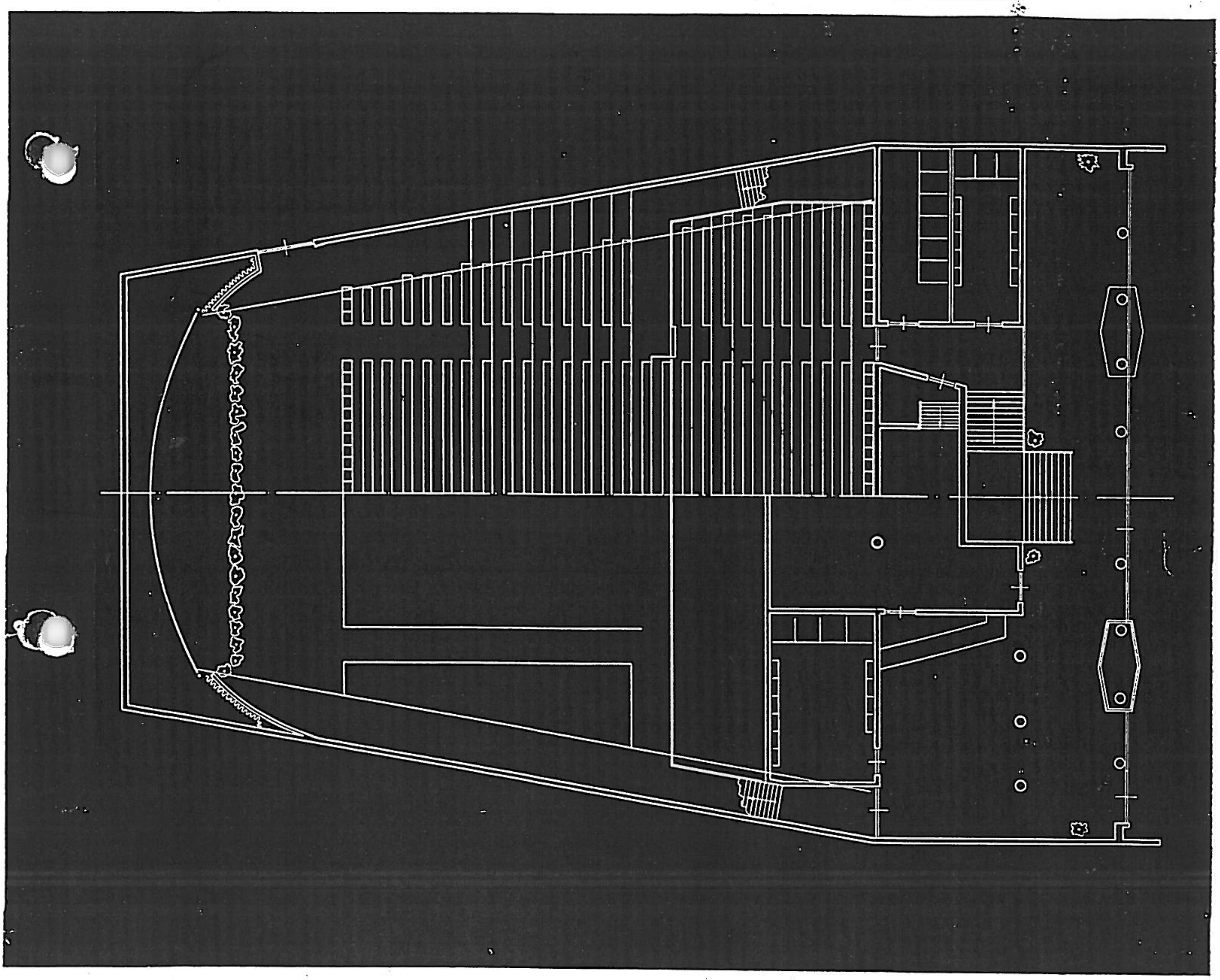
PLANNING A CINEMA



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PLANNING A CINEMA

INTRODUCTION

When, more than half a century ago, Cinematography was introduced into the world of entertainment, the audience had to be accommodated in existing theatres. These had, of course, been built without any provision for projecting motion pictures and were far from ideal. The pictures were, however, comparatively small and had an aspect ratio of 3 : 4, so that the screens could nearly always be fitted into the stage opening. For this reason cinema halls were for many years built in the same style as theatres.

The new projection systems developed between 1950 and 1960 differed so much from the previous system that it became impossible to project films to full advantage in theatre-type halls. In this publication a number of rules will be given which should be observed in designing technically and acoustically up-to-date cinemas. It is up to the architect to apply these rules aesthetically, at the same time observing local safety regulations.

Close co-operation between the architect, the local authorities and the manufacturer of the projection equipment is necessary because it is only by a combination of their experience that optimum results can be obtained.

Of the same importance as the technical outfit and the acoustical properties is the lighting of the auditorium, the foyer, the entrance hall, etc.

Philips technicians are following closely the developments in all respects of theatre planning and are always ready to put their knowledge at the disposal of cinema owners.

PROJECTION ROOM

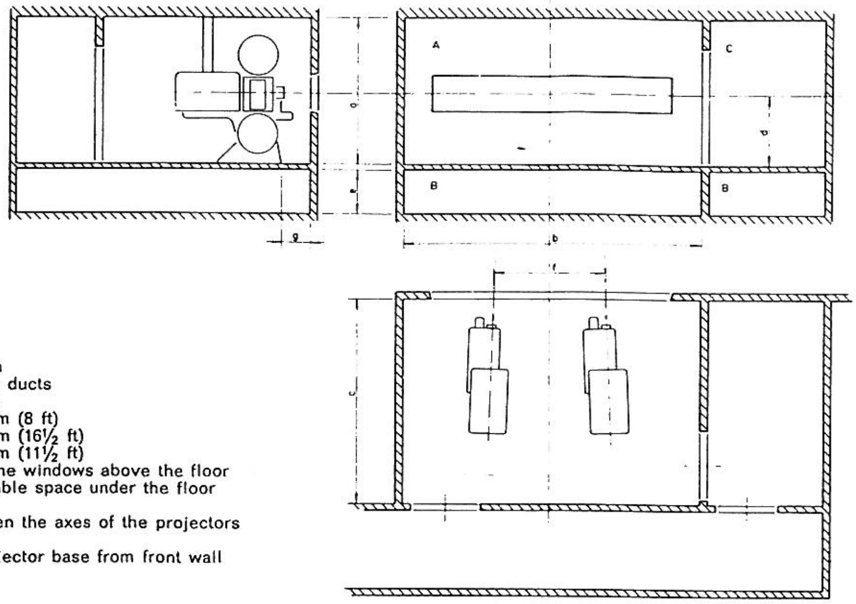


Fig. 1

A = projection room
B = space for cable ducts
C = rewinding room
a = height = 2.5 m (8 ft)
b = length = 5 m (16½ ft)
c = depth = 3.5 m (11½ ft)
d = centre line of the windows above the floor
e = height of the cable space under the floor = 75 cm (2½ ft)
f = distance between the axes of the projectors = 200 cm (6½ ft)
g = distance of projector base from front wall = 50 cm (20")

DIMENSIONS

A spacious projection room is desirable from every point of view. A general plan is shown in fig. 1. The projection room should be symmetrical to the centre line of the auditorium. It must meet local regulations.
The height, length and depth given in fig. 1 are the minimum dimensions recommended when two projectors are used. Strictly speaking a smaller projection room would suffice but this would make operation more difficult. With a view to possible extension in the future, it is even preferable to build a projection room with a length of 7 m (25 ft), accommodating three projectors.
The floor of the projection room should be made to withstand a load of 1000 kg/m² (205 lb/ft²).

INSTALLATION OF THE PROJECTORS

Symmetry with respect to the centre line of the auditorium

In order to minimize picture deformation due to off-centre projection, the projectors should be installed symmetrically with respect to the centre line of the auditorium. Thus, when two projectors are used, they should be equidistant from the centre line and when three projectors are used, the optical axis of the middle projector should coincide with it.

Distance between the projectors

To facilitate operation, the distance between the optical axes of the projectors should be about 2 m (6½ ft).

Distance from the walls

There should be ample room for free passage along the side walls and the rear wall. The projectors must be easily accessible from the front; a good distance between the bases of the projectors and the front wall is 50 cm (20").

Angles of rake of the projectors and of the screen (fig. 2)

The angle of rake α of the projectors should be as small as possible.
Too large a projection angle causes deformation of the projected picture due to:

- **Keystone effect;** this can be corrected by giving the black frame around the picture a rectangular shape and by using a trapezoidal mask in the projector, but by doing so the part of the picture shaded in fig. 3 is cut off, which may be annoying when sub-titles are used.
- **Curving of the horizontal lines** when curved screens are used.

These deformations can be limited to some extent by tilting the screen backwards. Care has then to be taken that the spectators in the front rows do not see the picture at too acute an angle. The angle of tilt of the screen should therefore not be more than 1/3 α (fig. 4).

RULE 1:

For curved screens:		For flat screens:	
α_{ideal}	$= 0°$	α_{ideal}	$= 0°$
$\alpha_{downward}$	= max. 8°	$\alpha_{downward}$	= max. 12°
α_{upward}	= max. 3°	α_{upward}	= max. 5°

PROJECTION-ROOM WINDOWS (fig. 1)

It is recommended that there should be a slot of about 50 cm (20") high over practically the whole width of the front wall of the projection room. All the required windows can be fitted into this slot; their exact place has to be indicated by the supplier of the projectors.
When the projectors are not to be tilted the centre line of the slot should be 119 cm (47") above the floor; when they are to be tilted the correct height must be determined by the supplier of the projectors.

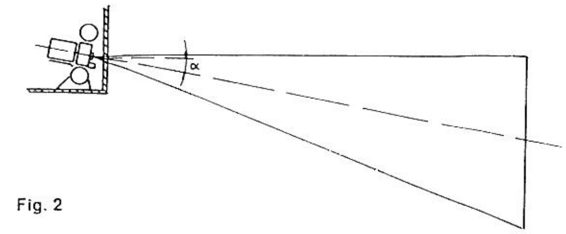


Fig. 2

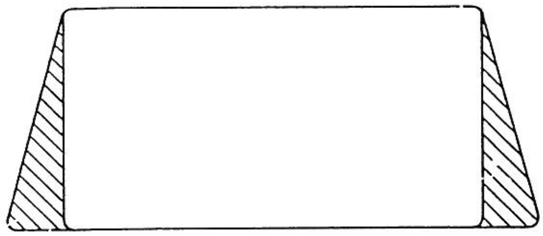


Fig. 3

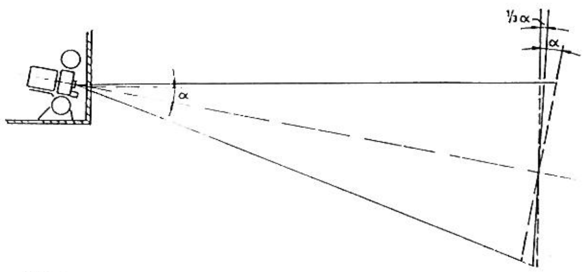


Fig. 4

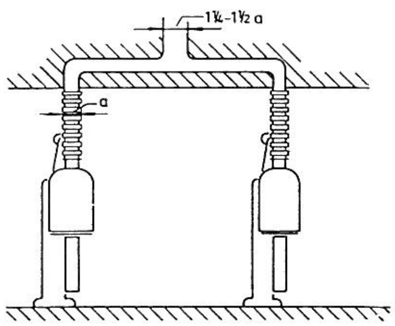


Fig. 5

VENTILATION OF ARC LAMPS

The flues of arc lamps should either be in communication with the open air or, if the draught is insufficient, be connected to a suction device. This device is always advisable when the arc current exceeds 60 A. The chimneys should be provided with cowls.

When two arc lamps are connected to the same exhaust pipe (fig. 5) the two flues should be of equal length and diameter.

The exhaust capacity of a suction device should be:

at 60 A:	1.7 m^3/min	=	60 ft^3/min
75 A:	2.2 ,,	=	79 ,,
90 A:	3.2 ,,	=	115 ,,
100 A:	3.3 ,,	=	117 ,,
125 A:	4.4 ,,	=	158 ,,
130 A:	5.5 ,,	=	195 ,,

WATER SUPPLY

When arc lamps of more than 50 A are used the projectors have to be water-cooled and when arc lamps of more than 100 A are used, so should the lamphouses. Modern equipment with other light sources is always supplied with water-cooling.

SOUND INSULATION

It is recommended to cover the ceiling of the projection room with a suitable sound-absorbing material so as to give the projectionists a quiet room to work in. Moreover, the sound insulation of the projection room must be sufficient to prevent sounds from being transmitted to the auditorium. There are two ways of sound transmission:

- **Direct transmission through the air**; this is sufficiently limited by a front wall consisting of a single layer of bricks (header bonded) or 12 cm (5″) of concrete. Still better is a cavity wall (stretcher-bonded bricks, cavity 5 cm = 2″). The brickwork should be of high quality, well plastered, so that there are no cracks or holes. The windows should be mounted with extreme care to avoid sound leaks.
- **Indirect transmission**, e.g. of the noise of footsteps or of vibrations of machines secured to the floor. This can be limited by a floor of sufficient thickness (at least 12 cm = 5″ for a concrete floor), covered with a sound-proof material (e.g. rubber or cork). Particularly good is the sound insulation provided by a judiciously laid floating floor.

OTHER ROOMS

REWINDING ROOM (fig. 1)

It is advisable to have next to the projection room a separate rewinding room in which a cabinet for storing film reels can also be placed. The dimensions of the top of the rewinding table should be at least 200 x 65 cm (6½ ft x 2 ft).

In the wall between the rewinding room and the projection room there should be a large window and the rewinding table should be placed under this window so that the projectionist can keep an eye on the projectors while he is rewinding the films.

SWITCHING ROOM

It is advisable — and often required by regulation — to have a separate switching room next to the projection room. Here can be mounted:

- the switchboard for the whole equipment;
- the dimming equipment for the auditorium lighting;
- the supply units for the projection lamps;
- the compressor for air cooling, if used, to be mounted on a resilient layer (rubber or cork).

The floor of the switching room should also be made to withstand loads up to 1000 kg/m^2 (205 lb/ft^2).

BATTERY ROOM

When a storage battery is to be used for emergency lighting, it must be placed in a separate, well-ventilated room.

AUDITORIUM

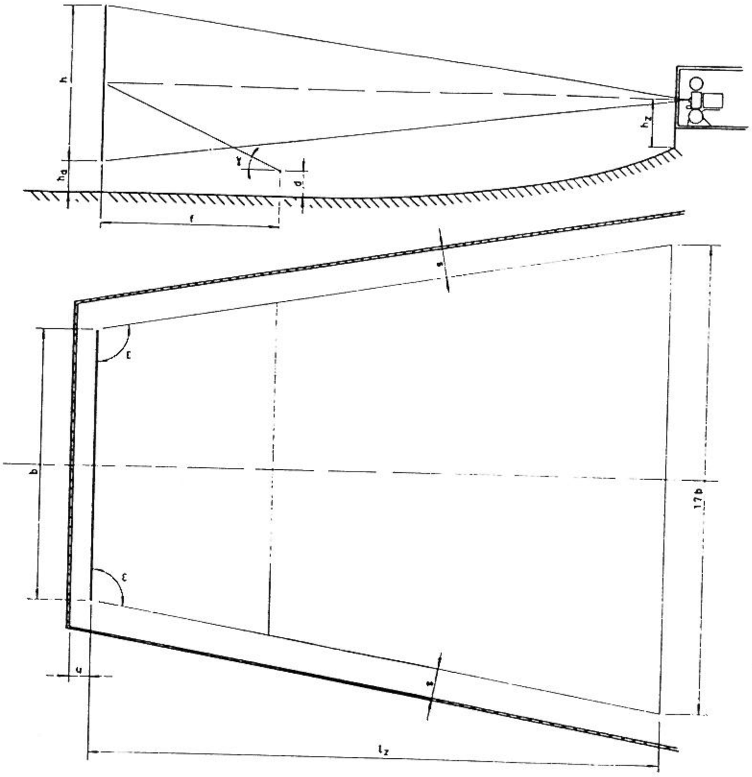


Fig. 6
h = picture height
b = picture width
γ = greatest viewing distance
l_z = viewing angle from the first row of seats
h_a = height of bottom of picture above the floor
d = eye level of a sitting person
f = distance between screen and first row of seats
h_z = distance between the optical axis of the light beam and the floor at the rear of the auditorium
ε = critical angle of the seating area
u = loudspeaker space behind the screen
s = aisle width

SIZE (fig. 6)

The dimensions of the auditorium should be such that all the spectators can see the picture under the most favourable conditions. This can only be achieved when the seating capacity does not exceed 1500; a good average is 800 to 1000. In larger cinemas the distances of the first row and of the last row to the screen differ too much. A picture that is large enough for the front rows will be too small for the rear ones, whereas a picture adapted to the latter will be too large for the spectators at the front of the hall.
Further, the dimensions of the hall must be such that:

- a projection screen with an aspect ratio of 1 : 2.2 can be fitted;
- the screen forms practically the whole front of the auditorium;
- the width of the picture is about half, at any rate not less than four tenths of the maximum viewing distance, i.e. the greatest distance between the screen and the rear seats.

