SMPTE RECOMMENDED PRACTICE

RP 12-1992
Revision of RP 12-1988

Screen Luminance for Drive-In Theaters

1 Scope

1.1 This practice specifies the luminance (measured brightness) of the projection screens for drive-in theaters intended for the projection of motion-picture film at 24 frames/sec.

1.2 The practice defines luminance ratios among portions of the total screen area, and defines the acceptable variations as viewed from positions within the audience area.

1.3 The practice applies to both diffusing and directional screens.

1.4 Recognizing the complexities and difficulties of drive-in projection, the practice describes criteria for evaluation of performance that is less than optimum, based upon a minimum luminance level and a maximum luminance variation.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this practice. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this practice are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

ANSI/IES RP16-1986, Nomenclature and Definitions for Illuminating Engineering

3 Measurement

3.1 Measurement of screen luminance and color of projection light is made with the projector in complete operation with its lens set at focus position, but with no film in the aperture, and under ambient light conditions similar to those existing during show time.

3.2 Screen luminance shall be measured with a photometer having the spectral luminous efficiency of the standard observer (photopic vision) as defined in ANSI/IES RP16.

3.3 The acceptance angle of the photometer shall be 2° or less. When in use within a theater, the instrument shall be so located along the line of sight to the screen area being measured as to accept light from a screen area no larger than a circle whose diameter is 10% of the screen width.

4 Luminance level

4.1 In an ideal situation, when permitted by the technology of motion-picture projection, and when the viewing environment is sufficiently close to that of the indoor theater, the screen luminance and distribution shall be that specified in ANSI/SMPTE 196M, 16 fL ± 2 fL (55 cd/m^2 ± 7 cd/m^2), as measured from a position on the longitudinal centerline of the ramp area and midway between the foremost and rearmost ramps.

4.2 The recommended minimum luminance at the center of the screen shall be 7 fL (24 cd/m^2), as measured from the central position defined in 4.1.

4.3 When maximum compromise must be made, as discussed in annexes A.1 and A.2, the luminance at the center of the screen, measured from any car position, shall in no case be less than 4.5 fL (15 cd/m^2).

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5 Luminance distribution

5.1 The luminance at a distance of 10% of the screen width from the side edges of the screen, and on its horizontal axis, as measured from the central position defined in 4.1, shall be compared with the center luminance reading obtained, and shall fall within the range of 55% to 100% of that reading. The distribution of projection illumination shall be symmetrical about the geometric center of the screen.

5.2 The minimum luminance measured from any car position to any point on the horizontal centerline of the screen within the 10% points defined in 5.1 shall be no less than 33% of the maximum luminance on the horizontal centerline measured from that same position.

6 Spectral distribution

The light reflected from the screen shall have a spectral distribution approximating that of a blackbody at a color temperature of 5400 K ± 400 K, the use of a short-arc xenon or carbon-arc light source being assumed.

7 Multiple projector adjustment

7.1 When the presentation involves changeovers among two or more projectors operating to the same screen format, their luminances as measured in 4.1 shall agree within a maximum range of 10%.

7.2 When the presentation involves changeovers among two or more projectors operating to different screen formats or areas, their luminances as measured in 4.1 shall agree within a maximum range of 15%.

7.3 The apparent color of the projection light from projectors intended for interchangeably sequential operation shall be consistent with one another within a range of no more than 400 K.

Annex A (informative)
Additional data

A.1 Standard luminance

As a minimum goal for theater maintenance and adjustment, it is a consensus that there is a working threshold for luminance below which picture quality is noticeably degraded. Under this condition, the operation becomes very sensitive to sky light, neighboring luminances interfere, adjustment of projection equipment becomes more critical, and mood or key variations in the prints become distracting and the presentation begins to lose its artistic purpose. Permissible luminance range is limited by the criterion that a good release print must provide acceptable quality when projected at any luminance within the range.

A.2 Operating luminance

Picture quality is most desirable in drive-in theaters where it is possible to achieve the luminance levels of indoor theaters. This practice recognizes, however, that there are many drive-in theaters wherein screen sizes, viewing conditions, and other factors dictate limitations not encountered in conventional indoor theaters. When a very large screen area, long projection throw distance, extended viewing distance, and high ambient light level are involved, it is necessary to achieve maximum efficiency in all elements of the system to ensure acceptable projection results.

The values in 4.2 and 5.2 represent an operating compromise that may be useful. They also describe the minimum condition for an acceptable projected image where stray and ambient light can be considered negligible.

A.3 Directional screens

A maximum permissible luminance distribution range on a given screen is specified in 5.1 and 5.2. This condition can be achieved by several procedures, including one or more of the following: choice of a screen with a suitable reflection pattern, limitation of the seating area so that no patron views the picture from an angle at which the luminance is outside the tolerance of the standard, and screen curvature.

