INTERNATIONAL STANDARD

ISO 11314

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Photography — Projectors — Image size/projection distance calculations

Photographie — Projecteurs — Calcul du rapport dimension de l'image/distance de projection

Reference number
ISO 11314:1995(E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11314 was prepared by Technical Committee ISO/TC 42, *Photography*.

Annexes A, B, C and D of this International Standard are for information only.

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Photography — Projectors — Image size/projection distance calculations

1 Scope

This International Standard specifies a method of calculating the expected size of the projected image from any type of projector given the focal length of the projection lens and the projection distance.

It also specifies a method of calculating the expected projection distance given the focal length of the projection lens and the dimensions of the required projected image size.

2 Definitions

For the purposes of this International Standard, the following definitions apply.

2.1 projection aperture: Aperture in the projector which controls the dimensions of the object area being projected.

NOTE 1 In an overhead projector, this area is known as the picture area (see ISO 7943-1).

2.2 object plane: That plane in the optical path of the projector which is coincident with the plane of the object for projection, for example film.

2.3 mask aperture: Aperture in a transparency frame or slide mount which limits the area being projected.

3 Symbols

H is the height of the projected image;

h is the height of the mask aperture or of the film projection aperture;

W is the width of the projected image;

w is the width of the mask aperture or of the film projection aperture;

l is the projection distance (last lens surface to screen, see figure C.1);

f is the focal length of the projection lens;

M is the magnification;

D is the projection distance from the object plane to the screen (see annex C);

d is the nodal point separation of the projection lens (see annex C).

NOTE 2 The same dimensional units should be used for H, h, W, w, l, f, d and D.

4 Calculation of size, distance and focal length

4.1 Mathematical relationship

The projection distance, the size of the projection screen and the focal length all have a fixed mathematical relationship to each other, and are determined by the following equation:

$$\frac{H}{h} = \frac{W}{w} = M = \frac{l-f}{f} \quad \ldots (1)$$

4.1.1 The height of the projected image is given by

$$H = \left(\frac{l-f}{f}\right) h \quad \ldots (2)$$

4.1.2 The width of the projected image is given by

$$W = \left(\frac{l-f}{f}\right) w \quad \ldots (3)$$

4.1.3 The projection distance is given by

$$l = \left(\frac{W}{w} + 1\right)f \qquad \ldots (4)$$

4.1.4 The focal length is given by

$$f = \frac{l}{W/w + 1} \qquad \ldots (5)$$

These equations have been used to calculate the approximate values given in tables A.1 to A.3 (annex A).

NOTE 3 The mathematical relationship in clause 4 does not show the exact dimensions for real lenses. The use of equations (2) through (5) will be sufficient for the determination of dimensions in a viewing room.

For exact values, the mathematical equations in annex B should be used.

5 Projectable-image dimensions

5.1 For standard projectable-image dimensions, reference should be made to the particular format of the projector. Relevant International Standards are listed in annex D. However, equipment exists which does not comply with the appropriate International Standard or for which a standard has not been published.

5.2 The equations in clause 4 and the dimensions given in tables A.1 to A.3 are only valid for perpendicular projection onto the screen.

5.3 Sometimes it is the object being projected (e.g. slide, filmstrip or overhead projection transparency) which governs the projectable-image dimensions and this may not comply with some relevant International Standards.

In these cases, it will be necessary to measure accurately the actual projectable-image dimensions in order to ensure that the equations given provide the correct results. Therefore, screen width dimensions for still projection given in table A.1 are based on mask aperture sizes and not on the larger projection aperture sizes.

6 Focal length of projection lens

6.1 For most projection lenses the actual focal length is not precisely that which is printed on the lens housing or given in the specification of the equipment to which it is fitted. This is due to allowable manufacturing tolerances.[1)]

6.2 Inaccurate results may be obtained from calculations when lens focal lengths are not accurate. Allowances need to be made for this when installing equipment and specifying screen sizes. Experimental trials are recommended.

1) Commercial tolerances of ± 5 % of stated focal length are normal.

Annex A
(informative)

Projection tables

A.1 Use of tables

The projection tables are divided into two parts (table A.1, and tables A.2 and A.3).

