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Radiography Formulas and Dose Limits Chart

Inverse square law, exposure formulas, grid factors, half-value layers and dose limits compared

For: Radiologic technology students, radiographers and radiation safety officers

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EXACT DEFINITION	FORMULA	REVERSE	WORKED EXAMPLE
From a point source, intensity is proportional to 1 ÷ distance^2	$I_2 = I_1 \times (d_1 \div d_2)^2$	$mAs_2 = mAs_1 \times (d_2 \div d_1)^2$ (to keep the same image exposure)	Moving from 1 m to 2 m cuts the dose rate to ¼; keeping image exposure at the longer SID needs 4 × the mAs

Factors to 4 significant figures. The 15% rule and grid factors are standard approximations.

Inverse square law factors

Distance ratio $d_2 \div d_1$	Dose rate factor $(d_1 \div d_2)^2$	mAs factor to keep exposure	Distance ratio $d_2 \div d_1$	Dose rate factor $(d_1 \div d_2)^2$	mAs factor to keep exposure
0.25	16	0.0625	**1.8**	0.3086	3.24
0.5	4	0.25	**2**	0.25	4
0.75	1.778	0.5625	**2.5**	0.16	6.25
1	1	1	**3**	0.1111	9
1.25	0.64	1.563	**4**	0.0625	16
1.5	0.4444	2.25	**5**	0.04	25
1.75	0.3265	3.063	**10**	0.01	100

Exposure and geometry formulas

Relationship	Formula	Worked example
mAs	mAs = mA × exposure time (s)	200 mA × 0.1 s = 20 mAs
Exposure maintenance	$mAs_2 = mAs_1 \times (SID_2 \div SID_1)^2$	10 mAs at 100 cm → 32.4 mAs at 180 cm
15% rule	+15% kVp ≈ doubles exposure to the image receptor; −15% kVp ≈ halves it	70 kVp + 15% = 80.5 kVp with half the mAs
Grid conversion	$mAs_2 = mAs_1 \times (GCF_2 \div GCF_1)$	5 mAs with no grid → 25 mAs with a 12:1 grid (GCF 5)
Magnification factor	MF = SID ÷ SOD	SID 100 cm, SOD 80 cm → MF 1.25
Object size	Object size = image size ÷ MF	50 mm image ÷ 1.25 = 40 mm
Heat units	HU = kVp × mA × s × c (c = 1 single-phase, 1.35 three-phase, 1.4 high-frequency)	80 kVp × 200 mA × 0.1 s × 1.4 = 2,240 HU

Grid conversion factors (GCF)

Grid ratio	GCF
No grid	1
5:1	2
6:1	3
8:1	4
12:1	5
16:1	6

Half-value layers: fraction transmitted

One tenth-value layer ≈ 3.32 half-value layers.

Number of HVLs	Fraction transmitted	Percent transmitted	Number of HVLs	Fraction transmitted	Percent transmitted
0	1	100	**5**	0.03125	3.13
1	0.5	50	**6**	0.01563	1.56
2	0.25	25	**7**	0.007813	0.781
3	0.125	12.5	**8**	0.003906	0.391
4	0.0625	6.25	**10**	9.766×10^{-4}	0.0977

Dose limits compared

Limit (per year unless stated)	ICRP 103 (international)	US NRC 10 CFR 20	NCRP Report 116 (US guidance)
Occupational, effective dose	20 mSv averaged over 5 years; at most 50 mSv in any year	50 mSv (5 rem)	50 mSv; cumulative 10 mSv × age in years
Lens of the eye	20 mSv averaged over 5 years; at most 50 mSv in any year (ICRP 118)	150 mSv (15 rem)	150 mSv
Skin, hands and feet	500 mSv	500 mSv (50 rem)	500 mSv
Public, effective dose	1 mSv	1 mSv (0.1 rem)	1 mSv continuous; 5 mSv infrequent
Embryo or fetus (declared pregnancy)	1 mSv for the rest of the pregnancy	5 mSv (0.5 rem) over the whole pregnancy	0.5 mSv per month

ALARA: time, distance, shielding

Principle	Rule of thumb
Time	Dose = dose rate × time: halve the time, halve the dose.
Distance	Inverse square law: double the distance, a quarter of the dose rate.
Shielding	Each half-value layer halves the intensity; n HVLs transmit $(½)^n$.

Sources and method

- **Standard radiographic technique relationships** — As taught in radiologic technology programmes (e.g. Bushong, Radiologic Science for Technologists)
- **ICRP Publication 103 (2007)** — Radiation weighting factors and dose limits; lens of the eye per ICRP Publication 118 (2011) (www.icrp.org/publication.asp?id=ICRP%20Publication%20103)
- **US NRC, 10 CFR Part 20** — Occupational (20.1201), embryo/fetus (20.1208) and public (20.1301) dose limits (www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html)
- **NCRP Report No. 116 (1993)** — Limitation of exposure to ionizing radiation (US guidance)

Inverse-square and half-value-layer factors are calculated exactly; formulas and grid factors are standard radiographic relationships; dose limits are quoted from the documents listed. Interactive version, corrections and more charts: **allunitconversions.com/radiography-formulas-chart**