Present directional screens show a large variation in gain with changes in the projection and viewing angles, necessitating the 3:1 luminance range in 5.2 when gain screens are fitted into existing theaters. Even this range effectively limits the maximum luminance gain of the screen, and the wider the theater becomes, the lower the maximum luminance gain must be to meet luminance specifications with most existing directional screens.

A.4 Luminance photometer

The measurement of luminance with uncertainty of less than 10% requires a good photometer. Since there are no true Lambertian surfaces, and even the theatrical matte screens may depart by more than 10%, the brightness will vary with the angle of observation. A photometer having a large field angle will indicate the average luminance within its field, and if this includes a large area of the screen (or of the screen and surround), this average may be substantially different from the observed brightness. It has been found that within the geometric restrictions under which photometers are used in theaters, their luminance indication correlates well with the observed brightness if the field angle of the photometer is about 2° or smaller.

A photometer having a small field angle may receive light from such a small screen area as to detect luminance differences due to defects in the screen, imaging of the projection source, etc. When measuring the luminances required in clauses 4 and 5, the luminances of immediately adjacent areas should be observed to be sure the reading is relevant.

A.5 Ambient light

Recognizing the limitations in an outdoor environment, every effort should be made to keep ambient light on the screen to a minimum. This may be done by careful placement of the screen and controlling light sources in and around the theater. Distracting light sources (signs, street lights, etc.) should be shielded, or kept out of the field of view of the audience.

Annex B (informative)
Bibliography

ANSI/SMPTE 196M-1986, Motion-Picture Film — Screen Luminance and Viewing Conditions — Indoor Theater Projection

SMPTE RECOMMENDED PRACTICE

Dimensions of Transverse Cemented Splices on 16-mm and 8-mm Type R Motion-Picture Film

1 Scope

1.1 Specifications

This practice specifies the dimensions of transverse cemented splices on 16-mm and 8-mm type R motion-picture film.

1.2 Types

Two types of splices are specified: a laboratory splice for professional applications and a projection splice for release prints and consumer or amateur reversal films.

1.3 Excepted splicers

It is not intended that this practice be prejudicial to diagonal, scarf, or tape splicers.

2 Dimensions

2.1 Specifications

The dimensions shall be as given in the figures and tables.

2.2 Film width at splice

Film width at the splice shall not exceed 0.317 in (8.05 mm) for 8-mm type R film and 0.630 in (16.00 mm) for 16-mm film. If the film has been widened during scraping, the extra width shall be removed.

2.3 Lateral offset for perforation overlap

Perforation overlapping shall not be offset laterally by more than 0.002 in (0.05 mm).

2.4 Lateral offset for film edges

Edges of the two spliced films shall not be offset laterally by more than 0.002 in (0.05 mm) unless a difference in the lateral shrinkage of the two strips makes it impossible to maintain the tolerance. Shoulders formed by such misalignment shall be beveled after the cement has dried.

2.5 Angle between edges

In the plan view, the angle between the respective edges of the spliced films shall be 180° ± 4′. Thus, the spliced film shall be aligned to the extent that, when one portion of the film is placed against a straightedge, the other portion will not deviate more than 0.006 in (0.15 mm), which is the approximate film thickness, in 6 in (152 mm).

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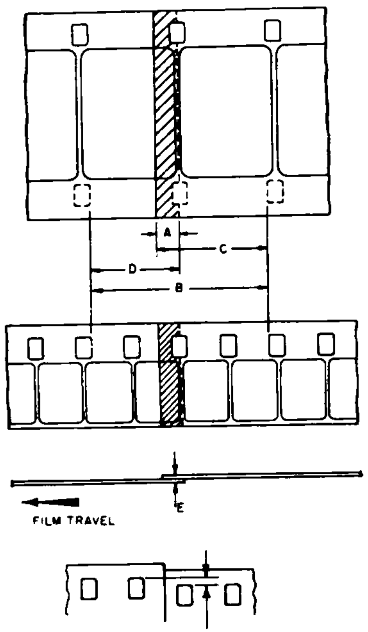

Figure 1 – Laboratory splices

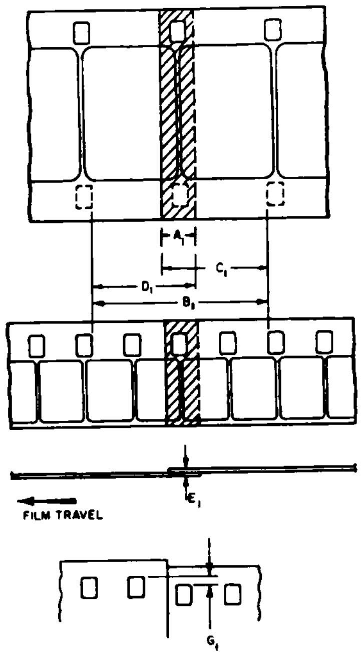

Figure 2 – Projection splices

Table 1 – Laboratory splice specifications

Dimensions	Inches	Millimeters
A	0.070 ± 0.003	1.78 ± 0.08
B	0.548 ± 0.001	13.92 ± 0.03
C	0.344 ± 0.003	8.74 ± 0.08
D	0.274 $^{+0.000}_{-0.003}$	6.96 $^{+0.00}_{-0.08}$
E	0.012 max	0.30 max
G	0.002 max	0.05 max
NOTE – Tolerances shown are not to be cumulative.		