Values have been calculated according to equation (1), modified as follows:

$$\frac{W}{w} = M = \frac{l-f}{f} \quad \ldots (A.1)$$

Table A.1 describes the relationship

$$M = \frac{W}{w} \quad \ldots (A.2)$$

Tables A.2 and A.3 describe the relationship

$$M = \frac{l-f}{f} \quad \ldots (A.3)$$

M is the connecting link between table A.1 and tables A.2 and A.3.

A.1.1 If W and w are known, use table A.1 and determine M. Then use M in tables A.2 and A.3 to find l or f.

A.1.2 If f and l are known, use tables A.2 and A.3 and determine M. Then use M in table A.1 to find W.

NOTE 4 The height H of the projected image is not included in table A.1. It can be calculated from the picture ratio of the mask aperture, or from the picture ratio of the film projection aperture.

A.2 Examples

A.2.1 Example 1

Question: What is the width of the projected image?

Given conditions are

— a 16 mm projector with a 50 mm projection lens;

— the projection distance is 10 m.

Focal length f and projection distance l are known; using tables A.2 and A.3, the magnification M can be determined.

Therefore

$f = 50$ mm

$l = 10$ m

$M = 199$ (from table A.2)

Then using table A.1

$M = 200$

film width = 16 mm

find film width $W = 1{,}93$ m

Answer: The width of the projected image is 1,93 m.

A.2.2 Example 2

Question: Which lens should be used with the slide projector?

Given conditions are

— a slide projector using 5 cm × 5 cm slides having a mask aperture of 22,5 mm × 34,3 mm is placed next to the 16 mm projector used in Example 1.

— at the same projection distance of 10 m, the projected slides should fill the given screen of width 1,93 m.

The width of the mask aperture, w, and width of the projected image, W, are known; use table A.1 to determine the magnification M.

Therefore

$w = 34{,}3$ mm

$W = 1{,}93$ m (between 1,71 and 2,06 in table A.1)

$M = 55$ (between 50 and 60 in table A.1)

Then using tables A.2 and A.3:

$M = 55$

projection distance = 10 m

find focal length = 181 mm

Answer: A lens with a focal length of 181 mm should be used.

