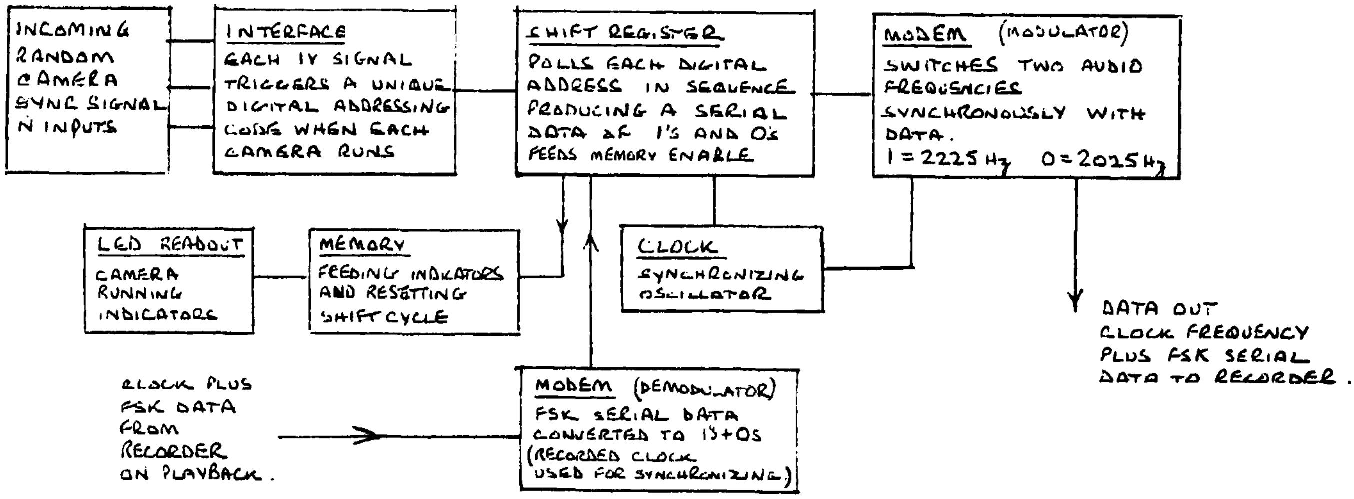

Fig. 7. Overall system diagram. By means of the dedicated minicomputer, the random parallel inputs become a serial data signal for recording and later playing back to indicate camera running.

camera positions are manually marked on the film, to indicate which camera roll to use for each take. An audible beep is also available in the slate marker for indicating camera starts and stops on the recorded soundtrack.

This filming technique enables camera crews to operate creatively without being delayed by slating mechanics, and yet gives adequate control in the editing room for accurate synchronization. A further bonus of the entire system is that it permits a television director to apply his skills in quickly assembling a program in television style, even though he is working in the film medium (Fig. 7).

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Standards & Recommended Practices

Approved SMPTE Recommended Practices

On 22 January 1976, the Board of Governors approved the following SMPTE Recommended Practices:

RP 63-1976, Specifications for Sound-Focusing Test Film for 16-mm Sound Reproducers, Photographic Type; and

RP 64-1976, Specifications for Sound-Focusing Test Film for 35-mm Sound Reproducers, Photographic Type.

Although these are new Recommended Practices, they are in fact transformations of American National Standards PH22.42-1962 (R1969) and PH22.61-1969 and do not reflect any technical changes. The two standards are being withdrawn as it is felt that documents specifying test materials should be developed as SMPTE Recommended Practices rather than American National Standards.

Proposed SMPTE Recommended Practices

Two Proposed SMPTE Recommended Practices are published here for a trial period and public review:

RP 73, 8-mm Type R (Regular 8) Sprocket Design;

RP 74, 16-mm Sprocket Design.

These documents are updated versions of the data originally found in RP 1-1950. Although they do not reflect any substantial technical change, they should be carefully reviewed by those concerned with the manufacture or use of sprockets.

Reaffirmation of American National Standards

On 10 May 1976, the American National Standards Institute approved reaffirmation of the following American National Standards:

PH22.35-1962, Dimensions for 16-Tooth 35-mm Motion-Picture Projector Sprockets;

PH22.152-1969, Dimensions of Projectable Image Area on 70-mm Motion-Picture Film; and

PH22.177-1970, Dimensions of Magnetic Striping of 35-mm Motion-Picture Film for Four-Track Magnetic Sound Release Prints.

