NORDISK RAPPORTSERIE OM STRÅLSKYDDSFRÅGOR

No. 4

Glandular tissue dose in film–screen mammography

REPORT ON NORDIC
RADIATION PROTECTION CO-OPERATION

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Glandular tissue dose in film–screen mammography

The radiation protection and nuclear safety authorities in
Denmark, Finland, Iceland, Norway and Sweden

Statens strålskyddsinstitut
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Arbetsgrupp:	Röntgendiagnostik
Författare:	Antti Servomaa, Markku Tapiovaara, STUK, Finland
Sammanfattning:	Rapporten ger konversionsfaktorena mellan luftkerma och absorberad stråldos til bröstkörtelvävnad, för olika bröstmodeller og bröstkörtelkompositioner, anodmaterial, filtermaterial och olika tjocklekar av dessa. Konversionsfaktorena är användbara för beräkning av absorberad stråldos til bröstkörtelvävnad vid film–folie mammografi.
Nyckelord:	Mammografi, stråldos til bröstkörtelvävnad, kvalitetssäkring, kvalitetskontroll
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Working group:	*X-ray Diagnostic*
Author:	*Antti Servomaa, Markku Tapiovaara, STUK, Finland*
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GLANDULAR TISSUE DOSE IN FILM-SCREEN MAMMOGRAPHY

1. Introduction

Mammography is an effective method in early detection of breast cancer, but involves exposing of the patient to ionising radiation. It is known, however, that generally the resulting benefits from mammography will substantially exceed the risks (NCRP 1986). Additionally to this requirement of justification, the principles of radiation protection require that x-ray examinations should be optimised (ICRP 1991), i.e., the radiation doses should be the lowest possible, but still allow obtaining radiographs of sufficient image quality for accurate diagnosis.

Several dosimetric quantities have been used in assessing the patient's dose from mammography. Of these quantities, the average absorbed dose to the glandular tissue has been considered to be most relevant for estimating the risk (Hammerstein *et al.* 1979, NCRP 1986). Direct measurement of average glandular tissue dose, D_g, cannot be done in practice, however, and must be calculated from the irradiation conditions of the mammographic examination.

The principal factors influencing the glandular tissue dose per view delivered in a mammographic examination are the breast size and adiposity, and the radiographic technique (e.g., x-ray spectrum, anti-scatter grid, image receptor, film processing, and film density). To a good accuracy the glandular tissue dose can be calculated from a measurement of entrance air kerma (or exposure) by using an appropriate conversion factor. This report gives the glandular dose conversion factors for various x-ray spectra and breast models.

2. Material and methods

The average glandular tissue dose, D_g, can be estimated from a measurement of the air kerma, K, by using D_{gN}, the average glandular tissue dose conversion factor, which shows the average glandular tissue dose from an exposure to radiation of 1 mGy air kerma

$$D_g = D_{gN}K \quad . \qquad (1)$$

Often, the incident air kerma (or entrance exposure) is measured at skin entrance plane, without backscatter (Rosenstein *et al.* 1985, Dance 1990, Wu *et al.* 1991), but in this report the air kerma is defined to be measured at the breast mid–plane (distance A/2 below skin plane, see fig 1), in order to achieve a better independence of the focal spot–to–skin distance.

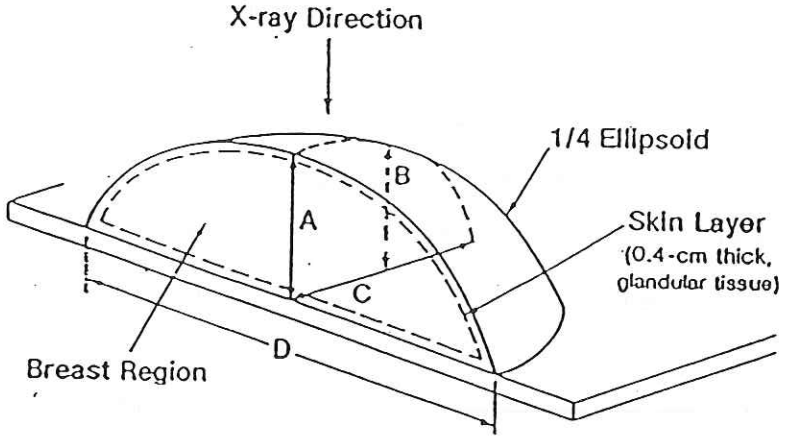
D_{gN} was calculated for various breast models (Rosenstein *et al.* 1985) and x–ray spectra by using the method and Monte Carlo data of Andersen and Rosenstein (1985). The imaging conditions and breast models considered are shown in Table 1. Figure 1 shows the breast models used: the firm compressed breast of uniform thickness and the moderate compressed breast of non–uniform thickness (Rosenstein *et al.* 1985). The names of the phantoms used in this reference are: small (3.5 cm), medium (5.2 cm) and large (6.9 cm). In Finland the thickness has been measured to range from 1.5 cm to 9.0 cm with an average thickness of 4.4 cm (Karila 1984). In Sweden the mean thickness of compressed breast was found to be 5.0 cm (Thilander *et al.* 1989). In assessing glandular dose the average breast is often considered to be 4.5 cm thick and glandular content 50%.

Table 1. *X–ray spectra (x–ray tube target, filter, x–ray tube voltage) and breast models used in the calculations.*

Target	Mo, W
Filter	Zr, Mo, Ru, Pd, Al
High voltage (kV)	20, 25, 30, 35
Breast thickness (cm)	3.5[1], 5.2[1], 6.0[2], 6.9[1]
Fraction of glandular tissue (%)	10, 50, 90

[1] Non–uniform breast thickness (see Fig. 1a)
[2] Uniform breast thickness (see Fig. 1b)

a)



b)

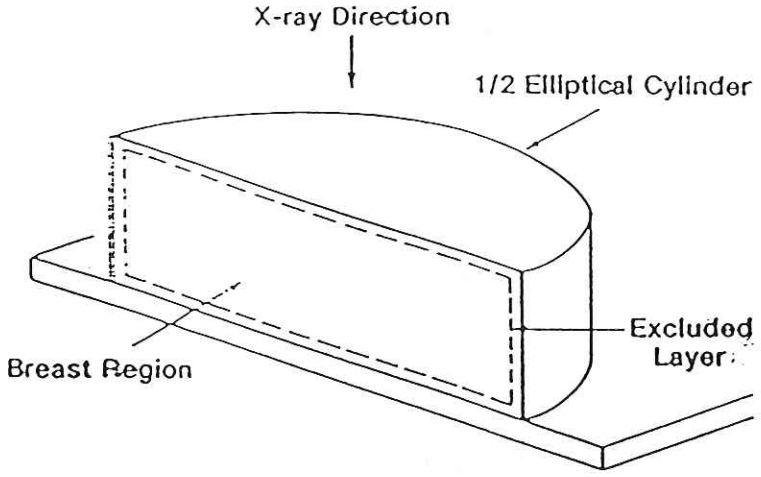


Figure 1. *The breast models used in this report (a) Non-uniform breast thickness – moderate compression. Craniocaudal view. Small breast: A = 4 cm, B = 3.5 cm, C = 4 cm, D = 12 cm. Medium breast: A = 6 cm, B = 5.2 cm, C = 8 cm, D = 18 cm. Large breast: A = 8 cm, B = 6.9 cm, C = 10 cm, D = 20 cm. (b) Uniform 6 cm breast thickness – firm compression. Craniocaudal view. (Rosenstein et al. 1985)*

The x–ray spectra from a molybdenum target, beryllium window x–ray tube (without any additional filtration) were measured using a germanium semiconductor detector (EG&G Ortec GLP–16195/10) and a multichannel analyser (Nuclear Data 62). The pulse–height spectra were corrected for the energy response of the detector by the method of Chen *et al.* (1984). The spectra were measured at a distance of about 3 m from the focal spot and were corrected for air attenuation to correspond to a distance of 50 cm from focus. The spectra from a tungsten target x–ray tube were generated by the method presented by Birch and Marshall (1979). The effect of various filters (Zr, Mo, Ru, Pd and Al) on the spectra was computed by using the attenuation coefficients of McMaster *et al.* (1969).

