trial microwave and cable interconnects, as well as the installation planning of the system; the augmentation of the PBS Technical Center facilities to provide multichannel operation necessitated by the requirement to originate programs to four transponders on the satellite; the design of the computer-controlled switching system to be employed by the Technical Center; and the operation and maintenance aspects of the system, including personnel training, documentation, and repair and system operations. In the afternoon, Topic Chairman for Equipment and Delivery Systems Robert Tenten, Home Box Office, reports his session will include, among other subjects, future satellite systems and remote control of satellite earth stations.

Don Donigi of Du Art Film Laboratories, Harold Freedman of Technicolor, Inc., and Frank Giovannell of Bebell Bebell are all topic chairmen for Laboratory Practices, which will run from Tuesday morning until Wednesday noon. These sessions, which are concurrent with television sessions, will include papers on advancement in chemical technology, engineering and operation of new equipment, and special techniques in handling original camera material, as well as many other subjects of a technical nature, including a system for edge numbering.

Digital Television Topic Chairman, Frederick M. Remley of the University of Michigan will have paper presentations on digital video recorders, frame stores and memory, analog-to-digital and digital-to-analog converters, methods of measuring distortion, digital time-base correctors and digital audio.

Film Production Chairman Dick DiBona of General Camera will include as part of his session Panavision's approach to film production, which will include a demonstration, films, and paper presentation.

Laser beam recording, a telecine projector, tape-to-film and film-to-tape will be some of the topics to be covered on Wednesday afternoon in Richard Marcus' session on Transfers. Also included will be papers on some of the latest technology in this art from leading companies currently engaged in this exciting industry.

The newest techniques in video production, an electronic graphic system used at the Super Bowl and other sporting events, a portable videocassette recorder for ENG and continuous motion color film telecine using CCD line sensors will be a few of the topics covered in the Thursday morning Video Production Session, according to Video Production Chairman Robert McAll, Vital Industries.

For Thursday morning, Topic Chairmen for Theatrical Sound Norman Prisament of Magna-Tech Electronic Co., Inc. and Ralph Friedman of Magno Sound are planning a program that will encompass all aspects of this subject. A new optical sound recording channel, stereo theater sound and automated sound effects retrieval are some of the topics included.

In the afternoon, Topic Chairmen for Television Sound Mark Schubin of Lincoln Center for the Performing Arts, Bob Lifton of Regent Sound Studios Inc., and James Townsend of WGBH-TV in Boston will have paper presentations including the following topics: digital audio; an inexpensive method of stereo simulcasting; a method of television sound dynamic range enhancement; current information on DATE, a four-channel hi-fidelity sound system for television network transmission; an update on stereo simulcasting.

Special Effects and Editing, concurrent with Television Sound on Thursday afternoon, will round out this exciting and informative program on *Imagery — Today/Tomorrow* for all SMPTE attendees.

Friday is being held open for any SMPTE committee meetings, to enable everyone to attend the sessions during the week.

Standards & Recommended Practices

Approved American National Standard

On 2 May 1978 the American National Standards Institute approved an American National Standard in the video tape recording field, C98.1-1978, Dimensions of 2-in Video Magnetic Recording Tape, which is a revision of ANSI C98.1-1963.

Inasmuch as compliance with American National Standards is purely voluntary, the standard will become truly effective when broad publicity is given to its existence. The Institute and the Society would appreciate any personal influence to promote its use where such action is appropriate. Copies of the standard may be obtained for a nominal fee from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

Approved SMPTE Recommended Practices

The Executive Committee for Standards Approval, acting on behalf of the Board of Governors, approved two SMPTE Recommended Practices on 4 August 1977: RP 75-1977, Specifications for Flutter Test Film for 35-mm Three-Track Sound Reproducers, Magnetic Type, and RP 76-1977, Specifications for Flutter Test Film for 16-mm Sound Reproducers, Magnetic Type. Both are transformations of withdrawn American National Standards; RP 75 replaces ANSI PH22.98-1963 and RP 76 replaces ANSI PH22.113-1966. Practices are available from Society Headquarters for $1.50 each.