Inasmuch as compliance with American National Standards is purely voluntary, standards will become truly effective when broad publicity is given to their existence. ANSI and SMPTE would appreciate any personal influence to promote the use of these standards where such action is appropriate. Copies of the standards may be obtained for a nominal fee from the American National Standards Institute, 1430 Broadway, New York, NY 10018. — Alex E. Alden, *Staff Engineer*.

SMPTE RECOMMENDED PRACTICE — RP 63-1976

Specifications for Sound-Focusing Test Film for 16-mm Sound Reproducers, Photographic Type

1. *Scope*

This recommended practice specifies a test film for use in focusing the scanning beam of 16-mm motion-picture photographic sound reproducers operating at 36 ft (11 m) per minute.

2. *Test Film Signal*

2.1 Frequency. The sound record on the film shall reproduce at a frequency of 7000 ± 100 Hz (Type A) or 5000 ± 100 Hz (Type B) when the linear speed of the film is 24 perforations per second or approximately 36 ft per minute (7.2 in or 18.3 cm per second).

2.1.1 Type A. A film with a 7000-Hz record to be used by manufacturers and laboratories, for precise adjustment of the sound-focusing system.

2.1.2 Type B. A film with a 5000-Hz record to be used when simpler instruments are available or when lower quality is adequate, for quick adjustment of the sound-focusing system.

2.2 Distortion. The total harmonic distortion of the recorded signals shall not exceed 1 percent.

2.3 Sound Record. The location and dimensions of the recorded sound record shall be in accordance with American National Standard Dimensions of Photographic Sound Records on 16-mm Motion-Picture Prints, PH22.41-1975.

2.4 Recording. The film shall have an originally recorded, variable-density sound track. The track shall be heavily overmodulated and developed to high contrast so that it is essentially a square-wave track. The signal level shall not fluctuate more than ± 0.5 dB within the test film length.

2.5 Flutter. The weighted peak flutter of the sound record shall not exceed ± 0.07 percent when measured in accordance with American National Standard Method for Measurement of Weighted Peak Flutter of Sound Recording and Reproducing Equipment, S4.3-1972.

2.6 Azimuth. The azimuth of the sound record shall be 90° ± 5′ to the reference edge of the film.

3. *Film Stock*

The film stock shall be splice-free, of the low-shrinkage, safety type in compliance with American National Standard Specifications for Motion-Picture Safety Film, PH22.31-1967 (R1973), and cut and perforated in accordance with long-pitch dimensions specified in American National Standard Dimensions for 16-mm Motion-Picture Film Perforated 1R, PH22.109-1974.

4. *Identification*

Each test film shall be identified by a suitable identification marking. This marking shall be printed lengthwise in the picture area and the spacing between consecutive titles shall be approximately 12 in (30 cm).

NOTE: Test films conforming to this practice are available from the Society of Motion Picture and Television Engineers.

Approved 22 January 1976

SMPTE RECOMMENDED PRACTICE — RP 64-1976

Specifications for Sound-Focusing Test Film for 35-mm Sound Reproducers, Photographic Type

1. *Scope*

This recommended practice specifies a test film for use in focusing the scanning beam of 35-mm motion-picture photographic sound reproducers operating at 90 ft (27.4 m) per minute.

2. *Test Film Signal*

2.1 Frequency. The sound record on the film shall reproduce at a frequency of 9000 ± 100 Hz (Type A) or 7000 ± 100 Hz (Type B) when the linear speed of the film is 96 perforations per second or approximately 90 ft per minute (18 in or 45.7 cm per second).

2.1.1 Type A. A film with a 9000-Hz record to be used by manufacturers and laboratories, for precise adjustment of the sound-focusing system.

2.1.2 Type B. A film with a 7000-Hz record to be used when simpler instruments are available or when lower quality is adequate, for quick adjustment of the sound-focusing system.

2.2 Distortion. The total harmonic distortion of the recorded signals shall not exceed 1 percent.

2.3 Sound Record. The location and dimensions of the recorded sound records shall be in accordance with American National Standard Dimensions of Photographic Sound Record on 35-mm Motion-Picture Prints, PH22.40-1967.