Table 2 – Projection splice specifications

Dimensions	Inches	Millimeters
A_1	0.100 $^{+0.000}_{-0.005}$	2.54 $^{+0.00}_{-0.13}$
B_1	0.548 ± 0.001	13.92 ± 0.03
C_1	0.324 $^{+0.000}_{-0.003}$	8.23 $^{+0.00}_{-0.08}$
D_1	0.324 $^{+0.000}_{-0.003}$	8.23 $^{+0.00}_{-0.08}$
E_1	0.012 max	0.30 max
G_1	0.012 max	0.05 max
NOTE – Tolerances shown are not to be cumulative.		

Annex A (informative) Explanatory notes

A.1 Dimension B (or B_1)

Dimension B (or B_1) controls the longitudinal registration of the two films being spliced. It is measured to the perforations that are most commonly used for registration on splicing blocks, and to the nearer edges of these perforations, which are generally used for registration.

A.2 Dimensions C and D

Dimensions C and D were chosen to give a splice which has one edge along the frameline. This provides the so-called invisible splice when printing A and B rolls of original photography.

A.3 Orienting the films

It is desirable to orient the films in splicing so that a magnetic head scanning the film would, at a splice, drop down onto the trailing film rather than bump up onto it.

A.4 Preventing white line

In order to prevent the appearance of a white line on the screen, the scraped area should be 0.001 in to 0.003 in (0.03 mm to 0.08 mm) narrower than the area covered by the overlapping film. Presence of this narrow uncemented area will not shorten the life of the splice.

A.5 Striped film

If the film being spliced contains a stripe, the stripe must be removed from the base of the film falling on top of the mating piece.

A.6 Splicing technique

Emulsion and binder must be completely removed by scraping in order to ensure a strong, long-lasting cement bond. The surface on the base side of the film to be joined must also be thoroughly cleaned. Sometimes it may be helpful to roughen the base surface slightly when certain films resist satisfactory splicing.

SMPTE RECOMMENDED PRACTICE

RP 74-1992
Revision of RP 74-1977

16-mm Sprocket Design

1 Scope

This practice provides dimensions and specifications for the design of sprockets used with 16-mm motion-picture raw stock or processed film.

2 Dimensions and specifications

2.1 The teeth shall be equally spaced at an index angle of 360/N° where N is the number of teeth. A suitable tolerance for the index angle is ± 1 minute of arc for sprockets having 8 to 17 teeth, ± 30 seconds of arc for sprockets having 18 to 34 teeth, and ± 20 seconds of arc for sprockets having 35 to 64 teeth.

2.2 The root diameter is computed from the equation:

$$D = N \times \frac{P}{\pi} - T$$

where N is the number of teeth, P is the sprocket pitch, and T is the film thickness. The different root diameters in tables 1a and 1b were derived using a value for T of 0.15 mm (0.006 in). If optimum working conditions are desired with film materials of different thickness, the root diameter values in tables 1a and 1b should be recomputed.

2.3 Figure 1 shows that either the entering or leaving film path may fall within the limits specified by radii R_1 and R_2. If the film path is convex with respect to the sprocket surface (curvature away from the sprocket surface), a minimum value of 4.762 mm (0.1875 in) for R_1 is recommended. This is an arbitrary choice, but seems appropriate for 16-mm equipment.

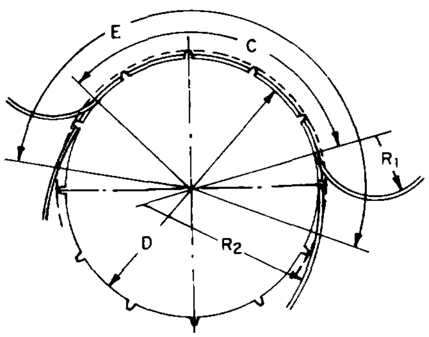

Figure 1 – Sprocket

The shape of the film path as the film leaves the root of the sprocket is determined by film stiffness, curl, set, and tension as well as by the shape and location of rollers or guides.

For the specified tooth shape, the film will be allowed to back-slip over the root circle a maximum distance of 0.066 mm (0.0026 in) for each tooth, measured at the pitch line (film thickness assumed to be 0.15 mm [0.006 in]), by the time the contact point between film and tooth has reached the assumed maximum working height of 0.66 mm (0.026 in), measured radially from the root circle.

