A METHOD OF CALCULATING
A TABLE OF
RADIOGRAPHIC EXPOSURE FACTORS

By

FRIEL and STURDY

relating to

The UNIQUE Friel-Sturdy Slide Rule

(Patent Pending 29187/45)

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TABLE IV.

Kv.	Log. $Kv^{-4} \times 10^8$	"H" Value	Kv.	Log. $Kv^{-4} \times 10^3$	"H" Value
100	0·000	0·000	69	0·6448	4·414
99	0·0176	1·041	68	0·6700	4·677
98	0·0352	1·084	67	0·6956	4·962
97.	0·0528	1·129	66	0·7220	5·272
96	0·0708	1·177	65	0·7484	5·603
95	0·0892	1·228	64	0·7752	5·960
94	0·1076	1·281	63	0·8028	6·322
93	0·1260	1·337	62	0·8304	6·767
92	0·1448	1·396	61	0·8588	7·224
91	0·1640	1·459	60	0·8872	7·713
90	0·1832	1·525	59	0·9164	8·249
89	0·2024	1·593	58	0·9464	8·839
88	0·2220	1·667	57	0·9764	9·471
87	0·2420	1·746	56	1·0072	10·16
86	0·2620	1·828	55	1·0382	10·91
85	0·2824	1·916	54	1·0704	11·76
84	0·3028	2·008	53	1·1028	12·67
83	0·3236	2·107	52	1·1360	13·68
82	0·3448	2·212	51	1·1696	14·78
81	0·3660	2·323	50	1·2040	16·00
80	0·3876	2·441	49	1·2392	17·35
79	0·4096	2·568	48	1·2752	18·85
78	0·4316	2·533	47	1·3116	20·49
77	0·4540	2·844	46	1·3488	22·32
76	0·4768	2·997	45	1·3872	24·39
75	0·4996	3·159	44	1·4260	26·67
74	0·5232	3·185	43	1·4660	29·24
73	0·5468	3·512	42	1·5072	32·15
72	0·5708	3·722	41	1·5488	35·38
71	0·5948	3·933	40	1·5916	39·04
70	0·6196	4·155			

TABLE V.

SPEED FACTOR VALUES.

	"S"
Dental Film	10
Double-wrapped Film	8
Occlusal Film	8
Plaster (dry)	Double MaS + 5 Kv

A METHOD OF CALCULATING A TABLE OF ADIOGRAPHIC EXPOSURE FACTORS

By

FRIEL, M.S.R. and D. H. STURDY, B.Sc.

THE F diographer knows, estimating the correct exposure d only after considerable experience, and one which e reduced to a set of rules for the benefit of the eed, even the experienced radiographer may find nat at a loss when confronted with a new apparatus, Tperformance, and some little time is necessary to acquire
1. A me t" of it and to judge exposures for use on that particular s, with any confidence. The radiographer will be con-
2. A m with this situation from time to time, where unfamiliar
3. A us has to be utilised. It is doubly important that a reliable od of judging exposures for unknown apparatus is available.
4. A With this end in view, an analysis has been made of the usual thods of judging exposures and of the factors involved. A simple
5. A hod of constructing a table of exposure values for different regions a normal patient has been worked out, which can be applied to any apparatus after a few trial exposures have been made. Such a table can, of course, be kept for future use, and it will apply to any unit having a similar performance. Variations in exposure values according to the size of the patient can be made in the usual way. Moreover, modifications can readily be introduced if it is desired to use a different type of film or intensifying screen, a different anode film distance, or to vary any other factor in a particular instance.

The problem confronting us in determining an exposure for any radiograph is to produce the greatest possible detail, with an adequate degree of contrast and density. This is done by selecting the most suitable values for a number of factors, having regard to the fixed factors with which we are presented.

1.—*The fixed factors are :*

(i) The radiographic efficiency of the apparatus, and
(ii) the absorption which the x-rays undergo in passing through the tissues of the patient, together with any splints, plasters, etc., which may be present.

2.—*The factors which we must select are :*

(i) Anode-film distance.
(ii) Hardness of rays—governed by Kv.
(iii) The speed of the film.
(iv) Use of and type of screens.
(v) Use of stationary grid or P.B.D.
(vi) Intensity of x-rays, governed by Ma.
(vii) Duration of exposure time.

It is not necessary to discuss here the considerations involved in the selection of the first five of these variable factors, as it will be agreed that this presents little difficulty to the experienced radiographer. What constitutes the problem for him is the selection of a suitable value of the M.a.S. to be used, *i.e.* the product of factors (vi) and (vii). This done, it is a simple matter to choose a suitable value for the Ma (if this is variable) and then to calculate the duration of exposure required.

To tackle the problem from first principles involves a consideration of the quantitative effect of all the factors, fixed and variable, upon the density of the resulting radiograph.

A radiographic exposure calculator, in the form of a slide rule has been evolved, which computes exposures taking into consideration all the above mentioned factors.

This article deals with a description of the rule and its applications, while the mathematical proof of each application is provided. It is claimed that the slide rule will enable the radiographer to compute exposure values with the minimum mental calculation and maximum consistency.

The "FRIEL-STURDY RADIOGRAPHIC CALCULATOR."

(Patent Pending 29187/45)

PART I.

1. Description

A slide rule is an instrument used for the multiplication and division of numbers, which are two fundamental operations of arithmetic. By its use, we can adopt a mechanical process equivalent to logarithmic addition and subtraction. The values are numbers on logarithmic scales, but the logarithms themselves are not marked on the scales.

