APERTURE CONDITION AND ASSUMED LENSES IN PARTICULAR EQUIPMENT

CARBON ELECTRODES										
POSITIVE		NEGATIVE								
DIA. mm	LENGTH inches	DIA. mm	LENGTH inches	AMP.	VOLTS	WATTS	TOTAL LUMENS	When IN USE FOR	NO FILM SCREEN LUMENS	NO FILM EFFICIENCY %
6	8½	5½	6	30	28			16 MM	2,900	
7	12	6	9	50	37			15 MM	5,800	
7	12	6	9	46	35			16 MM	6.300	
7	12-14	6	9	40	27.5			35 MM	6.500	
7	12-14	6	9	50	38	2,000	55,000		11,700	21.0
8	12-14	7	9	70	40	2,940	115,000		15,700	13.7
9	12-14	8	9	80	45			35 MM	16,600	
9	20	8	9	85	55-60			35 MM	19,500	
10	20	8	9	105	68	6,800	189,000			
10	20	8	9	110	59-60			35 MM*	25,800	
10	20	8	9	135	66-70			35 MM*	30,300	
11	20	⅜"	9	120	59-68	8,160	231,000	35 MM*	27,600	12.0
13.6	22	½"	9	150	78	11,700	368,000	4x5 slide	40,000	10.9
13.6	22	½"	9	160	77			35 MM	20,500	
13.6	22	½"	9	180	74	13,300	410,000	35 MM	24,000	5.9

"No Film Screen Lumens" and "No Film Efficiency" in this table differ from "Thru Film Screen Lumens" and "Thru Film Efficiency" respectively of figure 28 in that no film is in the projector in this consideration and no shutter is in use. Screen Lumens are a function of the lamp lumens, the efficiency of the condensers, lens and/or mirror, projection lens diameter, focal length, and the aperture size.

Film values would reduce screen lumens and efficiency by 50% assuming a .3 density film of .5 transmission coefficient.

Complete data sould be scured from the manufacturer. Results shown are assumed indicative for lamp size used. Variations in individual pieces of equipment can alter these values considerably.
5" P 1.9-F 2.0 lens assumed unless marked* which assumes 2" focal length P 1.5-F 1.6 lens.

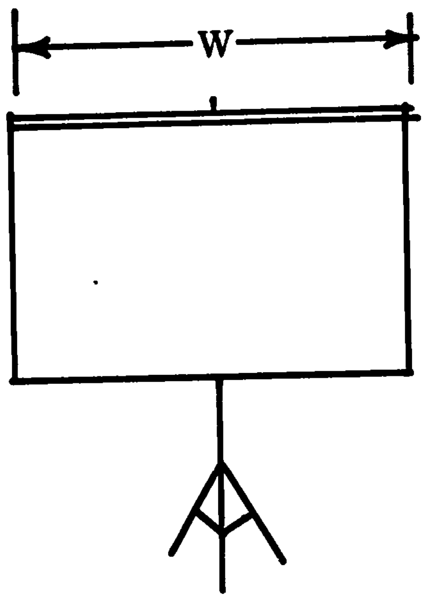
Data selected from I.E.S. Lighting Handbook, 3rd Edition, Figures 8-66, 8-88, 24-28, Kodak "Foundation for Audio Visual Projection" P. 10 and G.E. "Current Lighting Practice for Television Production" Fig. 6. and P.6 topic "Projected Backgrounds".

FIGURE 29. TV PROJECTOR EFFICIENCY

HIGHLIGHT BRIGHTNESS OF 5" TV PROJECTION TUBE	ASSUMED EFFICIENCY OF PROJECTOR	SCREEN LUMENS
2500 Foot Lamberts	85%	177 Lumens

FIGURE 30. RELATION OF SCREEN WIDTH TO TV PICTURE TUBE SIZE

TUBE SIZE (Diameter)	SCREEN WIDTH OF TUBE
5"	4"
8"	6.4"
10"	8"
15"	12"
17"	13.6"
19"	15.2"
21"	16.8"
23"	18.4"
24"	19.2"
27"	21.6"



APPENDIX

Definitions of terms and symbols used in this text.

Dx—The maximum distance a viewer may sit from the screen and still see all the detail.

Dn—The minimum distance a viewer may sit from the screen and comfortably see all the detail.

W—The screen width.

$\frac{Dx}{W}$—The dimensionless ratio of maximum seating distance to screen width (when each is expressed in the same units of measure).

$\frac{Dn}{W}$—The dimensionless ratio of minimum seating distance to screen width (each expressed in the same units).