2.4 The drive sprocket is most sensitive to tooth shape because the tooth action may take place over the entire working height and is, therefore, used to derive the desired shape. For the usual drive sprocket, the pitch is greater than the film pitch which causes the film to slip backward in relation to the sprocket travel. The direction of the friction force between the film and the root surface is such as to assist the feed or driving action.

2.4.1 Of the total 0.066-mm (0.0026-in) accommodation provided at each tooth for film slippage, approximately 0.013 mm (0.0005 in) is allocated to the combined tolerance of perforation pitch and sprocket tooth pitch (shorter-than-average perforation pitch combined with longer-than-average tooth pitch). An additional 0.010 mm (0.0004 in) is allocated for distortion of the perforation edge under light load (less than 0.56 N [2 oz-force] between the perforation edge and the tooth for acetate film of 0.15 mm [0.006 in] thickness). The remaining 0.043 mm (0.0017 mm) approximates 0.6% film shrinkage. It should be noted that another combination of greater load and lower shrinkage could fall within the same allowable maximum of 0.053 (0.0021 in). The user is cautioned against high loading because of possible destructive film fatigue and wear, film distortion away from the base circle, and malfunction. The selected values of R_1, working height and maximum pitch difference, in turn, determine the values of X_T which have been computed and tabulated.

2.4.2 For a concave film path with respect to the sprocket surface (curvature toward the sprocket radius center), the limiting radius, R_2, has been computed for the same X_T and the same accommodation of 0.066 mm (0.0026 in), assuming a parabolic schedule (displacement function proportionate to the square of time) of reduction versus time (see reference 1). These values of R_2 are set forth in tables 1a and 1b. For those exiting film paths from drive sprockets corresponding to larger values of R_1 and R_2, including a straight tangent path, the accommodation of 0.066 mm (0.0026 in) for film slippage takes place in less than 0.66 mm (0.026 in) of the working height (or more accommodation results at the same height). Conversely, the slowest accommodation corresponds to the exiting path defined by the minimum values of R_2. Therefore, the R_2 value is recommended where maximum uniformity of motion is desired.

2.5 The pitch of the usual holdback sprocket should be equal to or less than the pitch of the film. The shortest film pitch is assumed to be 7.536 mm (0.2967 in) corresponding to 0.8% shrinkage of long-pitch film (7.620 mm [0.300 in]). (This value is chosen rather than the 0.6% used for the tooth shape to avoid inadvertent interference at entering teeth.) The user may again exercise control by correct choice of the root diameter if a change is warranted. The friction between the film and the root surface, as well as against guides, assists in film holdback.

The tooth shape for a holdback sprocket has little control over the pitch differential accommodation, as the load shifts rather abruptly from the disengaging restraining tooth to the root of the following tooth. The tooth shape specified will ensure clearance at the entering position. If a holdback sprocket is to provide the best possible uniformity of motion, the design must be developed with care (see reference 1).

2.6 The pitch of combination sprockets, 7.600 mm (0.2992 in), should correspond to the pitch of film with 0.3% shrinkage. This value is closer to the feed sprocket pitch than to the holdback sprocket pitch to prevent the film from riding high on the teeth or being damaged by guides at the entering path when used for driving action with the sprocket pitch shorter than the film pitch. Entering guides may be needed for good holdback action when the sprocket pitch is longer than the film pitch.

2.7 The desired tooth shape can be generated by a hob corresponding to the basic rack specified by K_H and B_H in table 2 and figure 4. If the first hob covers the range of N from 8 to 17 inclusively and the second hob 18 to 64 inclusively, no deviations from the ideal tooth shape greater than 0.005 mm (0.0002 in) will occur.

2.8 The tooth width at the base, dimension W, allows ample material for rounding off the tip while preserving the 0.66 mm (0.026 in) or more of working height. The value chosen does not limit the angle of wrap on the sprocket as a wider tooth would. If the wrap length is defined as one-half the sum of the number of pitch lengths in the arc of engagement, E, and the number of pitch lengths in the arc of contact, C (figure 1), then the wrap length may be as high as 6¾ pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0.8%.

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Table 1a – Sprocket dimensions in millimeters

