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Cinematography — Sprockets for 8 mm Type S motion-picture film — Dimensions and design

Cinématographie — Tambours dentés pour film cinématographique 8 mm *type S — Dimensions et construction*

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FOREWORD

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Cinematography — Sprockets for 8 mm Type S motion-picture film — Dimensions and design

1 SCOPE AND FIELD OF APPLICATION

This International Standard lays down the dimensions and specifies requirements for the design of sprockets used with 8 mm Type S motion-picture raw stock or processed film.

2 REFERENCE

ISO 1700, *Cinematography — 8 mm Type S motion-picture raw stock film — Cutting and perforating dimensions.*

3 DIMENSIONS AND CHARACTERISTICS

3.1 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.

3.2 The root diameter D is computed from the equation :

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

where

P is the perforation pitch;

N is the number of teeth;

T is the film thickness.

The root diameters in table 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 other thicknesses, table 1B should be recomputed.

3.3 The minimum value of R_1, as depicted in figure 1, has been chosen as 3,96 mm (0.156 in). 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 tooth 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 0,046 mm (0.001 8 in) 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 working height, H, of 0,66 mm (0.026 in) (measured radially from the root circle).

This analysis applies to the feed sprocket, for which the sprocket pitch is generally greater than the perforation 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 root surface is such as to assist the feed or the driving action. Of the total 0,046 mm (0.001 8 in) accommodation provided at each tooth for film slippage, approximately 0,013 mm (0.000 5 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 0,008 mm (0.003 in) is allocated for, and corresponds approximately to, the distortion resulting from 0,58 N (56,7 gf) of contact loading. The remaining 0,25 mm (0.001 0 in) corresponds to 0,6 % of film shrinkage. It should be noted that a combination of 1,16 N (113,4 gf) of load and approximately 0,4 % shrinkage with pitch tolerances is about equivalent. By this procedure the values of X_T are determined. 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.

3.4 The minimum values of R_2 (see figure 1) have been computed for the same X_T and the same accommodation of 0,046 mm (0.001 8 in) assuming a displacement function proportional to the square of time (see annex, reference 2). These values of R_2 are set out in tables 1A and 1B. For the exit film paths corresponding to larger values of R_1 or R_2 including a straight tangent path, the accommodation of 0,046 mm (0.001 8 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). 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.

3.5 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 3 and figure 4). If the first hob covers the range of N from 12 to 24, inclusively, and the second hob covers the range of N from 25 to 84, inclusively, no deviations in tooth shape from the ideal greater than 0,003 05 mm (0.000 12 in) will occur.

3.6 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) working height. In some instances some additional height is available. 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 of 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 9 1/4 pitch lengths without producing interference at the entering teeth of a drive sprocket if the film shrinkage does not exceed 0,8 %.

3.7 The lateral profile of the sprocket 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 is urged against the guide by a spring or other means, the lateral dimensions *L* of the tooth can be increased. If the sprocket teeth are to perform the function of side guiding, then their lateral dimension *L* may be increased to

$$0{,}902\,^{0}_{-0{,}013}\ \text{mm}\ (0.035\,5\,^{0}_{-0.000\,5}\ \text{in})$$

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, nominally 0,13 mm (0.005 in).

3.8 In order for the film guides to function properly, the sprocket eccentricity as mounted in operation should not exceed 0,025 mm (0.001 0 in) and the lateral weave or wobble measured at the root circle should not exceed 0,025 mm (0.001 0 in). Less eccentricity may be required for a special application such as a sound printer sprocket.

3.9 In some cases of large-scale layouts or critical comparisons, it may be more convenient to work with values of X_T than values of *B*.

NOTE — The inch dimensions in this International Standard have been converted from the specified metric dimensions, but have not been carried out to two more places as specified in ISO 370. They do, however, reflect the engineering practice in the countries using the Imperial system of units.