Hence:

RULE 2: b = 2.2 x h (b = picture width; h = picture height)

RULE 3: b_{ideal} = 0.5 to 0.4 x l_z (l_z = greatest viewing distance)

DIMENSIONS OF THE PICTURE

Excessive magnification of the film frames results in poor quality of the projected picture because of the grain becoming visible.

Not only the magnification, but also the **brightness** plays a part in determining the maximum dimensions of the picture. Brightness = illumination x reflection coefficient; it is expressed in apostilbs (asb). For a good understanding, it is necessary to know (fig. 7) that:

- **the luminous flux,** expressed in **lumens (lm),** is the amount of light leaving the projection lens;
- **the illumination,** expressed in **lux (lx),** is the luminous flux divided by the illuminated area expressed in sq.metres;
  1 lux = the illumination of a surface of 1 m² by a luminous flux of 1 lumen;
- **the reflection coefficient of the screen** indicates the part of the incident light which is reflected, the rest being absorbed or having passed through the screen perforations.

Example:
When the luminous flux is 3000 lm and the illuminated area is 30 m², the illumination of this area is:

$$\frac{3000}{30}\ \text{lx} = 100\ \text{lx},$$

and when the reflection coefficient of the screen is 80 %, the brightness of the picture will be:

$$0.8 \times 100\ \text{asb} = 80\ \text{asb}.$$

In the U.K. and in the U.S.A. a much used unit of illumination is the foot-candle, the corresponding brightness unit being the foot-lambert.
1 foot-candle = 10.764 lx; 1 foot-lambert = 10.764 asb.

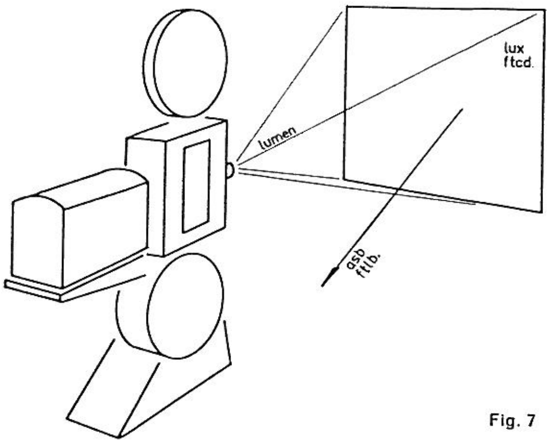


Fig. 7

In many countries there are strict regulations concerning the brightness of the picture; the recommended practice in the Netherlands is:
normal brightness: 140 asb; minimum: 100 asb;
maximum: 160 asb.

From the preceding it will be obvious that, to achieve a given brightness, the dimensions of the picture cannot be made arbitrarily large, unless one accepts the use of very powerful arc lamps which are expansive and uneconomical. It is therefore advisable not to make the picture width larger than is given by the following rule.

RULE 4:

For 70-mm films, CinemaScope films made from 70-mm negatives, and for Vista-Vision or Technirama films	$b_{70\,max.}$	= 20 m (65½ ft)
For CinemaScope films made from 35-mm negatives	$b_{CS\,max.}$	= 15 m (50 ft)
For normal films and for Wide-Screen films	$b_{WS\,max.}$	= 12 m (40 ft)

Preferably, the **height** of the projected picture should be the same for all 35-mm films, so that for showing these films only the side edges of the black screen masking need be movable.
The height of the picture is calculated from the aspect ratio, which is:

for 70-mm films . . . 1 : 2.2
for CinemaScope films 1 : 2.34
for Wide-Screen films . 1 : 1.66 or 1 : 1.75 or 1 : 1.85
(at the choice of the cinema owner)
for normal films . . . 1 : 1.37

POSITION OF THE PICTURE WITH RESPECT TO THE FRONT ROW (fig. 6)

The modern systems aim at giving the audience a strong feeling of participation. To achieve this, the bottom of the picture should not be too high above the floor, especially not when the floor in front of the first row is flat. If the screen has to be placed high, e.g. because of exits under it, the front part of the floor should preferably be made stepped, the top step being not more than 1 m (3½ ft) below the screen.

Practice has proved that it is best to follow:
RULE 5: h_a = 1.50 m (5 ft) for films without sub-titles
h_a = 1.80 m (6 ft) for films with sub-titles

To obtain the maximum seating capacity, one may be inclined to place the front row very close to the screen. This is inadvisable because the spectators in the front of the hall will then have to bend their heads too far back, which in the long run is very tiring. The distance between front row and screen should therefore be such that the patron sitting in the middle of the front row sees the centre of the screen at an angle of not more than 25°.
Hence:
RULE 6: $\gamma_{max.} = 25°$.

The eye level of a sitting person may on an average be taken at 120 cm (4 ft) above the floor.

RULE 7: d = 120 cm (4 ft)

The distance between the screen plane and the front row can be calculated from the formula:

$$f = \frac{\frac{1}{2}h + (h_a - d)}{\tan 25°}$$

Substituting the values given in rules 5 and 7, we find
RULE 8: For films without sub-titles:

$$f = \frac{\frac{1}{2}h + (150 - 120)}{\tan 25°} = 1.07\,h + 65\text{ cm } (2'2'')$$

For films with sub-titles:

$$f = \frac{\frac{1}{2}h + (180 - 120)}{\tan 25°} = 1.07\,h + 130\text{ cm } (4'4'')$$

Moreover, care has to be taken that the patrons cannot pass so close to the screen that they intercept the light beam. In modern cinemas — where there is no stage — plants or decorative gates are placed so that at the aisle left free for passage the light beam is at least about 2 m (6½ ft) above the floor.

It is also necessary to take measures to prevent standing persons from intercepting the light beam near the projection room. Hence:

RULE 9: h_z = min. 225 m (7½ ft)

Behind the screen there must be sufficient space for the loudspeaker assemblies; hence:

RULE 10: u = min. 1 m (3½ ft)

SEATING AREA

The seats should be placed in the space bordered by the two lines drawn at angles of max. 100° to the left and the right of the picture edge (fig. 6). Hence:

RULE 11: ε = max. 100°

AISLES

The best seats are near the centre line of the auditorium. As a central aisle would take away these seats it is advisable — if local regulations permit — to have only side aisles.

BALCONY (fig. 8)

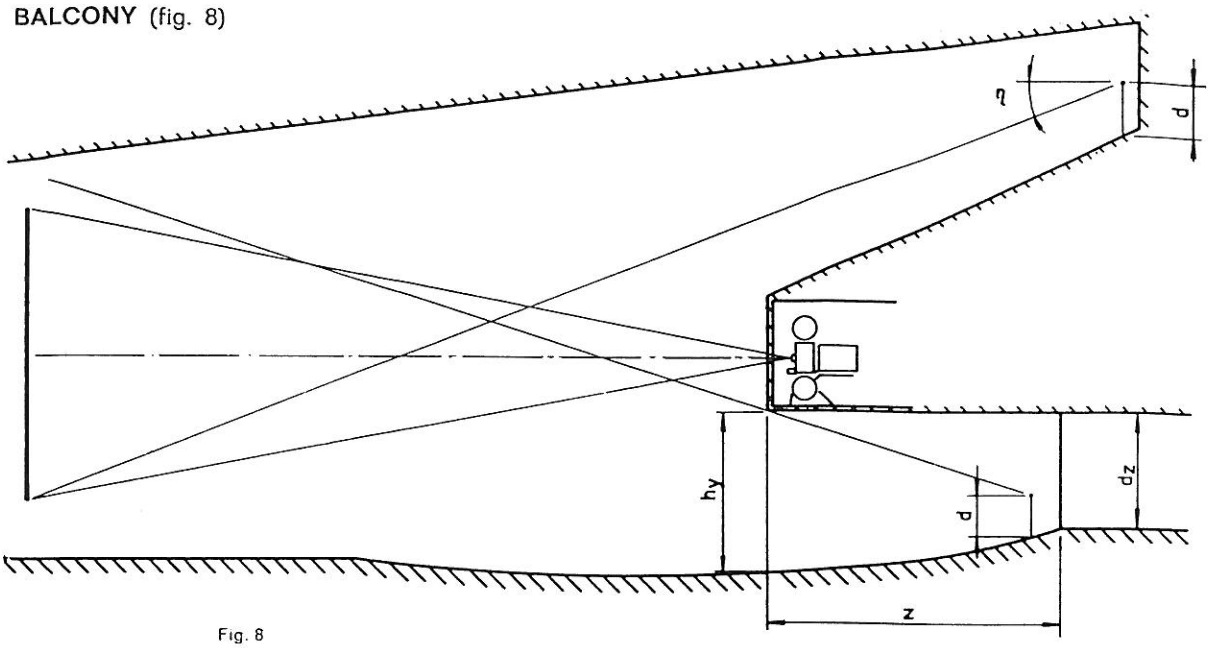


Fig. 8
d = eye level = 120 cm (4 ft)
d_z = distance between bottom of balcony and floor of hall
η = viewing angle to bottom of picture
z = depth of space under the balcony
h_y = height of front of balcony above the floor of the hall

Under all conditions, an auditorium built in the shape of an amphitheatre is preferable to one with a balcony for the following reasons:

- The projection room can be built into the rear wall at such a level that a practically horizontal projection is possible, which implies minimum risk of deformation of the picture. When there is a balcony, horizontal projection is possible only if the projection room is built into the front part of the balcony. The projection distance is then rather short so that lenses with a short focal length have to be used; these are always inferior to lenses with longer focal lengths.
- The viewing angles are more favourable. When there is a balcony it is unavoidable that part of the audience in the hall have to look up at the picture and that those on the balcony have to look down.
- People who have taken a (rather expensive) balcony seat have to climb the largest number of steps, whereas in an amphitheatre, the best seats are in the centre of the hall.

If, for reasons of seating capacity, a balcony proves to be unavoidable, the design of the balcony will have to satisfy the following demands:

- For psychological reasons, the spectators on the rear row of the hall (under the balcony) must still be able to see a strip of at least 1 m (3½ ft) of the ceiling over the picture.
- The spectators on the rear row on the balcony should see the bottom of the picture under an angle of not more than 30°, preferable under 20° or less.
  RULE 12: $\eta_{ideal} = \leqq 20°$; $\eta_{max.} = 30°$
- To avoid people feeling cramped for space, the minimum distance between the bottom of the balcony and the floor of the hall should not be less than 2.50 m (8½ ft).
  RULE 13: $d_{z\ min.} = 2.50$ m (8½ ft)
- For acoustical reasons it is recommended to make the space under the balcony not deeper than 2½ times the height measured at the front edge.
  RULE 14: $z_{max.} = 2½\ h_y$

SEATS (fig. 9)

A compromise will have to be found between the demand for maximum seating capacity and comfort of the patrons. Often the more expensive seats are more spacious than the cheaper ones. Generally, the rows of seats are staggered and often the end seats in every alternate row are made more spacious for corpulent persons.

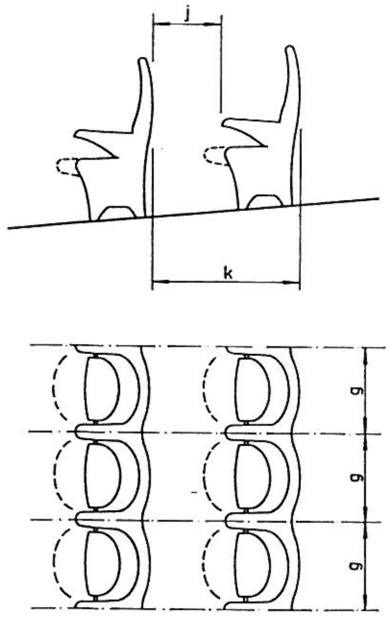


Fig. 9

Width of the seats

In some countries the minimum width is prescribed by national, regional or local regulations, which should therefore always be consulted first. As a modern spacious arm-chair has a width of 55 cm (21½"), it is logical to adopt:

RULE 15: g = about 55 cm (21½")

Spacing between the rows

The regulations in force in Germany prescribe that the chairback distance between two consecutive rows should be not less than 80 cm (31½"). In the U.K. it is 71 cm (28"). Both values are rather small. For a modern cinema it is preferable to adopt:

RULE 16: k = about 90 cm (3 ft)

Free passage between the rows

As a rule the free passage with the seats tipped up should be according to:

RULE 17: j = about 45 cm (1½ ft)

SLOPE OF THE FLOOR

Viewing conditions are mainly governed by the slope of the floor. Everybody should be able to see the bottom of the picture over the head of the person in front of him. Only when 70-mm films (with or without sub-titles) and 35-mm films without sub-titles are shown may the heads of the patrons in the front rows be visible at the bottom of the picture. It enhances the feeling of participation in the actions displayed on the screen.

When deciding upon the slope of the floor the architect has to take into account that:

- the difference in average eye level (fig. 11) between two consecutive rows has to be larger when 35-mm films with sub-titles may be shown in the theatre than when the films are always in the mother-tongue (originally or post-synchronized). A good directive is:
  RULE 18: p_{min} = 8 cm (3") for films without sub-titles
  p_{min} = 10 cm (4") for films with sub-titles
- for safety's sake the slope should not exceed a certain steepness;
- the heads of the spectators must not get into the light beam from the projector.

Determination of the floor slope

In figs. 10 and 11 a horizontal line is drawn from the bottom of the picture. **For the calculation** (fig. 10) it has been assumed that the spacing between the rows and the distance of the first row to the screen are equal (k). The actual distance of the **first row in the theatre** to the screen is f (Rule 8). Consequently, the first row in the theatre corresponds to row $\frac{f}{k}$, and the 2nd to nth row in the theatre to rows $\frac{f}{k} + 1 \ldots \frac{f}{k} + (n-1)$ in the calculation.

From fig. 11 it can be calculated that for an arbitrary row (A_n):

RULE 19: $h_n = n(h_1 + q_n p)$

in which $q_n = 1 + \frac{1}{2} + \frac{1}{3} \cdots\cdots\cdots + \frac{1}{n-1}$

The value of q_n thus calculated for the different rows in the theatre can be read from the adjacent table (if necessary by interpolation).

As, according to Rule 7, the eye level has to be 120 cm (4'), the floor at each row lies 120 cm (4') below h_n for that row calculated from Rule 19; hence:

RULE 20: $H_n = h_n - 120$ cm (4')
$= n(h_1 + q_n p) - 120$ cm (4')

in which H_n is the distance of the floor with respect to the horizontal drawn through the bottom of the picture;
when H_n is positive this means that the floor lies above the horizontal and when H_n is negative that it lies under it.

Example (fig. 11)

Given:

h_a = 150 cm = 5' (Rule 5)
d = 120 cm = 4' (Rule 7)
f = 650 cm = 21' (Rule 8)
k = 90 cm = 3' (Rule 16)
p = 10 cm = 4" (Rule 18)

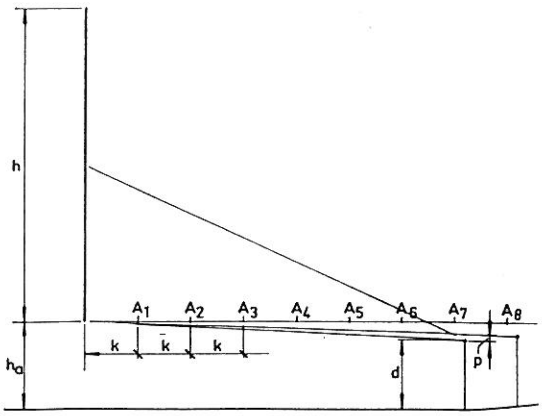


Fig. 10

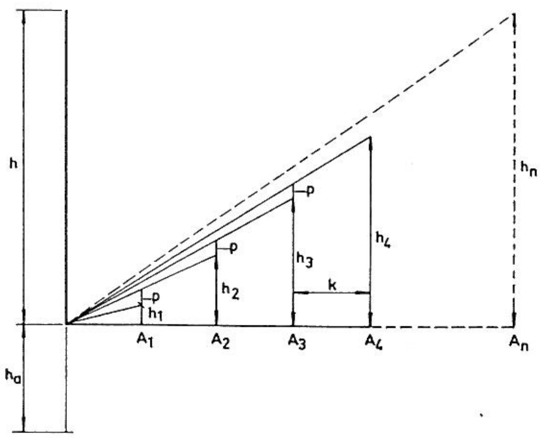
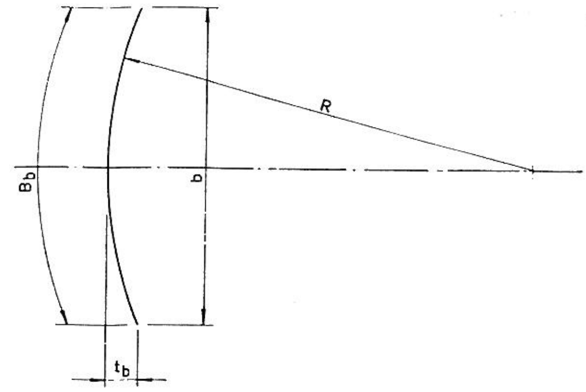