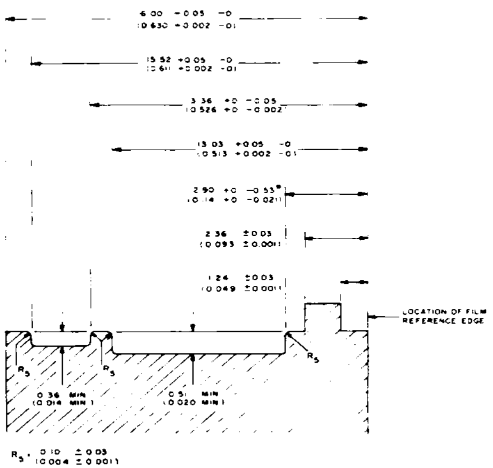
N	RDD	RDC	RDH	K	B	R_2	X_T
8	19.252	19.201	19.097	1.709	0.111	14.726	0.2478
9	21.678	21.620	21.503	1.750	0.121	15.933	0.2410
10	24.103	24.040	23.909	1.809	0.134	17.137	0.2355
11	26.529	26.459	26.315	1.875	0.149	18.387	0.2309
12	28.954	28.878	28.721	1.939	0.164	19.697	0.2270
13	31.380	31.297	31.127	2.001	0.178	21.037	0.2237
14	33.805	33.716	33.533	2.061	0.192	22.392	0.2209
15	36.231	36.135	35.940	2.120	0.206	23.769	0.2184
16	38.656	38.554	38.346	2.177	0.219	25.157	0.2162
17	41.082	40.974	40.752	2.233	0.233	26.559	0.2142
18	43.507	43.393	43.158	2.288	0.245	27.970	0.2124
19	45.933	45.812	45.564	2.342	0.258	29.374	0.2109
20	48.358	48.231	47.970	2.395	0.271	30.801	0.2094
21	50.784	50.650	50.376	2.446	0.283	32.214	0.2082
22	53.209	53.069	52.782	2.497	0.296	33.646	0.2070
23	55.635	55.489	55.188	2.547	0.308	35.082	0.2059
24	58.061	57.908	57.595	2.597	0.320	36.522	0.2049
26	62.912	62.746	62.407	2.695	0.343	39.420	0.2031
28	67.763	67.584	67.219	2.790	0.367	42.328	0.2016
30	72.614	72.423	72.031	2.883	0.390	45.254	0.2003
32	77.465	77.261	76.843	2.974	0.412	48.206	0.1991
34	82.316	82.099	81.656	3.064	0.434	51.166	0.1981
36	87.167	86.938	86.468	3.153	0.456	54.162	0.1971
38	92.018	91.776	91.280	3.241	0.478	57.158	0.1963
40	96.869	96.614	96.092	3.326	0.499	60.167	0.1956
42	101.720	101.453	100.904	3.412	0.520	63.207	0.1949
44	106.571	106.291	105.717	3.496	0.541	66.258	0.1943
46	111.422	111.129	110.529	3.579	0.562	69.337	0.1937
48	116.273	115.967	115.341	3.661	0.582	72.423	0.1932
50	121.124	120.806	120.153	3.743	0.603	75.537	0.1927
52	125.975	125.644	124.965	3.825	0.623	78.679	0.1922
54	130.826	130.482	129.778	3.904	0.642	81.822	0.1918
56	135.677	135.321	134.590	3.982	0.662	84.964	0.1915
60	145.379	144.997	144.214	4.139	0.702	91.351	0.1908
64	155.081	154.674	153.839	4.292	0.740	97.811	0.1902

N – Number of teeth
RDD – Root diameter +0.03 –0.00 of drive sprocket of 7.620 pitch
RDC – Root diameter +0.03 –0.00 of combination sprocket of 7.600 pitch
RDH – Root diameter +0.00 –0.03 of holdback sprocket of 7.559 pitch
K – Circular arc radius for tooth shape, +0.00 –0.05
B – Radial distance of arc center inside root circle, +0.013 –0.000
R_2 – Minimum radius of film path concave to sprocket
X_T – Offset of tooth at working height
R_1 – Minimum film path radius convex to sprocket, 4.762
Tooth working height – 0.660
Maximum pitch difference – 0.066
Film thickness – 0.152
Other thickness – Root diameter = N•pitch/π – thickness