2.4 Recording. The film shall be a print from an original negative and shall contain a sinusoidal, variable-area record recorded at 1 dB below 100 percent modulation. The variation in amplitude shall not be more than ± 0.25 dB.

2.5 Flutter. The weighted peak flutter of the sound record shall not exceed ± 0.04 percent when measured in accordance with American National Standard Method for Measurement of Weighted Peak Flutter of Sound Recording and Reproducing Equipment, S4.3-1972.

2.6 Azimuth. The azimuth of the sound record shall be 90° ± 5′ to the reference edge of the film.

3. *Film Stock*

The film stock shall be splice-free, of the low-shrinkage, safety type in compliance with American National Standard Specifications for Motion-Picture Safety Film, PH22.31-1967 (R1973), and cut and perforated in accordance with long-pitch dimensions specified in American National Standard Dimensions for 35-mm Motion-Picture Film Perforated KS, PH22.139-1974.

4. *Identification*

Each test film shall be identified by a suitable identification marking. This marking shall be printed lengthwise in the central portion of the film and the spacing between consecutive titles shall be approximately 12 in (30 cm).

NOTE: Test films conforming to this practice are available from the Society of Motion Picture and Television Engineers.

Approved 22 January 1976

PROPOSED

SMPTE RECOMMENDED PRACTICE

RP 73

Partial Revision of RP 1-1950

8-mm Type R (Regular 8) Sprocket Design

1. Scope

This practice provides dimensions and specifications for the design of sprockets used with 8-mm Type R (regular 8) 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 degrees where N is the number of teeth. A suitable tolerance for the index angle is ± 1 minute of arc for sprockets having 8 to 24 teeth and ± 30 seconds of arc for sprockets having 25 to 84 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 thicknesses, 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 3.962 mm (0.1560 in) for R_1 is recommended. This is an arbitrary choice, but seems appropriate for 8-mm equipment.

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 0.046 mm (0.0018 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.

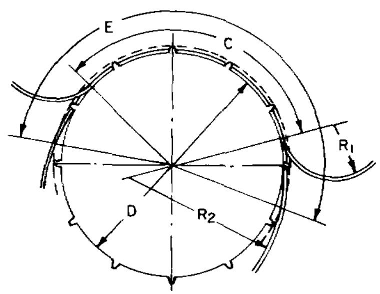


Fig. 1

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 0.046-mm (0.0018-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 0.023 mm (0.0009 in) approximates 0.6 percent film shrinkage. It should be noted that another combination of greater load and lower shrinkage could fall within the same allowable maximum of 0.033 mm (0.0013 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 0.046 mm (0.0018 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 or R_2, including a straight tangent path, the accommodation of 0.046 mm (0.0018 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 3.780 mm (0.1488 in) corresponding to 0.8 percent shrinkage of long-pitch film (3.810 mm [0.1500 in]). (This value is chosen rather than the 0.6 percent 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, 3.800 mm (0.1496 in), should correspond to the pitch of film with 0.3 percent 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_B and B_B in Table 2 and Figure 4. If the first hob covers the range of N from 12 to 24 inclusively and the second hob 25 to 84 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