Fig. 11

$A_1 \ldots A_n$ = consecutive rows adopted for the calculation
h = height of the picture on the screen
$h_1 \ldots h_n$ = consecutive eye levels with respect to the horizontal through the bottom of the picture
k = spacing of the rows
p = difference of eye level between two consecutive rows
h_a = distance between bottom of picture and floor

VALUES OF q_n FOR THE DIFFERENT ROWS

(n)	,0	,1	,2	,3	,4	,5	,6	,7	,8	,9
5	2.083	2.104	2.122	2.142	2.164	2.184	2.202	2.222	2.240	2.259
6	2.283	2.296	2.312	2.331	2.349	2.366	2.382	2.402	2.420	2.438
7	2.450	2.469	2.482	2.500	2.514	2.529	2.542	2.555	2.569	2.582
8	2.593	2.608	2.620	2.633	2.646	2.659	2.670	2.681	2.694	2.707
9	2.718	2.730	2.741	2.752	2.763	2.774	2.786	2.797	2.808	2.819
10	2.829	2.840	2.850	2.860	2.870	2.879	2.889	2.899	2.909	2.919
11	2.929	2.939	2.949	2.958	2.967	2.976	2.985	2.994	3.002	3.011
12	3.020	3.029	3.038	3.046	3.054	3.062	3.070	3.079	3.088	3.096
13	3.103	3.111	3.119	3.127	3.135	3.142	3.150	3.158	3.166	3.173
14	3.180	3.188	3.196	3.203	3.210	3.217	3.223	3.231	3.238	3.245
15	3.252	3.259	3.266	3.272	3.279	3.285	3.291	3.297	3.303	3.310
16	3.318	3.323	3.329	3 335	3.341	3.348	3.355	3.362	2.369	3.375
17	3.381	3.388	3.394	3.400	3.406	3.411	3.417	3.423	3.429	3.435
18	3.440	3.446	3.452	3.458	3.463	3.469	3.474	3.479	3.484	3.489
19	3.495	3.500	3.505	3.511	3.516	3.522	3.527	3.533	3.538	3.543
20	3.548	3.553	3.558	3.562	3.567	3.572	3.577	3.583	3.588	3.593
21	3.598	3.602	3.606	3.611	3.615	3.620	3.625	3.630	3.635	3.640
22	3.645	3.650	3.654	3.659	3.663	3.668	3.672	3.677	3.681	3.686
23	3.691	3.695	3.700	3.704	3.709	3.713	3.717	3.721	3.726	3.730
24	3.734	3.739	3.743	3.748	3.751	3.755	3.759	3.763	3.768	3.772
25	3.776	3.780	3.784	3.789	3.793	3.797	3.801	3.805	3.809	3.812
26	3.816	3.820	3.824	3.828	3.832	3.835	3.839	3.843	3.847	3.851
27	3.854	3.858	3.861	3.865	3.869	3.873	3.877	3.881	3.884	3.888
28	3.891	3.895	3.899	3.902	3.906	3.910	3.913	3.917	3.920	3.924
29	3.927	3.931	3.934	3.938	3.941	3.944	3.947	3.951	3.955	3.958
30	3.962	3.965	3.969	3.972	3.975	3.978	3.981	3.984	3.988	3.991
31	3.995	3.998	4.001	4.004	4.008	4.011	4.014	4.018	4.021	4.024
32	4.027	4.030	4.033	4.036	4.039	4.042	4.045	4.048	4.052	4.055
33	4.058	4.061	4.064	4.067	4.070	4.073	4.076	4.079	4.083	4.086
34	4.089	4.092	4.095	4.098	4.100	4.103	4.106	4.109	4.112	4.115
35	4.118	4.121	4.124	4.126	4.129	4.132	4.135	4.138	4.141	4.144
36	4.147	4.150	4.152	4.155	4.158	4.160	4.163	4.166	4.169	4.172
37	4.175	4.178	4.180	4.183	4.186	4.189	4.191	4.194	4.197	4.200
38	4.202	4.205	4.208	4.210	4.213	4.215	4.218	4.221	4.223	4.226
39	4.228	4.231	4.233	4.236	4.239	4.241	4.244	4.247	4.249	4.252
40	4.254	4.257	4.259	4.261	4.264	4.266	4.269	4.271	4.274	4.276
41	4.279	4.281	4.284	4.286	4.289	4.291	4.293	4.296	4.299	4.301
42	4.303	4.305	4.308	4.311	4.313	4.316	4.318	4.321	4.323	4.325
43	4.327	4.329	4.331	4.333	4.336	4.338	4.340	4.342	4.345	4.347
44	4.350	4.352	4.354	4.357	4.359	4.361	4.364	4.366	4.368	4.370
45	4.373	4.375	4.378	4.380	4.382	4.384	4.386	4.388	4.390	4.393
46	4.395	4.398	4.400	4.402	4.404	4.406	4.408	4.410	4.413	4.415
47	4.417	4.419	4.421	4.423	4.426	4.428	4.430	4.432	4.434	4.436
48	4.438	4.440	4.442	4.444	4.446	4.449	4.451	4.453	4.455	4.457
49	4.459	4.461	4.463	4.465	4.467	4.469	4.471	4.473	4.475	4.477
50	4.479	4.481	4.483	4.485	4.487	4.489	4.491	4.493	4.495	4.497



VALUES IN METRES

R	16		18		20		22		24		26		28		30		32	
b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b
6	6,04	0,28	6,03	0,25	6,03	0,25	6,02	0,21	6,02	0,19	6,01	0,17	6,01	0,16	6,01	0,15	6,01	0,14
6,50	6,55	0,34	6,54	0,30	6,53	0,27	6,52	0,25	6,52	0,22	6,52	0,21	6,51	0,19	6,51	0,18	6,51	0.17
7	7.06	0,39	7,05	0,35	7,04	0,31	7,03	0,29	7,02	0,27	7,02	0,25	7,02	0,23	7,02	0,21	7,01	0.19
7,50	7,58	0.45	7,56	0.40	7,55	0,36	7,54	0,33	7,53	0,30	7,53	0,28	7,52	0,26	7,52	0,24	7,52	0,22
8	8.09	0,51	8,07	0,46	8,06	0,41	8,05	0,37	8,04	0,34	8,03	0,31	8,03	0,29	8,03	0,27	8,03	0,25
8,50	8,60	0,58	8,58	0,52	8,57	0,46	8,56	0,42	8,54	0,38	8,53	0,35	8,53	0,33	8,53	0,30	8,53	0,28
9	9.13	0,64	9,09	0,58	9,08	0,52	9,07	0,48	9,05	0,44	9.05	0,40	9,03	0,37	9,03	0,34	9,03	0,32
9,50	9,65	0,72	9,62	0,64	9,59	0,57	9,58	0,52	9,56	0,48	9,55	0,44	9,54	0,41	9,54	0,38	9,53	0,35
10	10,17	0,80	10,13	0,71	10,11	0,64	10,09	0,58	10,07	0,53	10,06	0,49	10,05	0,45	10,05	0,42	10,05	0,39
10,50	10,70	0,89	10,65	0,79	10,63	0,71	10,60	0,64	10,58	0,59	10,57	0,54	10,56	0,50	10,55	0,47	10,55	0,44
11	11,24	0,98	11,18	0,87	11,15	0,78	11,11	0,70	11,09	0,64	11,08	0,60	11,07	0,55	11,06	0,51	11,05	0,48
11,50	11,77	1,07	11,70	0,95	11,67	0,85	11,63	0,77	11,61	0,70	11,60	0,65	11,58	0,60	11,57	0,56	11,56	0,52
12	12,31	1,17	12,23	1,03	12,19	0,92	12,15	0,83	12,12	0,76	12,11	0,70	12,09	0,65	12,08	0,61	12,07	0,57
12,50	12,85	1,27	12,77	1,12	12,71	1,01	12,67	0,91	12,65	0,83	12,63	0,77	12,60	0,71	12,59	0,66	12,58	0,62
13			13,30	1,22	13,24	1,09	13,20	0,99	13,16	0,91	13,15	0,83	13,12	0,77	13,10	0,71	13,09	0,67
13,50					13,77	1,18	13,72	1,07	13,68	0,97	13,66	0,90	13,63	0,83	13,62	0,77	13,61	0,72
14					14,30	1,27	14,25	1,14	14,20	1,04	14,18	0,96	14,14	0,89	14,13	0,83	14,12	0,78
14,50							14,77	1,23	14,73	1,13	14,70	1,04	14,66	0,96	14,65	0,89	14,63	0,83
15							15,30	1,33	15,25	1,21	15,22	1,18	15,18	1,03	15,16	0,96	15,14	0,90
15,50									15,78	1,29	15,74	1,19	15,70	1,10	15,67	1,02	15,65	0,96
16									16,31	1,37	16,27	1,27	16,22	1,17	16,19	1,09	16,18	1,02
16,50											16,79	1,35	16,74	1,25	16,71	1,16	16,69	1,08
17											17,32	1,43	17,27	1,33	17,23	1,23	17,20	1,15
17,50													17,79	1,41	17,75	1,31	17,72	1,22
18													18,31	1,49	18,28	1,38	18,24	1,29
18,50													18,84	1,58	18,81	1,46	18,77	1,37
19													19,37	1,66	19,33	1,55	19,29	1,44

R	34		36		38		40		42		44		46		48		50	
b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b
6																		
6,50																		
7	7,01	0,19	7,01	0.17	7,01	0,16	7,01	0,16	7,01	0,15	7,01	0,14						
7,50	7,51	0,22	7,51	0,20	7,51	0,18	7,51	0,18	7,51	0,17	7,51	0,16						
8	8,01	0,24	8,01	0,23	8,01	0,21	8,01	0,20	8,01	0,19	8,01	0,18	8,01	0,18	8,01	0,17	8,01	0,16
8,50	8,52	0,27	8,52	0,26	8,52	0,24	8,52	0,23	8,51	0,22	8,51	0,21	8,51	0,20	8,51	0,19	8,51	0,18
9	9,02	0,30	9,02	0,29	9,02	0,27	9,02	0,25	9,02	0,24	9,02	0,23	9,01	0,22	9,01	0,21	9,01	0,20
9,50	9,53	0,33	9,53	0,32	9,53	0,30	9,52	0,28	9,52	0,27	9,52	0,26	9,52	0,25	9,52	0,23	9,51	0,23
10	10,03	0,37	10,03	0,35	10,03	0,33	10,03	0,31	10,02	0,30	10,02	0,29	10,02	0,27	10,02	0,26	10,02	0,25
10,50	10,54	0,41	10,54	0,38	10,54	0,36	10,54	0,35	10,53	0,33	10,53	0,32	10,52	0,30	10,52	0,29	10,52	0,28
11	11,05	0,44	11,05	0,42	11,04	0,40	11,04	0,38	11,03	0,36	11,03	0,35	11,02	0,33	11,02	0,32	11,02	0,30
11,50	11,55	0,49	11,55	0,46	11,54	0,44	11,54	0,42	11,53	0,40	11,53	0,38	11,53	0,36	11,53	0,35	11,52	0,33
12	12,06	0,54	12,05	0,50	12,05	0,48	12,05	0,45	12,04	0,43	12,04	0,41	12,03	0,39	12,03	0,38	12,03	0,36
12,50	12,57	0,59	12,56	0,55	12,56	0,52	12,56	0,49	12,55	0,47	12,54	0,45	12,53	0,42	12,53	0,41	12,53	0,39
13	13,08	0,63	13,07	0,59	13,06	0,56	13,06	0,53	13,05	0,51	13,05	0,48	13,04	0,46	13,04	0,44	13,04	0,42
13,50	13,59	0,68	13,59	0,64	13,58	0,60	13,57	0,57	13,55	0,55	13,55	0,52	13,54	0,50	13,54	0,48	13,54	0,46
14	14,10	0,73	14,08	0,69	14,08	0,65	14,08	0,62	14,06	0,59	14,06	0,56	14,05	0,54	14,05	0,51	14,05	0,49
14,50	14,61	0,78	14,60	0,74	14,59	0,70	14,58	0,67	14,57	0,63	14,56	0,60	14,55	0,58	14,55	0,55	14,55	0,53
15	15,12	0,84	15,11	0,79	15,10	0,75	15,09	0,71	15,08	0,68	15,07	0,65	15,06	0,62	15,06	0,59	15,06	0,57
15,50	15,63	0,90	15,61	0,84	15,61	0,80	15,60	0,76	15,58	0,72	15,58	0,69	15,57	0,66	15,57	0,63	15,56	0,61
16	16,15	0,96	16,13	0,90	16,13	0,85	16,13	0,81	16,10	0,77	16,09	0,73	16,07	0,70	16,07	0,67	16,06	0,65
16,50	16,66	1,02	16,64	0,96	16,64	0,91	16,62	0,86	16,60	0,82	16,60	0,78	16,58	0,74	16,58	0,71	16,58	0,69
17	17,18	1,08	17,16	1,02	17,15	0,97	17,13	0,92	17,11	0,87	17,10	0,83	17,09	0,79	17,09	0,76	17,08	0,73
17,50	17,69	1,14	17,68	1,06	17,64	1,02	17,64	0,97	17,62	0,92	17,61	0,88	17,60	0,84	17,59	0,80	17,59	0,77
18	18,21	1,20	18,18	1,14	18,17	1,08	18,15	1,03	18,14	0,98	18,12	0,93	18,11	0,89	18,11	0,85	18,10	0,81
18,50	18,73	1,28	18,70	1,21	18,69	1,15	18,67	1,09	18,65	1,03	18,64	0,98	18,62	0,94	18,62	0,90	18,61	0,86
19	19,25	1,36	19,24	1,28	19,19	1,21	19,16	1,15	19,16	1,09	19,15	1,04	19,13	0,99	19,13	0,95	19,12	0,91

VALUES IN FEET

R	60		70		80		90		100		110		120		130	
b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b
24	24·2	1·2	24·1	1·0	24·1	0·9	24·1	0·8	24·1	0·7	24·1	0·7	24·1	0·6		
26	26·2	1·4	26·2	1·2	26·1	1·1	26·1	1·0	26·1	0·9	26·1	0·8	26·1	0·7	26·1	0·6
28	28·3	1·6	28·2	1·3	28·1	1·2	28·1	1·1	28·1	1·0	28·1	0·9	28·1	0·8	28·1	0·7
30	30·3	1·9	30·2	1·6	30·2	1·4	30·1	1·3	30·1	1·2	30·1	1·0	30·1	0·9	30·1	0·8
32	32·4	2·2	32·3	1·9	32·2	1·6	32·2	1·5	32·1	1·3	32·1	1·2	32·1	1·1	32·1	1·0
34	34·5	2·5	34·4	2·1	34·3	1·8	34·2	1·7	34·1	1·5	34·1	1·4	34·1	1·2	34·1	1·1
36	36·6	2·8	36·4	2·3	36·3	2·0	36·3	1·9	36·2	1·7	36·2	1·5	36·1	1·4	36·1	1·3
38	38·7	3·1	38·5	2·6	38·4	2·3	38·3	2·1	38·2	1·9	38·2	1·7	38·2	1·5	38·1	1·4
40	40·8	3·4	40·6	2·9	40·4	2·5	40·4	2·3	40·3	2 1	40·2	1·9	40·2	1·7	40·2	1·6
42	42·9	3·8	42·7	3·2	42·5	2·8	42·4	2·5	42·3	2·3	42·3	2·1	42·2	1·8	42·2	1·7
44	45·1	4·2	44·8	3·5	44·6	3·1	44·5	2·8	44·4	2·5	44·3	2·3	44·2	2·0	44·2	1·9
46	47·2	4·6	46·9	3·9	46·7	3·4	46·6	3·0	46·4	2·7	46·4	2·5	46·3	2·2	46·2	2·1
48	49·4	5·0	49·1	4·3	48·8	3·7	48·7	3·3	48·5	3·0	48·4	2·7	48·3	2·4	48·3	2·2
50	51·6	5·5	51·2	4·7	50·9	4·0	50·8	3·6	50·6	3·2	50·5	2·9	50·4	2·6	50·3	2·5
52	53·8	5·9	53·4	5·1	53·0	4·3	52·9	4·0	52·7	3·5	52·5	3·2	52·4	2·9	52·4	2·7
54			55·6	5·5	55·1	4·7	54·9	4·2	54·7	3·7	54·6	3·4	54·5	3·1	54·4	2·9
56			57·7	5·9	57·2	5·1	57·0	4·5	56·8	4·0	56·6	3·6	56·5	3·3	56·5	3·1
58			59·9	6·4	59·3	5·4	59·1	4·8	58·9	4·3	58·7	3·9	58·6	3·6	58·5	3·3
60			62·1	6·9	61·5	5·8	61·3	5·1	61·0	4·6	60·8	4·2	60·6	3·8	60·6	3·6
62			64·3	7·4	63·7	6·2	63·4	5·5	63·1	4·9	62·9	4·5	62·7	4·1	60·6	3·8
64					65·8	6·7	65·5	5·8	65·2	5·2	65·0	4·8	64·8	4·4	64·7	4·1
66					68·0	7·1	67·7	6·3	67·4	5·5	67·1	5·1	66·9	4·6	66·8	4·3
68					70·2	7·6	69·8	6·7	69·5	5·9	69·2	5·4	68·9	4·9	68·8	4·6
70					72·4	8·0	72·0	7·1	71·6	6·3	71·3	5·7	71·0	5·2	70·9	4·9
72							74·2	7·5	73·7	6·7	73·4	6·0	73·1	5·5	73·0	5·2
74							76·5	8·0	75·9	7·1	75·5	6·4	75·3	5·9	75·3	5·5