TABLE 1A — **Sprocket dimensions, in millimetres**

N	D_d	D_c	D_h	K	B	R_2	X_T
12	16,021	15,971	15,895	1,520	0,047	12,584	0,246 0
13	17,363	17,316	17,232	1,574	0,057	13,381	0,240 8
14	18,716	18,658	18,569	1,625	0,067	14,184	0,236 3
15	20,064	20,002	19,906	1,674	0,078	14,988	0,232 4
16	21,412	21,345	21,244	1,722	0,087	15,803	0,228 9
17	22,759	22,689	22,581	1,768	0,097	16,619	0,225 8
18	24,107	24,033	23,918	1,813	0,106	17,431	0,223 1
19	25,455	25,376	25,255	1,856	0,116	18,253	0,220 6
20	26,802	26,720	26,592	1,899	0,124	19,082	0,218 3
21	28,150	28,063	27,930	1,940	0,133	19,903	0,216 3
22	29,498	29,407	29,267	1,981	0,142	20,735	0,214 4
23	30,846	30,750	30,604	2,020	0,151	21,564	0,212 7
24	32,193	32,084	31,941	2,059	0,159	22,400	0,211 1
26	34,889	34,781	34,616	2,135	0,176	24,072	0,208 3
28	37,584	37,468	37,290	2,208	0,192	25,763	0,205 8
30	40,280	40,156	39,965	2,280	0,208	27,453	0,203 7
32	42,975	42,843	42,639	2,349	0,224	29,159	0,201 8
34	45,671	45,530	45,313	2,417	0,239	30,862	0,200 2
36	48,366	48,217	47,988	2,483	0,254	32,585	0,198 7
38	51,062	50,904	50,662	2,549	0,269	34,326	0,197 3
40	53,757	53,591	53,337	2,613	0,283	36,065	0,196 1
42	56,452	56,279	56,011	2,675	0,298	37,798	0,195 1
44	59,148	58,966	58,686	2,737	0,312	39,557	0,194 1
46	61,843	61,653	61,360	2,798	0,326	41,341	0,193 1
48	64,539	64,340	64,035	2,858	0,340	43,112	0,192 2
50	67,234	67,027	66,709	2,918	0,353	44,905	0,191 5
52	69,930	69,714	69,383	2,976	0,367	46,700	0,190 8
54	72,625	72,402	72,058	3,033	0,381	48,494	0,190 2
56	75,321	75,089	74,732	3,091	0,394	50,330	0,189 4
60	80,711	80,463	80,081	3,204	0,420	53,993	0,188 4
64	86,102	85,838	85,430	3,314	0,446	57,707	0,187 4
68	91,493	91,212	90,779	3,422	0,471	61,439	0,186 6
72	96,884	96,586	96,128	3,528	0,496	65,241	0,185 8
76	102,275	101,961	101,477	3,633	0,521	69,081	0,185 1
80	107,666	107,335	106,826	3,735	0,545	72,955	0,184 5
84	113,057	112,709	112,174	3,837	0,569	76,895	0,183 9

N = Number of teeth

D_d = Root diameter, $D\ ^{+0,03}_{\ \ 0}$ of drive sprocket of 4,234 pitch

D_c = Root diameter, $D\ ^{+0,03}_{\ \ 0}$ of combination sprocket of 4,221 pitch

D_h = Root diameter, $D\ ^{\ \ 0}_{-0,03}$ of hold-back sprocket of 4,201 pitch

Film thickness = 0,152. For other thicknesses :

$$\text{Root diameter} = N \times \frac{\text{pitch}}{\pi} - \text{thickness}$$

K = Circular arc radius for tooth shape, $^{\ \ 0}_{-0,05}$

B = Radial distance of arc centre inside root circle, $^{+0,013}_{\ \ 0}$

R_2 = Minimum radius of film path concave to sprocket

X_T = Offset of tooth at working height

Tooth working height, H = 0,660
Maximum pitch difference = 0,046
Minimum film path radius convex to sprocket, R_1 = 3,962

Numerical values in millimetres.