Table A.1 — Screen width W, in metres, in relation to magnification M

	Overhead projection		**Slide projection**					**Motion-picture projection**			
	Picture area (mm)		**Nominal size** (cm)					**Film width**			
	285 × 285	250 × 250	8,5 × 10	8,5 × 8,5	7 × 7	5 × 5	3 × 3	35 mm	16 mm	S8	
	Mask aperture (mm)							**Film projection aperture** (mm)			
	280 × 280 ± 2	247 × 247 ± 2	73 × 88 $^{0}_{-0,5}$	73 × 73 $^{0}_{-0,5}$	53,5 × 53,5 ± 0,7	22,5 × 34,3 ± 0,5	12 × 15,8 ± 0,1	15,29 (max.) 21,11 (nom.)	7,26 (max.) 9,65 (ref.)	4,01 (max.) 5,46 (ref.)	
	280,00	247,00	88,00	73,00	53,50	34,30	15,80	21,11	9,65	5,46	
M	**Width** W (m) **of projected image in relation to magnification** M										M
4	1,12	0,99	0,35	0,29	0,21						4
5	1,40	1,23	0,44	0,36	0,27						5
6	1,68	1,48	0,53	0,44	0,32	0,21					6
7	1,96	1,73	0,62	0,51	0,37	0,24					7
8	2,24	1,98	0,70	0,58	0,43	0,27					8
9	2,52	2,22	0,79	0,66	0,48	0,31					9
10	2,80	2,47	0,88	0,73	0,53	0,34	0,16	0,21			10
12	3,36	2,96	1,06	0,88	0,64	0,41	0,19	0,25			12
15	4,20	3,70	1,32	1,09	0,80	0,51	0,24	0,32			15
18	5,04	4,45	1,58	1,31	0,96	0,62	0,28	0,38			18
20	5,60	4,94	1,76	1,46	1,07	0,69	0,32	0,42	0,19		20
25	7,00	6,17	2,20	1,82	1,34	0,86	0,39	0,53	0,24		25
30	8,40	7,41	2,64	2,19	1,60	1,03	0,47	0,63	0,29		30
35		8,64	3,08	2,55	1,87	1,20	0,55	0,74	0,34	0,19	35
40			3,52	2,92	2,14	1,37	0,63	0,84	0,39	0,22	40
50			4,40	3,65	2,67	1,71	0,79	1,06	0,48	0,27	50
60			5,28	4,38	3,21	2,06	0,95	1,27	0,58	0,33	60
70			6,16	5,11	3,74	2,40	1,11	1,48	0,68	0,38	70
80			7,04	5,84	4,28	2,74	1,26	1,69	0,77	0,44	80
90			7,92	6,57	4,81	3,09	1,42	1,90	0,87	0,49	90
100			8,80	7,30	5,35	3,43	1,58	2,11	0,96	0,55	100
110				8,03	5,88	3,77	1,74	2,32	1,06	0,60	110
120				8,76	6,42	4,12	1,90	2,53	1,16	0,66	120
130					6,95	4,46	2,05	2,74	1,25	0,71	130
140					7,49	4,80	2,21	2,96	1,35	0,76	140
150					8,02	5,14	2,37	3,17	1,45	0,82	150
160					8,56	5,49	2,53	3,38	1,54	0,87	160
170						5,83	2,69	3,59	1,64	0,93	170
180						6,17	2,84	3,80	1,74	0,98	180
190						6,52	3,00	4,01	1,83	1,04	190
200						6,86	3,16	4,22	1,93	1,09	200
210						7,20	3,32	4,43	2,03	1,15	210
220						7,55	3,48	4,64	2,12	1,20	220
230						7,89	3,63	4,86	2,22	1,26	230
240						8,23	3,79	5,07	2,32	1,31	240
250						8,57	3,95	5,28	2,41	1,36	250
260						8,92	4,11	5,49	2,51	1,42	260
270							4,27	5,70	2,61	1,47	270
280							4,42	5,91	2,70	1,53	280
290							4,58	6,12	2,80	1,58	290
300							4,74	6,33	2,89	1,64	300
310							4,90	6,54	2,99	1,69	310
320							5,06	6,76	3,09	1,75	320
330							5,21	6,97	3,18	1,80	330
340							5,37	7,18	3,28	1,86	340
350							5,53	7,39	3,38	1,91	350
360							5,69	7,60	3,47	1,97	360
370							5,85	7,81	3,57	2,02	370
380							6,00	8,02	3,67	2,07	380
390							6,16	8,23	3,76	2,13	390
400							6,32	8,44	3,86	2,18	400

Table A.2 — Magnification M in relation to projection distance l and focal length f (Range of focal length f: 15 mm to 120 mm)

l	f (mm)																									l
m	15	18	20	22	25	28	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	m
1,5	99	82	74	67	59	53	42	37	32	29	26	24	22	20	19	18	17	16	15	14	13	13	12	12	1,5
2	132	110	99	90	79	70	56	49	43	35	35	32	30	28	26	24	23	21	20	19	18	17	16	16	2
2,5	166	138	124	113	99	88	70	62	55	49	44	41	37	35	32	30	28	27	25	24	23	22	21	20	2,5
3	199	166	149	135	119	106	85	74	66	59	54	49	45	42	39	37	34	32	31	29	28	26	25	24	3
3,5	232	193	174	158	139	124	99	87	77	69	63	57	53	49	46	43	40	38	36	34	32	31	29	28	3,5
4	266	221	199	181	159	142	113	99	88	79	72	66	61	56	52	49	46	43	41	39	37	35	34	32	4
4,5	299	249	224	204	179	160	128	112	99	89	81	74	68	63	59	55	52	49	46	44	42	40	38	37	4,5
5	332	277	249	226	199	178	142	124	110	99	90	82	76	70	66	62	58	55	52	49	47	44	42	41	5
6	399	332	299	272	239	213	170	149	132	119	108	99	91	85	79	74	70	66	62	59	56	54	51	49	6
7	466	388	349	317	279	249	199	174	155	139	126	116	107	99	92	87	81	77	73	69	66	63	60	57	7
8		443	399	363	319	285	228	199	177	159	144	132	122	113	106	99	93	88	83	79	75	72	69	66	8
9			449	408	359	320	256	224	199	179	163	149	137	128	119	112	105	99	94	89	85	81	77	74	9
10					399	356	285	249	221	199	181	166	153	142	132	124	117	110	104	99	94	90	86	82	10
12					439	428	342	299	266	239	217	199	184	170	159	149	140	132	125	119	113	108	103	99	12
14							399	349	310	279	254	232	214	199	186	174	164	155	146	139	132	126	121	116	14
16							456	399	355	319	290	266	245	228	212	199	187	177	167	159	151	144	138	132	16
18								449	399	359	326	299	276	256	239	224	211	199	188	179	170	162	156	149	18
20									443	399	363	332	307	285	266	249	234	221	210	199	189	181	173	166	20
22										439	399	366	337	313	292	274	258	243	231	219	209	199	190	182	22
24											435	399	368	342	319	299	281	266	252	239	228	217	208	199	24
26												432	399	370	346	324	305	288	373	259	247	235	225	216	26
28													430	399	372	349	328	310	294	279	266	254	242	232	28
30														428	399	374	352	332	315	299	285	272	260	249	30
32															426	399	375	355	336	319	304	290	277	266	32
34																424	399	377	357	339	323	308	295	282	34
36																	423	399	378	359	342	326	312	299	36
38																		421	399	379	361	344	329	316	38
40																			420	399	380	363	347	332	40