R	140		150		160		170		180		190		200	
b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b	B_b	t_b
24														
26														
28	28·1	0·6												
30	30·1	0·8	30·1	0·7										
32	32·1	0·9	32·1	0·8	32·1	0·8								
34	34·1	1·0	34·1	0·9	34·1	0·9	34·1	0·8						
36	36·1	1·2	36·1	1·1	36·1	1·0	36·1	1·0	36·1	0·9				
38	38·1	1·3	38·1	1·2	38·1	1·1	38·1	1·0	38·1	0·9	38·1	0·9		
40	40·1	1·5	40·1	1·4	40·1	1·3	40·1	1·2	40·1	1·1	40·1	1·0	40·1	1·0
42	42·2	1·6	42·1	1·5	42·1	1·4	42·1	1·3	42·1	1·2	42·1	1·1	42·1	1·1
44	44·2	1·7	44·2	1·6	44·1	1·5	44·1	1·4	44·1	1·3	44·1	1·2	44·1	1·2
46	46·2	1·9	46·2	1·8	46·2	1·7	46·2	1·6	46·1	1·5	46·1	1·4	46·1	1·3
48	48·2	2·0	48·2	1·9	48·2	1·8	48·2	1·7	48·2	1·6	48·1	1·5	48·1	1·4
50	50·3	2·3	50·2	2·1	50·2	2·0	50·2	1·9	50·2	1·8	50·2	1·7	50·1	1·6
52	52·3	2·5	52·3	2·3	52·2	2·1	52·2	2·0	52·2	1·9	52·2	1·8	52·2	1·7
54	54·3	2·7	54·3	2·5	54·3	2·3	54·3	2·2	54·2	2·0	54·2	1·9	54·2	1·8
56	56·4	2·9	56·3	2·7	56·3	2·5	56·3	2·3	56·3	2·2	56·2	2·1	56·2	2·0
58	58·4	3·1	58·4	2·9	58·3	2·6	58·3	2·5	58·3	2·3	58·3	2·2	58·2	2·1
60	60·5	3·3	60·4	3·0	60·4	2·8	60·3	2·7	60·3	2·5	60·3	2·4	60·2	2·3
62	60·5	3·5	62·5	3·3	62·4	3·0	62·4	2·9	62·4	2·7	62·3	2·6	62·3	2·4
64	64·6	3·8	64·5	3·5	64·4	3·2	64·4	3·1	64·4	2·9	64·3	2·8	64·3	2·6
66	66·7	4·0	66·6	3·7	66·5	3·5	66·4	3·3	66·4	3·1	66·3	2·9	66·3	2·7
68	68·7	4·3	68·6	4·0	68·5	3·7	68·5	3·5	68·4	3·3	68·4	3·1	68·3	2·9
70	70·8	4·6	70·7	4·2	70·6	3·9	70·5	3·7	70·5	3·5	70·4	3·4	70·4	3·1
72	72·9	4·8	72·7	4·5	72·6	4·1	72·6	3·9	72·5	3·7	72·4	3·5	72·4	3·3
74	74·9	5·0	74·8	4·7	74·7	4·4	74·7	4·1	74·6	3·9	74·5	3·7	74·4	3·4

From the data it follows that the first row **in the theatre** corresponds to row $\frac{650}{90}$ = row 7.22 **of the calculation.**

Furthermore, at the first row **in the theatre** the eye level ($h_{7.22}$) is 30 cm (1') below the horizontal drawn through the bottom of the picture. Substitution of this value in Rule 19 gives:

$-30 = 7.22\ (h_1 + 2.484 \times 10)$ or $h_1 = -27.6$ cm

Furthermore, $H_{7.22} = h_a = -30$ cm -120 cm $= -150$ cm.

The floor level at the different rows in the theatre is calculated from Rule 20 as shown in the following examples:

3rd row: $n = 9.22$; $H_{9.22} = 9.22\ (-27.6 + 2.745 \times 10) - 120 = -121.38$ cm

6th row: $n = 12.22$; $H_{12.22} = 12.22\ (-27.6 + 3.041 \times 10) - 120 = -85.66$ cm

20th row: $n = 26.22$; $H_{26.22} = 26.22\ (-27.6 + 3.823 \times 10) - 120 = +158.72$ cm

It makes no difference for the calculation whether h_n, h_1, p and d are expressed in centimetres or in inches; of course n and q_n are the same in both cases.

SCREEN AND SCREEN FRAME

Modern projection requires more light than the former projection systems (aspect ratio 1 : 1.37) to obtain the same brightness of the picture. This can be achieved:

- by using more powerful projection lamps (and hence more powerful rectifiers);
- by using a screen with a high reflection coefficient, which reflects the light mainly towards the spectators.

"Directional" (metallized or "Perlux") screens fulfil both conditions; their reflection coefficient is twice that of other screens and the amount of reflected light remains substantially constant up to an incidence angle of 30° with respect to the normal to the screen.

It should be borne in mind that directional screens obey the optical laws for mirrors (angle of incidence = angle of reflection). This implies that for projection at a large angle the screen should be tilted so as to obtain uniform light distribution all over the auditorium.

Curvature of the screen

Directional screens should be curved to concentrate the reflected light towards the spectators (fig. 12); if they are flat most of the lateral light rays will be reflected towards the side walls of the theatre.

Matt-white (non-directional) screens should not be curved; if they are, some of the reflected light will fall on other parts of the screen, thus reducing the contrast (fig. 13).

Consequently, for optical reasons, it is best to stick to:

RULE 21: Directional screens should be curved.
Matt-white screens should be flat.

The following calculations of the overall screen width and of the frame are based on the fact that at all sides the screen must be 15 cm (½ ft) larger than the picture (for hems and eyelets) and the frame must be 15 cm (½ ft) larger than the screen.

Calculation of the curvature when only 35-mm films will be shown

With the aid of the adjacent table, the following can be calculated for a given picture chord (b) and a given projection distance (R):

- the depth t_b in the centre of the screen;
- the length of curve B_b.

Fig. 12

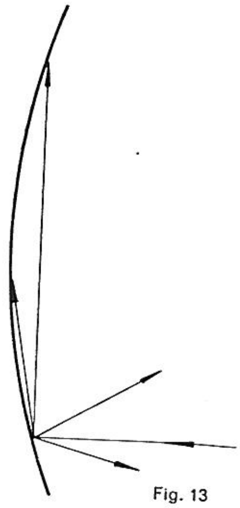


Fig. 13

The overall dimensions of the screen and of the frame are: (in which h = picture height)

screen: width $= B_b + 30$ cm (1 ft)
height $= h + 30$ cm (1 ft)
frame : width $= B_b + 60$ cm (2 ft)
height $= h + 60$ cm (2 ft)

Example:

Given: picture width = 10.50 m
picture height = 4.50 m
projection distance = 24 m

From the table results: $B_b = 10.58$ m
$t_b = 0.59$ m

The overall dimensions of the screen are:
width = 10.88 m; height = 4.80 m
The overall dimensions of the frame are:
width = 11.18 m; height = 5.10 m

Calculation of the curvature when both 35-mm and 70-mm films will be shown

For 70-mm films the screen has to be considerably more curved than for 35-mm films; it must be parabola-shaped (fig. 14).

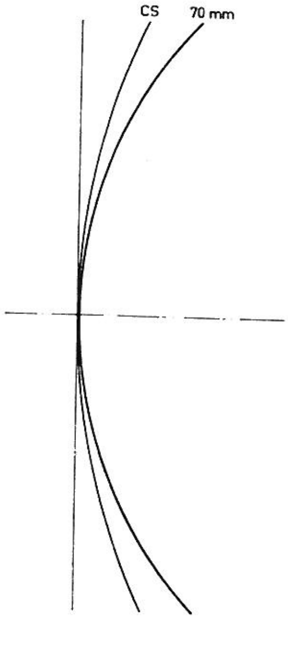


Fig.14

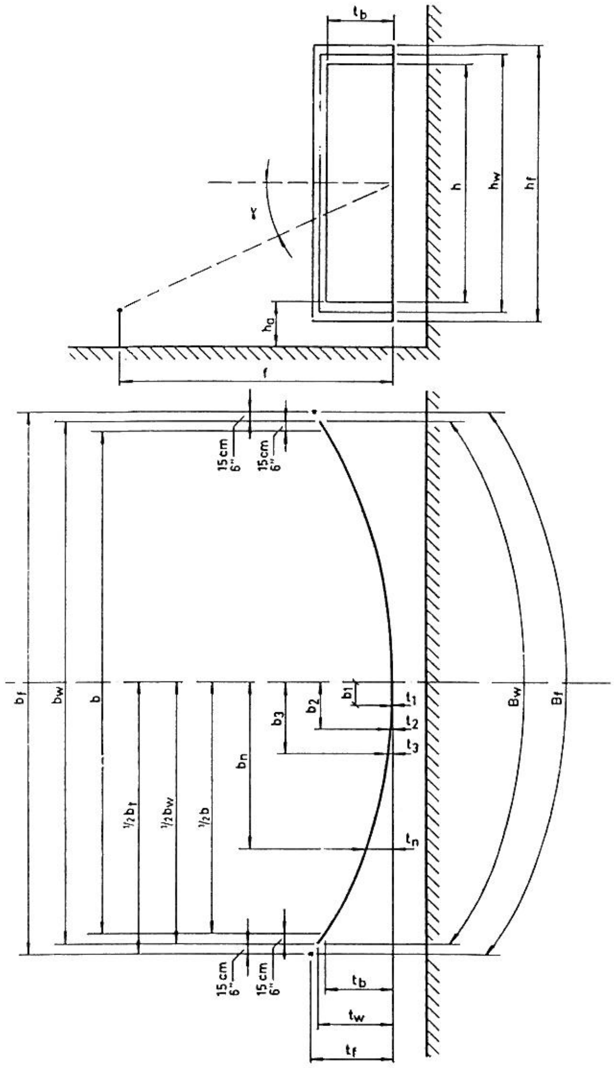


Fig. 15

t_b	=	picture depth
t_w	=	screen depth
t_f	=	frame depth
h	=	picture height
h_w	=	screen height
h_f	=	frame height
b	=	picture chord
b_w	=	screen chord
b_f	=	frame chord
B_w	=	screen width
B_f	=	frame width
h_o	=	height of bottom of picture above floor
f	=	distance between screen chord and first row
$t_1 \ldots t_n$		depth of the screen at the points $b_1 \ldots b_n$

For the sake of simplicity it is customary to base the calculation on one half of the screen, the other half being identical (fig. 15).
If the projection angle is more than 3°, the screen has to be tilted.

The depth t_b is calculated from:

RULE 22: $t_b = 0.125\,b$ for $\alpha = 0°$

$$t_b = 0.1\,b \begin{cases} \text{for } \alpha_{upward} = 1° \ldots 3° \\ \text{for } \alpha_{downward} = 1° \ldots 8° \end{cases}$$

in which b = given picture width
α = projection angle

If the projection angle is larger than 3° resp. 8°, the depth t_b must be calculated for each case in consultation with the manufacturer of the equipment.

The curvature of the screen is determined by the parameter r, which can be calculated from:

RULE 23: $r = \dfrac{(\frac{1}{2}\,b)^2}{t_b}$

To calculate and to plot the curvature of the screen the depth t_n at various points is calculated with the aid of:

RULE 24: $t_n = \dfrac{b_n^2}{r}$ (in which b_n = value of ½b at the choisen point)

The depths t_w and t_f at the ends of the screen and of the frame are calculated from:

RULE 25: $t_w = \dfrac{(\frac{1}{2}\,b_w)^2}{r}$, in which $\frac{1}{2}\,b_w = \frac{1}{2}\,b + 15$ cm (½ ft)

RULE 26: $t_f = \dfrac{(\frac{1}{2}\,b_f)^2}{r}$, in which $\frac{1}{2}\,b_f = \frac{1}{2}\,b + 30$ cm (1 ft)

The widths B_w and B_f of the screen and of the frame, measured along the arc, are calculated from:

RULE 27: $B_w = b_w + \dfrac{8\,t_w^2}{3\,b_w}$

RULE 28: $B_f = b_f + \dfrac{8\,t_f^2}{3\,b_f}$

The total heights H_w and H_f of the screen and of the frame are calculated from:

RULE 29: $H_w = h + 30$ cm (1 ft)

(h = given picture height $= \dfrac{b}{2.2}$)

RULE 30: $H_f = h + 60$ cm (2 ft)

Example:

Given: picture width = 16 m
picture height = 7.30 m
projection angle = 0°

Calculation:

$t_E = 16 \times 0.125 = 2\ m$

$r = \frac{8^2}{2} = 32$

$t_{100} = \frac{1^2}{32} = 0.03\ m$

$t_{150} = \frac{1.50^2}{32} = 0.07\ m$

$t_{200} = \frac{2^2}{32} = 0.125\ m$

$t_w = t_{815} = \frac{8.15^2}{32} = 2.075\ m$

$t_f = t_{830} = \frac{8.30^2}{32} = 2.15\ m$

$B_w = 16.30 + \frac{8(2.075)^2}{3 \times 16.30} = 17\ m$

$B_f = 16.60 + \frac{8(2.15)^2}{3 \times 16.60} = 17.35\ m$

$H_w = 7.30 + 0.30 = 7.60\ m$
$H_f = 7.30 + 0.60 = 7.90\ m$

SURROUND LOUDSPEAKERS

These loudspeakers serve for reproducing the "effects" track recorded on films provided with magnetic sound tracks (e.g. "magnetic" CinemaScope films and 70-mm films), thus enhancing the action on the screen. They are mounted on the side walls and on the rear wall of the auditorium (for the positioning see "Acoustical Part").

COMPLETE EXAMPLE OF THE PLANNING OF A CINEMA

Note: It makes no difference to the calculations whether the various values, expressed in this example in metres (or cm), are expressed in feet and inches. The figures in brackets at the end of the sentences refer to the rules.

The owner of a plot of land of about 47 m by 32 m (fig. 16) wishes to build a cinema which meets the following requirements:

- Amphitheatre-shaped auditorium; seating capacity: 900.
- Spacious entrance hall with lobby.
- Sufficient space for cloakrooms, lavatories, offices and a bar with candy shop.
- Suitable for the projection of:
  70-mm films and
  CinemaScope films, Wide-Screen films, standard films } with and without sub-titles.
- Optimum sound quality.
- Modern and attractive illumination of the façade and lighting of the auditorium, the lobby, etc.

