Beck Radiological Innovations
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Testing Report for Bar-Ray Products Inc.

11-17-2016

Introduction

The purpose of testing was to determine compliance of Bar-Ray shielding materials with IEC 61331-3 Ed. 2.0 released in May 2014. All materials were tested at 70, 90 and 110 kV under narrow beam conditions. Homogeneity of lead equivalence was measured at 90 kV. The IEC rationale for testing at 70, 90 and 110 kV is that these energies roughly correspond to x-ray scattering for beams generated at 80, 100 and 120 kV respectively. All combinations of each Bar-Ray material used in current products were tested.

Methodology

A Radcal Accu-Pro electrometer calibrated 13 February 2014 was used for all testing. The setup included an Accu-kV non-invasive kV sensor and a Radcal diagnostic silicon dosimeter both mounted at the margins of the x-ray field. A 10x6-6 ion chamber was used for narrow beam measurements. Aluminum HVL's were measured for each setting. Lead standards spanning the range from ~0.1 to ~1.4 mm in eight steps were employed to calibrate lead equivalence. Testing utilized a high frequency Universal x-ray generator. The x-ray tube had no added filtration, only the inherent filtration of the glass tube port and the collimator mirror. The acrylic faceplate was removed to better approximate the minimum filtration specified by IEC based on Aluminum HVL measurement. Evaluations were done on three samples of each material and results were averaged.

Results

Table 1 lists the average Kilovoltages measured during testing, together with the half value layers (HVL) in mm Al. For comparison the HVLs listed in Table 1 of IEC 61331-3 Ed. 2.0: 2014 are also listed.

Tables 2-7 show the measured percent attenuation at 70, 90 and 110 kV with the tables listing materials in order of increasing nominal lead equivalence. Each table also lists the percent attenuation of pure lead in the first row. Tables 8-13 list the measured lead equivalence at 70, 90 and 110 kV. Table 14 lists measured uniformity for all of the materials tested

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Table 1: Kilovoltages and HVLs of x-ray beams used in testing, also shown are IEC specified HVL values.

kV Set	kV measured	Measured HVL (mm Al)	IEC HVL (mm Al)
70	71.0	3.18	2.44
90	92.2	4.23	3.1
110	113.5	5.27	3.79

Table 2: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.175 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.175 mm Pb		92%	85%	80%
Starlite	1 x .175	88.6%	83.2%	77.7%
Prestige	1 x .175	88.5%	85.4%	77.2%

Table 3: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.20 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.20 mm Pb		94%	87%	83%
Cost Cruncher	1 x .20	93%	87%	83%
True-Lite	1 x .20	92%	85%	80%
Starlite	1 x .20	89%	86%	78%
Scatter Sentry	1 x .20	93%	87%	83%
Prestige	1 x .20	90%	87%	80%

Table 4: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.25 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.25 mm Pb		96%	90%	87%
Cost Cruncher	1 x .25	95.9%	90.6%	87.8%
True-Lite	1 x .25	95.7%	90.3%	86.9%
Starlite	1 x .25	93.2%	89.7%	83.5%
Starlite	2 x .125	93.9%	89.6%	85.4%
Scatter Sentry	1 x .25	95.0%	89.5%	85.5%
Prestige	2 x .125	93.8%	90.6%	83.8%

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Table 5: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.35 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.35 mm Pb		98%	94%	92%
Starlite	2 x .175	97.6%	95.8%	90.7%
Prestige	2 x .175	97.6%	95.6%	90.4%

Table 6: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.40 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.40 mm Pb		99%	96%	94%
Cost Cruncher	2 x .20	98.6%	95.5%	93.9%
True-Lite	2 x .20	98.0%	94.5%	91.8%
Starlite	2 x .20	97.8%	95.9%	91.4%
Scatter Sentry	2 x .20	98.6%	95.3%	93.6%
Prestige	2 x .20	98.2%	96.0%	91.7%

Table 7: Percent attenuation under narrow beam conditions for materials nominally equivalent to 0.50 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
0.50 mm Pb		99%	97%	96%
Cost Cruncher	2 x .25	99.3%	97.3%	96.2%
True-Lite	2 x .25	99.3%	97.2%	95.8%
Starlite	2 x .25	99.0%	97.6%	94.0%
Starlite	4 x .125	99.1%	97.5%	95.2%
Scatter Sentry	2 x .25	99.2%	96.9%	95.2%
Prestige	4 x .125	99.1%	97.4%	94.1%

Table 8: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.175 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
Starlite	1 x .175	0.155	0.175	0.168
Prestige	1 x .175	0.098	0.177	0.150

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Table 9: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.20 mm Pb at 90 kV

Material	Layers	70 kV	90 kV	110 kV
Cost Cruncher	1 x .20	0.199	0.203	0.205
True-Lite	1 x .20	0.196	0.192	0.184
Starlite	1 x .20	0.160	0.202	0.173
Scatter Sentry	1 x .20	0.199	0.205	0.200
Prestige	1 x .20	0.113	0.197	0.167

Table 10: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.25 mm Pb at 90 kV

Material	**Layers**	**70 kV**	**90 kV**	**110 kV**
Cost Cruncher	1 x .25	0.264	0.264	0.268
True-Lite	1 x .25	0.258	0.258	0.254
Starlite	1 x .25	0.152	0.234	0.204
Starlite	2 x .125	0.210	0.244	0.233
Scatter Sentry	1 x .25	0.237	0.242	0.234
Prestige	2 x .125	0.163	0.250	0.208

Table 11: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.35 mm Pb at 90 kV.