Table 1b – Sprocket dimensions in inches

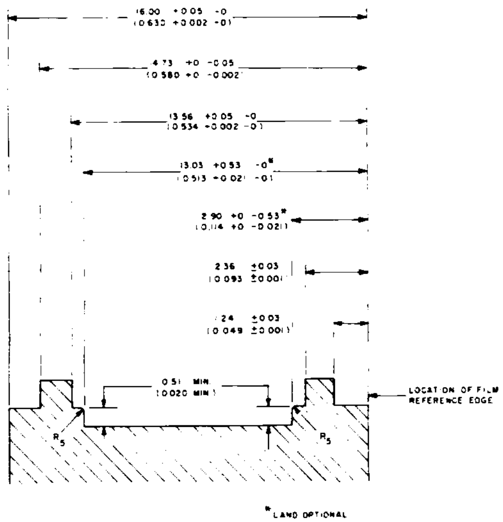
N	RDD	RDC	RDH	K	B	R_2	X_T
8	0.7580	0.7559	0.7519	0.0673	0.0044	0.5798	0.00976
9	0.8535	0.8512	0.8466	0.0689	0.0048	0.6273	0.00949
10	0.9489	0.9465	0.9413	0.0712	0.0053	0.6747	0.00927
11	1.0444	1.0417	1.0360	0.0738	0.0059	0.7239	0.00909
12	1.1399	1.1369	1.1307	0.0763	0.0065	0.7755	0.00894
13	1.2354	1.2322	1.2255	0.0788	0.0070	0.8282	0.00881
14	1.3309	1.3274	1.3202	0.0811	0.0076	0.8816	0.00870
15	1.4264	1.4226	1.4150	0.0835	0.0081	0.9358	0.00860
16	1.5219	1.5179	1.5097	0.0857	0.0086	0.9904	0.00851
17	1.6174	1.6131	1.6044	0.0879	0.0092	1.0456	0.00843
18	1.7129	1.7084	1.6991	0.0901	0.0096	1.1012	0.00836
19	1.8084	1.8036	1.7939	0.0922	0.0102	1.1565	0.00830
20	1.9039	1.8989	1.8886	0.0943	0.0107	1.2126	0.00824
21	1.9994	1.9941	1.9833	0.0963	0.0111	1.2683	0.00820
22	2.0948	2.0893	2.0780	0.0983	0.0117	1.3246	0.00815
23	2.1904	2.1846	2.1728	0.1003	0.0121	1.3812	0.00811
24	2.2859	2.2798	2.2675	0.1022	0.0126	1.4379	0.00807
26	2.4769	2.4703	2.4570	0.1061	0.0135	1.5520	0.00800
28	2.6678	2.6608	2.6464	0.1098	0.0144	1.6665	0.00794
30	2.8588	2.8513	2.8359	0.1135	0.0154	1.7817	0.00789
32	3.0498	3.0418	3.0253	0.1171	0.0162	1.8979	0.00784
34	3.2408	3.2322	3.2148	0.1206	0.0171	2.0144	0.00780
36	3.4318	3.4228	3.4043	0.1241	0.0180	2.1324	0.00776
38	3.6228	3.6132	3.5937	0.1276	0.0188	2.2503	0.00773
40	3.8137	3.8037	3.7831	0.1309	0.0196	2.3688	0.00770
42	4.0047	3.9942	3.9726	0.1343	0.0205	2.4885	0.00767
44	4.1957	4.1847	4.1621	0.1376	0.0213	2.6086	0.00765
46	4.3867	4.3752	4.3515	0.1409	0.0221	2.7298	0.00763
48	4.5777	4.5656	4.5410	0.1441	0.0229	2.8513	0.00761
50	4.7687	4.7561	4.7304	0.1474	0.0237	2.9739	0.00759
52	4.9596	4.9466	4.9199	0.1506	0.0245	3.0976	0.00757
54	5.1506	5.1371	5.1094	0.1537	0.0253	3.2213	0.00755
56	5.3416	5.3276	5.2988	0.1568	0.0261	3.3450	0.00754
60	5.7236	5.7085	5.6777	0.1630	0.0276	3.5965	0.00751
64	6.1056	6.0895	6.0567	0.1690	0.0291	3.8508	0.00749

N – Number of teeth
RDD – Root diameter +0.001 –0.000 of drive sprocket of 0.3000 pitch
RDC – Root diameter +0.001 –0.000 of combination sprocket of 0.2992 pitch
RDH – Root diameter +0.000 –0.001 of holdback sprocket of 0.2976 pitch
K – Circular arc radius for tooth shape, +0.000 –0.002
B – Radial distance of arc center inside root circle, +0.0005 –0.0000
R_2 – Minimum radius of film path concave to sprocket
X_T – Offset of tooth at working height
R_1 – Minimum film path radius convex to sprocket, 0.1875
Tooth working height – 0.0260
Maximum pitch difference – 0.0026
Film thickness – 0.0060
Other thickness – Root diameter = N•pitch/π – thickness



NOTE – Dimensions in millimeters, inches in parentheses.

Figure 2a – Recommended lateral profile for all equipment



NOTE – Dimensions in millimeters, inches in parentheses.

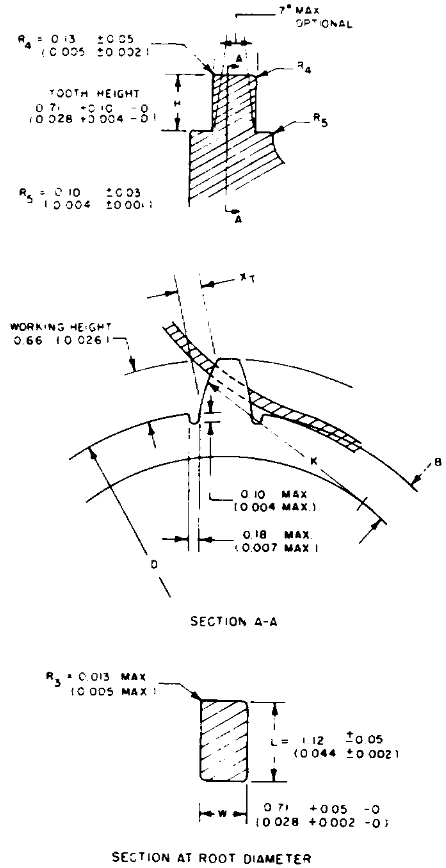
Figure 2b – Alternate lateral profile for silent equipment only