The rule consists of a body having a longitudinal groove in which a sliding strip can be moved independently, there being sufficient friction to prevent slipping.

A cursor carrying a fine transverse line which can be set in agreement with any graduation of the scales on the face of the body, or on the slides, is provided.

2. The Slides

Efficiency factor, Scale "*E*."—The lower scale "E" on the body of the rule, is graduated from 0·1—2·0, to cover the efficiency of any available set.

Distance factor, "*D*."—The adjacent scale to "E" allows for correction in exposure for any change in the anode film distance, this scale is graduated from 10″ to 72″. The 30″ reading, marked "X" is given as unity. A chart of conversion to cms. is also provided.

TABLE IIIA—*contd.*

Region	*Age*	*Kv.*	*Absorption Value*
Hips (A.P.)	5-10	55	2·5
Pelvis (A.P.)	5-10		2·5
Dorsal Spine (A.P.)	5-10		2·75
Lower Spine (A.P.)	5-10		3·0
Sinuses (O.M.)	1-5		3·0
Abdomen (A.P.)	1-5		3·0
Lungs (A.P.)	1-5	60	0·4
Skull (Lat.)	1-5		2·5
Mastoids (Lat.)	1-5		2·5
Cervical Spine (Lat.)	5-10		3·0
Skull (F.O.)	1-5		3·5
Sinuses (O.M.)	1-5	65	4
,, (Lat.)	5-10		4
Skull (Lat.)	5-10		5
Abdomen (A.P.)	5-10		5
Oesophagus (R.A.O.)	1-5		6
Lower Spine (Lat.)	1-5		7
Dorsal Spine (Lat.)	1-5		7
Teeth (Intra-Oral)	5-10	70	5
Lungs (Lat.)	1-5		6
Mastoid (Lat.)	5-10		7
Skull (F.O.)	5-10		8
Lungs (Lat.)	5-10		8
Oesophagus (R.A.O.)	5-10		8
Sinuses (O.M.)	5-10	75	6
Dorsal Spine (Lat.)	5-10		10
Lower Spine (Lat.)	5-10		10

TABLE III—*contd.*

Region	*Kv.*	*Absorption Factor*	*Kv.*	*Absorption Factor*
Sinuses (O.M.)	75	6	65	4
(Lat.)	65	4	55	3
Mastoid (Lat.)	70	7	60	2·5
Mandible (Lat.)	55	1·5	50	1·0
Teeth (Intra-Oral)	70	5		
Lungs (P.A.)	70	0·6	60	0·4
(Lat.)	70	8	70	6
Oesophagus (R.A.O.)	70	8	65	6
Abdomen (A.P.)	65	5	55	3

TABLE IIIA.

ABSORPTION VALUES FOR CHILDREN IN NUMERICAL ORDER.

Region.	*Age.*	*Kv.*	*Absorption Value.*
Hand (Lat.)	1–5	40	0·4
Ankle (A.P. & Lat.)	1–5		0·5
Elbow (A.P. & Lat.)	1–5		0·6
Hand (P.A.)	5–12		0·6
Knee (A.P. & Lat.)	1–5		0·7
Hand (Lat.)	1–5	45	0·6
,, (Lat.)	5–10		0·8
Elbow (A.P. Lat.)	5–10		0·8
Ankle (A.P. Lat.)	5–10		0·8
Shoulder (A.P.)	1–5		1·0
Knee (A.P. Lat.)	5–10		1·0
Hip (A P.)	1–5		1·25
Pelvis (A.P.)	1–5		1·25
Cervical Spine (A.P.)	1–5	50	1·0
Mandible (Lat.)	1–5		1·0
Shoulder (A.P.)	5–10		1·2
Dorsal Spine (A.P.)	1–5		1·2
Lower Spine (A.P.)	1–5		1·5
Lungs (P.A.)	5–10	55	0·6
Ribs (A.P.)	1–5		1·25
Ribs (A.P.)	5–10		1·5
Mandible (Lat.)	5–10		1·5
Cervical Spine (A.P.)	5–10		1·75
,, ,, (Lat.)	1–5		2·0

Absorption factor, Scale "A."—This factor is given on the lower of the middle scales. This scale is graduated from 0·5 to 200 to allow correction of exposure for any change in absorption for the various radiographic positions. The factor for a hand (P.A.) is 1 and marked "X."

The Hardness factor, "H" (Kv Scale).—The Kv values are marked on the upper of the middle scales adjacent to Scale "A" for selection of Kv from 40–100. This scale, although marked in Kv values for the convenience of the user, is a logarithmatic scale of ($Kv^{-4} \times 10^8$), being an empirical relationship of Kv to photographic effect.

A suggested Kv is given with each radiographic position on the back surface of the rule, but any other preferred Kv may be used, Unity is marked "X."

Film Speed and Stationary Grid or P.B.D. Factor, Scale "S." This factor is graduated from 0·5 to 20, on the upper scale of the upper slide. Unity is marked as "X," which is the speed of ordinary film between high speed screens, without the use of a stationary grid or P.B.D.

The necessary correction of MaS, occasioned by a change in the film or screen speed, or by the inclusion of the stationary grid or P.B.D. may be effected by the use of this scale.