3. Results

The calculated glandular tissue dose conversion factors are given in Appendixes 1–3. The data are given in mGy for 1 mGy air kerma at the breast mid–plane (without a phantom). For dosimeters that display the exposure in röntgens one can use the correspondence of 1 R to 8.69 mGy. Each table in the appendixes is for a given x–ray tube target and filter material, and shows the glandular tissue conversion factors for several breast models and the HVL at the various tube voltages and filter thicknesses.

Appendix 1 shows the glandular tissue dose conversion factors for non–uniform breasts containing glandular tissue 50% by weight.

Appendix 2 shows the glandular tissue dose conversion factors for uniform 6 cm thick breasts of 10% 50% and 90% glandular tissue content.

Appendix 3 shows the glandular tissue dose conversion factors for non–uniform breasts containing glandular tissue 10% and 90% by weight.

4. Discussion

The method and Monte Carlo data of calculating the glandular tissue dose conversion factors in this report are the same as used by Andersen and Rosenstein (1985). The conversion factors calculated by us are, however, slightly higher than their results when compared at equal half–value layer, HVL. This difference is due to the difference in x–ray spectra. Rosenstein's spectra were measured from glass–window x–ray tubes with a higher filtration than we have used and are mean values over

various x–ray spectra; we consider our spectral data to represent typical film–screen mammography better.

Figure 2 shows a comparison of glandular tissue conversion factor data from several studies for a 6 cm thick breast. The agreement between our results and those given in literature is good. The small differences between our data and the data of Dance (1990) are likely to be due to the difference in the phantom models of Rosenstein and Dance.

It is often sufficient to estimate the glandular dose simply as based on the HVL and incident air kerma, especially if a conventional mammographic technique is employed. Useful data for this purpose has been published by Rosenstein et al (1985), Dance (1990), and Wu et al (1991, 1994). For optimizing purposes when other filters than molybdenum are being considered, however, accurate conversion factors are needed. HVL is not a sufficient descriptor of x–ray beam quality for such studies (Wu *et al.* 1991, Servomaa and Tapiovaara 1991). The purpose of this report has been to provide such data.

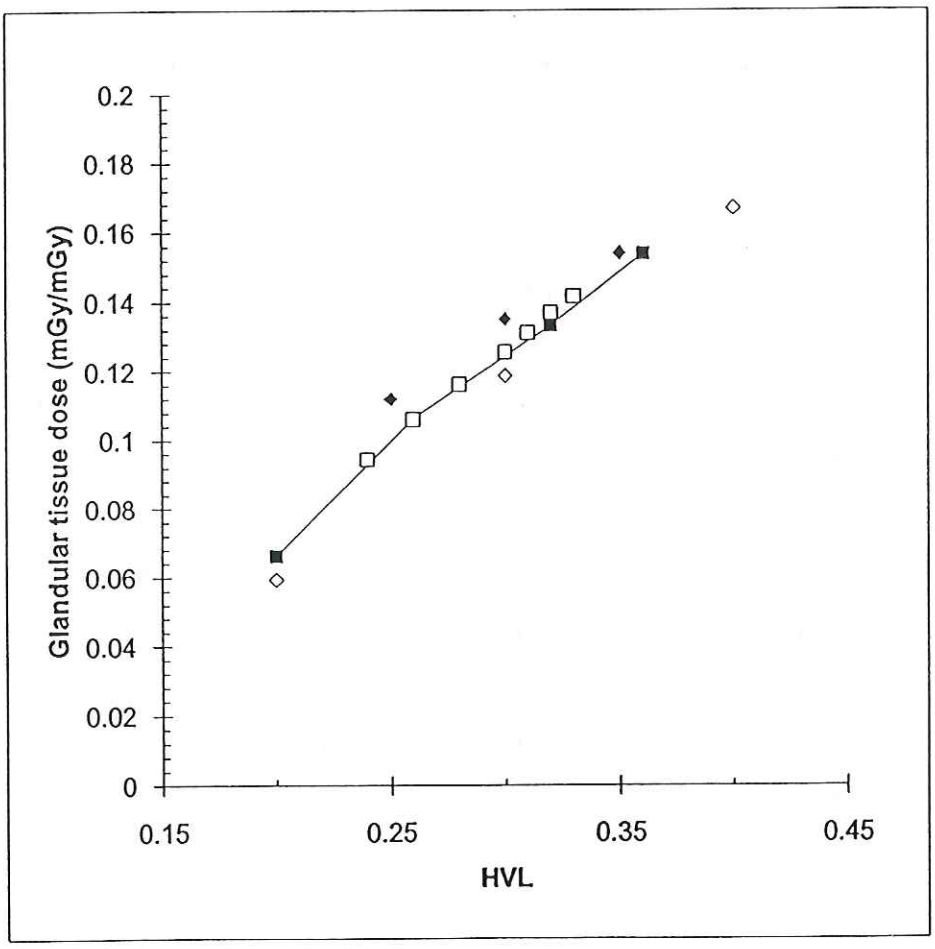


***Figure** 2. Glandular tissue dose conversion factors (mGy/mGy) for a 6 cm thick breast with glandular tissue content of 50%. The data shows the average glandular tissue dose for 1 mGy incident air kerma measured at the breast entrance plane without backscatter. Focal–spot to film distance 60 cm. All curves are for molybdenum anode x–ray tubes and 30 μm Mo filtration, except the data of Rosenstein et al. which are averaged over several spectra. ■ this report; □ Wu et al. (1991), ♦ Dance (1990), and ◊ Rosenstein et al. (1985).*

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Appendix 1: Glandular tissue dose (mGy) for 1 mGy incident air kerma (free-in-air) at breast mid-plane

- non uniform breast model
  - small, medium and large breast
  - glandular content 50%
- Mo and W-anode x-ray tubes
- Zr, Mo, Ru, Pd and Al filters
  - filter thickness 30–90 μm step 15 μm
  - Al-filter 0.30–0.90 mm Al step 0.15 mm Al
- 20–35 kV step 5 kV
- conversion factor mGy/mGy

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Zirconium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.15	0.077	0.055	0.040
20	0.045	0.18	0.098	0.070	0.051
20	0.06	0.21	0.114	0.083	0.060
20	0.075	0.23	0.129	0.093	0.068
20	0.09	0.25	0.142	0.104	0.076
25	0.03	0.19	0.123	0.092	0.068
25	0.045	0.22	0.143	0.106	0.078
25	0.06	0.25	0.159	0.120	0.089
25	0.075	0.28	0.174	0.131	0.097
25	0.09	0.3	0.186	0.140	0.105
30	0.03	0.23	0.162	0.125	0.094
30	0.045	0.27	0.182	0.140	0.106
30	0.06	0.3	0.198	0.153	0.115
30	0.075	0.33	0.212	0.171	0.122
30	0.09	0.35	0.223	0.171	0.129
35	0.03	0.26	0.194	0.153	0.117
35	0.045	0.3	0.214	0.168	0.129
35	0.06	0.34	0.229	0.180	0.137
35	0.075	0.36	0.241	0.189	0.144
35	0.09	0.38	0.250	0.197	0.150

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Molybdenum filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.2	0.115	0.084	0.061
20	0.045	0.25	0.144	0.107	0.078
20	0.06	0.28	0.168	0.125	0.092
20	0.075	0.31	0.189	0.142	0.105
20	0.09	0.34	0.206	0.155	0.115
25	0.03	0.26	0.177	0.136	0.101
25	0.045	0.32	0.212	0.163	0.122
25	0.06	0.37	0.238	0.184	0.139
25	0.075	0.4	0.259	0.201	0.152
25	0.09	0.43	0.276	0.215	0.163
30	0.03	0.32	0.217	0.170	0.129
30	0.045	0.37	0.249	0.194	0.147
30	0.06	0.42	0.269	0.212	0.160
30	0.075	0.45	0.285	0.224	0.170
30	0.09	0.47	0.298	0.235	0.178
35	0.03	0.36	0.247	0.196	0.150
35	0.045	0.41	0.274	0.216	0.166
35	0.06	0.45	0.291	0.231	0.176
35	0.075	0.47	0.303	0.241	0.184
35	0.09	0.49	0.312	0.249	0.190

