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SMPTE RECOMMENDED PRACTICE

RP 55-1997
Revision of RP 55-1993

8-mm Type S Sprocket Design

1 Scope

This practice provides the dimensions and specifications for the design and maximum pitch of sprockets used with 8-mm type S 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 12 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 P is the sprocket pitch, N is the number of teeth, and T is the film thickness. The different root diameters in tables 1A and 1B were derived using a value for T of 0.006 in (0.15 mm). If optimum working conditions are desired with different thickness film materials, tables 1A and 1B should be recomputed.

2.3 The minimum value of R_1 has been chosen as 0.156 in (3.96 mm). 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, set, and tension as well as by the shape and location of rollers or guides.

For the specified tooth shape, the film has been allowed to slip back over the root circle a distance of 0.0018 in (0.046 mm), measured at the pitch line (film thickness assumed to be 0.006 in or 0.15 mm) by the time the contact point between film and tooth has reached the maximum assumed working height of 0.026 in (0.66 mm) (measured radially from the root circle).

This analysis applies to the feed sprocket for which the sprocket pitch is generally greater than the film pitch and the film must slip in the direction opposite to the direction of motion. The direction of the friction force between the film and the root surface is such as to assist the feed or the driving action. Of the total 0.0018-in (0.046-mm) accommodation provided at each tooth for film slippage, approximately 0.0005 in (0.013 mm) 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 0.0003 in (0.008 mm) is allocated for and corresponds approximately to the distortion resulting from 2 oz (56.7 grams) of contact loading. The remaining 0.0010 in (0.025 mm) corresponds to 0.6% of film shrinkage. It should be noted that a combination of 4 oz (113.4 grams) of load and approximately 0.4% shrinkage with pitch tolerances is about equivalent. By this procedure, the values of X_T are determined.

2.4 The minimum value of R_2 has been computed for the same X_T and the same accommodation of 0.0018 in (0.046 mm) assuming a parabolic schedule (displacement function proportional to the square of time) of reduction versus time (reference 2). These values of R_2 are set forth in tables 1A and 1B. For exit film paths

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corresponding to larger values of R_1 and R_2, including a straight tangent path, the accommodation of 0.0018 in (0.046 mm) for film slippage takes place in less than 0.026 in (0.66 mm) of the working height (or more accommodation results at the same height). The accommodation takes place more slowly for the exit path defined by minimum values of R_2; therefore, these are recommended where maximum uniformity of motion is desired.

2.5 The desired tooth shape can be generated by a hob corresponding to the basic rack specified by K_H and B_H as tabulated (see table 2 and figure 4). If the first hob covers the range of N from 12 to 24, inclusively, and the second hob the range of N from 25 to 84, inclusively, no deviations in tooth shape greater than 0.00020 in (0.0051 mm) will occur.

2.6 The tooth width at the base, dimension W, allows ample material for rounding off the tip while preserving the 0.026 in (0.66 mm) 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 9¼ pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0.8%.

2.7 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 width, L, may be increased to 0.0355 in + 0 in – 0.0005 in (0.902 mm + 0 mm – 0.013 mm) 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, nominally 0.005 in (0.13 mm).

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

2.9 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 4, 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 0.026 in (0.66 mm) above the root circle.