Milliampere Second Scale (MaS).—From this scale the correct MaS necessary for a selected part, taken on a particular apparatus at a chosen Kv, using known film, with or without screens, stationary grid or P.B.D. at a known A.F.D. may be obtained. It is graduated from 0·5—300 MaS.

Transformation of Milliampere Seconds.—To facilitate the rapid calculation of the exposure time from the MaS at any selected Ma. value, two additional scales are provided—

1. Milliampere Scale - - Ma.
2. Seconds Scale - - T.

1. *The Milliampere Scale (Ma).*—This is marked on the Absorption factor scale—the same graduations being used as for the Absorption Factors, but the value of the Ma. is 10 times the Absorption value at any particular graduation.

The numerical value of the Ma. is marked beneath the absorption value in distinctive print.

2. *Seconds Scale (T·)*—This is located above the MaS. Scale, the graduations for Seconds being one-tenth of the value of the former.

The numerical values of Seconds are given above the MaS values, in distinctive print.

THE APPLICATIONS OF THE SLIDE RULE.

PART II.

Method.

We must first discover the radiographic efficiency of the apparatus by means of a few trial exposures, and then use this information in the computation of exposure values for various parts of the body.

(1) *To Calculate the Efficiency Factor "E" (for any x-ray apparatus).* The X-ray output for a given Kv and Ma varies with the type of tube and type of apparatus in use. A factor for each unit available can be arrived at by which comparable exposure can be obtained.

Make a good exposure for a hand (P.A.) at 45 Kv if possible, or the nearest available one, at 30″. As the absorption factor for a hand (P.A.) and the distance factor are both unity, by using ordinary film and standard screens we can conclude the MaS used, divided by the factor " H " will give a quotient, which can be taken to be the efficiency factor " E."

$$E=\frac{MaS}{H} \quad . \quad . \quad . \quad . \quad (1)$$

Example :

For an exposure for the hand (P.A.), 45 Kv. 20 MaS. 30″ AFD, is required.

Set Cursor to 20 MaS.	Move 45 Kv to Cursor.
Set Cursor to H " x "	Read off efficiency value for apparatus.
0·8 on Scale " E "	*Ans.*—Efficiency factor=0·8.

Proof :

Substituting given values in equation (1) MaS=20.

" H " Factor Value from Table 4   45 Kv = 24·4

$$E=\frac{20}{24 \cdot 4} = 0 \cdot 8 = \text{efficiency factor.}$$

(2) *To Calculate an Exposure.*—

1. The efficiency value for the apparatus, Factor " E " must be known.
2. When an A.F.D. other than 30″ is to be used, the required conversion factor " D " must be utilised.
3. The absorption factor "A" for the part to be X-rayed can be determined from Table II or (on the reverse surface of the rule). These values are for a normal adult patient of 112 lbs.
4. The Kv to be used can be selected against the region to be X-rayed in Table II, on the reverse surface of the rule. (For the purpose of mathematical calculations, " H " values for Kv's 40–100 are given in Table IV (p. 24).
5. When a stationary grid or P.B.D. or film other than ordinary, with high speed screens, are to be used, these factors must be allowed for (Factor " S ").

The product of these factors may then be taken to be the value of the MaS required for that radiographic position.

TABLE IIA—*contd.*

Region	*Kv.*	*Absorption Factor*
Stomach (A.P., P.A.)	80	10·0
Lungs (Lat.)		12·0
Duodenal Caps		15·0
Cervico-Dorsal Spine (Lat.)		65·0
Lumbar Spine (Lat.)		75·0
Femur, Neck (Lat.)		80·0
Coccyx (Lat.)		100·0
Abdomen (Lat.)	85	45·0
Liver (Lat.)		45·0
Gall Bladder (Lat.)		45·0
Urinary Tract (Lat.)		45·0
Sacrum (Lat.)		190·0
Lumbo-Sacral Joint (Lat.)		190·0
Pelvis (Lat.)	90	200·0

TABLE III.

REGIONAL ABSORPTION VALUES FOR CHILDREN.

(It is suggested that the exposure time should never exceed 0·5 seconds in most cases, hence a variation of Kv will often be required).

	Children 5–10		*Children* (1–5).	
Region.	*Kv.*	*Absorption Factor*	*Kv*	*Absorption Factor.*
Hand (P.A.)	40	0·6	40	0·4
(Lat.)	45	0·8	45	0·6
Elbow (A.P. & Lat.)	45	0·8	40	0·6
Shoulder	50	1·2	45	1·0
Ankle (A.P. & Lat.)	45	0·8	40	0·5
Knee (A.P. & Lat.)	45	1·0	40	0·7
Hip (A.P.)	55	2·5	45	1·25
Pelvis (A.P.)	55	2·5	45	1·25
Lower Spine (A.P.)	55	3·0	50	1·5
(Lat.)	75	10·0	65	7
Dorsal Spine (A.P.)	55	2·75	50	1·25
(Lat.)	75	10	65	7
Cervical Spine (A.P.)	55	1·75	50	1·0
(Lat.)	60	3·0	55	2·0
Ribs (A.P.)	55	1·5	55	1·25
Skull (F.O.)	70	8	60	3·5
(Lat.)	65	5	60	2·5