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.24	0.139	0.102	0.075
20	0.045	0.29	0.173	0.129	0.096
20	0.06	0.33	0.199	0.151	0.112
20	0.075	0.36	0.221	0.168	0.125
20	0.09	0.39	0.238	0.183	0.137
25	0.03	0.33	0.222	0.173	0.130
25	0.045	0.4	0.265	0.208	0.159
25	0.06	0.46	0.296	0.235	0.180
25	0.075	0.49	0.320	0.255	0.196
25	0.09	0.53	0.338	0.272	0.209
30	0.03	0.38	0.260	0.205	0.157
30	0.045	0.45	0.295	0.235	0.180
30	0.06	0.49	0.319	0.254	0.194
30	0.075	0.53	0.336	0.269	0.207
30	0.09	0.55	0.350	0.282	0.217
35	0.03	0.42	0.284	0.228	0.175
35	0.045	0.48	0.313	0.251	0.193
35	0.06	0.51	0.331	0.267	0.206
35	0.075	0.54	0.345	0.278	0.215
35	0.09	0.56	0.357	0.288	0.222

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.25	0.147	0.109	0.079
20	0.045	0.3	0.183	0.137	0.101
20	0.06	0.34	0.209	0.159	0.119
20	0.075	0.38	0.231	0.177	0.132
20	0.09	0.4	0.250	0.192	0.144
25	0.03	0.36	0.241	0.189	0.144
25	0.045	0.43	0.288	0.228	0.175
25	0.06	0.49	0.321	0.258	0.198
25	0.075	0.54	0.348	0.281	0.216
25	0.09	0.57	0.368	0.299	0.232
30	0.03	0.42	0.284	0.228	0.175
30	0.045	0.49	0.326	0.262	0.205
30	0.06	0.54	0.353	0.288	0.223
30	0.075	0.58	0.376	0.307	0.239
30	0.09	0.62	0.395	0.326	0.254
35	0.03	0.46	0.308	0.250	0.193
35	0.045	0.52	0.342	0.278	0.216
35	0.06	0.57	0.366	0.299	0.234
35	0.075	0.6	0.384	0.316	0.247
35	0.09	0.63	0.402	0.331	0.260

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Aluminium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.18	0.104	0.075	0.054
20	0.5	0.24	0.137	0.100	0.074
20	0.7	0.27	0.163	0.121	0.090
20	0.9	0.31	0.185	0.138	0.102
20	1.1	0.34	0.203	0.153	0.114
25	0.3	0.25	0.176	0.136	0.102
25	0.5	0.33	0.224	0.175	0.132
25	0.7	0.39	0.260	0.205	0.157
25	0.9	0.44	0.288	0.229	0.175
25	1.1	0.47	0.311	0.249	0.191
30	0.3	0.31	0.229	0.182	0.139
30	0.5	0.4	0.280	0.226	0.174
30	0.7	0.47	0.316	0.257	0.199
30	0.9	0.52	0.344	0.283	0.220
30	1.1	0.56	0.367	0.303	0.237
35	0.3	0.36	0.267	0.216	0.168
35	0.5	0.46	0.319	0.262	0.205
35	0.7	0.52	0.356	0.296	0.234
35	0.9	0.58	0.386	0.323	0.257
35	1.1	0.63	0.411	0.348	0.277

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Zirconium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.12	0.054	0.038	0.028
20	0.045	0.14	0.072	0.052	0.037
20	0.06	0.17	0.092	0.066	0.047
20	0.075	0.19	0.109	0.079	0.058
20	0.09	0.22	0.127	0.093	0.068
25	0.03	0.12	0.066	0.048	0.036
25	0.045	0.15	0.085	0.063	0.046
25	0.06	0.17	0.105	0.077	0.056
25	0.075	0.2	0.124	0.092	0.068
25	0.09	0.23	0.143	0.106	0.078
30	0.03	0.13	0.077	0.059	0.045
30	0.045	0.15	0.098	0.075	0.056
30	0.06	0.18	0.120	0.092	0.069
30	0.075	0.21	0.139	0.107	0.081
30	0.09	0.24	0.159	0.122	0.091
35	0.03	0.13	0.090	0.071	0.055
35	0.045	0.15	0.114	0.091	0.070
35	0.06	0.18	0.139	0.112	0.086
35	0.075	0.21	0.163	0.131	0.102
35	0.09	0.25	0.185	0.148	0.115

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Molybdenum filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.16	0.093	0.068	0.049
20	0.045	0.22	0.132	0.098	0.071
20	0.06	0.27	0.166	0.124	0.092
20	0.075	0.31	0.192	0.145	0.108
20	0.09	0.35	0.214	0.162	0.121
25	0.03	0.18	0.121	0.091	0.068
25	0.045	0.25	0.169	0.130	0.097
25	0.06	0.31	0.209	0.161	0.122
25	0.075	0.37	0.241	0.186	0.140
25	0.09	0.41	0.264	0.205	0.155
30	0.03	0.18	0.136	0.106	0.081
30	0.045	0.26	0.188	0.147	0.112
30	0.06	0.33	0.229	0.180	0.137
30	0.075	0.39	0.259	0.204	0.155
30	0.09	0.43	0.280	0.221	0.168
35	0.03	0.19	0.154	0.124	0.096
35	0.045	0.27	0.209	0.169	0.131
35	0.06	0.35	0.253	0.205	0.159
35	0.075	0.41	0.283	0.229	0.177
35	0.09	0.45	0.303	0.244	0.189

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.030	0.20	0.124	0.092	0.067
20	0.045	0.27	0.170	0.129	0.094
20	0.060	0.33	0.205	0.157	0.116
20	0.075	0.37	0.231	0.176	0.132
20	0.090	0.40	0.250	0.192	0.145
25	0.030	0.25	0.185	0.145	0.109
25	0.045	0.37	0.225	0.203	0.154
25	0.060	0.45	0.301	0.242	0.185
25	0.075	0.51	0.334	0.269	0.208
25	0.090	0.55	0.358	0.290	0.226
30	0.030	0.27	0.213	0.169	0.130
30	0.045	0.40	0.285	0.230	0.177
30	0.060	0.49	0.331	0.268	0.208
30	0.075	0.55	0.360	0.295	0.229
30	0.090	0.59	0.382	0.313	0.244
35	0.030	0.29	0.235	0.192	0.150
35	0.045	0.43	0.310	0.254	0.199
35	0.060	0.62	0.354	0.291	0.228
35	0.075	0.58	0.381	0.314	0.246
35	0.090	0.62	0.399	0.330	0.259

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.22	0.133	0.101	0.074
20	0.045	0.3	0.184	0.139	0.102
20	0.06	0.35	0.219	0.167	0.124
20	0.075	0.39	0.243	0.186	0.140
20	0.09	0.42	0.262	0.203	0.152
25	0.03	0.29	0.217	0.173	0.131
25	0.045	0.42	0.295	0.237	0.183
25	0.06	0.51	0.344	0.281	0.217
25	0.075	0.58	0.379	0.311	0.243
25	0.09	0.63	0.405	0.335	0.264
30	0.03	0.33	0.260	0.212	0.165
30	0.045	0.49	0.344	0.283	0.222
30	0.06	0.6	0.394	0.328	0.258
30	0.075	0.67	0.427	0.358	0.283
30	0.09	0.72	0.452	0.381	0.302
35	0.03	0.36	0.287	0.239	0.188
35	0.045	0.54	0.372	0.312	0.246
35	0.06	0.64	0.419	0.353	0.280
35	0.075	0.71	0.449	0.380	0.303
35	0.09	0.76	0.471	0.399	0.319