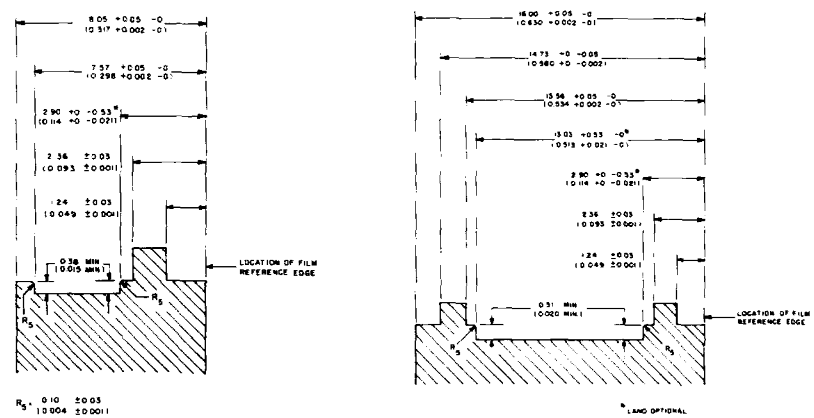


Fig. 2

Dimensions in Millimeters
Inches in Parentheses

Lateral Profile for Single-Width Equipment

Lateral Profile for Double-Width Equipment

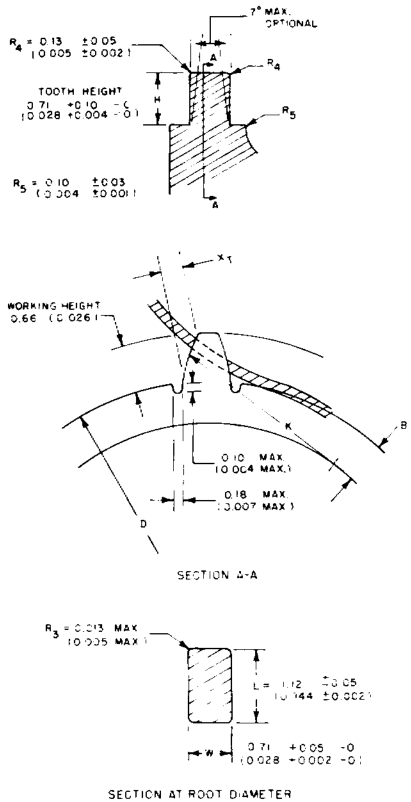
of working height. The value chosen does not limit the angle of wrap on the sprocket as a wider tooth would. If the wrap length is defined as one half the sum of the number of pitch lengths in the arc of engagement, E, and the number of pitch lengths in the arc of contact, C (Figure 1), then the wrap length may be as high as 13½ pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0.8 percent.

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 +0 —0.013 mm (0.0710 +0 —0.0005 in) with special consideration given to tooth alignment, smoothness of the sides and rounding or tapering at the tips.

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 +0.05 —0 mm (0.010 +0.002 —0 in).

2.10 In order for the film guides 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.



Dimensions in Millimeters
Inches in Parentheses

Fig. 3

Table 1A
Sprocket Dimensions in Millimeters

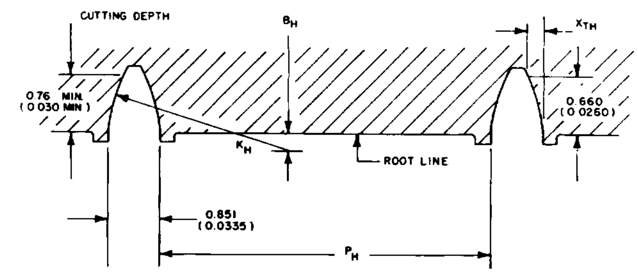
N	RDD	RDC	RDH	K	B	R_2	X_T
12	14.401	14.363	14.287	1.457	0.034	11.837	0.2534
13	15.614	15.573	15.490	1.510	0.044	12.576	0.2477
14	16.827	16.782	16.693	1.560	0.054	13.317	0.2428
15	18.039	17.992	17.896	1.608	0.064	14.065	0.2385
16	19.252	19.201	19.099	1.655	0.073	14.816	0.2347
17	20.465	20.411	20.303	1.700	0.082	15.573	0.2313
18	21.678	21.620	21.506	1.744	0.092	16.328	0.2283
19	22.890	22.830	22.709	1.787	0.100	17.097	0.2255
20	24.103	24.040	23.912	1.828	0.109	17.853	0.2231
21	25.316	25.249	25.115	1.869	0.118	18.625	0.2208
22	26.529	26.459	26.319	1.909	0.126	19.387	0.2188
23	27.741	27.668	27.522	1.947	0.134	20.160	0.2169
24	28.954	28.878	28.725	1.986	0.142	20.941	0.2151
26	31.380	31.297	31.131	2.060	0.158	22.497	0.2120
28	33.805	33.716	33.538	2.132	0.174	24.065	0.2093
30	36.231	36.135	35.944	2.202	0.190	25.634	0.2070
32	38.656	38.554	38.351	2.270	0.204	27.224	0.2049
34	41.082	40.974	40.757	2.336	0.219	28.814	0.2031
36	43.507	43.393	43.164	2.401	0.234	30.413	0.2015
38	45.933	45.812	45.570	2.464	0.248	32.032	0.2000
40	48.358	48.231	47.976	2.526	0.262	33.652	0.1987
42	50.784	50.650	50.383	2.588	0.276	35.285	0.1975
44	53.209	53.069	52.789	2.648	0.290	36.929	0.1964
46	55.635	55.489	55.196	2.707	0.303	38.582	0.1954
48	58.061	57.908	57.602	2.766	0.316	40.263	0.1944
50	60.486	60.327	60.009	2.823	0.330	41.928	0.1935
52	62.912	62.746	62.415	2.880	0.343	43.617	0.1928
54	65.337	65.165	64.821	2.936	0.356	45.307	0.1921
56	67.763	67.584	67.228	2.991	0.368	47.019	0.1914
60	72.614	72.423	72.041	3.100	0.394	50.461	0.1902
64	77.465	77.261	76.854	3.206	0.418	53.962	0.1891
68	82.316	82.099	81.666	3.311	0.443	57.517	0.1881
72	87.167	86.938	86.479	3.413	0.467	61.089	0.1873
76	92.018	91.776	91.292	3.514	0.490	64.739	0.1865
80	96.869	96.614	96.105	3.612	0.513	68.430	0.1858
84	101.720	101.453	100.918	3.709	0.536	72.157	0.1852