Approved International Standard

The International Organization for Standardization (ISO) recently approved an International Standard, the technical content of which is published here for your information. ISO 3820-1978, Cinematography — Sprockets for 8-mm Type S Motion-Picture Film — Dimensions and Design, does not have a comparable American National Standard but is in accord with SMPTE Recommended Practice on 8-mm Type S (Super 8) Sprocket Design, RP 55-1974.

This material is reproduced with permission from the ISO and is copyrighted by the American National Standards Institute, 1430 Broadway, New York, NY 10018, from which complete copies are available.

Reaffirmed American National Standards

The American National Standards Institute approved reaffirmation of two American National Standards on 2 May 1978: PH22.83-1972, Specifications for Location and Spacing of Edge Numbers on 16-mm Motion-Picture Film, and PH22.148-1967, Specifications for Film Image Area Used for Review Room Viewing of 35-mm and 16-mm Motion-Picture Prints Intended for Television Transmission. — Alex E. Alden, *Manager of Engineering Services.*

ANSI C98.1-1978
Revision of C98.1-1963

American National Standard dimensions of 2-in video magnetic recording tape

Approved May 2, 1978
Secretariat: Society of Motion Picture and Television Engineers

1. Scope

This standard specifies the dimensions for the width, thickness and curvature of 2-in video magnetic recording tape.

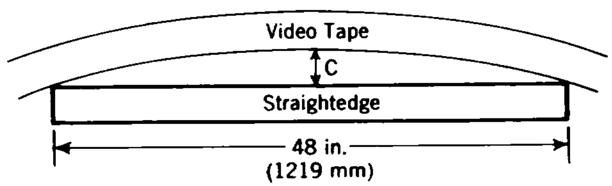
2. Dimensions

2.1 Width. The width of the tape shall be 2.0000 + 0 — 0.0025 in (50.800 + 0 — 0.064 mm).

2.2 Thickness. The combined thickness of the base and magnetic material coating shall not exceed 0.0015 in (0.038 mm).

3. Curvature

3.1 Specification. The curvature of the tape shall not exceed 0.0625 in (1.588 mm) in 48 in (1219 mm).



3.2 Measurement. Curvature shall be measured by constraining the tape to lie in a plane under zero tension and by positioning a 48 in (1219 mm) long straightedge, as shown in the figure. The maximum deviation, C, of the tape edge from the straightedge shall be taken as the curvature.

SMPTE RECOMMENDED PRACTICE

RP 76–1977

Specifications for Flutter Test Film for 16-mm Sound Reproducers, Magnetic Type

1. *Scope*

This practice specifies a test film for determining the presence of flutter in 16-mm motion-picture magnetic sound reproducers operating at 36 ft (11 m) per minute.

2. *Test Film Signal*

2.1 Frequency. The sound record on the film shall be an original recording which will reproduce at a frequency of 3150 ± 25 Hz when the linear speed of the film is 24 perforations per second or approximately 36 ft per minute (7 in or 18 cm per second).

2.2 Distortion. The total harmonic distortion of the recorded signal 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 Position, Dimensions and Reproducing Speed of 200-Mil Magnetic Sound Record on 16-mm Motion-Picture Film, PH22.97-1975. The sound record may also be recorded so that it extends from one edge of the film to the other.

2.4 Recorded Level. The recorded signal shall have a recorded level of 6.0 ± 1.5 dB below the reference level of a frequency of 1000 Hz having an rms short circuit flux per unit track width of 200 nanowebers per meter (0 dB). 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, ANSI/IEEE Std 193-1971.

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

3. *Film Stock*

3.1 The film stock shall be full-coat, splice-free and of the low-shrinkage, safety type in compliance with American National Standard Specifications for Motion-Picture Safety Film, PH22.31-1967 (R1973).

3.2 Test films made on triacetate base shall be 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.

3.3 Test films made on polyester base shall be perforated in accordance with short-pitch dimensions specified in ANSI PH22.109-1974.

3.4 The film stock shall be conditioned for 10 days at 20°C ± 3° (68°F ± 5.4°) at a relative humidity of 50 ± 10 percent prior to recording.