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Aluminium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 50% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.15	0.079	0.058	0.041
20	0.5	0.2	0.122	0.087	0.066
20	0.7	0.26	0.159	0.119	0.087
20	0.9	0.3	0.188	0.142	0.105
20	1.1	0.34	0.211	0.160	0.119
25	0.3	0.17	0.121	0.093	0.070
25	0.5	0.26	0.192	0.151	0.115
25	0.7	0.35	0.252	0.201	0.154
25	0.9	0.43	0.297	0.239	0.185
25	1.1	0.49	0.330	0.268	0.208
30	0.3	0.18	0.155	0.125	0.097
30	0.5	0.3	0.250	0.206	0.161
30	0.7	0.44	0.328	0.274	0.216
30	0.9	0.85	0.383	0.322	0.257
30	1.1	0.64	0.411	0.359	0.287
35	0.3	0.19	0.183	0.153	0.122
35	0.5	0.35	0.296	0.252	0.203
35	0.7	0.53	0.386	0.333	0.268
35	0.9	0.67	0.446	0.389	0.315
35	1.1	0.78	0.490	0.429	0.349827

Appendix 2: Glandular tissue dose (mGy) for 1 mGy incident air kerma (free–in–air) at breast mid–plane

- uniform breast model of 6 cm thick
  - glandular content 10%, 50% and 90%
- Mo and W–anode x–ray tubes
- Zr, Mo, Ru, Pd and Al filters
  - filter thickness 30–90 μm step 15 μm
  - Al–filter 0.30–0.90 mm Al step 0.15 mm Al
- 20–35 kV step 5 kV
- conversion factor mGy/mGy

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Zirconium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.15	0.062	0.049	0.041
20	0.045	0.18	0.077	0.062	0.052
20	0.06	0.21	0.091	0.074	0.061
20	0.075	0.23	0.102	0.083	0.069
20	0.09	0.25	0.113	0.091	0.077
25	0.03	0.19	0.099	0.081	0.069
25	0.045	0.22	0.114	0.093	0.079
25	0.06	0.25	0.128	0.105	0.089
25	0.075	0.28	0.139	0.114	0.097
25	0.09	0.3	0.150	0.123	0.105
30	0.03	0.23	0.132	0.110	0.094
30	0.045	0.27	0.148	0.123	0.106
30	0.06	0.3	0.161	0.133	0.114
30	0.075	0.33	0.171	0.142	0.122
30	0.09	0.35	0.181	0.150	0.128
35	0.03	0.26	0.161	0.135	0.117
35	0.045	0.3	0.176	0.147	0.128
35	0.06	0.34	0.189	0.158	0.137
35	0.075	0.36	0.198	0.166	0.144
35	0.09	0.38	0.205	0.171	0.148

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Molybdenum filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.2	0.092	0.074	0.062
20	0.045	0.25	0.115	0.094	0.079
20	0.06	0.28	0.135	0.110	0.093
20	0.075	0.31	0.152	0.124	0.105
20	0.09	0.34	0.166	0.136	0.115
25	0.03	0.26	0.144	0.119	0.101
25	0.045	0.32	0.171	0.142	0.122
25	0.06	0.37	0.193	0.160	0.138
25	0.075	0.4	0.211	0.175	0.151
25	0.09	0.43	0.224	0.186	0.161
30	0.03	0.32	0.178	0.148	0.128
30	0.045	0.37	0.203	0.169	0.145
30	0.06	0.42	0.220	0.183	0.159
30	0.075	0.45	0.234	0.194	0.168
30	0.09	0.47	0.244	0.203	0.175
35	0.03	0.36	0.204	0.171	0.148
35	0.045	0.41	0.226	0.189	0.165
35	0.06	0.45	0.239	0.200	0.175
35	0.075	0.47	0.250	0.209	0.182
35	0.09	0.49	0.257	0.215	0.188

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Ruthenium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.24	0.110	0.090	0.076
20	0.045	0.29	0.138	0.113	0.096
20	0.06	0.33	0.160	0.131	0.112
20	0.075	0.36	0.177	0.146	0.124
20	0.09	0.39	0.192	0.159	0.136
25	0.03	0.33	0.182	0.151	0.130
25	0.045	0.4	0.217	0.181	0.157
25	0.06	0.46	0.244	0.204	0.176
25	0.075	0.49	0.264	0.221	0.192
25	0.09	0.53	0.280	0.235	0.205
30	0.03	0.38	0.214	0.178	0.155
30	0.045	0.45	0.243	0.204	0.176
30	0.06	0.49	0.262	0.220	0.192
30	0.075	0.53	0.277	0.234	0.204
30	0.09	0.55	0.290	0.244	0.213
35	0.03	0.42	0.236	0.199	0.174
35	0.045	0.48	0.260	0.219	0.191
35	0.06	0.51	0.275	0.231	0.203
35	0.075	0.54	0.287	0.242	0.212
35	0.09	0.56	0.296	0.250	0.219

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Palladium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.25	0.117	0.096	0.081
20	0.045	0.3	0.146	0.120	0.101
20	0.06	0.34	0.169	0.138	0.117
20	0.075	0.38	0.186	0.154	0.131
20	0.09	0.4	0.201	0.167	0.143
25	0.03	0.36	0.197	0.165	0.143
25	0.045	0.43	0.237	0.198	0.173
25	0.06	0.49	0.266	0.223	0.196
25	0.075	0.54	0.289	0.244	0.213
25	0.09	0.57	0.307	0.260	0.228
30	0.03	0.42	0.236	0.198	0.173
30	0.045	0.49	0.270	0.228	0.199
30	0.06	0.54	0.295	0.250	0.219
30	0.075	0.58	0.315	0.267	0.235
30	0.09	0.62	0.333	0.283	0.250
35	0.03	0.46	0.257	0.217	0.191
35	0.045	0.52	0.287	0.243	0.213
35	0.06	0.57	0.306	0.260	0.229
35	0.075	0.6	0.323	0.275	0.243
35	0.09	0.63	0.338	0.289	0.255

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Aluminium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.3	0.18	0.082	0.067	0.055
20	0.5	0.24	0.109	0.089	0.075
20	0.7	0.27	0.130	0.106	0.090
20	0.9	0.31	0.148	0.121	0.102
20	1.1	0.34	0.163	0.133	0.114
25	0.3	0.25	0.144	0.119	0.102
25	0.5	0.33	0.183	0.152	0.131
25	0.7	0.39	0.214	0.178	0.154
25	0.9	0.44	0.237	0.199	0.173
25	1.1	0.47	0.257	0.215	0.188
30	0.3	0.31	0.190	0.159	0.138
30	0.5	0.4	0.232	0.197	0.171
30	0.7	0.47	0.265	0.224	0.197
30	0.9	0.52	0.290	0.246	0.216
30	1.1	0.56	0.310	0.265	0.234
35	0.3	0.36	0.223	0.190	0.167
35	0.5	0.46	0.269	0.230	0.204
35	0.7	0.52	0.303	0.260	0.231
35	0.9	0.58	0.329	0.284	0.254
35	1.1	0.63	0.353	0.306	0.274

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Zirconium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.12	0.043	0.035	0.029
20	0.045	0.14	0.058	0.046	0.038
20	0.06	0.17	0.072	0.058	0.048
20	0.075	0.19	0.086	0.070	0.059
20	0.09	0.22	0.100	0.081	0.068
25	0.03	0.12	0.052	0.043	0.036
25	0.045	0.15	0.068	0.055	0.046
25	0.06	0.17	0.083	0.068	0.058
25	0.075	0.2	0.098	0.081	0.068
25	0.09	0.23	0.113	0.092	0.077
30	0.03	0.13	0.061	0.051	0.044
30	0.045	0.15	0.078	0.064	0.055
30	0.06	0.18	0.094	0.078	0.067
30	0.075	0.21	0.112	0.092	0.078
30	0.09	0.24	0.125	0.104	0.089
35	0.03	0.13	0.070	0.059	0.052
35	0.045	0.15	0.091	0.076	0.067
35	0.06	0.18	0.110	0.093	0.082
35	0.075	0.21	0.130	0.109	0.097
35	0.09	0.25	0.147	0.124	0.109