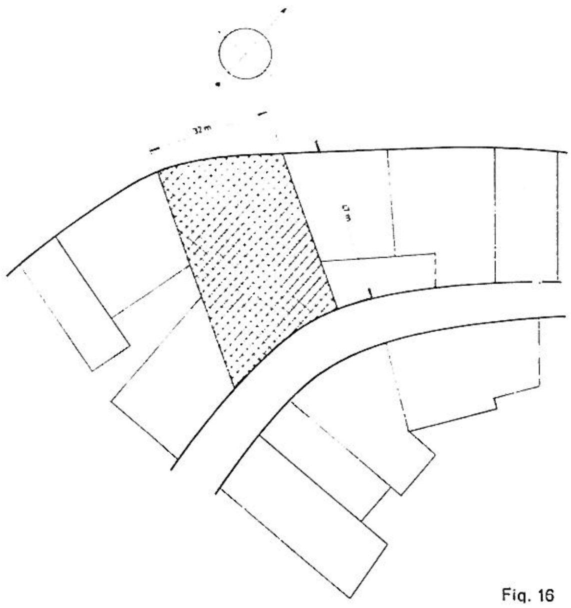


Fig. 16

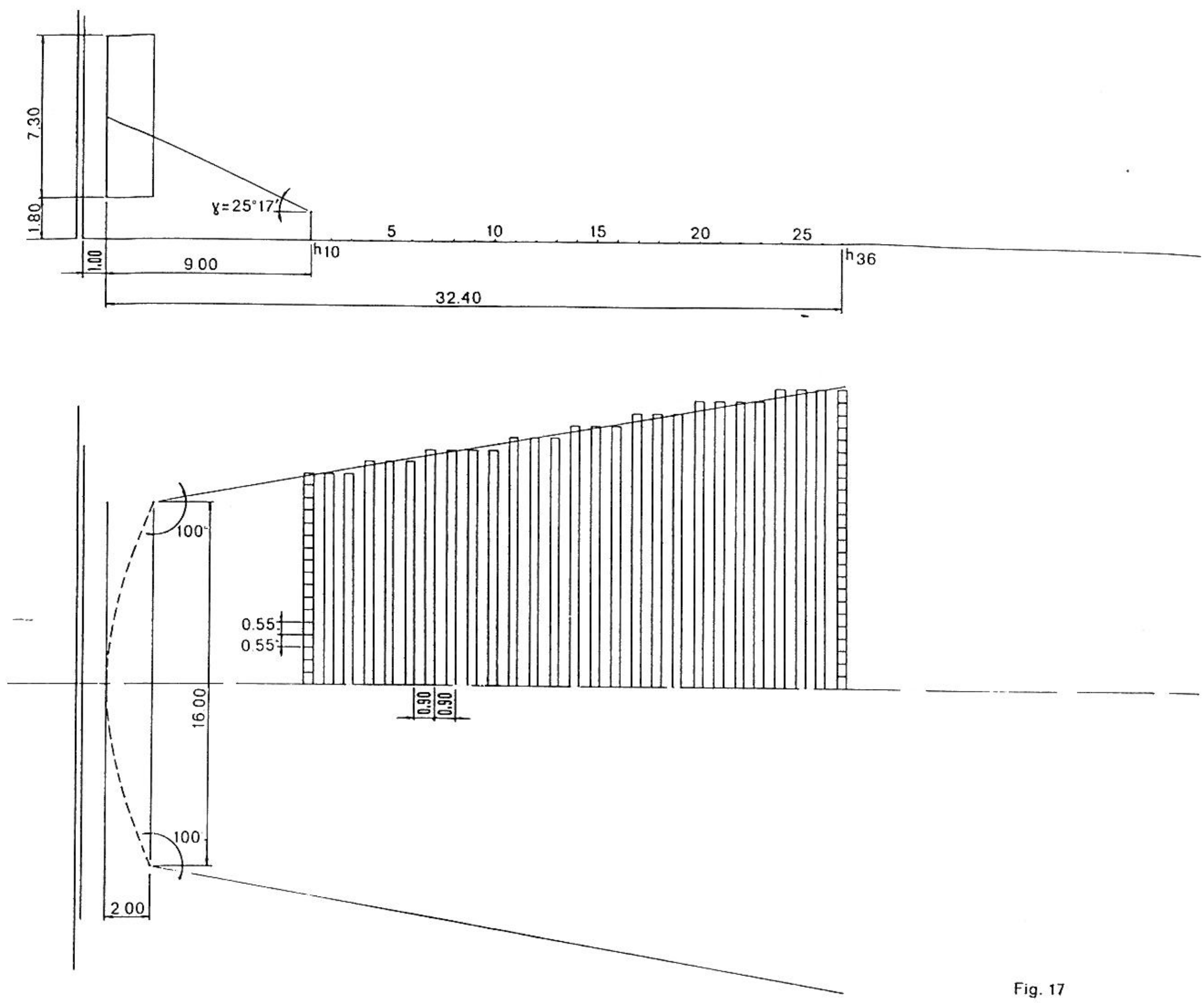


Fig. 17

DETERMINATION OF THE SIZE OF THE AUDITORIUM (fig. 17)

Given: Available land: 47 m x 32 m.
Seating capacity: 900.

Calculation:

Each seat will need an area of 0.9 x 0.55 m²
= 0.5 m² . . . (15 + 16)

and hence for 900 seats . . . . 450 m²
The aisles, the stage, etc. can be estimated at 200 m²
so that the total area of the auditorium amounts to 650 m²

Let us start from an auditorium with a depth of 33 m and a width of 20 m, the latter being quite adequate for auditoriums where 70-mm films will be shown (Rule 4). When we reckon with a total depth of 4 m for the projection room, the office and the lavatories, there remains for the entrance hall, the lobby, etc. a space with a depth of 47 m — 33 m — 4 m = 10 m and with an area of 10 x 20 m² = 200 m².

The depth of the space behind the screen for the loudspeaker assemblies has to be 1 m (Rule 10), so that the actual depth of the auditorium is 32 m.

SCREEN AND SCREEN FRAME

Ideal picture width = ½ x longest viewing distance
= 16 m . . . . (3)

Largest picture height (for 70-mm films)

$\frac{16}{2.2}$ = 7.30 m . . . . . (2)

Height of the bottom of the picture above the floor
= 1.80 m . . . . (5)

Depth of picture = 0.125 x 16 m = 2 m . . . (22)

Parameter = $\frac{8^2}{2}$ = 32 . . . . (23)

The curvature of the screen and of the frame can now be calculated and plotted as indicated on page 9 and 10.

SEATS (fig. 17)

Distance between first row of seats and screen:
1.07 x 730 + 130 cm = 911 cm . . . . (8)

Chairback distance between the consecutive rows:
90 cm . . . . (16)

Note:

The first row in this theatre would correspond to row $\frac{911}{90}$ = row 10.12 in the calculation of the floor slope.

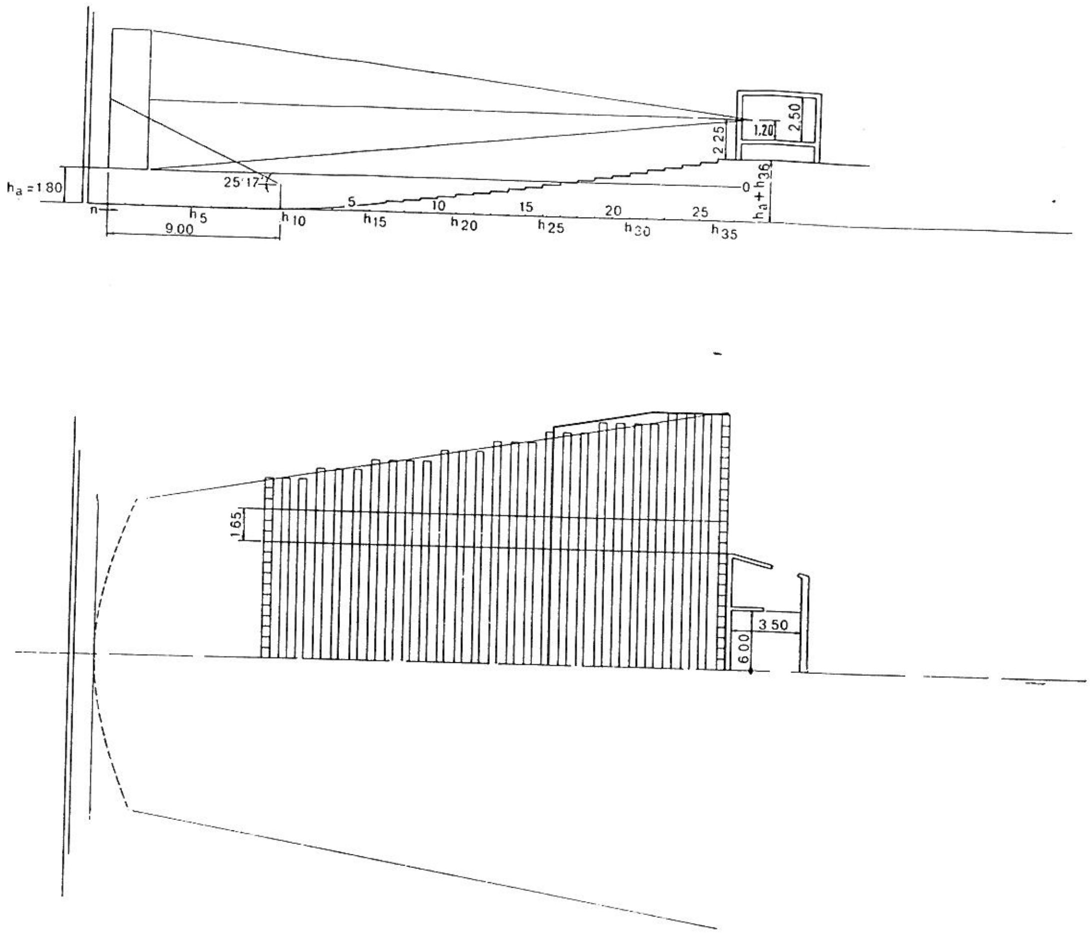


Fig. 18

This value can be substituted, but to simplify the calculation, the distance between the first row and the screen plane is often rounded off to a whole multiple of 90, i.e. the first row will be placed somewhat nearer to the screen plane or somewhat farther away from it than would result from Rule 8. In practice this means that the viewing angle γ from the centre of the first row to the centre of the screen will not be 25° (Rule 6) but:

$$\tan \gamma = \frac{180 + 365 - 120}{190} = 1.4722 \text{ or } \gamma = 25°17',$$

the difference of 17' being, of course, negligible.

Based on the above, we have supposed in this example that the first row will be at 9 m from the screen plane.

Available space for the seats: 32 m — 9 m = 23 m, so that $\frac{2300}{90} = 25.4$ rows can be placed behind the first row and 23 m — 22.5 m = 0.5 m would remain free at the rear. Very often the last row in the theatre is built against the rear wall, as will be done in this example. Based on the above calculation, one further row is then added in the planning which implies that the depth of the auditorium is now planned definitely to be:
1 m (loudspeaker space) + 9 m + 26 x 0.9 m = 33.4 m instead of the first planned 33 m. This auditorium can then contain 26 + 1 = 27 rows of seats.

According to Rule 11, the front angles of the seating area are max. 100°; this area can now be plotted and the number of seats can be counted without taking into account the space needed for the entrances, exits, aisles, etc.; it is found to be 1118.

The side walls are planned in parallel with the 100°-lines, which is completely in accordance with acoustical requirements.

SLOPE OF THE FLOOR (fig. 18)

The first row in the theatre corresponds to row $\frac{900}{90}$ = row 10 in the calculation; hence:
h_{10} = — (180 — 120) cm = — 60 cm . . . (5 + 7)
i.e. the eye level at the first row in the theatre lies 60 cm below the horizontal through the bottom of the picture. The eye level at h_1 in the calculation (90 cm from the screen plane) is derived from:
—60 = 10(h_1 + 2.829 x 10) . . . . (19)
or h_1 = —34.3 cm
The floor level at the last row in the theatre (row h_{36} in the calculation) is:
H_{36} = 36 (—34.3 + 4.147 x 10) —120 cm = 138.12 cm (20)
i.e. it lies 138 cm above the horizontal through the bottom of the picture and 138 + 180 cm = 318 cm above the floor at the first row in the theatre.

The slope of the floor between these two rows can be calculated as indicated on page 9.

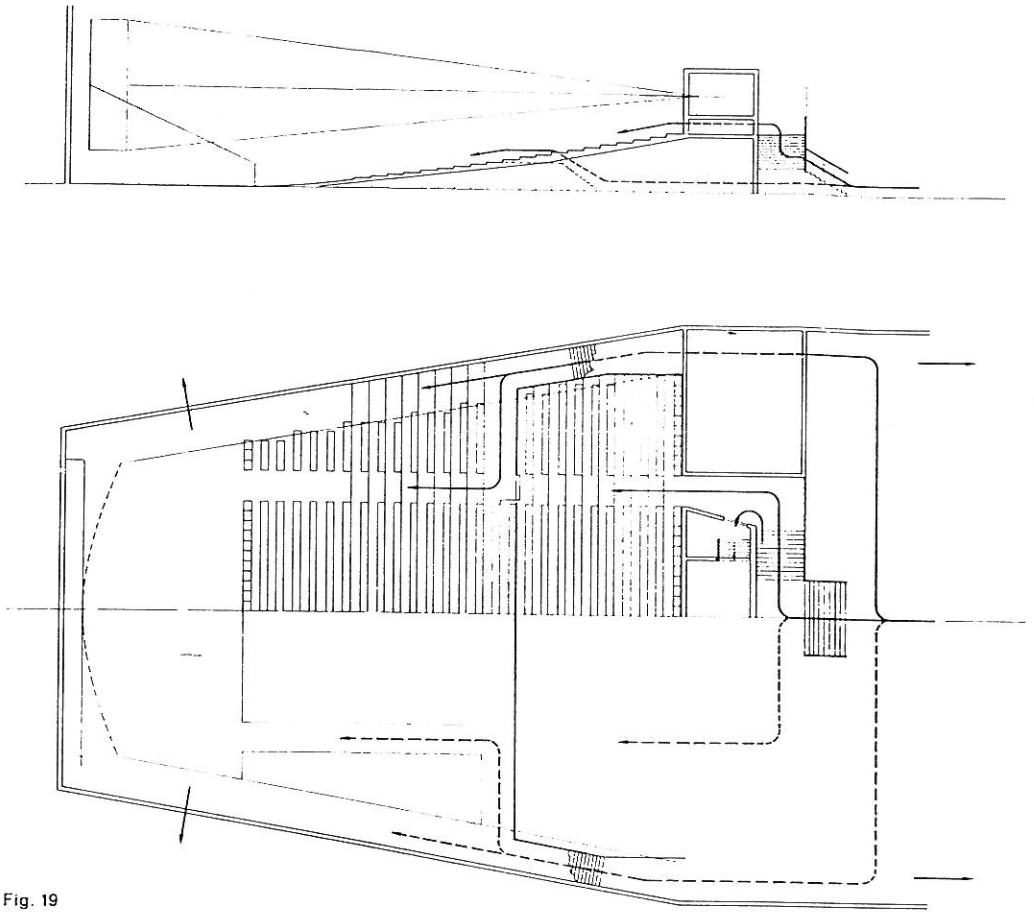


Fig. 19

PROJECTION ROOM

The distance between the centre of the light beam from the projector and the floor of the auditorium at the last row = min. 225 cm . . . . (9)

If we assume that the centre line of the projection-room windows will be 119 cm above the floor of the projection room, the latter will be 318 + 225 — 119 = 424 cm above the level at the first row in the theatre.

The dimensions of the projection room will be:
width x depth x height = 500 x 350 x 250 cm.

Under the floor of the projection room there will be a space with a height of at least 75 cm for the cable ducts.

From the plan we see that the angle of projection is almost 0°, as it should preferably be according to Rule 1.

To obtain optimum conditions in the cinema, the calculations and planning indicated so far should be followed exactly according to this example. All the other points may be decided upon by the architect solely on the grounds of aesthetics. Here are just a few hints which may prove to be useful.

ENTRANCES AND GANGWAYS (fig. 19)

We assumed that according to local regulations:

- the aisles must have a width of 1.65 m ("so that three persons can walk side by side");
- there must be no more than 22 seats per row.

We found that the floor at the last row of seats lies 3.18 m above that at the first row (zero level). To make it as easy as possible for the patrons to reach their seats, we planned the entrances as follows:
The auditorium is divided into a rear part and a front part.

The patrons for the (cheaper) front part enter by either of two side doors at the rear of the lobby, a gangway and a 1.46 m high staircase (10 steps), from where they descend gradually in the auditorium towards their rows.

The patrons for the (more expensive) rear part enter by a wide, also 1.46 m high staircase in the centre at the rear of the lobby, a landing (on which they can rest) and either of two gradually rising gangways (total slope: 1.72 m) at both sides of the projection booth, from where they also descend gradually in the auditorium towards their rows.

This division permits of separating at the entrance the patrons for the cheaper and the more expensive seats, a further selection being obtained by numbering the seats at the left with even numbers and those at the right with odd numbers.

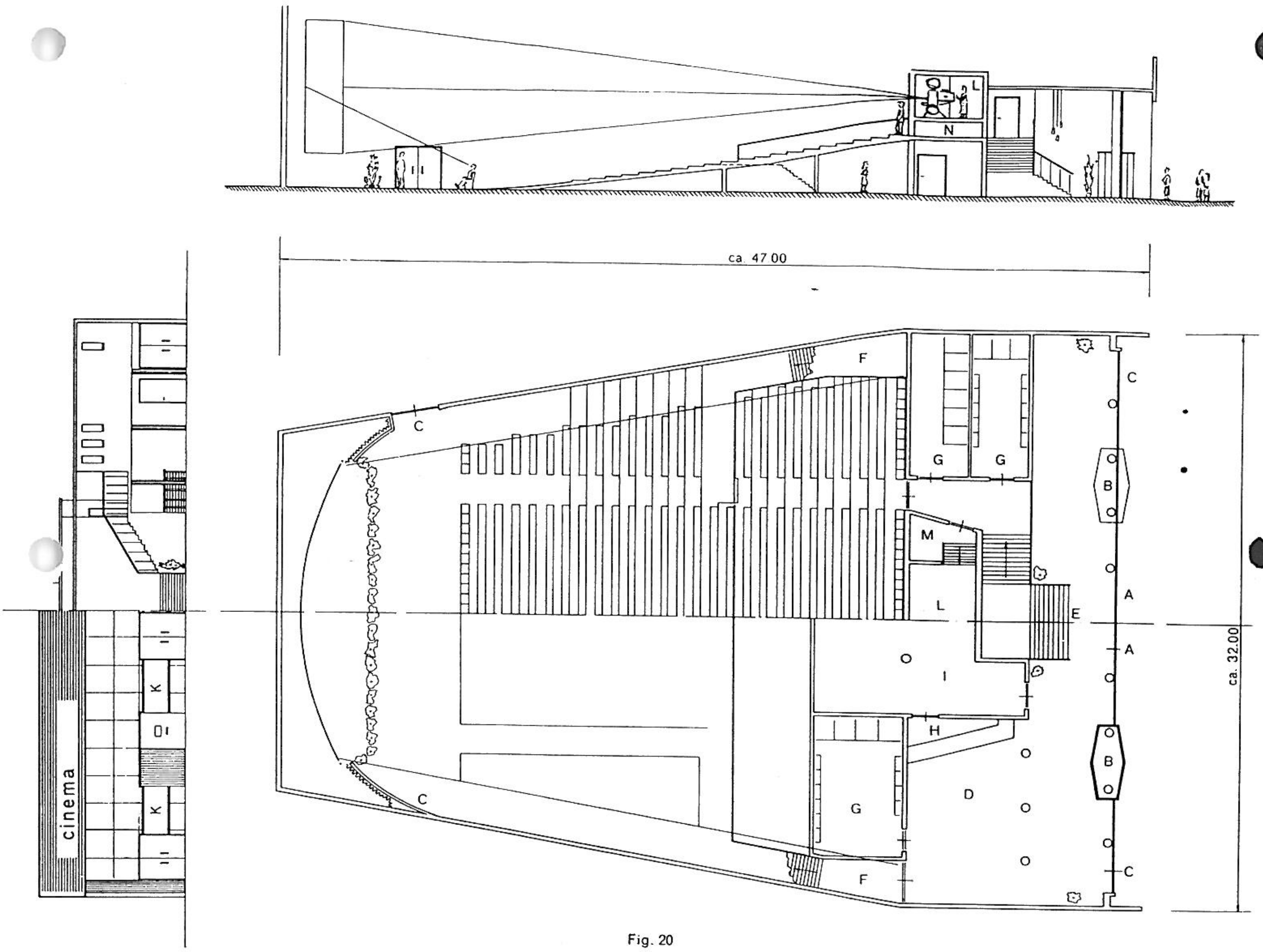


Fig. 20

A = entrances	G = lavatories
B = box office	H = bar + candy shop
C = exit	I = office + stores
D = lobby	K = display windows
E = steps at the rear	L = projection booth
F = entrance to front part of auditorium	M = control room
	N = space for cable ducts

SEATING CAPACITY

The condition of max. 22 seats per row makes it necessary to plan two longitudinal gangways each with a width of 1.65 m. For easy access to the front centre block of seats, the rows 16 and 17 of the side blocks have been substituted by gangways.