Table A.3 — Magnification M in relation to projection distance l and focal length f (Range of focal length f: 125 mm to 400 mm)

l	f (mm)																											l
m	125	130	135	140	145	150	155	160	165	170	175	180	185	200	220	250	270	290	300	315	340	350	355	400				m
1,5	11	10	10	10	9	9	9	8	8	8	8	7	7	7	6	5	5	4	4	4	3	3	3	3				1,5
2	15	14	14	13	13	12	12	12	11	11	10	10	10	9	8	7	6	6	6	5	5	5	5	4				2
2,5	19	18	18	17	16	16	15	15	14	14	13	13	13	12	10	9	8	8	7	7	6	6	6	5				2,5
3	23	22	21	20	20	19	18	18	17	17	16	16	15	14	13	11	10	9	9	9	8	8	7	7				3
3,5	27	26	25	24	23	22	22	21	20	20	19	18	18	17	15	13	12	11	11	10	9	9	9	8				3,5
4	31	30	29	28	27	26	25	24	23	23	22	21	21	19	17	16	14	13	12	12	11	10	10	9				4
4,5	35	34	32	31	30	29	28	27	26	25	25	24	23	22	19	17	16	15	14	13	12	12	12	10				4,5
5	39	37	36	35	33	32	31	30	29	28	28	27	26	24	22	19	18	16	16	15	14	13	13	12				5
6	47	45	43	42	40	39	38	37	35	34	33	32	31	29	26	23	21	20	19	18	17	16	16	14				6
7	55	53	51	49	47	46	44	43	41	40	39	38	37	34	31	27	25	23	22	21	20	19	19	17				7
8	63	61	58	56	54	52	51	49	47	46	45	43	42	39	35	31	29	27	26	24	23	22	22	19				8
9	71	68	66	63	61	59	57	55	54	52	50	49	48	44	40	35	32	30	29	28	25	25	24	22				9
10	79	76	73	70	68	66	64	62	60	58	56	55	53	49	44	39	36	33	32	31	28	28	27	24				10
12	95	91	88	85	82	79	76	74	72	70	68	66	64	59	54	47	43	40	39	37	34	33	33	29				12
14	111	107	103	99	96	92	89	87	84	81	79	77	75	69	63	55	51	47	46	43	40	39	38	34				14
16	127	122	118	113	109	106	102	99	96	93	90	88	85	79	72	63	58	54	52	50	46	45	44	39				16
18	143	137	132	128	123	119	115	112	108	105	102	99	96	89	81	71	66	61	59	56	52	50	50	44				18
20	159	153	147	142	137	132	128	124	120	117	113	110	107	99	90	79	73	68	66	62	58	56	55	49				20
22	175	168	162	156	151	146	141	137	132	128	125	121	118	109	99	87	80	75	72	69	64	62	61	54				22
24	191	184	177	170	165	159	154	149	144	140	136	132	129	119	108	95	88	82	79	75	70	68	67	59				24
26	207	199	192	185	178	172	166	162	157	152	148	143	140	129	117	103	95	89	86	82	75	73	72	64				26
28	223	214	206	199	192	186	179	174	169	164	159	155	150	139	126	111	103	96	92	88	81	79	78	69				28
30	239	230	221	213	206	199	193	187	181	175	170	166	161	149	135	119	110	102	99	94	87	85	84	74				30
32	255	245	236	228	220	212	205	199	193	187	182	177	172	159	144	127	118	109	106	101	93	90	89	79				32
34	271	260	251	242	233	226	218	212	205	199	193	188	183	169	154	135	125	116	112	107	99	96	94	84				34
36	287	276	266	256	247	239	231	224	217	211	205	199	194	179	163	143	132	123	119	113	105	102	100	89				36
38	303	291	280	270	261	252	244	237	229	223	216	211	204	189	172	151	140	130	126	120	111	108	106	94				38
40	319	306	295	285	275	266	257	249	241	234	228	221	215	199	181	159	147	137	132	126	117	113	112	99				40