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Molybdenum filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.16	0.074	0.060	0.049
20	0.045	0.22	0.104	0.085	0.071
20	0.06	0.27	0.131	0.107	0.091
20	0.075	0.31	0.153	0.125	0.106
20	0.09	0.35	0.170	0.139	0.119
25	0.03	0.18	0.096	0.078	0.067
25	0.045	0.25	0.133	0.110	0.094
25	0.06	0.31	0.167	0.138	0.117
25	0.075	0.37	0.191	0.159	0.136
25	0.09	0.41	0.211	0.175	0.151
30	0.03	0.18	0.108	0.090	0.077
30	0.045	0.26	0.150	0.124	0.107
30	0.06	0.33	0.182	0.152	0.131
30	0.075	0.39	0.206	0.171	0.148
30	0.09	0.43	0.224	0.186	0.162
35	0.03	0.19	0.122	0.104	0.090
35	0.045	0.27	0.167	0.142	0.124
35	0.06	0.35	0.203	0.171	0.150
35	0.075	0.41	0.227	0.191	0.168
35	0.09	0.45	0.244	0.206	0.180

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Ruthenium filtration

Firm compression – Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.03	0.2	0.098	0.079	0.067
20	0.045	0.27	0.135	0.110	0.093
20	0.06	0.33	0.163	0.133	0.114
20	0.075	0.37	0.184	0.152	0.130
20	0.09	0.4	0.200	0.166	0.142
25	0.03	0.25	0.147	0.123	0.106
25	0.045	0.37	0.205	0.170	0.148
25	0.06	0.45	0.244	0.205	0.178
25	0.075	0.51	0.272	0.229	0.200
25	0.09	0.55	0.293	0.247	0.216
30	0.03	0.27	0.169	0.145	0.124
30	0.045	0.4	0.229	0.193	0.169
30	0.06	0.49	0.268	0.227	0.198
30	0.075	0.55	0.295	0.250	0.219
30	0.09	0.59	0.314	0.266	0.234
35	0.03	0.29	0.188	0.160	0.140
35	0.045	0.43	0.250	0.213	0.188
35	0.06	0.52	0.288	0.245	0.216
35	0.075	0.58	0.312	0.266	0.235
35	0.09	0.62	0.329	0.281	0.247

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Palladium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.030	0.22	0.107	0.088	0.074
20	0.045	0.30	0.146	0.120	0.101
20	0.060	0.35	0.174	0.143	0.122
20	0.075	0.39	0.194	0.160	0.137
20	0.090	0.42	0.211	0.174	0.150
25	0.030	0.29	0.174	0.145	0.125
25	0.045	0.42	0.238	0.200	0.175
25	0.060	0.51	0.281	0.238	0.209
25	0.075	0.58	0.312	0.266	0.234
25	0.090	0.63	0.337	0.289	0.253
30	0.030	0.33	0.208	0.177	0.155
30	0.045	0.49	0.280	0.238	0.211
30	0.060	0.60	0.325	0.277	0.246
30	0.075	0.67	0.356	0.305	0.270
30	0.090	0.72	0.379	0.326	0.290
35	0.030	0.36	0.231	0.198	0.175
35	0.045	0.54	0.304	0.261	0.232
35	0.060	0.64	0.348	0.298	0.266
35	0.075	0.71	0.375	0.232	0.289
35	0.090	0.76	0.396	0.342	0.305

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Aluminium filtration

Firm compression - Uniform breast thickness 6 cm
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content is given by weight

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Glandular tissue content 10% mGy/mGy	50% mGy/mGy	90% mGy/mGy
20	0.3	0.15	0.063	0.051	0.043
20	0.5	0.2	0.096	0.078	0.066
20	0.7	0.26	0.125	0.102	0.086
20	0.9	0.3	0.148	0.122	0.104
20	1.1	0.34	0.167	0.137	0.117
25	0.3	0.17	0.096	0.079	0.068
25	0.5	0.26	0.153	0.128	0.110
25	0.7	0.35	0.203	0.170	0.147
25	0.9	0.43	0.241	0.203	0.176
25	1.1	0.49	0.269	0.228	0.199
30	0.3	0.18	0.123	0.104	0.091
30	0.5	0.3	0.201	0.171	0.151
30	0.7	0.44	0.267	0.229	0.203
30	0.9	0.55	0.315	0.272	0.243
30	1.1	0.64	0.352	0.304	0.272
35	0.3	0.19	0.145	0.125	0.110
35	0.5	0.35	0.239	0.208	0.186
35	0.7	0.53	0.318	0.277	0.250
35	0.9	0.67	0.374	0.328	0.297
35	1.1	0.78	0.415	0.365	0.331

Appendix 3: Glandular tissue dose (mGy) for 1 mGy incident air kerma (free-in-air) at breast mid-plane

- Non-uniform breast model
  - small, medium and large breasts
  - glandular content 10% and 90%
- Mo and W-anode x-ray tubes
- Zr, Mo, Ru, Pd and Al filters
  - filter thickness 30–90 μm step 15 μm
  - Al-filter 0.30–0.90 mm Al step 0.15 mm Al
- 20–35 kV step 5 kV
- Conversion factor mGy/mGy

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Zirconium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.15	0.090	0.068	0.049
20	0.045	0.18	0.112	0.085	0.062
20	0.06	0.21	0.130	0.100	0.074
20	0.075	0.23	0.146	0.114	0.084
20	0.09	0.25	0.160	0.125	0.093
25	0.03	0.19	0.138	0.110	0.083
25	0.045	0.22	0.160	0.128	0.096
25	0.06	0.25	0.178	0.143	0.108
25	0.075	0.28	0.194	0.157	0.119
25	0.09	0.3	0.208	0.169	0.128
30	0.03	0.23	0.181	0.148	0.114
30	0.045	0.27	0.201	0.166	0.128
30	0.06	0.3	0.220	0.181	0.138
30	0.075	0.33	0.235	0.193	0.147
30	0.09	0.35	0.246	0.204	0.155
35	0.03	0.26	0.214	0.178	0.139
35	0.045	0.3	0.235	0.197	0.153
35	0.06	0.34	0.251	0.211	0.163
35	0.075	0.36	0.265	0.221	0.173
35	0.09	0.38	0.274	0.230	0.180

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Molybdenum filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.2	0.131	0.101	0.075
20	0.045	0.25	0.163	0.129	0.096
20	0.06	0.28	0.189	0.151	0.114
20	0.075	0.31	0.211	0.170	0.128
20	0.09	0.34	0.229	0.186	0.142
25	0.03	0.26	0.197	0.161	0.123
25	0.045	0.32	0.235	0.193	0.148
25	0.06	0.37	0.262	0.219	0.168
25	0.075	0.4	0.284	0.238	0.184
25	0.09	0.43	0.301	0.254	0.197
30	0.03	0.32	0.239	0.200	0.155
30	0.045	0.37	0.273	0.229	0.177
30	0.06	0.42	0.295	0.249	0.192
30	0.075	0.45	0.312	0.264	0.205
30	0.09	0.47	0.325	0.275	0.214
35	0.03	0.36	0.270	0.229	0.191
35	0.045	0.41	0.298	0.253	0.198
35	0.06	0.45	0.316	0.269	0.211
35	0.075	0.47	0.330	0.281	0.220
35	0.09	0.49	0.339	0.290	0.227