2.9 The lateral profile has been derived on the assumption that the film is channel-guided at or near the sprocket. This guiding may be provided by fixed guides, by the flanges of an adjacent roller at the entering position or, preferably, by flanges on the sprocket itself. When a fixed guide is needed at the perforated edge and the film urged against the guide by a spring or other means, the lateral dimension, L, of the tooth can be increased somewhat. If the sprocket teeth are to perform the function of side guiding, then their lateral dimension, L, may be increased to 1.803 mm +0 mm −0.013 mm (0.0710 in +0 in −0.0005 in) with special consideration given to tooth alignment, smoothness of the sides, and rounding or tapering at the tips (see figures 2a and 2b).

When the sprocket teeth have been increased in width to perform the function of lateral guiding, the R_3 value for the radius of the corners of the sprocket tooth should be increased to comply with the radius of the perforation fillet, 0.25 mm +0.05 mm −0 mm (0.010 in +0.002 in −0 in).

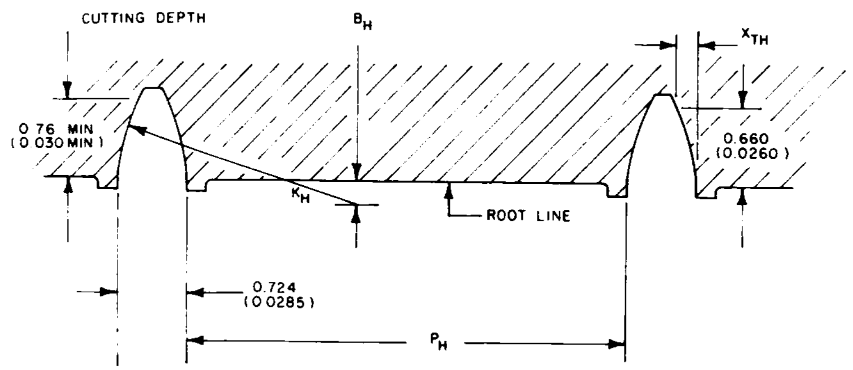
2.10 In order for the film guide to function properly, the sprocket eccentricity as mounted in operation shall not exceed 0.025 mm (0.0010 in), and the lateral weave or wobble measured at the root circle shall not exceed ± 0.025 mm (0.0010 in). Less eccentricity may be required for a special application such as a sound printer sprocket.

2.11 In some cases of large-scale layouts or critical comparisons, it may be more convenient to work with values of X_T than with values of B. As shown in figure 3, X_T is the distance measured perpendicular to the radial line intersecting the root of the tooth from a point on the tooth which is 0.66 mm (0.026 in) above the root circle. Further information on sprocket design is contained in reference 2.



NOTE – Dimensions in millimeters, inches in parentheses.

Figure 3 – Sprocket tooth



NOTE – Dimensions in millimeters, inches in parentheses.

Figure 4 – Basic rack

Table 2 – Rack dimensions

Tooth range	Rack pitch, P_H ± 0.003 mm (± 0.0001 in)	Shape radius, K_H +0 –0.03 mm (+0 –0.001 in)	Distance of center below root, B_H +0.005 –0 mm (+0.002 –0 in)	Offset at 0.66-mm (0.026-in) height, X_{TH}
8–17	7.559 mm (0.2976 in)	2.248 mm (0.0885 in)	0.264 mm (0.0104 in)	0.1831 mm (0.00721 in)
18–64	7.602 mm (0.2993 in)	3.594 mm (0.1415 in)	0.617 mm (0.0243 in)	0.1816 mm (0.00715 in)

Annex A (informative)
Additional data

A.1 It is intended that the pitch of feed sprockets shall always be equal to or greater than the pitch of the film. The longest film pitch was assumed to be 7.620 mm (0.3000 in), corresponding to zero shrinkage with no allowance for plus tolerance during perforating. The pitch of unprocessed film under some conditions of high humidity may be longer. On the other hand, processed film perforated with the maximum plus tolerance at low-humidity conditions may be shorter by 0.2% or 0.3%.

Another condition which gives rise to an effectively long film pitch is film distortion at the perforation resulting from higher-than-normal force at the contact point of the driving tooth. A classical example is the prolongment of film life if the root diameter of the 16-tooth intermittent sprocket for 35-mm projectors is increased from 24.039 mm (0.9464 in), corresponding to unshrunk film, to 24.130 mm (0.9500 in). Presumably, the improvement can be explained in part by a better tooth action if the sprocket pitch is equal to or greater than the effective pitch between the loaded perforation and the following perforation, which must engage freely. The designer may exercise control of the pitch by proper selection of the root diameter. The same hobs are usable for the new diameter.