TABLE IIA—*contd.*

Region	*Kv.*	*Absorption Factor*
Cranium (Lat.)	65	18·0
Scapula (Lat.)		20·0
Pelvis (A.P.)		20·0
Coccyx (A.P.)		20·0
Sacro-Iliac Joints (A.P.)		25·0
Sacrum (A.P.)		25·0
Lumbo-Sacral Joint (A.P.)		25·0
Lumbar Spine (A.P.)		25·0
Sinuses (Obl.)		25·0
Mastoid (Lat. Obl.)		36·0
Tempero-Mandibular Joint (Lat. Obl.)		36·0
Diaphragm (In.) P.A.	70	·75
Lungs (A.P. & P.A.)		1·0
Diaphragm (Ex.) P.A.		2·25
Ribs, Upper (Obl.)		7·0
Abdomen (A.P.)		10·0
Liver		10·0
Gall Bladder		10·0
Urinary Tract (Upper A.P.)		10·0
,, ,, (Lower A.P.)		17·0
Sternum (Lat.)		20·0
Lumbar Spine (Obl.)		25·0
Femur, Upper (Lat.)		30·0
Hips (Lat.)		30·0
Lungs (Lordotic)	75	4·0
Lungs (Obl.)		5·0
Oesophagus (Rt. Obl.)		7·0
Diaphragm (Rt. Obl.)		8·0
Ribs, Lower (A.P.)		17·0
Gall Bladder (A.P.) Small Cone.		17·0
Sacro-Iliac Joints (Obl.)		20·0
Ribs, Lt. (Obl.)		20·0
Gall Bladder (Obl.)		20·0
Dorsal Spine (A.P.)		23·0
Cranium (F.O., O.F.)		25·0
Sinuses (O.M.)		30·0
Bladder (Obl.)		30·0
Facial Bones (O.M.)		35·0
Facial Bones (M.O.)		40·0
Dorsal Spine (Lat.)		50·0
Facial Bones (30° O.M.)		55·0

$$\text{MaS} = E \times D \times A \times H \times S \quad . \quad . \quad . \quad . \qquad (2)$$

$$\text{hence, t (time)} = \frac{E \times D \times A \times H \times S}{\text{Ma.}} \quad . \quad . \qquad (3)$$

Example.—To calculate the exposure for an elbow (A.P.) on an apparatus having an Efficiency factor = 0·6, using ordinary film, with high speed screens, at an A.F.D. of 30″

E=0·6   D=1 (30″)   A=2·4   S=1.

Move A "x" to "E" value 0·6. Set Cursor to "A" value 2·4. Move H "x" to cursor. (50 Kv is suggested on reverse surface of rule, but 56 is the nearest available on apparatus). Set cursor to 56 Kv on Scale "H."

Read MaS value 14·4 on upper Scale.

To transform MaS (if required) move Ma value (15) on Ma Scale to Cursor. Set cursor to Ma "X" read off time on Scale "t" above MaS.

Answer 56 Kv : 15 Ma : 1·0 Secs. : 30″ A.F.D.

Proof : E=0·6 : D=1·0 (30″) : A=2·4, H =10 (56 Kv) from Table IV.

Substituting these values in equation (3)

$$t = \frac{0{\cdot}6 \times 2{\cdot}4 \times 10}{15} = 0{\cdot}96 \text{ secs., } 1{\cdot}0 \text{ sec. (approx.)}$$

Answer 56 Kv : 15 Ma : 1·0 secs. : 30″ A.F.D.

Confirmation of Efficiency factor.—We are now in a position to confirm the value of "E" by taking radiographs of two or three other parts of the average patient, using the exposures calculated as above. If their density is not satisfactory, the necessary adjustment should be made and the radiographs repeated. A new value of "E" may then be calculated by the use of the equation—

$$E = \frac{\text{MaS}}{D \times A \times H \times S} \quad . \quad . \quad . \quad . \qquad (4)$$

Example :

The exposure for Elbow (A.P.) was found to be 56 Kv, 17 MaS 30″ A.F.D. Set cursor to 17 MaS. Move 56 Kv on scale "H" to cursor. Set cursor to H "x" Move "A" 2·4 (absorption factor for Elbow A.P.) to cursor. Set cursor to A "x." Read off "E" value 0·7 on Scale "E."

Answer Efficiency factor = 0·7.

Proof : MaS 17 : S=1 : Kv=56 (H 10) : A=2·4 D=1.

Substituting these values in equation (4).

$$E = \frac{17}{1 \times 10 \times 2{\cdot}4 \times 1} = \frac{17}{24} = 0{\cdot}71.$$

Answer Efficiency factor = 0·7 approx.

In this way, several values of "E" may be calculated and the mean taken. This precaution is necessary on account of the 20% latitude shown by X-ray film, which makes an absolutely accurate determination of these factors impossible. On the other hand, *because of this latitude after these initial calculations, it is not necessary to use a greater accuracy than 5% in determining the values of any of the required factors, that is to say, two significant figures are sufficient.* This greatly reduces the calculation required. Most portable sets, in any case, are provided with timers graduated in intervals of not less than 20%, so that calculation of exposure times *to greater accuracy is redundant.*

We have seen how the calculation of MaS may be made when the following conditions apply—

(1) A.F.D. = 30″

(2) Film speed and stationary grid or P.B.D. factors are unity.

The following examples will show how the necessary correction in MaS are made when any factors are changed.

3.—*Alteration of A.F.D. (also use of P.B.D.)*—To calculate the exposure for Dorsal spine A.P. on a unit having an efficiency factor of 0·55, using ordinary film, with high speed screens and P.B.D. at an A.F.D. of 36″

E=0·55 : D=36″ (1·44) : A=23 : S=3.