3.5 The film shall be recorded and packaged within the temperature and humidity limits specified in Sec. 3.4. The recorded film shall be packaged in a metal can and sealed either with a low-moisture permeability plastic tape or a fabric tape having a moisture barrier.

4. *Identification*

Each test film shall be identified by a suitable identification marking.

5. *Calibration*

5.1 Flux. The short circuit flux on the test film shall be determined by means of the calibrated short-gap ferromagnetic core reproducer technique. This technique is described in American National Standard Method of Measuring Recorded Flux of Magnetic Sound Records at Medium Wavelengths, ANSI/IEEE Std 317-1972.

5.2 Level. The signal level specified in Sec. 2.4 shall be measured with a standard volume indicator conforming to American National Standard Volume Measurements of Electrical Speech and Program Waves, ANSI/IEEE Std 152-1953 (R1976).

NOTE: A test film made in accordance with this practice is available from the Society of Motion Picture and Television Engineers.

Approved 4 August 1977

SMPTE RECOMMENDED PRACTICE **RP 75–1977**

Specifications for Flutter Test Film for 35-mm Three-Track Sound Reproducers, Magnetic Type

1. *Scope*

This practice specifies a test film for determining the presence of flutter in 35-mm motion-picture magnetic sound reproducers operating at 90 ft (27 m) per minute and designed for three 0.200-in (5.08-mm) sound records.

2. *Test Film Signal*

2.1 Frequency. The sound record on each of the three tracks shall be an original recording which will reproduce at a frequency of 3150 ± 25 Hz when the linear speed of the film is 96 perforations per second or approximately 90 ft per minute (18 in or 46 cm per second).

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 Position, Dimensions and Reproducing Speed of Three 200-Mil Magnetic Sound Records on 35-mm and One Record on 17½-mm Motion-Picture Film, PH22.86-1975. The sound record may also be recorded so that it extends from one edge of the film to the other.

2.4 Recorded Level. The recorded signal shall have a recorded level of 6.0 ± 1.5 dB below the reference level of a frequency of 1000 Hz having an rms short circuit flux per unit track width of 200 nanowebers per meter (0 dB). 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 ± 0.04 percent when measured in accordance with American National Standard Method for Measurement of Weighted Peak Flutter of Sound Recording and Reproducing Equipment. ANSI/IEEE Std 193-1971.

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

2.7 Signal Phase. The recorded signal in each of the three records shall be in an in-phase relationship to the other two. A recording made as described in the Appendix is considered to be in phase.

3. *Film Stock*

3.1 The film stock shall be full-coat, splice-free and of the low-shrinkage, safety type in compliance with American National Standard Specifications for Motion-Picture Safety Film, PH22.31-1967 (R1973).

3.2 The difference in compliance between triacetate and polyester bases will establish different head wear patterns. A change from one base to the other may cause a temporary loss of high-frequency response until a new wear pattern is established. Therefore, it is recommended that users employ test films having the same film base as used in production recording for any given recorder/reproducer.

3.2.1 Test films made on triacetate base shall be 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.

3.2.2 Test films made on polyester base shall be perforated in accordance with short-pitch dimensions specified in ANSI PH22.139-1974.

3.3 The film stock shall be conditioned for 10 days at 20°C ± 3° (68°F ± 5.4°) at a relative humidity of 50 ± 10 percent prior to recording.

3.4 The film shall be recorded and packaged within the temperature and humidity limits specified in Sec. 3.3. The recorded film shall be packaged in a metal can and sealed either with a low-moisture permeability plastic tape or a fabric tape having a moisture barrier.

4. *Identification*

Each test film shall be identified by a suitable identification marking.

Approved 4 August 1977

5. *Calibration*

5.1 Flux. The short circuit flux on the test film shall be determined by means of the calibrated short-gap ferromagnetic core reproducer technique. This technique is described in American National Standard Method of Measuring Recorded Flux of Magnetic Sound Records at Medium Wavelengths. ANSI/IEEE Std 347-1972.

5.2 Level. The signal level specified in Sec. 2.4 shall be measured with a standard volume indicator conforming to American National Standard Volume Measurements of Electrical Speech and Program Waves, ANSI/IEEE Std 152-1953 (R1976).