TABLE 1B — **Sprocket dimensions, in inches**

N	D_d	D_c	D_h	K	B	R_2	X_T
12	0.630 7	0.628 8	0.625 8	0.059 8	0.001 9	0.495 4	0.009 69
13	0.683 8	0.681 7	0.678 4	0.062 0	0.002 2	0.526 8	0.009 48
14	0.736 9	0.734 6	0.731 1	0.064 0	0.002 6	0.558 4	0.009 30
15	0.789 9	0.787 5	0.783 7	0.065 9	0.003 1	0.590 1	0.009 15
16	0.843 0	0.840 4	0.836 4	0.067 8	0.003 4	0.622 2	0.009 01
17	0.896 0	0.893 3	0.889 0	0.069 6	0.003 8	0.654 3	0.008 89
18	0.949 1	0.946 2	0.941 7	0.071 4	0.004 2	0.686 3	0.008 78
19	1.002 2	0.999 1	0.994 3	0.073 1	0.004 6	0.718 6	0.008 69
20	1.055 2	1.052 0	1.046 9	0.074 8	0.004 9	0.751 3	0.008 59
21	1.108 3	1.104 8	1.099 6	0.076 4	0.005 2	0.783 6	0.008 52
22	1.161 3	1.157 8	1.152 2	0.078 0	0.005 6	0.816 3	0.008 44
23	1.214 4	1.210 6	1.204 9	0.079 5	0.005 9	0.849 0	0.008 37
24	1.267 4	1.263 5	1.257 5	0.081 1	0.006 3	0.881 9	0.008 31
26	1.373 6	1.369 3	1.362 8	0.084 1	0.006 9	0.947 7	0.008 20
28	1.479 7	1.475 1	1.468 1	0.086 9	0.007 6	1.014 3	0.008 10
30	1.585 8	1.580 9	1.573 4	0.089 8	0.008 2	1.080 8	0.008 02
32	1.691 9	1.686 7	1.678 7	0.092 5	0.008 8	1.148 0	0.007 94
34	1.798 1	1.792 5	1.784 0	0.095 2	0.009 4	1.215 0	0.007 88
36	1.904 2	1.898 3	1.889 3	0.097 8	0.010 0	1.282 9	0.007 82
38	2.010 3	2.004 1	1.994 6	0.100 4	0.010 6	1.351 4	0.007 77
40	2.116 4	2.109 9	2.099 9	0.102 9	0.011 1	1.419 9	0.007 72
42	2.222 5	2.215 7	2.205 2	0.105 3	0.011 7	1.488 1	0.007 68
44	2.328 7	2.321 5	2.310 5	0.107 8	0.012 3	1.557 4	0.007 64
46	2.434 8	2.427 3	2.415 7	0.110 2	0.012 8	1.627 6	0.007 60
48	2.540 9	2.533 1	2.521 1	0.112 5	0.013 4	1.697 3	0.007 57
50	2.647 0	2.638 9	2.626 3	0.114 9	0.013 9	1.767 9	0.007 54
52	2.753 1	2.744 6	2.731 6	0.117 2	0.014 4	1.838 6	0.007 51
54	2.859 3	2.850 5	2.836 9	0.119 4	0.015 0	1.909 2	0.007 49
56	2.965 4	2.956 3	2.942 2	0.121 7	0.015 5	1.981 5	0.007 46
60	3.177 6	3.167 8	3.152 8	0.126 1	0.016 5	2.125 7	0.007 42
64	3.389 8	3.379 4	3.363 4	0.130 5	0.017 6	2.271 9	0.007 38
68	3.602 1	3.591 0	3.574 0	0.134 7	0.018 5	2.418 9	0.007 35
72	3.814 3	3.802 6	3.784 6	0.138 9	0.019 5	2.568 5	0.007 31
76	4.026 6	4.014 2	3.995 2	0.143 0	0.020 5	2.719 7	0.007 29
80	4.238 8	4.225 8	4.205 7	0.147 0	0.021 5	2.872 2	0.007 26
84	4.451 1	4.437 4	4.416 3	0.151 1	0.022 4	3.027 4	0.007 24

N = Number of teeth

D_d = Root diameter, $D^{+0.001}_{0}$ of drive sprocket of 0.166 7 pitch

D_c = Root diameter, $D^{+0.001}_{0}$ of combination sprocket of 0.166 2 pitch

D_h = Root diameter, $D^{0}_{-0.001}$ of hold-back sprocket of 0.165 4 pitch

Film thickness = 0.006 0. For other thicknesses :

$$\text{Root diameter} = N \times \frac{\text{pitch}}{\pi} - \text{thickness}$$

K = circular arc radius for tooth shape, $^{0}_{-0.002}$

B = Radial distance of centre arc of inside root circle, $^{+0.000\,5}_{0}$

R_2 = Minimum radius of film path concave to sprocket

X_T = Offset of tooth at working height

Tooth working height, H = 0.026 0
Maximum pitch difference = 0.001 8
Minimum film path radius convex to sprocket, R_1 = 0.156 0

Numerical values in inches.