Example :

Set cursor to "E" value 0·55. Move D "x" to cursor.
Set cursor to 36″ on Scale "D." Move A "x" to cursor.
Set cursor to A 23. Move H "x" to cursor. (65 Kv is suggested on back surface. The nearest available is 67).
Set cursor to 67 Kv. Move S "x" to cursor.
Set cursor to P.B.D. factor S "3."
Read MaS value on upper Scale 273.
If required MaS may be transformed as follows—
Move Ma value, on Ma Scale (Scale "A") to cursor.
Set cursor to Ma "x." Read time of exposure required on Scale "T" above MaS Scale.

Answer: 67 Kv. 50 Ma : 5·5 sec. (approx.) 36″ A.F.D. with P.B.D.

Proof : E=0·55 D=1·44 (36″) : A=23. H=5 : 0 (67 Kv). S=3·0 (P.B.D.)

Substituting these values in Equation (3)

$$t=\frac{0{\cdot}55\times1{\cdot}44\times23\times5\times3}{50}=5{\cdot}46 \text{ seconds.}$$

Answer: 67 Kv : 50 Ma : 5·5 Secs. (approx.) 36″ A.F.D. with P.B.D.

TABLE IIa—*contd.*

Region.	*Kv.*	*Absorption Factor*
Nasal Bone (Screen Lat.)	55	1·8
Teeth (Intra-Oral, Upper & Lower 1–4)		2·5
Teeth (Intra-Oral, Upper & Lower 4–8)		3·0
Foot (Lat.)		3·0
Clavicle (A.P. & P.A.)		4·0
Teeth (Occ. lower anterior)		4·0
,, (,, ,, posterior)		6·0
Elbow (full flexion)		6·5
Teeth (Occ. Upper)		7·5
Sternum (Left Ant. Oblique)		20·0
Nasal Bone (Lat. Dental film)	60	1·2
Ankle (Lat.)		2·2
Os Calcis (Lat.)		2·2
Ankle (A.P.)		2·8
Humerus (A.P. & Lat.)		4·0
Lower Leg (Lat.)		4·0
,, ,, (A.P.)		5·0
Knee (A.P. & Lat.)		5·0
Femur (Lower Lat.)		6·5
Shoulder (A.P.)		7·0
,, (Joint space)		7·0
Femur (Lower A.P.)		7·5
Scapula (A.P.)		8·0
Patella (P.A.)		8·0
Mandible (P.A.)		8·0
,, (Lat. Body)		10·0
Facial Bones (Lat.)		10·0
Mandible (P.A. Oblique)		12·0
,, (Lat. ramus)		15·0
Temporo-mandibular Joint (Lat.)		15·0
Sternum (Right Ant. Oblique)		25·0
Ribs (A.P. & P.A.)	65	2·0
Nasal Bones (S.I.)		3·0
Os Calcis (D.P. & P.D.)		7·5
Humerus (Lat. head)		9·0
Sinuses (Lat.)		9·0
Cervical Spine (A.P. 1–3)		10·0
Cervical Dorsal Spine (A.P.)		12·0
Cervical Spine (A.P. 3–7, Lat. 1–7)		12·0
Facial Bones (Oblique)		15·0
Mastoid (A.P.P.A. obls.)		16·0
Femur, Upper (A.P.)		17·0
Hips (A.P.)		17·0
Mandible (P.A.)		17·0

	Kv.	Absorption Factor
Abdominal Viscera		
A.P.	70	10
P.A.	70	14
Lat.	85	45
Lat. (Vert. film)	85	45
Liver		
P.A.	70	10
Lat.	85	45
Gall Bladder		
P.A. } Small Cone		10
A.P. } Small Cone	70	17
Lat.	85	45
Cholecystography		
P.A. Erect	70	17
Obl. (Small Cone)	75	20

	Kv.	Absorption Factor
Urinary Tract		
A.P. Upper	70	10
A.P. Lower	70	17
Lat.	85	45
Cystography		
Left Obl.	75	30
Alimentary Tract		
Oesophagus / Rt. Ant. Obl.	75	7
Stomach P.A. / Colon P.A.	80	10

TABLE IIA.

Region.	*Kv.*	*Absorption Factor.*
Toes (D.P.)	40	0·5
,, (Oblique)		0·7
Hand (P.A.)	45	1·0
Thumb (A.P. & Lat.)		1·0
Hand (Oblique)		1·4
Wrist (P.A.)		1·5
,, (Oblique)		1·8
Sterno-clavicular Joint (P.A.)		10·0
Forearm (A.P. & Lat.)	50	1·8
Toes (Lat.)		2·0
Foot (Oblique)		2·0
Hand (Lat.)		2·2
Foot (D.P.)		2·2
Elbow Joint (A.P. & Lat.)		2·4
,, ,, (Slight flexion)		2·4
Acromio-clavicular Joint (A.P.)		2·6
Elbow Joint (A.P. ⅔rds exten.)		2·8
Wrist Joint (Lat.)		3·5
Elbow Joint (90° exten.)		3·5
Patella (Lat.)		3·8
Sterno-clavicular Joint (Left)		10·0
,, ,, ,, (Right)		15·0
Sternum (P.A.)		20·0

3A. To calculate the change of MaS required for an alteration of A.F.D. from 30″ to 60″ when the MaS at the former distance is 10.