N — Number of teeth
RDD — Root diameter +0.03 −0.00 of drive sprocket of 3.810 pitch
RDC — Root diameter +0.03 −0.00 of combination sprocket of 3.800 pitch
RDH — Root diameter +0.00 −0.03 of holdback sprocket of 3.780 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, 3.962
Tooth working height −0.660
Maximum pitch difference − 0.046
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
12	0.5670	0.5655	0.5625	0.0574	0.0013	0.4660	0.00998
13	0.6147	0.6131	0.6098	0.0594	0.0017	0.4951	0.00975
14	0.6625	0.6607	0.6572	0.0614	0.0021	0.5243	0.00956
15	0.7102	0.7083	0.7046	0.0633	0.0025	0.5537	0.00939
16	0.7580	0.7559	0.7519	0.0652	0.0029	0.5833	0.00924
17	0.8057	0.8036	0.7993	0.0669	0.0032	0.6131	0.00911
18	0.8535	0.8512	0.8467	0.0687	0.0036	0.6428	0.00899
19	0.9012	0.8988	0.8941	0.0704	0.0039	0.6731	0.00888
20	0.9489	0.9465	0.9414	0.0720	0.0043	0.7029	0.00878
21	0.9967	0.9941	0.9888	0.0736	0.0046	0.7333	0.00869
22	1.0444	1.0417	1.0362	0.0752	0.0050	0.7633	0.00861
23	1.0922	1.0893	1.0835	0.0767	0.0053	0.7937	0.00854
24	1.1399	1.1369	1.1309	0.0782	0.0056	0.8244	0.00847
26	1.2354	1.2322	1.2256	0.0811	0.0062	0.8857	0.00835
28	1.3309	1.3274	1.3204	0.0839	0.0069	0.9474	0.00824
30	1.4264	1.4226	1.4151	0.0867	0.0075	1.0092	0.00815
32	1.5219	1.5179	1.5099	0.0894	0.0080	1.0718	0.00807
34	1.6174	1.6131	1.6046	0.0920	0.0086	1.1344	0.00800
36	1.7129	1.7084	1.6994	0.0945	0.0092	1.1974	0.00793
38	1.8084	1.8036	1.7941	0.0970	0.0098	1.2611	0.00787
40	1.9039	1.8989	1.8888	0.0994	0.0103	1.3249	0.00782
42	1.9994	1.9941	1.9836	0.1019	0.0109	1.3892	0.00778
44	2.0948	2.0893	2.0783	0.1043	0.0114	1.4539	0.00773
46	2.1904	2.1846	2.1731	0.1066	0.0119	1.5190	0.00769
48	2.2859	2.2798	2.2678	0.1089	0.0124	1.5852	0.00765
50	2.3813	2.3751	2.3626	0.1111	0.0130	1.6507	0.00762
52	2.4769	2.4703	2.4573	0.1134	0.0135	1.7172	0.00759
54	2.5723	2.5656	2.5520	0.1156	0.0140	1.7837	0.00756
56	2.6678	2.6608	2.5468	0.1178	0.0145	1.8511	0.00754
60	2.8588	2.8513	2.8363	0.1220	0.0155	1.9867	0.00749
64	3.0498	3.0418	3.0257	0.1262	0.0165	2.1245	0.00744
68	3.2408	3.2322	3.2152	0.1304	0.0174	2.2644	0.00741
72	3.4318	3.4228	3.4047	01344	0.0184	2.4051	0.00737
76	3.6228	3.6132	3.5942	0.1383	0.0193	2.5488	0.00734
80	3.8137	3.8037	3.7837	0.1422	0.0202	2.6941	0.00731
84	4.0047	3.9942	3.9731	0.1460	0.0211	2.8408	0.00729