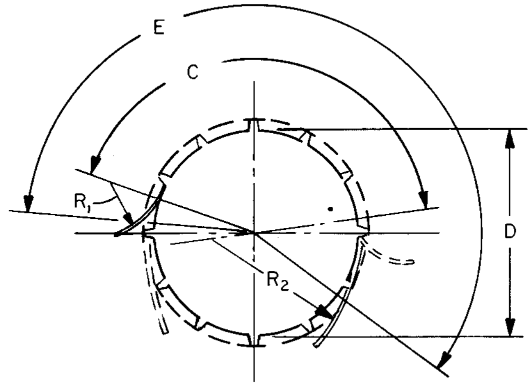


Figure 1 – Sprocket/film relationship

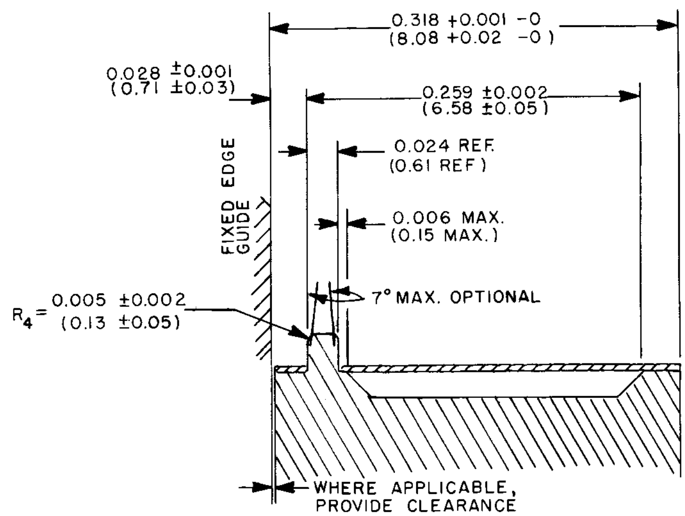
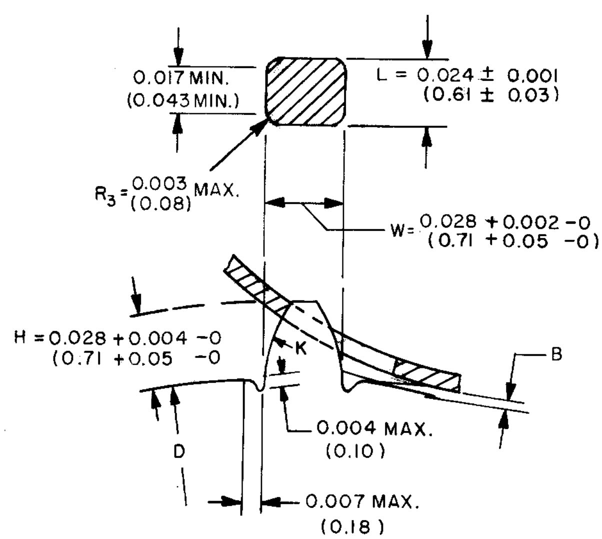


Figure 2 – Sprocket drum profile



Dimensions in inches;
millimeters in parentheses.

Figure 3 – Sprocket drum side profile

Table 1A – Sprocket dimensions, inch specifications

	Root diameter, D						
N	DD	DC	DH	K	B	R_2	X_T
12	0.6307	0.6288	0.6258	0.0598	0.0018	0.4954	0.00968
13	0.6838	0.6817	0.6784	0.0620	0.0022	0.5267	0.00947
14	0.7369	0.7346	0.7311	0.0640	0.0026	0.5583	0.00930
15	0.7899	0.7875	0.7837	0.0659	0.0030	0.5900	0.00914
16	0.8430	0.8404	0.8364	0.0678	0.0034	0.6220	0.00901
17	0.8961	0.8934	0.8890	0.0696	0.0038	0.6540	0.00888
18	0.9491	0.9463	0.9417	0.0714	0.0041	0.6862	0.00878
19	1.0022	0.9992	0.9943	0.0731	0.0045	0.7185	0.00868
20	1.0552	1.0521	1.0470	0.0747	0.0049	0.7509	0.00859
21	1.1083	1.1050	1.0996	0.0764	0.0052	0.7835	0.00851
22	1.1614	1.1579	1.1523	0.0780	0.0056	0.8161	0.00843
23	1.2144	1.2108	1.2049	0.0795	0.0059	0.8488	0.00837
24	1.2675	1.2637	1.2576	0.0811	0.0062	0.8815	0.00830
26	1.3736	1.3695	1.3629	0.0840	0.0069	0.9474	0.00819
28	1.4797	1.4753	1.4682	0.0869	0.0075	1.0136	0.00810
30	1.5859	1.5811	1.5735	0.0897	0.0081	1.0802	0.00801
32	1.6920	1.6869	1.6788	0.0924	0.0087	1.1471	0.00794
34	1.7981	1.7927	1.7840	0.0951	0.0094	1.2143	0.00787
36	1.9042	1.8985	1.8893	0.0977	0.0099	1.2819	0.00782
38	2.0104	2.0043	1.9946	0.1003	0.0105	1.3499	0.00776
40	2.1165	2.1101	2.0999	0.1028	0.0111	1.4183	0.00772
42	2.2226	2.2159	2.2052	0.1053	0.0117	1.4870	0.00767
44	2.3287	2.3217	2.3105	0.1077	0.0122	1.5561	0.00763
46	2.4349	2.4275	2.4158	0.1101	0.0128	1.6256	0.00760
48	2.5410	2.5333	2.5211	0.1124	0.0133	1.6954	0.00756
50	2.6471	2.6392	2.6264	0.1148	0.0138	1.7656	0.00753
52	2.7532	2.7450	2.7317	0.1171	0.0144	1.8362	0.00751
54	2.8594	2.8508	2.8370	0.1194	0.0149	1.9072	0.00748
56	2.9655	2.9566	2.9423	0.1216	0.0154	1.9786	0.00746
60	3.1777	3.1682	3.1529	0.1260	0.0165	2.1226	0.00741
64	3.3900	3.3798	3.3635	0.1303	0.0175	2.2682	0.00737
68	3.6022	3.5914	3.5741	0.1346	0.0185	2.4154	0.00734
72	3.8145	3.8030	3.7847	0.1388	0.0194	2.5644	0.00731
76	4.0267	4.0146	3.9953	0.1428	0.0204	2.7150	0.00728
80	4.2390	4.2262	4.2059	0.1469	0.0214	2.8673	0.00726
84	4.4512	4.4379	4.4165	0.1509	0.0223	3.0214	0.00723