NOTE: A test film made in accordance with this practice is available from the Society of Motion Picture and Television Engineers.

Appendix

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

In-phase relationship of the sound records, as printed by a multiple-head recorder, can be ensured if the individual coils of the recording head are similar and are assembled in the same manner.

The relationship is accomplished by connecting the winding in series so that the end of each coil is connected to the beginning of the next coil maintaining a consistent direction of winding.

The relationship is also accomplished in a parallel-type connection if the corresponding beginning leads are connected together and the corresponding ending leads are connected together and the direction of winding of each coil is kept consistent with other coils.

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.

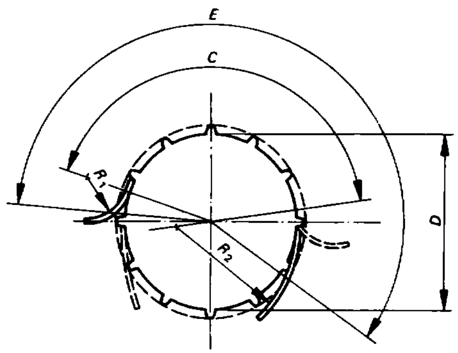


FIGURE 1 – Sprocket/film relationship

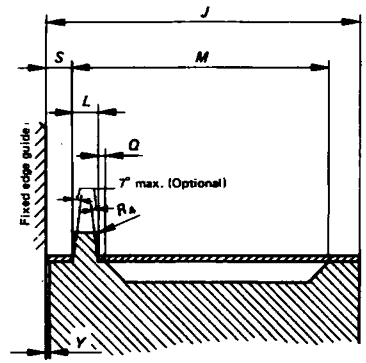


FIGURE 2 – Sprocket drum profile

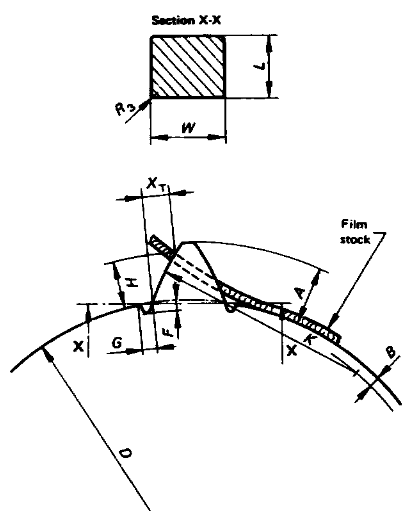


FIGURE 3 – Sprocket tooth side profile

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	

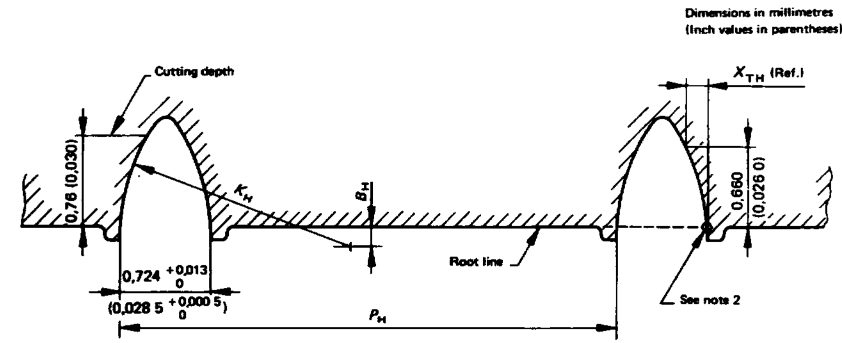


FIGURE 4 – Basic rack

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)		Teeth 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.

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 3.3) as well as the relative paths taken by the base and tip of the sprocket tooth and by the film were used in the computations of X_T. When X_T is 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. Also, 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 backslip 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 life of the film. 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 the 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 centre 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 centre 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 of the order of 0,005 mm (0.000 2 in).

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 productions 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 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 to 24 teeth, and the second, 25 to 84 teeth. It was found that the maximum errors along the entire tooth height compared with 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.