N — Number of teeth
RDD — Root diameter +0.001 −0.000 of drive sprocket of 0.1500 pitch
RDC — Root diameter +0.001 −0.000 of combination sprocket of 0.1496 pitch
RDH — Root diameter +0.000 −0.001 of holdback sprocket of 0.1488 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, 0.1560
Tooth working height — 0.0260
Maximum pitch difference — 0.0018
Film thickness — 0.0060
Other thickness — Root diameter = N·pitch/π — thickness



Dimensions in Millimeters
Inches in Parentheses

Fig. 4
Basic Rack

Table 2

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 (+0.0002 −0 in)	Offset at 0.66-mm (0.026-in) Height, X_{TH}
12-24	3.769 mm (0.1484 in)	1.938 mm (0.0763 in)	0.147 mm (0.0058 in)	0.1707 mm (0.00672 in)
25-84	3.797 mm (0.1495 in)	3.294 mm (0.1297 in)	0.488 mm (0.0192 in)	0.1702 mm (0.00670 in)

Appendix

(The Appendix is not a part of this SMPTE Recommended Practice, but is included for information purposes only.)

A1. 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 3.810 mm (0.1500 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 percent.

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.

A2. 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 application 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, 3.962 mm (0.1560 in), was chosen for 8-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 the 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 12-24 teeth and the second 25-84 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.

A3. An exception to these pitch considerations is the radial tooth design (see Reference 3).

References

1. CHANDLER, J. S. Some theoretical considerations in the design of sprockets for continuous film movement. *Jour. SMPE*, vol 37, no. 2, Aug 1941, pp 164-176.

2. CHANDLER, J. S.; LYMAN, D. F.; and MARTIN, L. R. Proposals for 16-mm and 8-mm sprocket standards. *Jour. SMPE*, vol 48, no. 6, June 1947, pp 483-520.

3. STREIFFERT, J. G. The radial-tooth, variable-pitch sprocket. *Jour. SMPTE*, vol 57, no. 6, Dec 1951, pp 529-550.

PROPOSED

SMPTE RECOMMENDED PRACTICE

RP 74

Partial Revision of RP 1-1950

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 degrees 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 thicknesses, 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.

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.

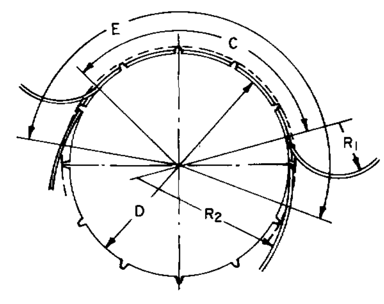


Fig. 1

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 in) approximates 0.6 percent 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 mm (0.0021 in). The user is cautioned against

THIS PROPOSAL IS PUBLISHED FOR COMMENT ONLY 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.

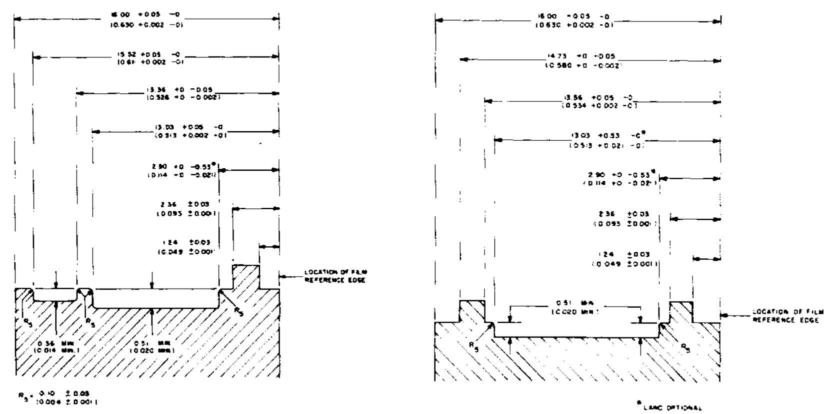
2.4.2 For a concave film path with respect to the sprocket surface (curvature toward the sprocket radius center), the limiting radius, R_2, has been computed for the same X_T and the same accommodation of 0.066 mm (0.0026 in), assuming a parabolic schedule (displacement function proportionate to the 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 or 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 percent shrinkage of long-pitch film (7.620 mm [0.300 in]). (This value is chosen rather than the 0.6 percent 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 percent 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.