N = Number of teeth.
DD = Root diameter, D + 0.001 – 0 of drive sprocket of 0.1667 pitch.
DC = Root diameter, D + 0.001 – 0 of combination sprocket of 0.1662 pitch.
DH = Root diameter, D + 0 – 0.001 of holdback sprocket of 0.1654 pitch.
Film thickness = 0.006. For other thickness: root diameter = N times pitch/π – thickness.
K = Circular arc radius for tooth shape, + 0 – 0.002.
B = Radial distance of arc center inside root circle, + 0.0005 – 0.
R_2 = Minimum radius of film path concave to sprocket.
X_T = Offset of tooth at working height.

Table 1B – Sprocket dimensions, millimeter specifications

N	Root diameter, D DD	DC	DH	K	B	R_2	X_T
12	16.021	15.972	15.895	1.520	0.046	12.583	0.2458
13	17.369	17.316	17.232	1.574	0.056	13.378	0.2406
14	18.717	18.660	18.569	1.625	0.067	14.180	0.2361
15	20.064	20.004	19.907	1.674	0.077	14.987	0.2322
16	21.412	21.347	21.244	1.721	0.086	15.798	0.2288
17	22.760	22.691	22.581	1.768	0.096	16.612	0.2257
18	24.108	24.035	23.919	1.812	0.105	17.430	0.2229
19	25.455	25.379	25.256	1.856	0.114	18.251	0.2204
20	26.803	26.722	26.593	1.898	0.123	19.074	0.2181
21	28.151	28.066	27.930	1.940	0.132	19.900	0.2161
22	29.499	29.410	29.268	1.980	0.141	20.728	0.2142
23	30.847	30.754	30.605	2.020	0.150	21.559	0.2125
24	32.194	32.097	31.942	2.059	0.158	22.391	0.2109
26	34.890	34.785	34.617	2.134	0.175	24.064	0.2081
28	37.586	37.472	37.291	2.208	0.191	25.745	0.2056
30	40.281	40.160	39.966	2.279	0.207	27.436	0.2035
32	42.977	42.847	42.640	2.348	0.222	29.135	0.2017
34	45.672	45.535	45.315	2.416	0.238	30.844	0.2000
36	48.368	48.222	47.989	2.482	0.252	32.562	0.1985
38	51.063	50.910	50.664	2.547	0.267	34.288	0.1972
40	53.759	53.597	53.339	2.611	0.282	36.025	0.1960
42	56.455	56.285	56.013	2.674	0.296	37.770	0.1949
44	59.150	58.972	58.688	2.735	0.310	39.525	0.1939
46	61.846	61.660	61.362	2.796	0.324	41.289	0.1930
48	64.541	64.347	64.037	2.856	0.338	43.063	0.1921
50	67.237	67.035	66.711	2.915	0.352	44.847	0.1914
52	69.932	69.722	69.386	2.974	0.365	46.641	0.1906
54	72.628	72.410	72.060	3.032	0.379	48.444	0.1900
56	75.324	75.097	74.735	3.088	0.392	50.258	0.1894
60	80.715	80.472	80.084	3.201	0.418	53.915	0.1882
64	86.106	85.847	85.433	3.310	0.444	57.613	0.1873
68	91.497	91.222	90.782	3.419	0.469	61.352	0.1864
72	96.888	96.597	96.131	3.525	0.494	65.135	0.1856
76	102.279	101.972	101.480	3.628	0.518	68.961	0.1849
80	107.670	107.347	106.829	3.732	0.543	72.830	0.1843
84	113.061	112.722	112.179	3.832	0.566	76.744	0.1837

N = Number of teeth.
DD = Root diameter, D + 0.025 – 0 of drive sprocket of 4.234 pitch.
DC = Root diameter, D + 0.025 – 0 of combination sprocket of 4.221 pitch.
DH = Root diameter, D + 0 – 0.025 of holdback sprocket of 4.201 pitch.
Film thickness = 0.152. For other thickness: root diameter = N times pitch/π – thickness.
K = Circular arc radius for tooth shape, + 0 – 0.051.
B = Radial distance of arc center inside root circle, + 0.013 – 0.
R_2 = Minimum radius of film path concave to sprocket.
X_T = Offset of tooth at working height.