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.030	0.24	0.158	0.123	0.092
20	0.045	0.29	0.193	0.155	0.116
20	0.060	0.33	0.222	0.181	0.136
20	0.075	0.36	0.245	0.200	0.152
20	0.090	0.39	0.264	0.217	0.166
25	0.030	0.33	0.244	0.204	0.158
25	0.045	0.40	0.290	0.245	0.190
25	0.060	0.46	0.322	0.275	0.215
25	0.075	0.49	0.346	0.298	0.234
25	0.090	0.53	0.366	0.316	0.249
30	0.030	0.38	0.284	0.241	0.188
30	0.045	0.45	0.321	0.274	0.217
30	0.060	0.49	0.345	0.297	0.232
30	0.075	0.53	0.364	0.314	0.247
30	0.090	0.55	0.379	0.328	0.259
35	0.030	0.42	0.310	0.265	0.208
35	0.045	0.48	0.339	0.292	0.230
35	0.060	0.51	0.359	0.310	0.244
35	0.075	0.54	0.373	0.323	0.255
35	0.090	0.56	0.384	0.334	0.265

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.25	0.167	0.131	0.098
20	0.045	0.3	0.205	0.165	0.124
20	0.06	0.34	0.234	0.190	0.144
20	0.075	0.38	0.257	0.211	0.161
20	0.09	0.4	0.275	0.228	0.175
25	0.03	0.36	0.264	0.222	0.173
25	0.045	0.43	0.313	0.267	0.209
25	0.06	0.49	0.348	0.299	0.236
25	0.075	0.54	0.374	0.326	0.258
25	0.09	0.57	0.396	0.346	0.275
30	0.03	0.42	0.310	0.265	0.208
30	0.045	0.49	0.351	0.304	0.241
30	0.06	0.54	0.381	0.331	0.264
30	0.075	0.58	0.404	0.354	0.283
30	0.09	0.62	0.423	0.373	0.299
35	0.03	0.46	0.334	0.289	0.229
35	0.045	0.52	0.369	0.321	0.255
35	0.06	0.57	0.394	0.344	0.275
35	0.075	0.6	0.413	0.362	0.291
35	0.09	0.63	0.429	0.380	0.305

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Aluminium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.18	0.119	0.091	0.067
20	0.5	0.24	0.155	0.122	0.091
20	0.7	0.27	0.184	0.146	0.109
20	0.9	0.31	0.207	0.167	0.125
20	1.1	0.34	0.227	0.184	0.139
25	0.3	0.25	0.194	0.160	0.123
25	0.5	0.33	0.246	0.206	0.159
25	0.7	0.39	0.284	0.241	0.188
25	0.9	0.44	0.313	0.267	0.209
25	1.1	0.47	0.337	0.290	0.228
30	0.3	0.31	0.250	0.212	0.166
30	0.5	0.4	0.304	0.261	0.206
30	0.7	0.47	0.342	0.297	0.236
30	0.9	0.52	0.371	0.325	0.259
30	1.1	0.56	0.395	0.348	0.278
35	0.3	0.36	0.289	0.249	0.199
35	0.5	0.46	0.343	0.299	0.241
35	0.7	0.52	0.382	0.336	0.272
35	0.9	0.58	0.406	0.366	0.298
35	1.1	0.63	0.438	0.391	0.321

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Zirconium filtration

Moderate compression – Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.12	0.063	0.047	0.035
20	0.045	0.14	0.084	0.063	0.046
20	0.06	0.17	0.105	0.081	0.059
20	0.075	0.19	0.125	0.097	0.060
20	0.09	0.22	0.144	0.113	0.084
25	0.03	0.12	0.076	0.059	0.044
25	0.045	0.15	0.097	0.076	0.056
25	0.06	0.17	0.119	0.093	0.070
25	0.075	0.2	0.140	0.110	0.083
25	0.09	0.23	0.160	0.128	0.096
30	0.03	0.13	0.087	0.069	0.053
30	0.045	0.15	0.110	0.089	0.068
30	0.06	0.18	0.133	0.108	0.083
30	0.075	0.21	0.157	0.127	0.097
30	0.09	0.24	0.176	0.144	0.110
35	0.03	0.13	0.100	0.082	0.064
35	0.045	0.15	0.127	0.105	0.083
35	0.06	0.18	0.154	0.129	0.101
35	0.075	0.21	0.180	0.151	0.120
35	0.09	0.25	0.204	0.171	0.136

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Molybdenum filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.16	0.106	0.082	0.061
20	0.045	0.22	0.148	0.117	0.087
20	0.06	0.27	0.185	0.148	0.112
20	0.075	0.31	0.214	0.174	0.131
20	0.09	0.35	0.237	0.194	0.147
25	0.03	0.18	0.135	0.108	0.083
25	0.045	0.25	0.188	0.154	0.117
25	0.06	0.31	0.231	0.191	0.147
25	0.075	0.37	0.264	0.220	0.170
25	0.09	0.41	0.289	0.243	0.188
30	0.03	0.18	0.151	0.124	0.097
30	0.045	0.26	0.207	0.173	0.133
30	0.06	0.33	0.251	0.211	0.163
30	0.075	0.39	0.283	0.238	0.185
30	0.09	0.43	0.305	0.259	0.201
35	0.03	0.19	0.169	0.143	0.113
35	0.045	0.27	0.229	0.196	0.155
35	0.06	0.35	0.275	0.236	0.188
35	0.075	0.41	0.307	0.264	0.209
35	0.09	0.45	0.329	0.283	0.224

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.2	0.140	0.110	0.083
20	0.045	0.27	0.191	0.154	0.116
20	0.06	0.33	0.229	0.186	0.142
20	0.075	0.37	0.255	0.211	0.160
20	0.09	0.4	0.276	0.229	0.175
25	0.03	0.25	0.204	0.170	0.132
25	0.045	0.37	0.278	0.236	0.185
25	0.06	0.45	0.327	0.281	0.221
25	0.075	0.51	0.360	0.313	0.247
25	0.09	0.55	0.386	0.336	0.267
30	0.03	0.27	0.231	0.197	0.155
30	0.045	0.4	0.308	0.266	0.211
30	0.06	0.49	0.242	0.310	0.246
30	0.075	0.55	0.388	0.339	0.288
30	0.09	0.59	0.410	0.360	0.288
35	0.03	0.29	0.254	0.220	0.176
35	0.045	0.43	0.334	0.291	0.234
35	0.06	0.52	0.380	0.334	0.268
35	0.075	0.58	0.409	0.360	0.289
35	0.09	0.62	0.427	0.377	0.304

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.22	0.153	0.121	0.091
20	0.045	0.3	0.206	0.167	0.125
20	0.06	0.35	0.242	0.199	0.151
20	0.075	0.39	0.268	0.222	0.168
20	0.09	0.42	0.288	0.241	0.184
25	0.03	0.29	0.237	0.201	0.158
25	0.045	0.42	0.319	0.275	0.217
25	0.06	0.51	0.371	0.323	0.258
25	0.075	0.58	0.406	0.358	0.287
25	0.09	0.63	0.433	0.383	0.308
30	0.03	0.33	0.281	0.244	0.194
30	0.045	0.49	0.368	0.325	0.261
30	0.06	0.6	0.418	0.374	0.303
30	0.075	0.67	0.455	0.406	0.330
30	0.09	0.72	0.480	0.432	0.352
35	0.03	0.36	0.308	0.272	0.220
35	0.045	0.54	0.397	0.353	0.288
35	0.06	0.64	0.446	0.399	0.326
35	0.075	0.71	0.476	0.429	0.351
35	0.09	0.76	0.499	0.451	0.369

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Aluminium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 10% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.15	0.092	0.070	0.052
20	0.5	0.2	0.138	0.108	0.081
20	0.7	0.26	0.178	0.143	0.107
20	0.9	0.3	0.209	0.170	0.128
20	1.1	0.34	0.234	0.191	0.145
25	0.3	0.17	0.135	0.109	0.084
25	0.5	0.26	0.211	0.177	0.138
25	0.7	0.35	0.274	0.235	0.207
25	0.9	0.43	0.321	0.277	0.220
25	1.1	0.49	0.356	0.310	0.246
30	0.3	0.18	0.169	0.144	0.114
30	0.5	0.3	0.270	0.235	0.189
30	0.7	0.44	0.351	0.311	0.252
30	0.9	0.55	0.409	0.365	0.298
30	1.1	0.64	0.449	0.404	0.331
35	0.3	0.19	0.198	0.173	0.140
35	0.5	0.35	0.316	0.282	0.232
35	0.7	0.53	0.410	0.370	0.307
35	0.9	0.67	0.473	0.430	0.360
35	1.1	0.78	0.517	0.474	0.398