Set cursor to MaS value 10, on upper Scale.
Move D " x " to cursor. Set cursor to 60″ on Scale " D."
Read off 40 MaS on upper Scale.

Proof : $MaS_1=10$: $D_1=1{\cdot}0$ (30″) : $D_2=4{\cdot}0$ (60″).

$$\frac{MaS_2}{MaS_1}=\frac{D2}{D1} \qquad MaS_1=\frac{4\times10}{1}=40.$$

Answer: =40 MaS at 60″ A.F.D.

3B. Given an exposure for Chest P.A. as 67 Kv : 50 Ma : 0·4 secs. at 48″, find the MaS value for an A.F.D. of 30″.

Set cursor to 20 MaS. Move 48″ on Scale " D " to cursor.
Set cursor on 30″ on Scale "D." Read off 7·7 MaS on upper Scale.
If transformation of MaS is required—
Move Ma 50 to cursor. Set cursor to Ma " x."
Read off 0·15 secs. (approx.) on Scale " T."

Answer: 67 Kv : 50 Ma : 0·15 secs. : 30″ A.F.D.

Proof : $MaS_1=20$. $D_1=2{\cdot}56$ (48″). $D_2=1{\cdot}0$ (30″).

$$MaS_2=\frac{1\times20}{2{\cdot}58}=7{\cdot}7.$$

Answer: 67 Kv : 50 Ma : 0·15 secs. 30″ A.F.D.

4A. *Alteration of Kv Factor.*—To calculate the change of MaS required when an alteration is made in Kv value at a constant distance.

Example :

Given an exposure for skull (S.M.V.) as 81 Kv : 44 Ma : 5·0 secs. at 30″ A.F.D. Change the Kv to 88 in order to reduce the time.

Set cursor to 220 MaS. Move 81 Kv (H2·25) to cursor.
Set cursor to 88 Kv (H 1·7). Read off 159 MaS on upper Scale.
Since Ma=42, time=3·8 secs.
This latter figure can be obtained by moving Ma 42 to cursor, set cursor to Ma " X "—read off 3·8 secs. on Scale " T."

Answer: 88 Kv. 42 Ma : 3·8 Secs. : 30″ A.F.D.

Proof : $MaS_1=220$: $H_2=1{\cdot}7$ (88 Kv) : $H_1=2{\cdot}3$ (81 Kv).

$$MaS_2=\frac{H_2}{H_1}\times MaS_1=\frac{1{\cdot}7\times220}{2{\cdot}3}=162{\cdot}6.$$

Answer 88 Kv. 42 Ma : 3·8 Secs. : 30″ A.F.D.

4B. Give an exposure for Chest P.A., as 67 Kv : 50 Ma : 0·4 Secs : 48″ A.F.D., find the Kv required for an A.F.D. of 60″ keeping exposure time and Ma the same.

Example :

Set cursor to 20 MaS on upper Scale. Move 48″ on " D " to cursor.
Set cursor to 60″ on " D." Move 67 Kv (H5) to cursor.
Return cursor to 20 MaS on upper Scale.
Read off 74 Kv on Scale " H."

Answer: 74 Kv : 50 Ma : 0·4 Secs : at 60″ A.F.D.

4B. *Proof:* $H_1 = 5 \cdot 0$ (67 Kv): $D_1 = 2 \cdot 58$ (48″): $D_2 = 4 \cdot 0$ (60″)

$$H_2 = \frac{D_1}{D_2} \times H_1 = \frac{2 \cdot 58}{4} \times 5 = 3 \cdot 22 \text{ (74 Kv)}$$

Answer: 74 Kv : 50 Ma : 0·4 Secs : 60″ A.F.D.

5.—*Alterations in Milliamperes*—

To calculate the change in time required for an alteration in Ma at any MaS value, when other factors remain unchanged.

Given an exposure for a Chest P.A. as 67 Kv, 50 Ma, 0·4 Secs. 48″ A.F.D., find the exposure time for a set at 20 Ma.

Set cursor to Seconds value 0·4. Move Ma " x " to cursor.
Set cursor to 50 Ma. Move Ma 20 to cursor.
Set cursor to Ma " x." Read off 1 second on Scale " T."
Answer: 67 Kv : 20 Ma : 1·0 Sec : 48″ A.F.D.

Proof: $T_2 = \frac{Ma_1}{Ma_2} \times T_1$. Substituting: $Ma_1 = 50$. $T_1 = 0 \cdot 4$: $Ma_2 = 20$.

$$T = \frac{50 \times 0 \cdot 4}{20} = 1 \cdot 0$$

Answer: 67 Kv : 20 Ma : 1·0 Sec : 48″ A.F.D.

5B. To calculate the change in time required for an alteration in Kv at any fixed Ma value.

Given an exposure for a Wrist P.A. as 50 Kv, 40 Ma, 0·4 Secs. 30″ A.F.D. Find the exposure time required when the Kv is lowered to 45.

Set cursor to 0·4 on Scale " T." Move 50 Kv to cursor.
Set cursor to 45 Kv. Read off 0·6 Secs. on Scale " T."
Answer: 45 Kv : 40 Ma : 0·6 Sec : 30″ A.F.D.