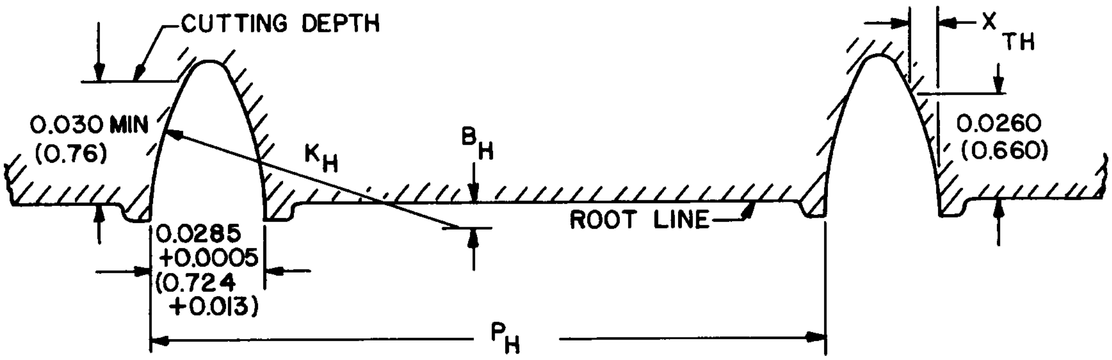


Figure 4 – Basic rack

Table 2 – Basic racks for hobs to make sprockets

Range of teeth	Pitch of rack, P_H ± 0.0001 inch (± 0.0025 mm)		Shape radius, K_H + 0 – 0.001 inch (+ 0 – 0.025 mm)		Distance of center below root, B_H + 0.0002 – 0 inch (+ 0.005 – 0 mm)		Offset at 0.026-inch (0.66-mm) height, X_{TH}	
	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters
12–24	0.1651	4.194	0.0799	2.029	0.0067	0.170	0.00671	0.1704
25–84	0.1662	4.221	0.1327	3.371	0.0200	0.508	0.00671	0.1704

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 0.1667 in (4.234 mm), 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 longer film pitch is the film distortion at the perforation resulting from higher-than-normal force at the contact point of the driving tooth. A classical example is the proven benefit to film life if the root diameter of the 16-tooth intermittent sprocket for 35-mm projectors is increased from 0.9464 in (24.039 mm [corresponding to unshrunk film]) to 0.950 in (24.13 mm). 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. If he desires, 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. An exception to these pitch considerations is the radial-tooth design concept (see reference 1).

A.2 It is intended that the pitch of holdback sprockets shall be equal to or less than the pitch of the film. The shortest film pitch is assumed to be 0.1654 in (4.201 mm), corresponding to 0.8% shrinkage of long pitch film (0.1667 in, 4.234 mm). (This value is chosen rather than the 0.6% used for the tooth shape to avoid inadvertent interference at entering teeth.) The user can again exercise control by correct choice of the root diameter if he believes that a change is warranted. The friction between the film and the root surface assists in holding back and, in addition, the friction against guides also assists.

The tooth shape for a holdback sprocket has little control over the pitch differential accommodation as this occurs rather abruptly near the root of the tooth at the start of disengagement. The tooth shape specified will ensure clearance at the entering position. If a holdback sprocket is to provide good uniformity of motion, in many cases, it may be designed as a drive sprocket with an external guide shoe of the minimum R_2 shape to control the entering film path (see reference 2).

A.3 It is intended that the pitch of combination sprockets, 0.1662 in (4.221 mm), correspond to film with 0.3% shrinkage. This value is chosen closer to the feed sprocket pitch than to the holdback sprocket pitch to avoid the tendency of the film to ride high on the teeth or to be 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. Further information on sprocket design is contained in reference 3.

A.4 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 designed for feeding will serve well for holdback.

The value of R_1, 0.156 in (3.96 mm), was chosen 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 thickness, about 0.012 in (0.30 mm), for the tooth (measured in the direction of film travel) at the working height. A larger value of R_1 would result in more flutter and unsteadiness in case of the R_2 path. 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 slipback 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, the condition for 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 2). Computing the values of R_2 would hardly be possible without an electronic computer since a method of successive approximations must be used. The exiting radius R_2 defines the curve of the tooth face. A carefully modified, epicycloid best fits this ideal curve. It is far simpler to specify and to 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 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 0.0002 in (0.005 mm).

The arc specification is convenient and lends itself to small quantity production of sprockets with a single formed cutter and indexing means. For larger quantity production, 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 denotes an important improvement over the use of the involute. Therefore, further computer studies investigated the use of hobs with circular arc cutting faces 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.

Annex B (informative)
Bibliography

1 Streiffert, J.G. The radial-tooth, variable-pitch sprocket. Journal of the SMPTE 57:529-550; December 1951.

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3 Chandler, J.S.; Lyman, D.F.; and Martin, L.R. Proposals for 16-mm and 8-mm sprocket standards. Journal of the SMPTE 48:483-520; June 1947.