SMPTE RECOMMENDED PRACTICE

RP 73-1992
Revision of RP 73-1977

8-mm Type R (Regular 8) Sprocket Design

1 Scope

This practice provide 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° 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 for 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.

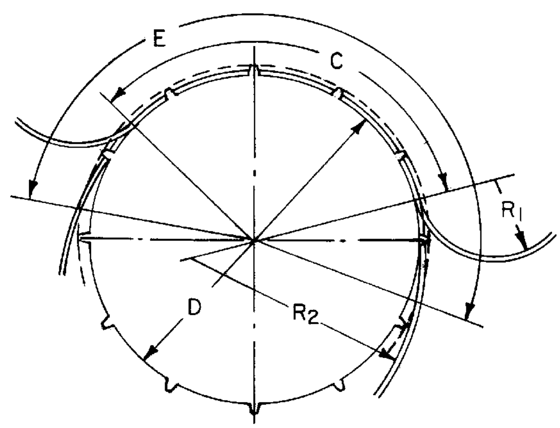

Figure 1 – Sprocket

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.

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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	58.601	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

NOTES

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	2.6468	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	0.1344	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

NOTES

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 or 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

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% 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 existing film paths from drive sprockets corresponding to larger values of R_1 and 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% shrinkage of long-pitch film (3.810 mm [0.1500 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.

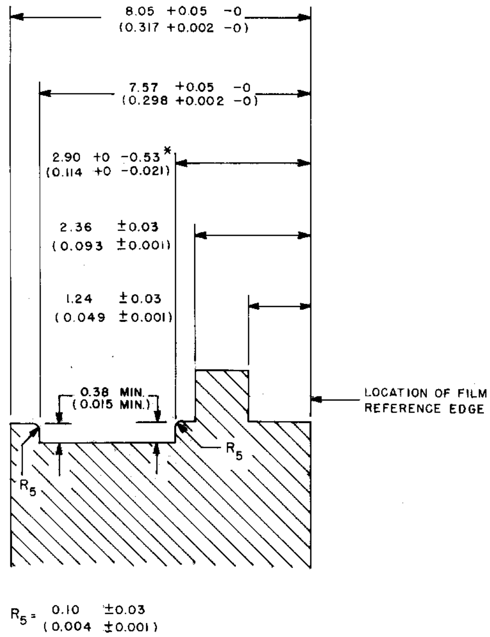
The tooth shape for a holdback sprocket has little control over the pitch differential accommodation, as the load shifts rather abruptly from the disengaging restraining tooth to the root of the following tooth. The tooth shape specified will ensure clearance at the entering position. If a holdback sprocket 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, 3.800 mm (0.1496 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 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.

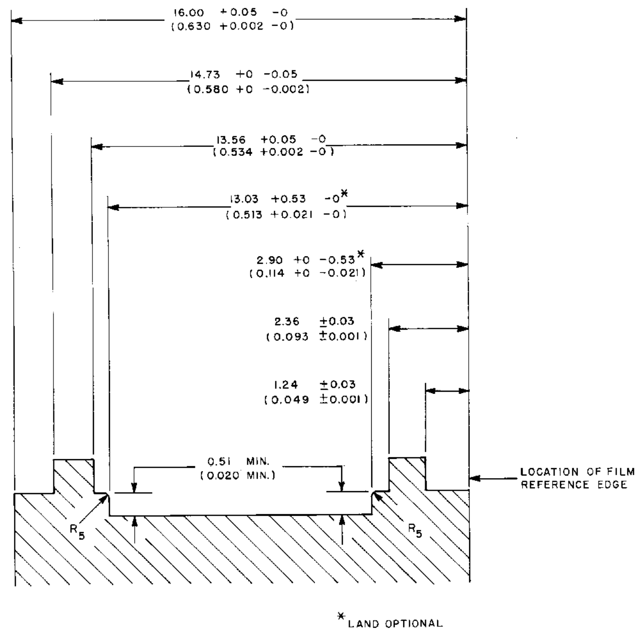
2.8 The tooth width at the base, dimension W, allows ample material for rounding off the tip while preserving the 0.66 mm (0.026 in) or more of working height. The value chosen does not limit the angle of wrap on the sprocket as a wider tooth would. If the wrap length is defined as one-half the sum of the number of pitch lengths in the arc of engagement, E, and the number of pitch lengths is the arc of contact, C (figure 1), then the wrap length may be as high as 13-1/2 pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0.8%.

2.9 The lateral profile (see figures 2a and 2b) 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



NOTE – Dimensions in millimeters, inches in parentheses.

Figure 2a -- Lateral profile for single-width equipment



NOTE – Dimensions in millimeters, inches in parentheses.