Proof: $T_2 = \frac{H_2}{H_1} \times T_1$ Substituting: $H_2 = 24.39$ (45 Kv): $H_1 = 16$ (50 Kv): $T_1 = 0 \cdot 4$

$$T_2 = \frac{24.39 \times 0 \cdot 4}{16} = 0 \cdot 6 \text{ (approx.)}$$

Answer: 45 Kv : 40 Ma : 0·6 Sec : 30″ A.F.D.

6. To calculate a factor for a new stationary grid or P.B.D.

Example:

Given an exposure for pelvis A.P. 70 Kv, 125 MaS, 30″ A.F.D. with grid of known speed 2, in relationship to ordinary film, calculate the " speed " of a new grid, with which it was found necessary to use 150 MaS (all other factors unchanged) to obtain similar results.

Set cursor to 125 MaS. Move S " 2 " to cursor.
Set cursor to 150 MaS. Read off 2·4 on Scale " S."
Answer:=New grid factor=2·4.
Proof: Substituting above values as follows—

$$\frac{S_2}{S_1} = \frac{MaS_2}{MaS_1} \qquad S_2 = \frac{150}{125} \times 2 = \frac{12}{5} = 2 \cdot 4$$

Answer: New Grid Speed = 2·4

	Kv.	Absorption Factor
Base of Skull		
Submento-Vertical	80	50
Nasal Accessory Sinuses		
Occipito-Mental	75	30
Lat.	65	9
Sub. Mento-Vert.	80	40
Obl. (small cone)		25
Mastoid Cells (small cone)		
Lat. Obl.	65	36
Obl. A.P.		16
Obl. P.A.		16

	Kv.	Absorption Factor
Facial Bones		
Occipito-Mental	75	35
Mento Occipital	75	40
30° Occipito Men.	85	55
Lat.	60	10
Obl.	65	15
Nasal Bones		
Superior Inferior	65	3·0
Lat. (Scr.)	55	1·8
Alt. Lat. (Dental)	60	1·2

Jaw and Teeth

	Kv.	Absorption Factor
Mandible		
P.A.	65	17
Obl. P.A.	60	12
Lat. with angle Bd. Ramus Angle & Body. / Lat. without Angle Bd. Ramus Angle & Body.	60	15
Lat. with angle Bd. Body & angle / Lat. without angle Bd. Body & angle	60	10
Tempero Mandib Joints		
Lat. Obl. (Small Cone)	65	36
Lat. (Small Cone)	60	15
Occlusal		
Up. Ant.	55	7·5
Up. Obl.		7·5
Lr. Occlucal		4
Lr. Ant.		4
Lr. Post.		6

Intra-Oral	Kv.	Absorption Factor
Upper Teeth		
1. Cent. Incisor	55	2·5
2. Lat. Incisor		2·5
3. Canine		2·5
4, 5, Pre Molars		3
6, 7, 8 Mollars		3
Lower Teeth		
1. Cent. Incisor		2·5
2. Lat. Incisor		2·5
3. Canine		3
4, 5, Pre Molars		3
6, 7, 8. Molars		3
Thoracic Viscera		
A.P.	70	1·0
P.A.	70	1·0
Lat.	80	12
Lordotic	75	4·0
R. Ant. Obl.	75	5·0
L. Ant. Obl.	75	5·0
Diaphragm		
P.A. Ex. (on one film)	70	1·5
P.A. In. (on one film)	70	·75
R. Ant. Obl.	75	8·0

Lower Extremity—*contd.*

	Kv.	Absorption Factor
Lower Leg		
A.P.	60	5·0
Lat.		4·0
Knee Joint		
A.P.	60	5·0
Lat.		
Patella		
P.A.	60	8·0
Lat.	50	3·8
Femur Lower		
A.P.		7·5
Lat.	60	6·5
Lat. (Vert. film)		6·5

	Kv.	Absorption Factor
Femur Upper		
A.P.	65	17
Lat.	70	30
Lat. (Vert film)	70	
Neck of Femur		
Lat.	80	80
Hip Joints		
A.P. Single Hip	65	17
A.P. Both Hips	65	17
Lat. Obl.	70	30
Pelvis		
A.P.	65	20
Lat.	90	200
Sacro-Iliac Joints		
A.P.	65	25
Obl.	75	20

Spine.

	Kv.	Absorption Factor
Coccyx.		
A.P.	65	20
Lat.	80	100
Sacrum		
A.P.	65	25
Lat.	85	190
Lumbo-Sacral Joint		
A.P.	65	25
Lat.	85	190
Lumbar Vertebrae		
A.P.	65	25
Lat.	80	75
Obl.	70	25
Dorsal Vertebrae		
A.P. (Expiration)	75	23
Lat. (Inspiration)	75	50

	Kv.	Absorption Factor
Cervico-Dorsal Region		
A.P.	65	12
Lat. (Inspiration)	80	65
Cervical Vertebrae		
A.P. 3–7	65	12
A.P. 1–3	65	10
Lat.	65	12
Thorax, Ribs		
P.A. / A.P. Inspiration	65	2
A.P. Lr. Ribs Ex.	75	17
Obl. Lr. Ribs. Ex.	70	20
Obl. Upp. Ribs In.	70	7·0
Sternum		
R. Ant. Obl. Ex.	60	25
Lt. Ant. Obl. In.	55	20
P.A. (Centre from right) (breathing)	50	20
Lat. Inspiration	70	20

Skull

	Kv.	Absorption Factor
Cranium		
Fronto-Occipital	75	25
Occipito-Frontal	75	25

	Kv.	Absorption Factor
Lat.	65	18
30° Fronto-Occ.	80	30

7. *To calculate the speed of New Films or Intensifying Screens.*

Example :

Give an exposure for Skull O.F., 70 kv : 120 MaS : 30″ A.F.D. on P.B.D. with ordinary film between high speed screens, calculate the speed of film which requires only 90 MaS to produce a radiograph of similar density.