The friction between the film and the root surface of the normal feed sprocket assists in the driving action; however, friction between the film and guide members which control edge position and film path should be minimized.

A.2 No unique formula has been used to compute the sprocket data. However, there was a logical sequence of

computer operations performed in deriving the sprocket data, taking practical as well as theoretical considerations into account. The computations were limited to the applications of the sprockets as feed sprockets where the tooth must meet shape requirements. Holdback sprockets contact film only near the root diameter and any sprocket tooth design for feeding will serve as well for holdback.

The value of R_1, 4.762 mm (0.1875 in), was chosen for 16-mm as the smallest radius one would expect to use as the path along which the film is guided while leaving the sprocket. This value also results in adequate tooth width at the working height, about 0.305 mm (0.0120 in). A larger value of R_1 would result in a smaller X_T, thus producing a larger R_2 value. This would result in more flutter and unsteadiness (see 2.4.2). The driven edges of the film perforations in stripping off the sprocket in the path designated by R_1 must not interfere as they pass the tips of the sprocket teeth. As can be readily appreciated, if the offset of the teeth at the maximum working height is too small, the edges of the perforations would be under load at the tips of the sprocket teeth, and the film would suddenly snap to the position where the next tooth takes up the load with resultant shock loading and film gouging. The last tooth fully engaged with the film essentially carries the film load. When the film strips off this last tooth, the film slips back relative to the sprocket base until the next perforation (which is now the last perforation) carries the film load. The maximum back-slip of the film (see 2.3), as well as the relative paths taken by the base and the tip of the sprocket tooth and by the film, were used in computations of X_T. With X_T established for each N, the position of one point along the shape of each sprocket tooth relative to the root position has been determined.

It is necessary that the face of each sprocket tooth be as erect as possible to give good load-carrying capacity and a minimum tendency for the film to ride up on the tooth. And, of course, the tooth must not force the film to slip along the base of the sprocket in the forward direction at any point as this would increase the load because of friction, and would require more total back-slip and tooth slant. Yet, the tooth shape must provide smooth transfer of the film load from one tooth to the next, at disengagement, for long film life. This leads to another requirement that cannot be overlooked in sprocket specifications, i.e., the condition of maximum steadiness of film motion or minimum flutter within the design range of pitch differentials. If the film on exiting from the sprocket is made to ride up the sprocket teeth smoothly, a condition of minimum flutter can be achieved where a smooth transfer of film load from one tooth to the next can be obtained (several teeth are usually engaged simultaneously). The minimum value of the radius (concave toward the sprocket) defining the exiting film path for minimum flutter or maximum smoothness has been designated as R_2 and is listed in tables 1a and 1b for each value of N (see reference 1). Computing the values of R_2 would hardly be possible without an electronic computer because a method of successive approximations must be used. The limiting radius, R_2, of the film leaving the drive sprocket defines the shape of the tooth face. A carefully modified epicycloid best fits this ideal curve. It is far simpler to specify and use the specifications if the curve of the tooth face is a circular arc with radius and center given. On investigation, it was found that errors would be sufficiently small to make the circular-arc specification practical. From the data for the tooth face as derived in computing R_2, a point on the face was selected at one third the working tooth height. Using the position of this point with the established root and tip positions, the radius and its center were computed for each sprocket. Comparing the positions of points along the sprocket face as defined by the circular arc to those as defined by the ideal curve derived in computing R_2, the maximum deviations at other than the three fixed points were in the order of 0.005 mm (0.0002 in).

The arc specification is convenient and lends itself to small-quantity production of sprockets with a single formed cutter and indexing means. For large-quantity production, the use of hobs is more economical. Many sprockets have been produced using involute shapes of some specified pressure angle. The slope of the resultant tooth at the root is undesirably reduced, and the tooth shape is poorer for steadiness and flutter. The use of the circular arc, as specified by K and B in tables 1a and 1b, denotes an important improvement over the use of the involute. Therefore, further computer studies investigated the use of hobs with circular arc cutting faces (see K_H and B_H in table 2 and figure 3) to generate the sprocket teeth. The computer program was made to minimize fit errors for offset values at maximum working heights and at one-third heights. As a result, two hobs are specified; the first covers the range of 8–17 teeth and the second 18–64 teeth. It was found that the maximum errors along the entire tooth height compared to a theoretically correct shape are even less (about two-thirds) than those for the circular arc specifications.

It is anticipated that sprockets not specified by the tables will be specified by interpolation.

A.3 An exception to these pitch considerations is the radial tooth design (see reference 3).

Annex B (informative)
Bibliography

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