Material	**Layers**	**70 kV**	**90 kV**	**110 kV**
Starlite	2 x .175	0.285	0.409	0.318
Prestige	2 x .175	0.285	0.402	0.311

Table 12: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.40 mm Pb at 90 kV.

Material	**Layers**	**70 kV**	**90 kV**	**110 kV**
Cost Cruncher	2 x .20	0.436	0.422	0.425
True-Lite	2 x .20	0.453	0.391	0.370
Starlite	2 x .20	0.294	0.418	0.335
Scatter Sentry	2 x .20	0.443	0.413	0.413
Prestige	2 x .20	0.426	0.423	0.343

Table 13: Measured lead equivalence under narrow beam conditions for materials nominally equivalent to 0.50 mm Pb at 90 kV.

Material	Layers	70 kV	90 kV	110 kV
Cost Cruncher	2 x .25	0.582	0.554	0.551
True-Lite	2 x .25	0.577	0.541	0.524
Starlite	2 x .25	0.412	0.546	0.416
Starlite	4 x .125	0.535	0.572	0.486
Scatter Sentry	2 x .25	0.546	0.515	0.488
Prestige	4 x .125	0.426	0.528	0.421

Table 14: Uniformity measurements (maximum deviation from mean value in mm Pb equivalent)

Layers	Uniformity (mm Pb equiv.)
Cost Cruncher 0.2	0.0039
Cost Cruncher .25	0.0032
Cost Cruncher 2 x 0.2	0.0081
Cost Cruncher 2 x 0.25	0.0021
Truelite 0.2	0.0021
True-lite .25	0.0041
True-lite 0.2 x2	0.0028
True-Lite 2 x 0.25	0.0074
Starlite .175	0.0031
Starlite 0.2	0.0026
Starlite .25	0.0034
Starlite .125 x 2	0.0067
Starlite 2 x .175	0.0037
Starlite 0.2 x2	0.0008
Starlite 2 x 0.25	0.0063
Starlite 4 x .125	0.0080
Scatter Sentry .2	0.0028
Scatter Sentry .25	0.0038
Scatter Sentry 2 x 0.2	0.0035
Scatter Sentry 2 x 0.25	0.0093
Prestige .175	0.0032
Prestige 0.2	0.0010
Prestige .125 x 2	0.0065
Prestige 2 x .175	0.0029
Prestige 2 x 0.2	0.0031
Prestige 4 x .125	0.0080

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Comments and Overall Conclusions:

These tests are a good faith effort to evaluate the test materials under IEC 61331-3 Ed. 2.0 May 2014 but some aspects of the testing procedure may have to be modified as laboratories gain experience with the methods. For example the x-ray machines in most hospitals in the US and Europe use x-ray beams that are heavily filtered to minimize radiation exposure of patients. The new version of IEC 61331-3 Ed. 2.0 May 2014 alters the specified beam hardness from a heavily copper filtered beam in the 1994 version to a minimum aluminum filter in the present version. Even with partially dismantling the beam collimator in my testing system I was unable to reduce the filtration to meet the newer requirement (Table 1). It is doubtful that most hospitals will be able to measure materials in the exact beam hardness specified in the new procedure.

The accepted tolerance in lead equivalence allowed by IEC 61331-3 Ed. 2.0 May 2014 is 7% below the specified value. Overall, all Bar-Ray materials meet the new IEC requirements for narrow beam testing at 90 kV. This is as expected since Bar-Ray production tests are also done at 90 kV although with a much harder x-ray beam. Cost Cruncher (pure lead), Scatter Sentry and True-Lite meet the requirements at all three kV settings. Starlite and Prestige show some reduction in lead equivalence at both 70 and 110 kV. The discrepancies at 70 kV are generally not meaningful since a tiny change in attenuation at this kV corresponds to a large change in lead equivalence. For example two layers of Starlite 0.2 produced an attenuation of 97.8% at 70 kV; this is 26% below that of pure lead in lead equivalence but less than 1% lower in attenuation.

If these measurements are compared with those measured on Bar-Ray materials in 2012, it should be noted that lead and the tested materials all have higher attenuation than reported in 2012. This does not mean a change in the material but is due to the less penetrating x-ray beam specified in IEC 61331-3 Ed. 2.0 2014 compared to that in IEC 61331-3 Ed. 1.0 1994 used in the 2012 report.

Uniformity values were good for all materials, showing a maximum deviation from mean values of 0.009 mm Pb or less.

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