Set cursor to 120 MaS. Move S "x" to cursor.
Set cursor to 90 MaS. Read off 0·66.
Answer: Factor for New Film 0·66.

Proof : $\frac{MaS_2}{MaS_1}=\frac{S_2}{S_1}$ $\qquad S_2=\frac{90}{120}=0{\cdot}66$

Answer: Factor for New Film = 0·66

8. *To prepare a Complete Exposure Chart.*

Much time can be saved when constructing a complete exposure chart by referring to the factors given in order of absorption value. It will be found that having obtained the time of exposure for a region, by the usual method, if the absorption factor for the part is placed against the time value (Scale "T") by moving the cursor to any other absorption factor, the corresponding time may be read directly on Scale "T," provided all the other factors remain unchanged.

Example : The factors for a forearm are—
Kv 50. Absorption 1·8. Efficiency factor=0·5 : Ma=15.
By using the method explained on example 2, page 8, the time of exposure required would be 1 second.

Set cursor to 1 second on Scale "T." Move absorption factor 1·8 to cursor.

If cursor is set to absorption factor for the other regions requiring 50 Kv, the approximate time required may be read directly on Scale "T."

Region.	*Absorption Factor.*	*Time.*
Toes (Obl.)	2·0	1·2
Foot (Obl.)	2·0	1·2
Hand (Lat.)	2·2	1·3
Foot (D.P.)	2·2	1·3
Elbow (A.P. Lat.)	2·4	1·4
Acromio-Clavicular Joint (A.P.)	2·6	1·5
Elbow Joint (full flexion)	3·5	1·9
Patella (Lat.)	3·8	2·0
Sterno-clavicular Joints (Lt.)	10·0	5·5

9. *A rapid method of Transforming Exposures.*

A rapid method of transforming exposures from one set to another of similar design, which is found to have a different efficiency value.

1. Set cursor to efficiency value of first set. Move A " x " to cursor.
2. Set cursor to efficiency value of new set. Read off value on Scale " A " and note this value.
3. Set cursor to known exposure time for part required—on Seconds Scale. Move A " x " to cursor.
4. Set cursor to 2nd reading on Scale " A." Read off corrected time on Seconds Scale.

Example :

To correct change in exposure time required for a Knee A.P., on a set having an efficiency factor of 0·5, for a similar set having an efficiency of 0·35.

Known Exposure 0·6 Secs. Efficiency 0·5.

1. Set cursor to 0·5 on Scale " E." Move A " x " to cursor.
2. Set cursor to 0·35. Read off 0·7 on Scale " A." (Note this value).
3. Set cursor to 0·6 secs. on Seconds Scale. Move A " x " to cursor.
4. Set cursor to 0·7 on Scale " A." Read off corrected time of exposure to be 0·425 on Seconds Scale.

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APPENDICES.

TABLE I.

Anode Film Distance in inches	*Factor " D "*
10	0·11
15	0·25
20	0·44
24	0·64
30	1·00
33	1·21
36	1·44
40	1·77
48	2·56
56	3·48
60	4·00
72	5·76

TABLE II.

UPPER EXTREMITY.

	Kv.	*Absorption Factor*
Hand		
P.A.	45	1·0
Lat.	50	2·2
Obl. Pa.	45	1·4
Alt. Obl.	45	1·4
Fingers		
P.A. } Lat. }	45	0·6
Thumb		
A.P. } Lat. }	45	1·0
Wrist		
P.A.	45	1·5
Lat.	50	3·5
Obl.	45	1·8
Forearm		
A.P. } Lat. }	50	1·8
Elbow Joint		
Lat. } A.P. }	50	2·4
Modified A.P.		
(*a*) Not fully Ext.		2·4
(*b*) ⅔ Ext.	50	2·8

	Kv	*Absorption Factor*
Modified A.P. contd.		
(*c*) 90° Ext.	50	3·5
(*d*) Full flexion	55	6·5
Humerus		
A.P. } Lat. }	60	4·0
Lat. (of head)	55	9·0
Shoulder		
A.P.	60	7·0
Joint Space	60	7·0
Acromio-clavicular Joint		
A.P.	50	2·6
Scapula		
A.P.	60	8·0
Lat.	65	20·0
Clavicle		
A.P. } P.A. }	55	4·0
Sterno-clavicular Joint		
Rt. Ant. Obl. }	50	15·0
Lt. Ant. Obl. }		10·0
P.A.	45	10·0

LOWER EXTREMITY.

Toes		
Dorsi-Planter	40	0·5
Lat.	50	1·8
Ant. Obl.	40	0·7
Foot		
Dorsi-Plantar	50	2·2
Lat.	55	3·0
Obl.	50	2·0
Ant. Obl.	50	2·0

Os Calcis		
Dorsi-Plantar	65	7·5
Lat.	60	2·2
Planta-Dorsal	65	7·5
Ankle Joint		
A.P. Single Ankle	60	2·8
A.P. Both Ankles	60	2·8
Lat.	60	2·2