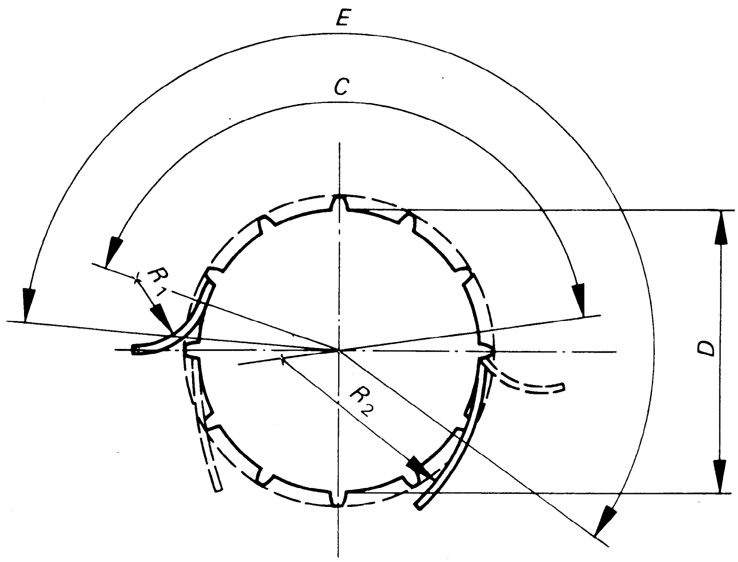

FIGURE 1 – **Sprocket/film relationship**

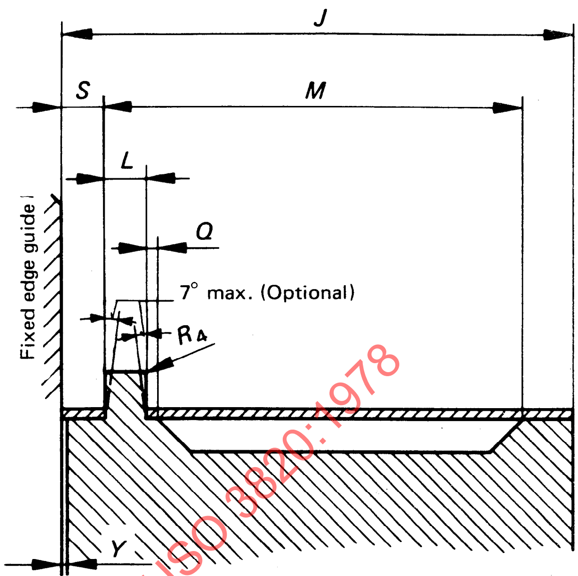

FIGURE 2 – **Sprocket drum profile**

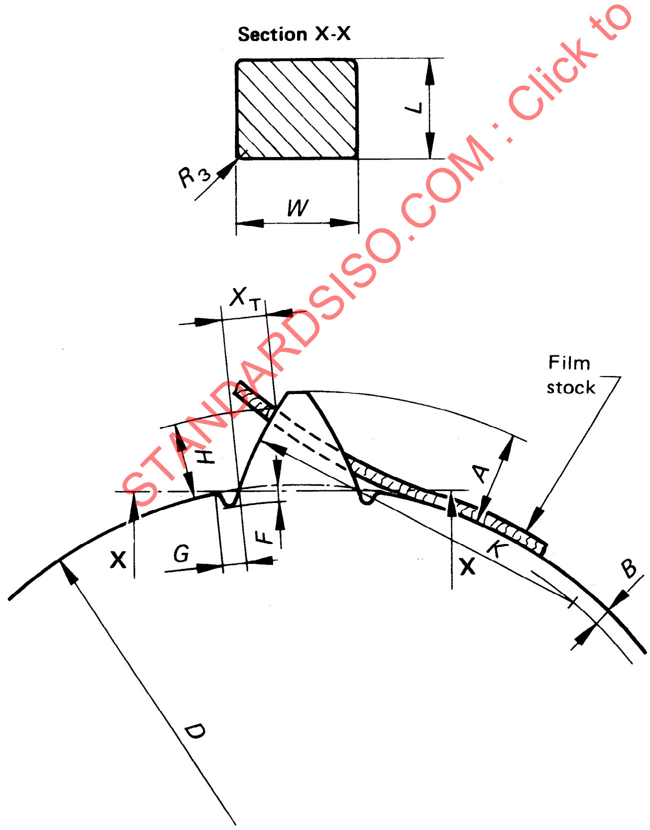

FIGURE 3 – **Sprocket tooth side profile**

TABLE 2 – **Dimensions**

Dimension	mm	in
A	$0,71^{+0,10}_{0}$	$0.028^{+0.004}_{0}$
B	See tables 1A and 1B	
C	See 3.6	
D	See tables 1A and 1B	
E	See 3.6	
F max.	0,10	0.004
G max.	0,18	0.007
H	0,66	0.026
K	See tables 1A and 1B	
J	$8,08^{+0,03}_{0}$	$0.318^{+0.001}_{0}$
L	0,61 ± 0,03	0.024 ± 0.001
M	6,58 ± 0,05	0.259 ± 0.002
Q max.	0,15	0.006
R_1	See 3.3	
R_2	See tables 1A and 1B	
R_3 max.	0,08	0.003
R_4	0,13 ± 0,05	0.005 ± 0.002
S	0,71 ± 0,03	0.028 ± 0.001
W	$0,71^{+0,05}_{0}$	$0.028^{+0.002}_{0}$
Y (where applicable)	Provide clearance	

Dimensions in millimetres
(Inch values in parentheses)