Annex B
(informative)

Calculations

B.1 Use of the exact equations

B.1.1 Equations (B.1) to (B.6) take the position of the two nodal points of a projection lens system into consideration. In practice the use of equations (B.1) to (B.6) will be important only to the manufacturer of projection equipment. For the determination of screen size and projection distance in a viewing room, the use of equations (2) to (5) will be sufficient, since the position of the nodal point is generally unknown.

B.1.2 Equations (B.1) to (B.6) can be used for all types of projectors. The choice of equations depends on whether the projection distance is to be measured from the object plane to the screen [equations (B.1) to (B.3)] or from the lens secondary (image) nodal point to the screen [equations (B.4) to (B.6)].

B.1.3 In practice, equations (B.1) to (B.3) will be used with projectors where the optical path is straight (e.g. for projection of slides, filmstrips and motion-picture films). Equations (B.4) to (B.6) will be used with projectors where the optical path is folded through the use of a mirror (e.g. overhead projectors and episcopes or opaque projectors).

B.2 Projection distance measured from the object plane

Projection image dimensions are calculated as follows.

The projected-image height is given by

$$H = \left[\frac{2}{1 - \left(1 - \frac{4f}{D-d}\right)^{1/2}} - 1 \right] h \qquad \ldots (B.1)$$

The projected-image width is given by

$$W = \left[\frac{2}{1 - \left(1 - \frac{4f}{D-d}\right)^{1/2}} - 1 \right] w \qquad \ldots (B.2)$$

The projection distance is given by

$$D = f\left(2 + M + \frac{1}{M}\right) + d \qquad \ldots (B.3)$$

where M is the magnification which is defined as

$$\frac{W}{w} \text{ or } \frac{H}{h}$$

B.3 Projection distance measured from lens secondary (image) nodal point

Dimensions of the projected image are calculated as follows.

The height of the projected image is given by

$$H = \left(\frac{T}{f} - 1\right) h \qquad \ldots (B.4)$$

The width of the projected image is given by

$$W = \left(\frac{T}{f} - 1\right) w \qquad \ldots (B.5)$$

The projection distance is given by

$$T = f(1 + M) \qquad \ldots (B.6)$$

where T is the projection distance from the lens secondary (image) nodal point to the screen.

Annex C
(informative)