The total number of lost seats can now be counted; it is found to be 194, so that the definite total seating capacity is 1118 — 194 = 924.

COMPLETE LAY-OUT

A complete lay-out of the building is given in fig. 20.

SURVEY OF SYMBOLS USED

$A_1 \ldots A_n$ = consecutive rows adopted for the calculation

B_b = picture width, B_f = frame width, B_w = screen width — measured along the arc

b = picture width, b_f = frame width, b_w = screen width — measured along the chord

d = eye level of a sitting person

d_z = distance between bottom of balcony and floor of the hall

f = distance between screen and first row of seats in the axis of the auditorium

g = chair width

H_n = distance of the floor with respect to horizontal drawn through the bottom of the picture

$h_1 \ldots h_n$ = consecutive eye levels with respect to the horizontal drawn through the bottom of the picture

h = picture height

h_a = height of the bottom of the picture above the floor

h_f = frame height

h_w = screen height

h_z = distance between optical axis of the light beam and floor at the rear of the auditorium

j = free passage between consecutive rows with seats tipped up

k = chairback distance between consecutive rows

l_z = greatest viewing distance

p = difference in average eye level between two consecutive rows

r = parameter for determining the curvature of the screen

s = aisle width

t_b = picture depth

t_f = frame depth

t_w = screen depth

u = loudspeaker space behind the screen

z = depth of the space under the balcony

α = rake of the projectors

γ = viewing angle from the first row of seats

ε = critical angle of the seating area

η = viewing angle to the bottom of the picture

INTRODUCTION

Modern cine technique aims at making the audience feel they are taking part in the action on the screen. The transition from a small screen picture — which gave the spectators the impression that they were looking at the scene through a small window — to a picture almost covering the natural angle of vision was an important step in this direction.

The accompanying sound had to follow this development. Whereas for a small picture one loudspeaker was sufficient to make the direction and movement of the sound apparently coincide with the picture on the screen, several loudspeakers, each supplied with a separate signal, are required to achieve this "stereophonic" correspondence with large pictures. Moreover, the sound is no longer restricted to what is shown on the screen; sounds produced outside the field of vision — ambient sounds — are often included to enhance the impression of reality. For this reason, sound equipment for modern films, such as 70-mm films or CinemaScope films with magnetic sound tracks, comprises a great number of loudspeakers mounted along the side-walls and behind the audience, and possibly even in the ceiling. These "surround" loudspeakers (also called "ambient" loudspeakers) obtain their signals from a separate sound track of the film, on which only the ambient sound is recorded.

Moving sound sources or sounds which have to come from a definite direction cannot be reproduced in a true-to-life way if all the loudspeakers receive the same signals simultaneously. To reproduce the movement or the direction, each loudspeaker or group of loudspeakers has to receive its own sound signals. In practice, however, it has been found that often the visual suggestion is sufficient to give the sound a definite movement or direction.

It should further be pointed out that the sound is intended only to support the picture. The sound effects should never distract the attention of the audience too much.

A special application of the surround loudspeakers is their use for the reproduction of reverberation. This well-known acoustic phenomenon presents itself especially in large buildings, such as churches and cathedrals; it can be considered as a special form of ambient sound. In fact it is constituted by a great number of sound reflections of decreasing intensity coming from random directions. When reverberation recorded on the film is reproduced only by the loudspeakers behind the screen, it is given a definite direction, from the front of the hall towards the audience, so that the patrons get the impression that all the sound is coming from an opening at the front of the hall. When, however, the reverberation is reproduced by the surround loudspeakers, the spectators get more or less the impression that they themselves are present at the scene of action.

The film producer aims at recording the sound in such a way that the cinema patrons can undergo the desired acoustical sensation. He endeavours to have the sound maintain all its natural characteristics, such as dynamics and timbre, through all the processes to which it is submitted. However, his preoccupations extend no further than to the recording of the sound on the film.
It will be obvious that the sound has to be scanned from the sound tracks and reproduced by the cinema loudspeakers in such a way that the quality of the recorded sound is maintained as far as possible. In the present state of technique, the demand for undistorted sound reproduction of wide dynamic range can be satisfied to a high extent. Nevertheless, sound tracks and sound equipment of good quality alone are no guarantee for the creation of a satisfactory impression; the acoustics of the auditorium have also to meet definite requirements. Of course, sound perception is entirely subjective, but knowledge of the characteristics of hearing in general and of the conduction of sound as a physical phenomenon makes it possible to give clear directives for ensuring that the auditorium will have good acoustic properties.

REVERBERATION

The acoustics required of a hall for speech and for music are different. In cinemas, the aim will always be to achieve good intelligibility of the spoken word.

Direct and indirect sound

In a hall the listeners hear:
the **direct sound**, i.e. the sound which reaches them directly from the loudspeakers, and
the **indirect sound**, which reaches them from random directions after one or more reflections from obstacles (wall, ceiling and floor of the hall, etc.).

The human ear determines the direction of a sound source from the first sound to arrive. As the path travelled by the direct sound is always shorter than that travelled by the reflections, the direct sound always reaches the listeners first, thus indicating to them the direction in which the sound source is located.

The greater part of sound perceived consists of indirect sound, which therefore is decisive for the sound intensity. The more often the sound has been reflected, the lower the intensity of the reflection will be, because part of the sound energy is lost at each reflection (due to absorption). Consequently, the intensity of the indirect sound decreases in the course of time.

As a measure for the rapidity of sound decay the **reverberation time** has been adopted, which, by definition, is the time in seconds in which the sound intensity has dropped to one millionth of its original value.

Sabine has found the following formula for the reverberation time:

$$T = 0.16\frac{V}{A}$$

where T = reverberation time, in seconds
V = volume of the hall, in cu.metres
A = total absorption, in sq.metres of "open window"

The optimum reverberation time depends on the size of the hall. For cinemas the most favourable reverberation time at medium frequencies is indicated in fig. 1 as a function of the volume. When the reverberation time is much shorter than that indicated, the hall sounds "dead". When it is too long, the reverberation of each sound will have a masking effect on the following sound and good intelligibility is then lost.

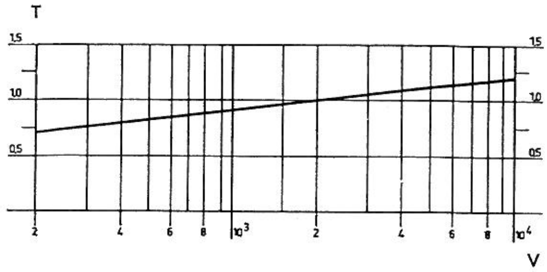


Fig. 1

However, the acoustics of the hall are determined not only by the reverberation time but also by the way in which the sound decays, i.e. by the trend of the reverberation. There must be no fluctuations in the decrease of the intensity.

The whole trend of the reverberation is determined by:

- the shape and dimensions of the hall;
- the reflecting or absorbing properties of the material employed;
- the places where they have been applied.

SHAPE OF THE HALL

The human ear has the property of merging into one single perception all the sounds it receives within 0.05 second. Consequently, the indirect sound which arrives within this time after the direct sound supplies a reinforcement of the latter. The farther the listeners are away from the loudspeakers, the lower the intensity of the direct sound is and the larger this reinforcement will have to be in order to obtain the best possible uniformity of sound distribution over the hall. The useful reflections should therefore be directed towards the rear of the hall. This can be achieved by giving the ceiling and the walls a certain direction (fig. 2). A condition is that AB + BC — AC $\leq$ 17 m (which corresponds to a time difference of 0.05 sec, the velocity of sound in air being about 340 m/sec).

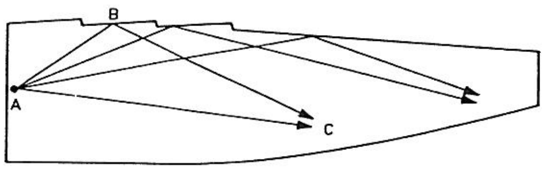


Fig. 2

From the above it will be clear that, properly speaking, the listeners hear only the "tail" of the reverberation, viz. the part which arrives more than 0.05 second after the direct sound. In this part of the indirect sound there must be no strong reflections, and no concentrations of reflections noticeable above the average level of the reverberation; these would produce an annoying echo. Possible causes of echoes are, for instance, a high ceiling or a distant wall. When the ceiling or a wall is concave, the echo effect is further intensified because the reflected sound is concentrated in a definite place (in the same way as light is concentrated by a concave mirror). Sometimes disturbing reflections can be avoided by covering the wall surface that is responsible for them with sound-absorbing material.

Each hall has a great number of natural frequencies at which it comes into resonance. When the conditions of the hall are such that some of these frequencies are given preference, the notes of these frequencies are very strong and thus become predominant. This phenomenon of predominant resonances may easily present itself in small, regularly shaped (e.g. rectangular) halls. For good sound reproduction the natural frequencies must be distributed uniformly over the whole frequency range. An acoustically ideal hall has an infinite number of natural resonances of equal intensity. This cannot be achieved in practice, but it is quite possible to avoid accumulation of resonances by giving the hall an irregular shape or by breaking the walls of rectangular halls. However, the irregularity should never obstruct the transmission of useful sound reflections. In a cinema hall, divergence of the side walls is mostly sufficient.

General rules

For the construction of a hall, the following rules may serve as a guide:

RULE 1: Acoustically the ratio of length : width : height is not critical; extreme values ("coffin") should be avoided.

RULE 2: Total length of the hall = max. 35 m (115 ft). Length of hall under balcony = max. 2½ × distance between floor of hall and underside of balcony.

RULE 3: Volume:
3 ... 5 m^3 (110 ... 180 ft^3) per person for small resp. large halls.

RULE 4: Avoid parallel walls and concave faces of walls and ceiling.

RULE 5: See that useful sound reflections are directed as much as possible towards the rear of the hall.

SOUND ABSORPTION

The extent to which a material absorbs the sound is indicated by the absorption coefficient α.
The absorption (A) is expressed in "sq.metres of open window" (for which $\alpha = 1$) by multiplying the surface (S) of the material by the absorption coefficient (α), i.e.

$$A = \alpha S.$$

Consequently, the total absorption in a hall where materials with different absorption coefficients α_1, α_2 ...... α_n and surfaces $S_1, S_2 \ldots S_n$ are used is:

$$A = \alpha_1 S_1 + \alpha_2 S_2 + \ldots\ldots + \alpha_n S_n.$$

Strictly speaking, Sabine's formula holds only for diffuse sound, uniform distribution of the absorption and not too large values of α, conditions never wholly fulfilled in a cinema. Nevertheless it gives a good estimate of the reverberation time.
As a rule, the absorption of a given material is not the same at all frequencies. Most materials — and also air — absorb the higher notes more easily than the lower ones. For this reason, in nearly all halls the reverberation time rises towards the lower frequencies and drops towards the higher ones. Listeners are so much accustomed to these conditions that they accept them as "natural". The reverberation curve of a cinema hall need therefore not be flat. However, care has to be taken that the difference in absorption of the low and the high notes does not become so great that it affects intelligibility or clearness of the sound. Thus, for instance, when in a hall the high frequencies are unduly absorbed, the hall sounds "dull".
Correction of too little or too much absorption in a definite frequency range by applying to the loudspeakers less or more low or high frequencies by means of the tone controls of the amplifier will certainly improve the tone of the indirect sound, but at the cost of the direct sound.
Especially for the patrons close to particular loudspeakers, the perceived sound will then no longer be true-to-life.

Although from the above it will be clear that it is inadvisable to correct acoustic imperfections by electrical means, one may be forced to attenuate the low notes by means of the tone control on the amplifier if the hall has annoying natural resonances. However, the correct method to ensure the desired balance between the absorption in the low and in the high frequency range is to choose judiciously:

- the kind of sound absorbing material and the way in which it is fixed to the walls;
- the amount of this material;
- the places where it is applied.

Sound-absorbing materials can be divided into three groups:
- porous materials,
- panels,
- resonators.

Porous materials

As a rule the absorption coefficient of porous materials increases with the frequency. The absolute value depends on the structure of the material and its thickness.
Examples are: blankets of mineral fibres, such as glass-wool and rock-wool, and plates of cellulose fibres, such as softboard and Celotex.
At the high frequencies, the absorption coefficient of the blankets is much higher than that of plates, the latter being more important for the absorption of the low frequencies (see panels).
For practical reasons mineral-wool blankets have to be covered with a protecting material, which, of course, has to be pervious to sound, for example a thin cloth or perforated plates of plywood, gypsum, metal, etc. The degree of perforation should amount to at least 15 %, in order to avoid any considerable reduction in absorption at the high frequencies. A low degree of perforation will increase the absorption of the low frequencies (see resonators).

Panels

Panels of e.g. plywood or hardboard, applied at some distance from the wall (e.g. fixed to furring strips) are put into vibration by the incident sound waves. At the resonance frequency, which lies generally in the lower frequency range and which depends on the kind of material, the dimensions of the panel and the distance between panel and wall, a maximum of sound energy is absorbed. To increase the absorption, the panel has to be damped. This damping can be inherent in the structure of the panel (e.g. softboard or Celotex), or it has to be applied specially by lining the rear of the panel with softboard or Celotex or by filling the space between panel and wall with mineral-wool.

Resonators

A resonator in its simplest form is a cavity, which is connected with the large air volume of the hall only by means of a narrow opening (analogously to a bottle). The air in the resonator is put into vibration by the sound waves and the resonator absorbs energy depending on its damping. The absorption coefficient has its maximum value at the resonance frequency of the resonator, which depends on the dimensions of the cavity and its narrow opening.
Current resonators are: perforated or slotted hard panels that are fixed on furring strips, the space between the panels and the wall being partly filled with mineral-wool,

Aspect

In principle there are two ways of combining the aesthetic and acoustic requirements:

- by making the acoustic lining itself decorative;
- by covering the acoustic lining with a decorative material pervious to sound, e.g. a thin cloth or a material with many small openings.

Sound absorption by the audience

The absorption by the audience forms an important portion of the total absorption of the hall. It is fairly constant over the whole frequency range. The seats should be upholstered to form substitutes for the absorption by the audience if not all the seats are occupied.

General rules

For the acoustic treatment of the hall, the following rules may serve as a guide:

RULE 6: To deaden the noise of footsteps and scuffing, the floor should be covered with a resilient material, such as carpets, linoleum, asphalt tiles.

RULE 7: To make the reverberation time more or less independent of the number of patrons, the seats should be heavily upholstered.

RULE 8: The reverberation time of the loudspeaker-location back-screen (i.e. on the stage in theatres) should not differ much from those of the hall. If necessary, this space can be damped effectively by suspending some heavy curtains or mineral-wool blankets from the ceiling, perpendicular to the wall behind the screen.

RULE 9: For good sound transmission to the rear of the hall the ceiling should be acoustically hard, e.g. plaster on metal laths or gypsum board.

RULE 10: The rear wall of the auditorium and the front wall of the projection booth should be covered with a material having a very high absorption coefficient, since from these walls reflections can reach the front rows with too long a time delay. As in this respect high frequencies are more annoying than low frequencies, this absorbing material should be effective especially in the higher frequency range (mineral-wool blankets).

RULE 11: The greater part of the side-walls has to be lined with sound-absorbing materials, applied so as to produce a proper balance in the absorption of the lower and higher notes.