Dimensions in Millimeters
Inches in Parentheses

Fig. 2

Recommended Lateral Profile for All Equipment

Alternate Lateral Profile for Silent Equipment Only

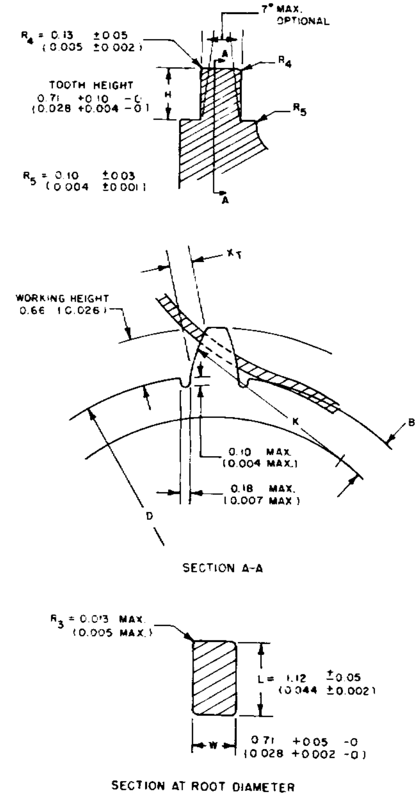
2.8 The tooth width at the base, Dimension W, allows ample material for rounding off the tip while preserving the 0.66 mm (0.026 in) or more of working height. The value chosen does not limit the angle of wrap on the sprocket as a wider tooth would. If the wrap length is defined as one half the sum of 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 6¼ pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0.8 percent.

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 +0 —0.013 mm (0.0710 +0 —0.0005 in) with special consideration given to tooth alignment, smoothness of the sides and rounding or tapering at the tips.

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 +0.05 —0 mm (0.010 +0.002 —0 in).

2.10 In order for the film guides 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.



Dimensions in Millimeters
Inches in Parentheses

Fig. 3

Table 1A
Sprocket Dimensions in Millimeters

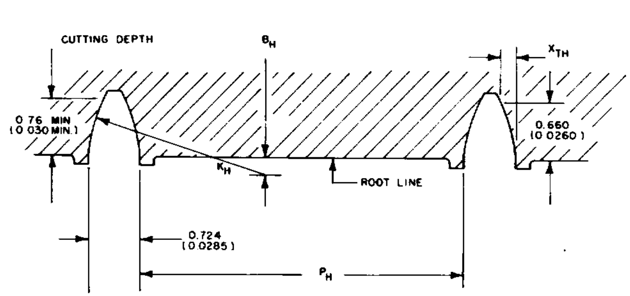
N	RDD	RDC	RDH	K	B	R_2	X_T
8	19.252	19.201	19.097	1.709	0.111	14.726	0.2478
9	21.678	21.620	21.503	1.750	0.121	15.933	0.2410
10	24.103	24.040	23.909	1.809	0.134	17.137	0.2355
11	26.529	26.459	26.315	1.875	0.149	18.387	0.2309
12	28.954	28.878	28.721	1.939	0.164	19.697	0.2270
13	31.380	31.297	31.127	2.001	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	01376	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



Dimensions in Millimeters
Inches in Parentheses

Fig. 4
Basic Rack

Table 2

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 (+0.0002 —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)

Appendix

(The Appendix is not a part of this SMPTE Recommended Practice, but is included for information purposes only.)

A1. 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 percent.

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.

A2. 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 application 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 the 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 at 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.

A3. An exception to these pitch considerations is the radial tooth design (see Reference 3).

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