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Zirconium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.15	0.069	0.047	0.033
20	0.045	0.18	0.087	0.060	0.043
20	0.06	0.21	0.102	0.070	0.051
20	0.075	0.23	0.116	0.081	0.058
20	0.09	0.25	0.128	0.089	0.063
25	0.03	0.19	0.113	0.079	0.058
25	0.045	0.22	0.130	0.092	0.067
25	0.06	0.25	0.146	0.104	0.075
25	0.075	0.28	0.160	0.113	0.082
25	0.09	0.3	0.173	0.122	0.089
30	0.03	0.23	0.151	0.110	0.082
30	0.045	0.27	0.169	0.123	0.091
30	0.06	0.3	0.184	0.133	0.098
30	0.075	0.33	0.197	0.143	0.105
30	0.09	0.35	0.207	0.150	0.110
35	0.03	0.26	0.181	0.136	0.102
35	0.045	0.3	0.199	0.148	0.112
35	0.06	0.34	0.213	0.159	0.119
35	0.075	0.36	0.224	0.167	0.125
35	0.09	0.38	0.234	0.174	0.130

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Molybdenum filtration

Moderate compression – Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.2	0.104	0.071	0.052
20	0.045	0.25	0.131	0.092	0.066
20	0.06	0.28	0.154	0.108	0.101
20	0.075	0.31	0.174	0.123	0.089
20	0.09	0.34	0.190	0.135	0.098
25	0.03	0.26	0.165	0.119	0.086
25	0.045	0.32	0.197	0.143	0.105
25	0.06	0.37	0.222	0.161	0.120
25	0.075	0.4	0.243	0.177	0.131
25	0.09	0.43	0.258	0.189	0.140
30	0.03	0.32	0.204	0.150	0.110
30	0.045	0.37	0.232	0.170	0.127
30	0.06	0.42	0.252	0.186	0.138
30	0.075	0.45	0.268	0.198	0.147
30	0.09	0.47	0.280	0.206	0.154
35	0.03	0.36	0.231	0.174	0.130
35	0.045	0.41	0.257	0.192	0.144
35	0.06	0.45	0.273	0.205	0.153
35	0.075	0.47	0.285	0.213	0.160
35	0.09	0.49	0.295	0.220	0.165

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.24	0.127	0.087	0.063
20	0.045	0.29	0.159	0.112	0.081
20	0.06	0.33	0.184	0.130	0.094
20	0.075	0.36	0.205	0.146	0.107
20	0.09	0.39	0.222	0.159	0.116
25	0.03	0.33	0.207	0.152	0.113
25	0.045	0.4	0.249	0.184	0.137
25	0.06	0.46	0.278	0.207	0.155
25	0.075	0.49	0.301	0.227	0.170
25	0.09	0.53	0.320	0.242	0.182
30	0.03	0.38	0.244	0.182	0.136
30	0.045	0.45	0.277	0.207	0.155
30	0.06	0.49	0.300	0.226	0.169
30	0.075	0.53	0.318	0.239	0.181
30	0.09	0.55	0.331	0.251	0.189
35	0.03	0.42	0.268	0.203	0.153
35	0.045	0.48	0.296	0.223	0.169
35	0.06	0.51	0.313	0.237	0.180
35	0.075	0.54	0.327	0.249	0.188
35	0.09	0.56	0.337	0.257	0.194

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.25	0.135	0.094	0.068
20	0.045	0.3	0.168	0.119	0.086
20	0.06	0.34	0.193	0.138	0.101
20	0.075	0.38	0.215	0.154	0.113
20	0.09	0.4	0.232	0.168	0.123
25	0.03	0.36	0.226	0.167	0.124
25	0.045	0.43	0.270	0.203	0.152
25	0.06	0.49	0.303	0.229	0.173
25	0.075	0.54	0.329	0.251	0.190
25	0.09	0.57	0.350	0.268	0.204
30	0.03	0.42	0.268	0.203	0.152
30	0.045	0.49	0.307	0.234	0.212
30	0.06	0.54	0.335	0.257	0.196
30	0.075	0.56	0.358	0.276	0.211
30	0.09	0.62	0.376	0.293	0.223
35	0.03	0.46	0.291	0.223	0.169
35	0.045	0.52	0.325	0.250	0.189
35	0.06	0.57	0.348	0.269	0.205
35	0.075	0.6	0.366	0.284	0.219
35	0.09	0.63	0.382	0.299	0.229

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

Mo-anode x-ray tube
Aluminium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.18	0.093	0.064	0.055
20	0.5	0.24	0.124	0.086	0.062
20	0.7	0.27	0.150	0.105	0.064
20	0.9	0.31	0.170	0.120	0.090
20	1.1	0.34	0.188	0.132	0.097
25	0.3	0.25	0.163	0.119	0.086
25	0.5	0.33	0.209	0.154	0.114
25	0.7	0.39	0.244	0.181	0.135
25	0.9	0.44	0.272	0.203	0.152
25	1.1	0.47	0.293	0.221	0.166
30	0.3	0.31	0.214	0.161	0.124
30	0.5	0.4	0.264	0.201	0.152
30	0.7	0.47	0.299	0.230	0.175
30	0.9	0.52	0.327	0.253	0.193
30	1.1	0.56	0.350	0.274	0.209
35	0.3	0.36	0.251	0.194	0.148
35	0.5	0.46	0.301	0.237	0.178
35	0.7	0.52	0.338	0.268	0.207
35	0.9	0.58	0.367	0.295	0.229
35	1.1	0.63	0.392	0.318	0.251

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Zirconium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.12	0.048	0.032	0.023
20	0.045	0.14	0.064	0.044	0.031
20	0.06	0.17	0.082	0.056	0.040
20	0.075	0.19	0.099	0.068	0.048
20	0.09	0.22	0.115	0.079	0.058
25	0.03	0.12	0.060	0.041	0.030
25	0.045	0.15	0.066	0.054	0.039
25	0.06	0.17	0.096	0.067	0.048
25	0.075	0.2	0.113	0.079	0.058
25	0.09	0.23	0.130	0.091	0.066
30	0.03	0.13	0.070	0.052	0.038
30	0.045	0.15	0.090	0.066	0.048
30	0.06	0.18	0.109	0.081	0.060
30	0.075	0.21	0.129	0.094	0.069
30	0.09	0.24	0.146	0.107	0.078
35	0.03	0.13	0.083	0.064	0.048
35	0.045	0.15	0.106	0.082	0.062
35	0.06	0.18	0.129	0.100	0.076
35	0.075	0.21	0.152	0.117	0.090
35	0.09	0.25	0.173	0.133	0.102

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Molybdenum filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.16	0.084	0.059	0.041
20	0.045	0.22	0.120	0.084	0.061
20	0.06	0.27	0.152	0.107	0.067
20	0.075	0.31	0.177	0.127	0.092
20	0.09	0.35	0.198	0.142	0.104
25	0.03	0.18	0.110	0.079	0.058
25	0.045	0.25	0.157	0.110	0.083
25	0.06	0.31	0.194	0.142	0.105
25	0.075	0.37	0.224	0.163	0.121
25	0.09	0.41	0.246	0.192	0.133
30	0.03	0.18	0.127	0.093	0.070
30	0.045	0.26	0.175	0.130	0.097
30	0.06	0.33	0.214	0.159	0.119
30	0.075	0.39	0.242	0.180	0.133
30	0.09	0.43	0.262	0.194	0.145
35	0.03	0.19	0.144	0.110	0.084
35	0.045	0.27	0.197	0.152	0.115
35	0.06	0.35	0.238	0.183	0.139
35	0.075	0.41	0.266	0.205	0.155
35	0.09	0.45	0.285	0.219	0.166