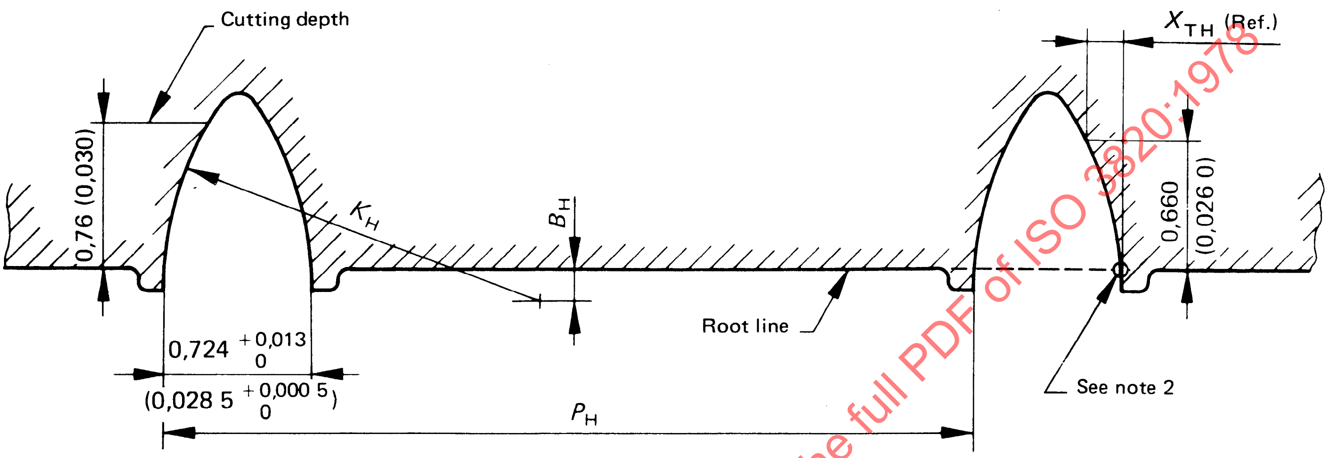

FIGURE 4 — **Basic rack**

TABLE 3 — **Basic racks for hobs to make sprockets**

Range of teeth	**Pitch of rack, P_H** ± 0,002 5 mm (± 0.000 1 in)		**Tooth shape radius, K_H** $^{0}_{-0,025}$ mm ($^{0}_{-0.001}$ in)		**Distance of centre below root, B_H** $^{+0,005}_{0}$ mm ($^{+0.000\ 2}_{0}$ in)		**Reference dimension — Offset at 0,66 mm (0.026 in) height, X_{TH}**	
	mm	in	mm	in	mm	in	mm	in
12 to 24	4,194	0.165 1	2,028	0.079 9	0,169	0.006 7	0,170 3	0.006 71
25 to 84	4,221	0.166 2	3,371	0.132 7	0,507	0.020 0	0,170 3	0.006 71

NOTES

1 For some purposes the stated ranges of hobs may be extended in the numbers of teeth specified. However, for more critical uses such as for low flutter or good picture steadiness, the stated ranges should be observed together with suggested film paths.

2 Dimension X_{TH} applies only to the root line of the rack and not to the base.

ANNEX

ADDITIONAL INFORMATION ON SPROCKET DESIGN

A.1 It is intended that the pitch of feed sprockets should always be equal to or greater than the pitch of the film. The longest film pitch was assumed to be 4,234 mm (0.166 7 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 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 24,039 mm (0.946 4 in) (corresponding to unshrunk film) to 24,130 mm (0.950 0 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. 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 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.[1)]

A.2 It is intended that the pitch of holdback sprockets should be equal to or less than the pitch of the film. The shortest film pitch is assumed to be 4,201 mm (0.165 4 in), corresponding to 0,8 % shrinkage of long pitch film 4,234 mm (0.166 7 in). (This value is chosen rather than the 0,6 % used for the tooth shape to avoid inadvertent interference at entering teeth.) The user again exercises 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.[2)]

A.3 It is intended that the pitch of combination sprockets, 4,221 mm (0.166 2 in), 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.

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 equally well for holdback.

The value of R_1 of 3,962 mm (0.156 in) [or 4,763 mm (0.187 5 in) for 16 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 tooth width at the working height, about 0,3 mm (0.012 in). 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

1) "The radial-tooth variable-pitch sprocket," by J.G. Streiffert, *Journal of the Society of motion picture and television engineers,* December 1951.

2) "Some theoretical considerations in the design of sprockets for continuous film movement," by J.S. Chandler, *Journal of the Society of motion picture and television engineers*, August 1941.