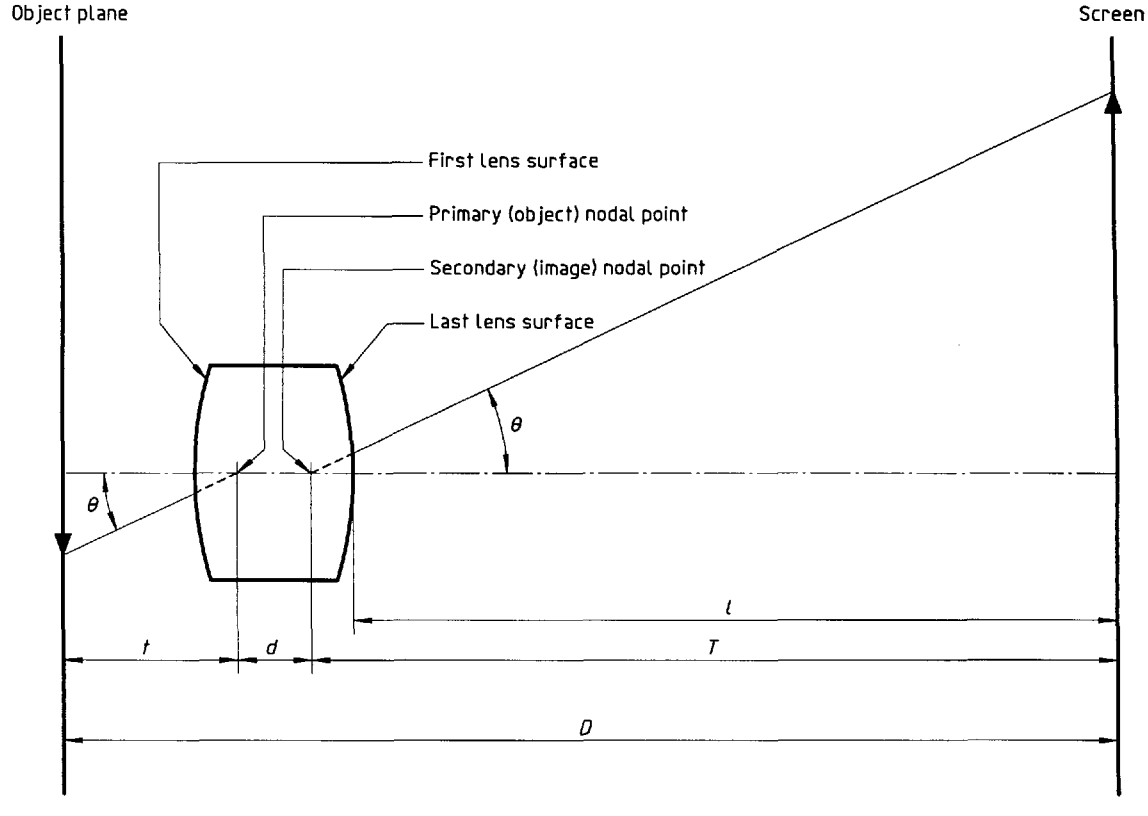
Nodal points and nodal point separation

Many rays pass through a lens from an off-axis point on the objective to a corresponding point on the image. One of these rays from each point on an object enters and leaves the lens on parallel paths.

The point at which the produced (extended) entering ray intersects the optical axis is the primary (image) nodal point.

The point at which the negatively produced exiting ray intersects the optical axis is the secondary (image) nodal point.

The distance between the two nodal points is the nodal point separation, d.



Key

θ is the angle between the optical axis and the rays entering and leaving the lens and passing through the nodal points;
t is the distance from the object plane to the lens primary (image) nodal point;
T is the projection distance from the lens secondary (image) nodal point to the screen;
d is the nodal point separation of the projection lens;
D is the projection distance from the object plane to the screen;
l is the projection distance from the last lens surface to the screen (see 4.1).

Figure C.1 — Positions of nodal points

Annex D
(informative)

Bibliography

[1] ISO 359:1983, *Cinematography — Projectable image area on 16 mm motion-picture prints — Dimensions and location.*

[2] ISO 686:1985, *Photography — 35 mm filmstrips — Specifications for double-frame and single-frame formats.*

[3] ISO 1755:1987, *Photography — Projector slides — Dimensions.*

[4] ISO 2467:1980, *Cinematography — Image area produced by 65 and 70 mm motion-picture camera aperture and maximum projectable image area on 70 mm motion-picture prints — Positions and dimensions.*

[5] ISO 2907:1984, *Cinematography — Maximum projectable image area on 35 mm motion-picture film — Position and dimensions.*

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[7] ISO 7943-1:1987, *Photography — Overhead projectors — Part 1: Projection stages — Dimensions.*

[8] ISO 7943-2:1987, *Photography — Overhead projectors — Part 2: Transparencies and transparency frames — Dimensions.*

[9] ISO 9559:1989, *Photography — 35 mm filmstrip projectors — Specifications for frame masks.*

ICS 37.040.10

Descriptors: photography, motion-picture projectors, slide projectors, overhead projectors, photographic images, projection, distance, rules of calculation, magnification.

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