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Ruthenium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.2	0.113	0.078	0.056
20	0.045	0.27	0.157	0.110	0.081
20	0.06	0.33	0.190	0.136	0.099
20	0.075	0.37	0.214	0.154	0.113
20	0.09	0.4	0.234	0.168	0.124
25	0.03	0.25	0.173	0.128	0.094
25	0.045	0.37	0.239	0.178	0.133
25	0.06	0.45	0.284	0.215	0.161
25	0.075	0.51	0.316	0.241	0.182
25	0.09	0.55	0.339	0.260	0.197
30	0.03	0.27	0.199	0.151	0.114
30	0.045	0.4	0.269	0.205	0.155
30	0.06	0.49	0.313	0.241	0.182
30	0.075	0.55	0.343	0.264	0.200
30	0.09	0.59	0.364	0.281	0.214
35	0.03	0.29	0.222	0.174	0.132
35	0.045	0.43	0.293	0.230	0.176
35	0.06	0.52	0.336	0.264	0.201
35	0.075	0.58	0.362	0.283	0.217
35	0.09	0.62	0.381	0.298	0.229

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Palladium filtration

Moderate compression - Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

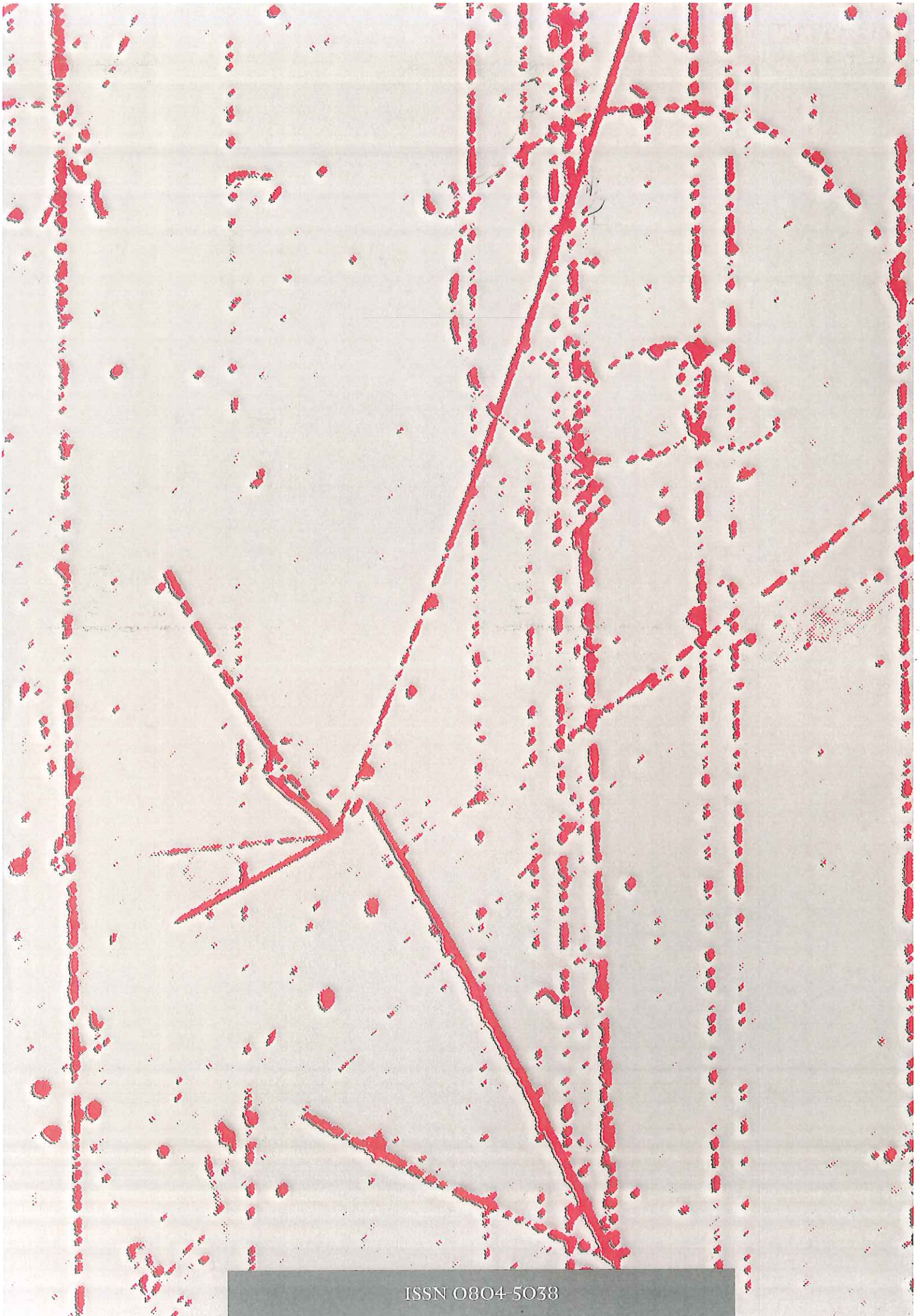
X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.03	0.22	0.124	0.086	0.062
20	0.045	0.3	0.169	0.121	0.087
20	0.06	0.35	0.203	0.145	0.106
20	0.075	0.39	0.226	0.162	0.120
20	0.09	0.42	0.244	0.177	0.130
25	0.03	0.29	0.204	0.153	0.114
25	0.045	0.42	0.277	0.212	0.160
25	0.06	0.51	0.327	0.251	0.191
25	0.075	0.58	0.360	0.280	0.214
25	0.09	0.63	0.387	0.303	0.232
30	0.03	0.33	0.245	0.190	0.145
30	0.045	0.49	0.327	0.255	0.196
30	0.06	0.6	0.376	0.297	0.228
30	0.075	0.67	0.409	0.326	0.251
30	0.09	0.72	0.433	0.346	0.268
35	0.03	0.36	0.273	0.216	0.167
35	0.045	0.54	0.354	0.283	0.219
35	0.06	0.64	0.400	0.322	0.250
35	0.075	0.71	0.373	0.348	0.269
35	0.09	0.76	0.452	0.366	0.284

GLANDULAR TISSUE DOSE (mGy) FOR 1 mGy INCIDENT AIR KERMA (FREE-IN-AIR) AT BREAST MID-PLANE

W-anode x-ray tube
Aluminium filtration

Moderate compression – Non-uniform breast thickness
Craniocaudal view (breast models: FDA 85-8239)
Glandular tissue content 90% (by weight)

X-ray tube voltage kV	Filter thickness mm	HVL mm Al	Small breast mGy/mGy	Medium breast mGy/mGy	Large breast mGy/mGy
20	0.3	0.15	0.071	0.049	0.036
20	0.5	0.2	0.110	0.077	0.055
20	0.7	0.26	0.145	0.102	0.075
20	0.9	0.3	0.173	0.123	0.090
20	1.1	0.34	0.194	0.139	0.101
25	0.3	0.17	0.112	0.082	0.060
25	0.5	0.26	0.180	0.133	0.100
25	0.7	0.35	0.237	0.178	0.135
25	0.9	0.43	0.281	0.214	0.161
25	1.1	0.49	0.313	0.241	0.182
30	0.3	0.18	0.145	0.112	0.085
30	0.5	0.3	0.236	0.186	0.143
30	0.7	0.44	0.312	0.249	0.192
30	0.9	0.55	0.365	0.295	0.229
30	1.1	0.64	0.404	0.329	0.255
35	0.3	0.19	0.173	0.139	0.108
35	0.5	0.35	0.282	0.231	0.181
35	0.7	0.53	0.369	0.307	0.242
35	0.9	0.67	0.429	0.361	0.285
35	1.1	0.78	0.471	0.400	0.318



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