EXAMPLE OF THE ACOUSTIC TREATMENT OF A CINEMA HALL

This example is based on the hall resulting from the example given in the Cinema Part of this documentation. Determined are therefore in principle:

- the shape and size of the hall (5900 m³),
- the number of seats (924),
- the surface of the gangways (about 200 m²),
- the size of the screen (110 m²);
- the side walls are divergent, so that annoying resonances are avoided; for better sound distribution, the parts of the side walls and of the ceiling near the screen should be still more divergent (figs. 3 and 4).

In this example the kind and amount of the acoustic materials and the places where they are applied is based on preliminary calculations and on practical experience in similar halls. It is supposed therefore that:

- the gangways are covered with carpets;
- the chairs are heavily upholstered;
- the ceiling (fig. 4) consists of a reflecting part (plaster) and of an absorbing part, for example a grate of laths with mineral wool between grate and ceiling (fig. 5);
- the part of the rear wall above the audience is lined with mineral-wool, covered with a thin tissue;
- the upper part of the side walls is lined with mineral-wool, unpainted softboard panels with a slight space between them (fig. 6) and with painted softboard panels applied so that only 50 % of this surface is covered (fig. 7); the panels are fixed on horizontal laths; their height and width vary; the whole lining is covered with a thin tissue;
- the lower part of the side walls is not covered with sound-absorbent material;
- at the proscenium, the divergent parts of ceiling and side walls are of plaster;
- when the curtains in front of the screen are open, they are drawn up behind the side walls of the proscenium (fig. 4);
- the ceiling in the space behind the screen is covered with softboard panels of different sizes, applied at some distance from each other (fig. 8);
- two heavy curtains are suspended from this ceiling, perpendicular to the wall behind the screen (figs. 3 and 4).

As follows from the tables on page 25, the total absorbent surface in the hall is:

$$\left.\begin{array}{l}\text{for bass frequencies: } 487 + 312 = 799\ \text{m}^2\\ \text{for treble frequencies: } 540 + 381 = 921\ \text{m}^2\end{array}\right\}\ \text{of open window}$$

The volume of the hall is 5900 m³. From Sabine's formula follows:

reverberation time for bass frequencies: $\dfrac{0.16 \times 5900}{799} = 1.2$ sec

reverberation time for treble frequencies: $\dfrac{0.16 \times 5900}{921} = 1.0$ sec.

According to fig. 1, these are good values for the hall in question.

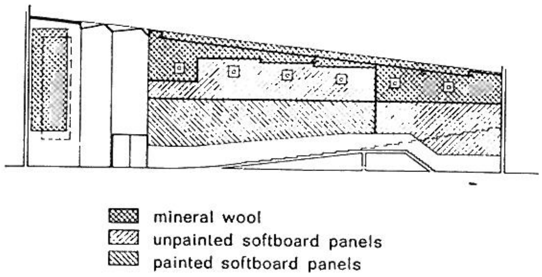


Fig. 3

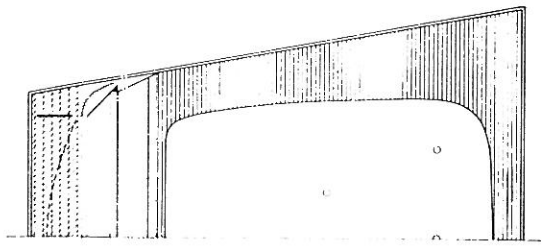


Fig. 4

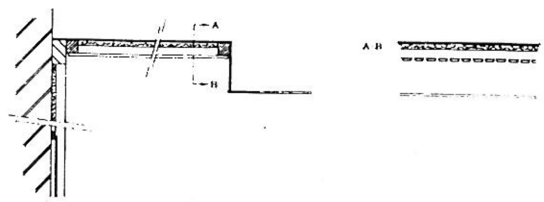


Fig. 5

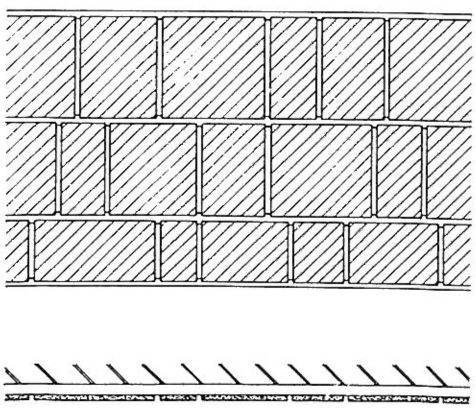


Fig. 6

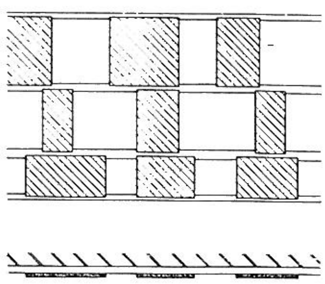


Fig. 7

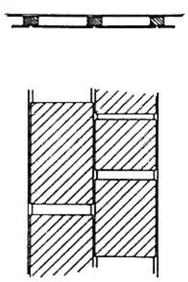


Fig. 8

SURROUND LOUDSPEAKERS

The surround loudspeakers are mounted on multiplex baffles of at least 2½ ft x 2½ ft (75 x 75 cm) and with a thickness of at least ⅝" (15 mm).
Mineral-wool is glued to the back of the baffles.
To gain room, recesses are made in the walls at the places where the loudspeakers will be mounted (fig. 9). The baffles are fixed free from the wall by means of brackets. As the hall given in the example is rather wide, five loudspeakers are necessary in the ceiling to get a good sound distribution. To ensure diffuse sound radiation, a diffuser has to be mounted under each of these loudspeakers (fig. 10).

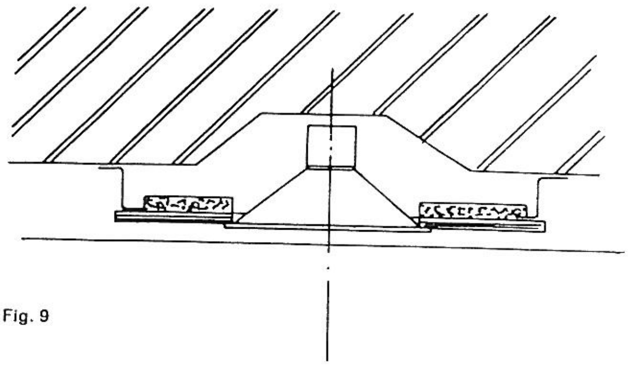


Fig. 9

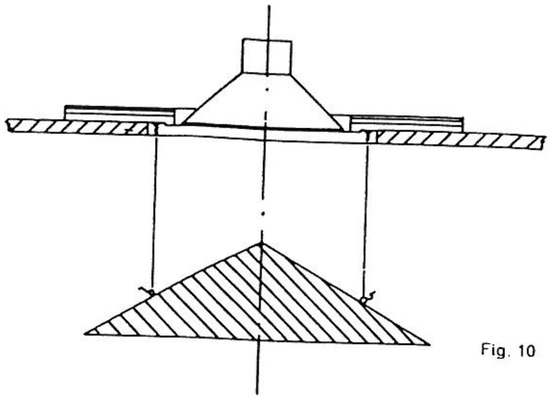


Fig. 10

CALCULATION OF THE REVERBERATION TIME

Covering	S	α_b	α_t	A_b	A_t
Carpets	200	0.15	0.3	30	60
Curtains	70	1	1	70	70
Screen	110	0.2	0.2	22	22
Ceiling: plaster	530	0.05	0.05	27	27
Ceiling: softboard	60	0.5	0.5	30	30
Ceiling: gridwork	230	0.7	0.4	161	92
Divergent wall surfaces at the proscenium	120	0.05	0.05	6	6
Side walls: mineral-wool	100	0.3	0.9	30	90
Side walls: softboard, unpainted	120	0.5	0.5	60	60
Side walls: softboard, painted	44	0.5	0.1	22	5
Front wall	180	0.03	0.05	6	9
Rear wall	77	0.3	0.9	23	69
Total				487	540

S = surface in m^2
α_b = absorption coefficient for bass frequencies
α_t = absorption coefficient for treble frequencies

A_b = absorbent surface in m^2 of open window for bass frequencies
A_t = absorbent surface in m^2 of open window for treble frequencies

In the hall there are 924 seats. An average of 75 % is supposed to be occupied, which gives:

Seats	Number	A'_b	A'_t	A_b	A_t
Occupied	693	0.35	0.45	243	312
Unoccupied	231	0.3	0.3	69	69
Total				312	381

A'_b = absorbent surface per seat in m^2 of open window for bass frequencies
A'_t = absorbent surface per seat in m^2 of open window for treble frequencies
A_b = total absorbent surface in m^2 of open window for bass frequencies
A_t = total absorbent surface in m^2 of open window for treble frequencies

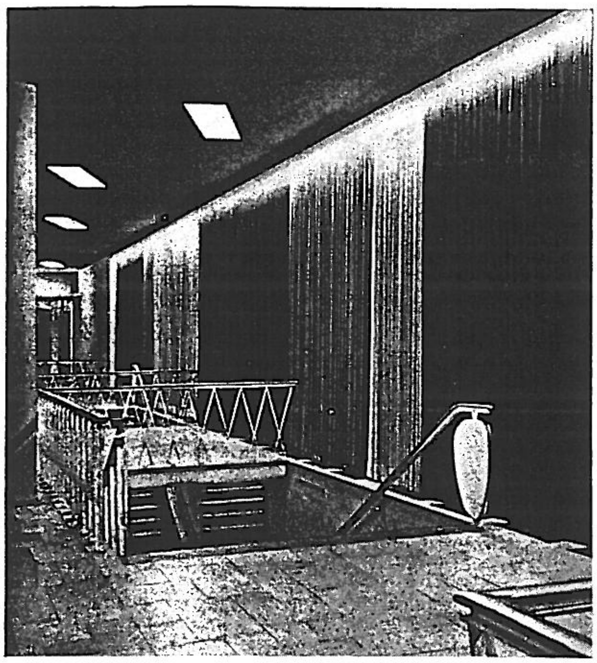


Fig. 1

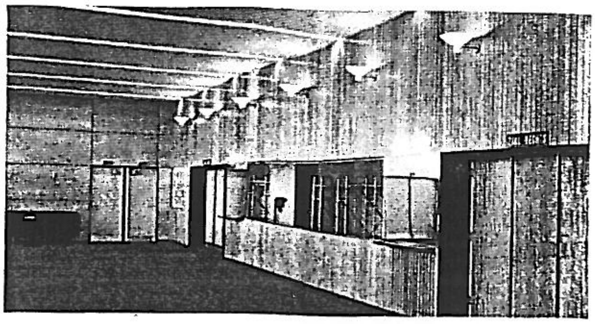


Fig. 2

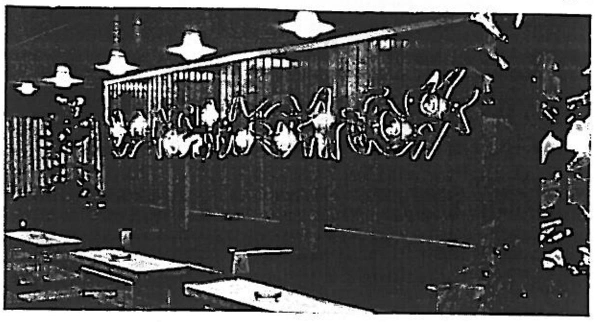


Fig. 3

FAÇADE

There are several distinct features which a modern frontage should possess if it is to have maximum appeal and value:

- it should attract attention from afar;
- it should stand out from surrounding displays by its brightness and colour; it should "sell" the theatre and its programme;
- it should be of appealing design;
- the underside of the marquee should be bright and sparkling, leading customers right up to the box office;
- the name of the theatre should be clearly legible from all essential points; a horizontal arrangement of characters permits of quick perception; a vertical arrangement decreases the legibility.

ENTRANCE HALL (figs. 1, 2, 3)

The architectural style, the decorative composition and the furnishings are the basic elements of interest and appeal. But they are fixed and static. Lighting is a pervading, vitalizing force. That is why lighting for the theatre cannot be standardized. It can perform too many profitable functions for the theatre to be limited in its use. The principal aspect from a designer's point of view is the co-ordination of the architectural elements and the variable elements, so that the sum total is a pleasing balance and harmony.

The function of the **outer lobby** is principally that of a passage way to the inner lobby or foyer and it should be interesting and impressive. The lighting should create a feeling of spaciousness, freedom and festivity. This is accomplished by ceiling and wall areas of fairly high brightness. Some life and sparkle in the lighting equipment is desirable (direct spotlamps in the ceiling or occasional wall fittings). An average illumination level of 200—300 lux (20—30 ft-c), measured in a horizontal plane, is adequate to let the eyes accommodate to the difference between the high-level entrance lighting and the darkened auditorium.

Several possibilities of enlivening the space are provided by wall areas used for advertising. Provision should be made for highlighting these displays with an appropriate lighting scheme.

Lamps in the ceiling, in cornices, etc., should generally be recessed or screened from view, so that they harmonize with the decorative pattern.

Lamps in warm colour are often necessary — for the fluorescent lamps the colours white de luxe (34) and warm-white de luxe (32). Here the various colour combinations are limited only by the conception of the designer.

The **foyer** serves functionally not only as a distribution centre to the auditorium entrances and exits, but in many cases also as a lounge and waiting room. Here an illumination level of 50—100 lux (5—10 ft-c) is quite adequate to condition the eyes for the auditorium; it prevents a feeling of gloom and permits of ready recognition of friends and acquaintances.

AUDITORIUM

Introduction

In the cinema, the lighting equipment forms an essential part of the technical installation. The neon signs and the illuminated film announcements are designed to attract the attention of the public. The brightly lit entrance invites passers-by to enter. Decorative lighting in the hall and gangways contributes to the right atmosphere. The transition from high daylight brightness outside the cinema to the relatively low brightness inside should be imperceptible to the public and produce no annoying contrast. Easy adaptation of the eyes to the brightness level in the auditorium is obtained by gradual transition from the brightness at the entrance to that in the auditorium.

The auditorium lighting affords a means of giving expression to the architecture; it enables the architect to reinforce the representative character of the interior. Illuminated surfaces, strips of light, and decorative

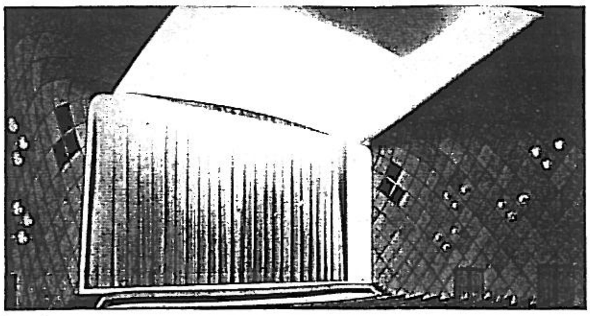


Fig. 4

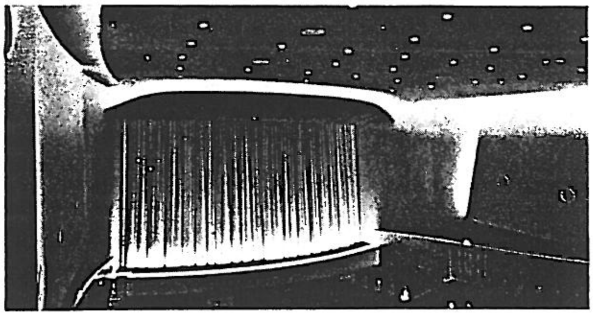


Fig. 5

ornaments are the elements of which the architect can avail himself to achieve the desirable atmosphere, the latter depending much on the brightness levels prevailing in the auditorium and on the colour contrasts. Besides the creation of the correct atmosphere, the purpose of the lighting in the auditorium is the ensuring of good visibility, so that the audience can without difficulty find their seats or reach the exit.

Illumination

At the beginning of the performance the illumination in the auditorium should be about 50 lux (5 ft-c); the patrons can then easily find their seats.

During the performance, a certain amount of light is necessary to enable the patrons to move safely. Practice has shown that for this purpose an illumination of about 2 lux (0.2 ft-c) is sufficient. When, during the interval, advertising slides are projected, an illumination of 5 lux (0.5 ft-c) in the auditorium and of about 10 lux (1 ft-c) at the exits allows of good visibility of the screen picture and yet gives the audience sufficient light to move from their seats.

Quality of lighting

In the auditorium not only the horizontal, but also the vertical illumination is of importance, especially for the recognition of faces. A more or less flattering lighting is appreciated by the patrons.

To preclude annoying stray light on the screen, the front of the auditorium is generally given directional lighting. But a markedly directional lighting from the ceiling results in hard, deep shadows on the faces and gives them an unnatural appearance. On the other hand, a wholly indirect, very diffuse lighting — from cornices, for example — does not provide any relief or shadow effects at all. For this reason a combination of both systems is to be recommended.

Ornaments with diffusing glass bulbs, glass cups, etc., although certainly quite suitable for decoration, should preferably not be used for the general lighting. For decorative purposes it is enough to provide these diffusers with small lamps, so that they have a low brightness. If they are used for general lighting by equipping them with large lamps they will cause glare.