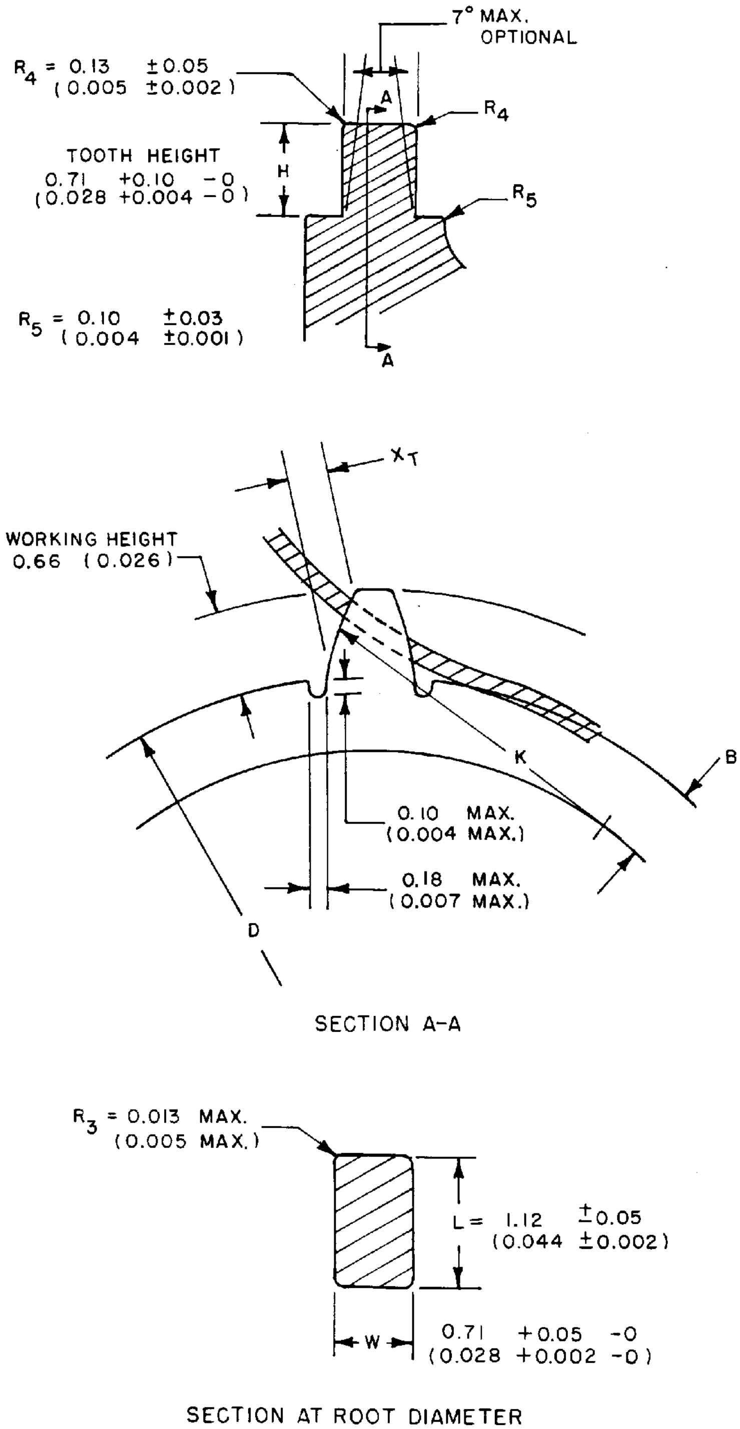
Figure 2b -- Lateral profile for double-width equipment

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.

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).

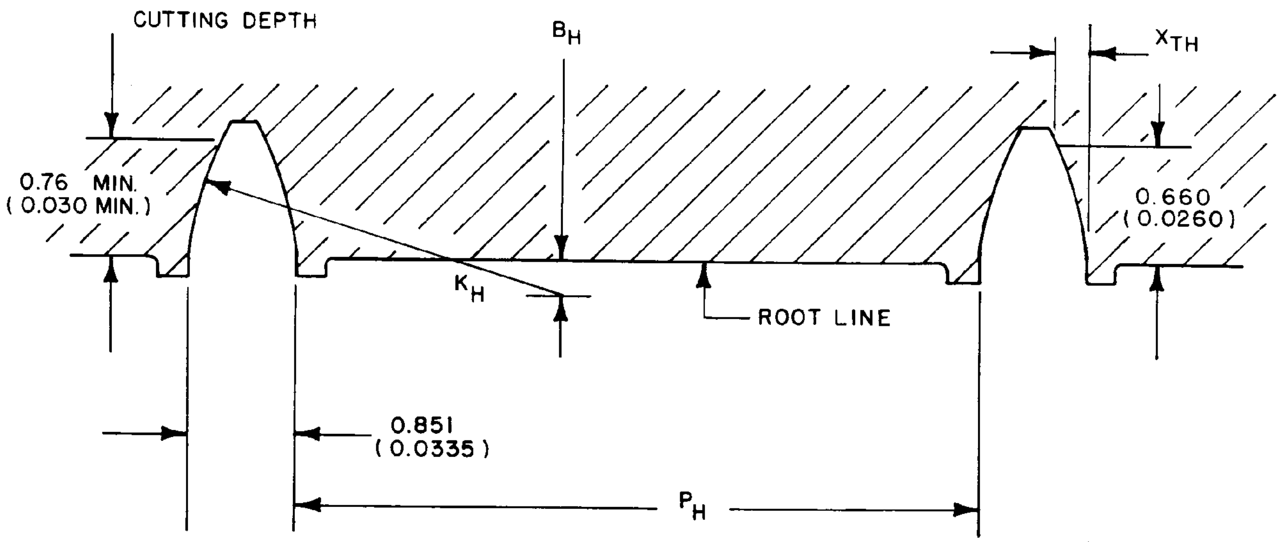
2.10 In order for the film guides to function properly, the sprocket eccentricity as mounted in operation shall not exceed 0.025 mm (0.0010 in), and the lateral weave or wobble measured at the root circle shall not exceed +0.025 mm (0.0010 in). Less eccentricity may be required for a special application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



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 (+0.0002 --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 (0.0588 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)

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 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%.

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 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.

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

Annex B (informative)
Bibliography

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