θ—The maximum side viewing angle; in a horizontal plane at the center of the screen between the projection axis and a person located as remotely to one side of the screen as he can possibly be and still comfortably see all the detail on the screen in proper brilliance.

l—The length of the room in feet.

b—The breadth of the room in feet.

d—The diagonal of the room in feet.

d′—The half room diagonal of the room divided along its breadth.

α—The acute angle formed in a horizontal plane between the length side of the room and its diagonal.

α'—The acute angle formed in a horizontal plane between the long side of the room and the half room diagonal.

B—The viewing angle formed between the projection axis and the point where the minimum viewing distance arc strikes the edge of the room.

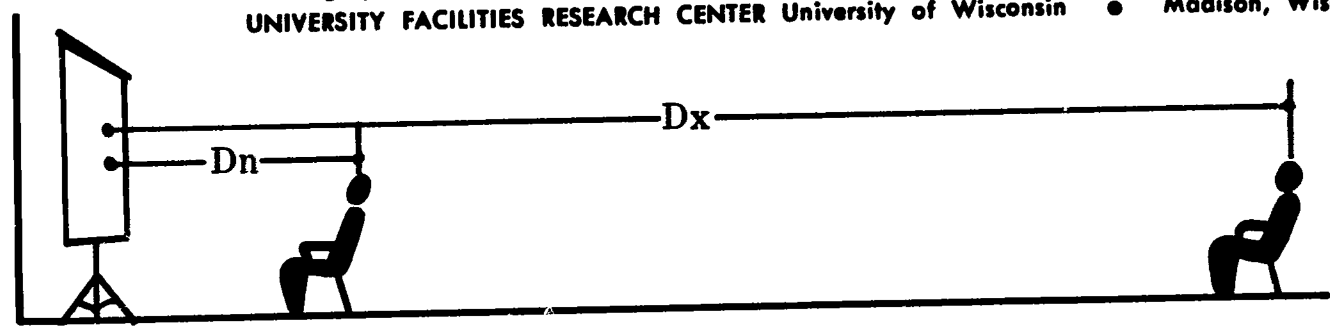
G—Gain—The ratio of the intensity of light from a given screen at a given viewing angle as compared to the reflected brightness from a screen of pure white magnesium carbonate of the same size, viewed at the saem distance and side viewing angle and receiving its light from the same or equal projection and lamp placed an equal distance from the screen.

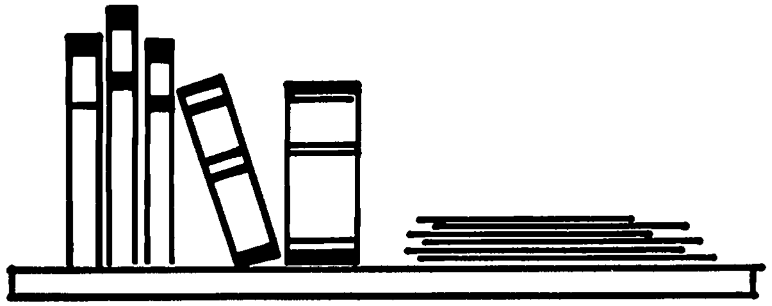
Ga—Average gain—The gain of a screen obtained by averaging the individual gains of the screen at each angle in the viewing section.

Gd—Design gain—The gain of a screen near its maximum viewing angle—the criterion for design. This value is usually less than the average gain.

Gp—Peak gain—The highest gain of a screen as viewed from all points within a viewing sector—usually on or very near the projection axis.

Mimeographed copies of the derivations are available upon request from the UNIVERSITY FACILITIES RESEARCH CENTER University of Wisconsin • Madison, Wisconsin 53706





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Committee on Institutional Cooperation

This is a voluntary organization of the following eleven middle western universities: University of Chicago, University of Illinois, Indiana University, State University of Iowa, University of Michigan, Michigan State University, University of Minnesota, Northwestern University, The Ohio State University, Purdue University and The University of Wisconsin. Officially named the "Committee on Institutional Cooperation of the Council of Ten and the University of Chicago," the unit grew out of a series of informal meetings of the presidents of the universities and was formally constituted in 1957. The Committee is made up of one representative from each institution, appointed by his president. A small professional staff carries out the programs approved by the Committee.

The goal of the Committee is to improve educational and public services and research pursuits while minimizing costs by: (1) encouraging cooperative efforts among the eleven institutions, (2) identifying specialized areas of teaching and research in which cooperative arrangements may be desirable and (3) initiating cooperative activities in instruction and research, particularly in graduate areas, among the universities.

After the Committee was established, it requested and was awarded a grant from the Carnegie Corporation of New York to carry on its work. This grant extends through 1963. Staff offices are located on the campus of Purdue University at Lafayette, Indiana.

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