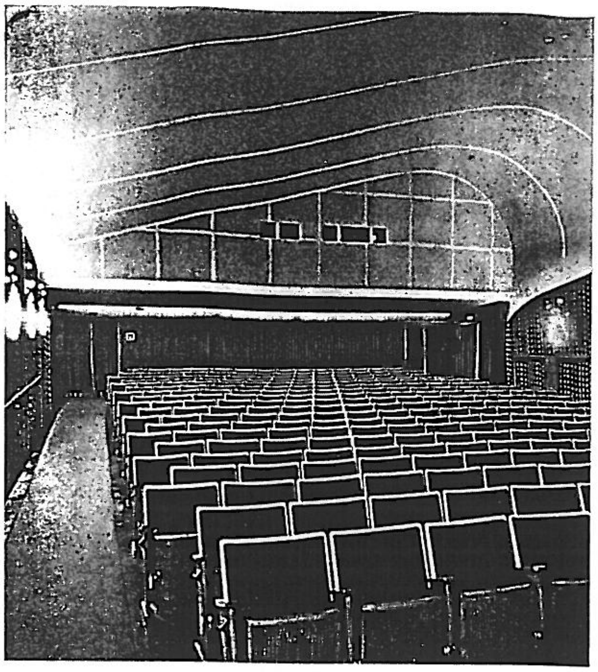


Fig. 6

Systems of lighting

- **Direct lighting**

  Direct lighting has the advantage that it permits of achieving a high light efficiency. The initial and running costs are low. It gives the necessary sparkle to jewellery, etc. and thus creates an atmosphere of gaiety and festivity. It has, however, the disadvantage that, since the lighting is generally directed from above, hard shadows are produced, resulting in great contrasts. Moreover, by means of direct lighting alone, it is not easy to achieve a good spatial effect in the auditorium. Although very good built-in fittings exist, there is with exclusively direct lighting a risk of the light sources located within the field of vision annoying the spectators. In order to keep the contrast between the light sources and their surroundings small it is recommended to have the ceiling in light shades of colour.

- **Indirect lighting**

  Completely indirect lighting is often used in architecture because of the beautiful, decorative effect that can be achieved with it. As the ceiling and the walls act as large, diffusely radiating secondary light sources, a very uniform, quiet atmosphere is obtained, but this suffers from a total lack of interesting shadow play and highlights. It can lead to a dreary, flat lighting which gives rise to a drowsy effect (fig. 4).

A correct combination of the two systems will mostly yield the best results. The really objectionable effects of the one system are then counterbalanced by the favourable effects of the other (fig. 5).

Light sources

At the beginning of the performance a gradual dimming of the light is necessary. This can be achieved most simply with incandescent lamps or with neon tubes. But with the present electronic dimming devices the dimming of fluorescent lamps presents no great technical difficulties; however, to obviate the complications of gradual dimming, these lamps are often dimmed in steps.

The light colour of the lamps also plays a role. Incandescent lamps, and also fluorescent lamps in the colours warm white de luxe (32) and white de luxe (34), whether

Fig. 7

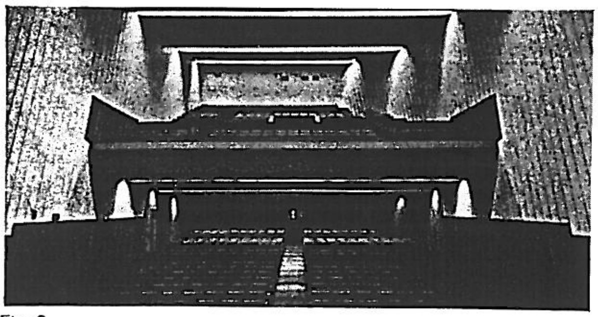


Fig. 8

Fig. 9

or not in conjunction with incandescent lamps, give good results for illuminating faces and clothes.
The light sources should be fitted so as to lie outside the direct field of vision. For light strips this can be achieved, for example, by fitting them at the junction of ceiling and side-walls. In the ceiling it is preferable to use properly screened, if possible built-in lamps.
Wall-mounted ornaments, applied for architectural or aesthetic reasons, may certainly have a decorative effect but they do not generally provide satisfactory results for the general lighting of the auditorium. These ornaments should have a low brightness, so that they do not distract (fig. 6).

Brightness

To achieve a pleasant visual impression of the space, great contrasts of brightness should be avoided. The brightness of the light source or of the reflecting material must be low as compared with the direct surroundings. Light sources should be screened against direct view.
The brightness contrast between the projection screen and its black frame is very great, sometimes up to 1 : 1000. It is therefore recommended to throw a little light on the surroundings of the frame by means of light sources well screened towards the auditorium. They can, for example, be mounted on the proscenium, behind the curtains, but at any rate so that the light does not fall on to the screen; this would reduce or even spoil the contrasts of the projected picture.
Sometimes decorative lighting during the performance is provided with ultra-violet light from "black light" lamps. Textiles used at present, and also washing powders, residues of which may be found in the clothing, often give rise to fluorescence under ultra-violet radiation. Therefore the auditorium should be screened from direct ultra-violet radiation.

Optical effects of the lighting

Local circumstances may force the architect to use relatively unfavourable dimensions for the length, width and height of the auditorium. The shape of the hall can be modified apparently by accenting a certain direction by means of the lighting.

- Longitudinal lighting of the ceiling makes the auditorium seem longer. This effect can be further enhanced by means of a bright illumination of the front and rear walls (fig. 7).
- Transverse lighting of the ceiling emphasizes the width of the auditorium. This effect can be enhanced by brightly illuminating the sidewalls (fig. 8).
- A greater height of the hall can be suggested by a markedly vertical lighting of the side-walls; the effect can be enhanced by designing the ceiling as a bright, radiant surface (fig. 9).
- If the auditorium should appear less high, the ceiling and the upper part of the walls should be kept rather dark and the lower part of the walls should be made bright (fig. 10).

Combinations of the above possibilities may create a large, lofty hall or give the idea of a small, intimate room.

Ceiling and wall decorations and finishes may be considered part of the lighting system, because they do not only form the background of the light elements but also give expression to the appearance of the hall.

- Walls and ceiling shaped as large, uniform surfaces joined by continuous light strips, create a great spatial effect.
- Subdivision of walls and ceiling into smaller surfaces, with emphasis on detail, makes a room seem smaller.

A good finish of the plastering should receive special attention (with indirect or semi-indirect lighting shiny walls are extremely annoying and ugly).

Local lighting

Gangways, steps and seating rows generally have weak illumination during the performance. Modern electro-luminiscence panels afford an ideal solution; furthermore there exist small projecting or built-in fittings with incandescent lamps.
If a cinema auditorium is also used for concerts and stage performances, a different atmosphere of the hall is required, since these performances are often given with more or less full lighting. The illumination of the audience

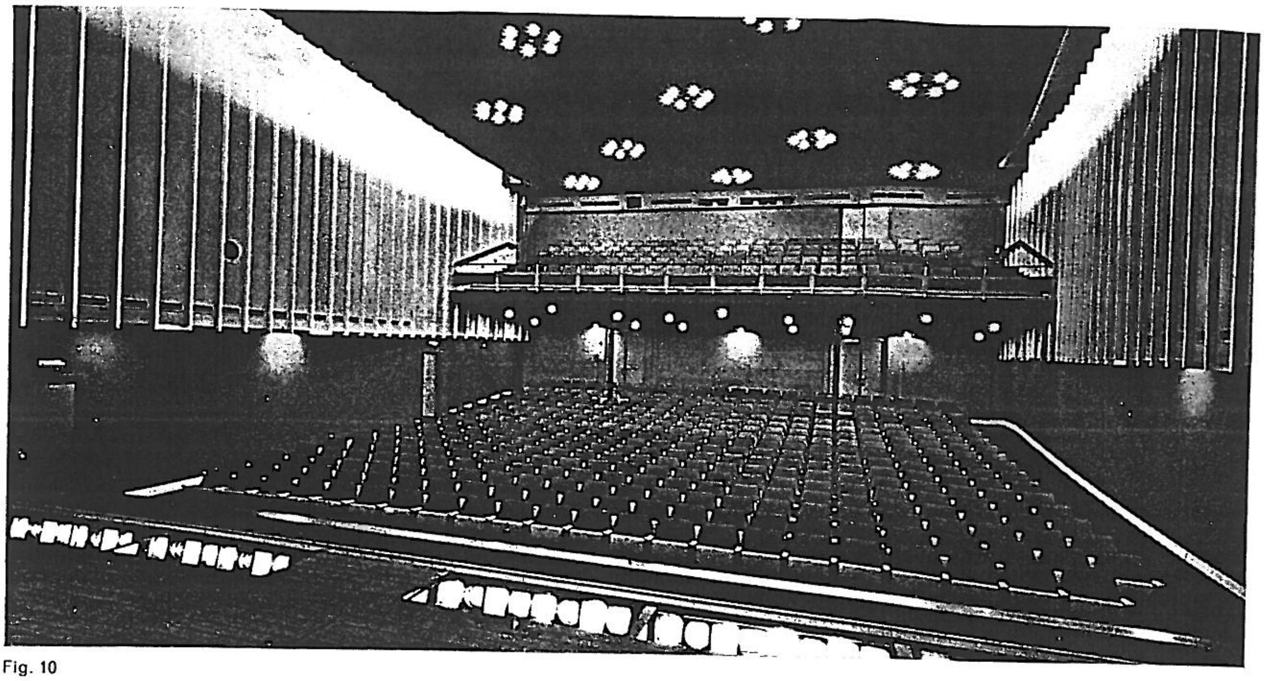


Fig. 10

here plays a much greater part; the clothes of the patrons and the reflections from the jewellery, etc. greatly determine the atmosphere.
A considerably higher level of lighting is desirable (100—150 lux or 10—15 ft-c) because the reading of texts, programmes or scores is important. For these performances a well considered combination of direct and indirect lighting is necessary.

Cabling

It is recommended that the installation should be designed in such a way that it can be extended later on without major alterations. Therefore cable gauges and switching groups should be amply dimensioned. This will, of course, entail higher initial cost, but subsequently large savings may be achieved.

Maintenance of the installation

In the design of the lighting installation account must be taken of a certain decrease of light efficiency. Cleaning and timely replacement of the lamps can keep this reduction within reasonable limits. However, a decrease of 20 to 25 %, depending on the system used, must be reckoned with. In the design one should therefore not shrink from an illumination level 20 to 25 % higher than that measured after, say, a year's normal use.
Lamps and fittings should be disposed in such a way as to permit of ready replacement and cleaning. With large installations this is possible by means of special catwalks above the ceiling and behind the walls, so that no ladders or scaffolding need be used.

Emergency lighting

Independent of the normal lighting, an emergency lighting system is a legal requirement. In the event of breakdown of the mains, it must ensure adequate lighting in the hall to let the patrons find the way to the exits, if this should be necessary. Illuminated signs should indicate permanently the position of the exits. Size, brightness and colour of the letters are often laid down in the safety regulations, which may differ in the various countries.

SHORT THEORY NECESSARY FOR THE CALCULATION

The illumination in a room depends on:

- the lighting system applied (direct, indirect, etc.),
- the type and number of light sources,
- the coefficient of utilization of the installation.

The **coefficient of utilization** depends largely on the **"room index"** (symbol "k"), i.e. the ratio between length, width and height of the room.
Hence, the room index is an inherent characteristic of each room; it indicates how the room deals with the available light.
By means of elaborate laboratory tests, the following empyrical formula has been found:

$$k = \frac{2 \times \text{length} + 8 \times \text{width}}{10 \times \text{height}}$$

Most manufacturers give tables showing the coefficients of illumination of their fittings for various room indexes.

The **number of light sources** required for a certain installation can be calculated as follows:

$$\Phi = \frac{E \times S \times d}{\eta} \quad \text{or} \quad E = \frac{\eta \times \Phi}{S \times d}$$

where: Φ = luminous flux (in lumens)
E = illumination (in lux)
d = depreciation factor
η = coefficient of utilization

$$\text{Number of light sources} = \frac{\Phi}{\text{luminous flux per light source}}$$

A good lighting for a cinema auditorium is:

- indirect lighting at the junction of ceiling and walls, either by fluorescent or by incandescent lamps, mounted in cornices,

in conjunction with:

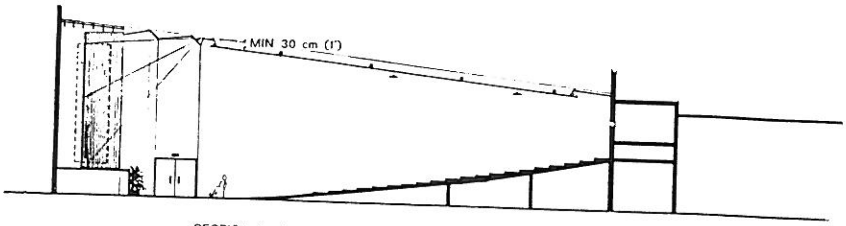
- direct lighting by means of incandescent lamps recessed in the ceiling.

EXAMPLE OF THE CALCULATION OF THE LIGHTING OF A CINEMA AUDITORIUM

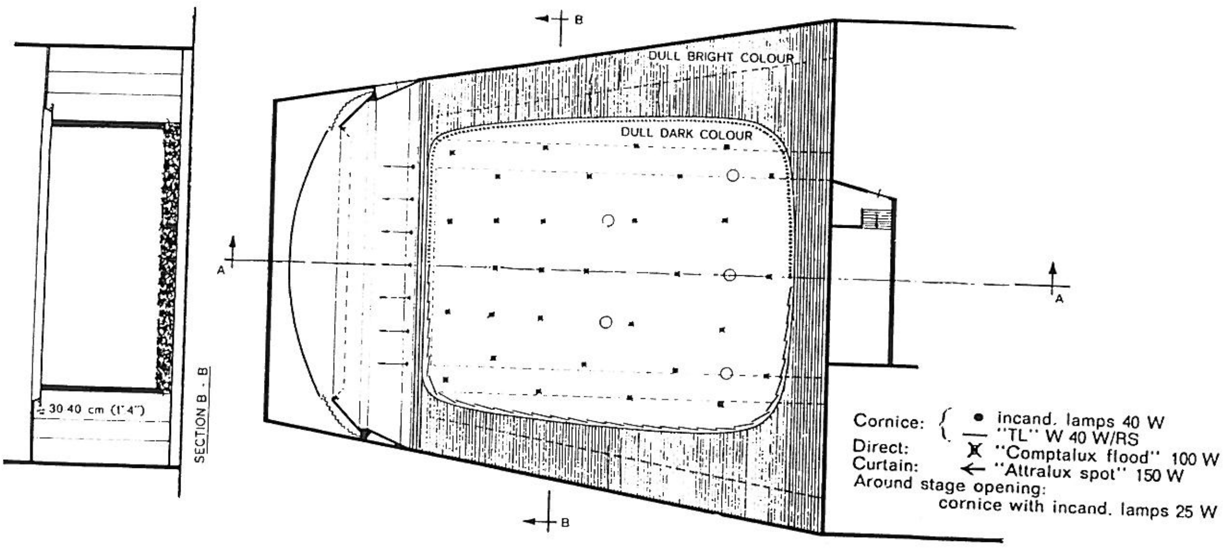
This example is based on the following data:

length x width x height or auditorium . . 25 x 25 x 7.5 m
room index (k) 3.3
average reflection factor of ceiling . . . 70 %
of walls . . . 50 %
illumination level (E) of indirect lighting . 30 lux
of direct lighting . . 45 lux

max. utilization factor (η) under the given conditions (quoted by the manufacturer):
of new fluorescent lamps in cornices . . . 0.26
of new incandescent lamps in cornices . . 0.25
of new incandescent lamps recessed in the ceiling . . 0.85
depreciation factor of all these lamps . . 1.5
floor surface . . . . 625 m²



SECTION A - A



INDIRECT LIGHTING (illumination level 30 lux)

- **By means of fluorescent lamps**
  PHILIPS "TL" M 40W/RS, white de luxe 34).

$$\Phi = \frac{30 \times 625 \times 1.5}{0.26} = 108{,}173 \text{ lumen}$$

Luminous flux per lamp: 1900 lumen

Number of lamps: $\frac{108{,}173}{1900} =$ **57.**

Note: When the lamps are arranged as indicated in the drawing, a maximum of 64 lamps (length 1.25 m) can be fitted in the cornices (total length 75 m).
The illumination will then be:

$$E = \frac{121{,}600 \times 0.26}{625 \times 1.5} = 32 \text{ lux.}$$

- **By means of incandescent lamps**
  To achieve uniform light distribution all over the ceiling, it is best to use frosted incandescent lamps of 40 W, spaced about 25 cm apart.

$$\Phi = \frac{30 \times 625 \times 1.5}{0.25} = 122{,}300 \text{ lumen}$$

Luminous flux per lamp: 430 lumen

Number of lamps: $\frac{122{,}300}{430} =$ **280.**

Note: The cornices can contain up to 296 lamps.
The illumination will then be:

$$E = \frac{126{,}280 \times 0.25}{625 \times 1.5} = \text{about 32 lux.}$$

DIRECT LIGHTING (illumination level 45 lux)

Mirrored lamps, "Comptalux flood" 100 W, will be used.

$$\Phi = \frac{45 \times 625 \times 1.5}{0.85} = 49{,}633 \text{ lumen}$$

Luminous flux per lamp: 1200 lumen

Number of lamps: $\frac{49{,}633}{1200} =$ **41.**