TÜV NORD X-ray Technology

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Hanover, 28.11.2012

Technical Report
Testing the radiation protection properties of hollow wall boxes against X-ray radiation in accordance with DIN EN 61331-1 dated August 2006 and DIN 6812: 2010.

Client:	Kaiser GmbH & Co. KG Ramsloh 4 D-58579 Schalksmühle
Contractor:	TÜV NORD EnSys Hannover GmbH & Co. KG Am TÜV 1 30519 Hanover
Test Procedure:	X-ray room at the Technical Centre Am TÜV 1 30519 Hannover
Period of testing:	October 2012

Task

As a rule, structural radiation protection measures are required for X-ray rooms used for X-ray diagnostics. In Germany, the basis for planning and carrying out the testing is DIN 6812. Lead-lined lightweight boards made of plasterboard and special radiation protection plates with higher density gypsum mixtures are available for these protection measures. For the electrical installation of the devices, cavity wall boxes are used in cavity walls, making the installation process simple. The cavity wall boxes that are commonly used are made of thin plastic and have no radiation protection properties. For this reason, the mounting hole must be manually closed off at the back with lead sheeting. Kaiser has developed a cavity wall box that makes the installation of the electrical equipment easier.

The finished hollow wall box is cylindrically shaped, with a base that is almost flat. The transition from the wall to the base is chamfered at 45°. The openings for the supply lines are cut out here during installation. In addition, each box contains two incompletely shielded openings near the fastening tab (tab bearing).

Specifying a lead equivalent for the material in accordance with DIN 61331-1 is therefore not sufficient, because additional changes are made when using the product. There may also be gaps in the transitions between wall and the cavity wall box. These gaps are dependent on the thickness of the cavity walls, the number of boxes installed and the direction of the radiation involved. This is why structural feed-throughs must also be evaluated. This allows the suitability of the boxes to be determined for walls with a lead equivalent of up to 3 mm.

Figure 1 View of the radiation protection box

Test basis

When evaluating their suitability as a component for an X-ray room according to DIN 6812: 2010, the evaluation of the cavity wall box samples was carried out taking into account the limit values for the personal dose according to the X-ray Ordinance. The measurement of the attenuation of X-ray radiation takes into account the permissible averaging over 100 cm² in accordance with DIN IEC 60601-1-3. The test set-up was similar to DIN EN 61331-1.

Procedure

The cavity wall boxes were tested recessed into a wall with two plasterboard panels on the side of the box and two plasterboard panels on the opposite side in a triple combination. The mounting side of the wall is reinforced with 3mm of lead at the back.

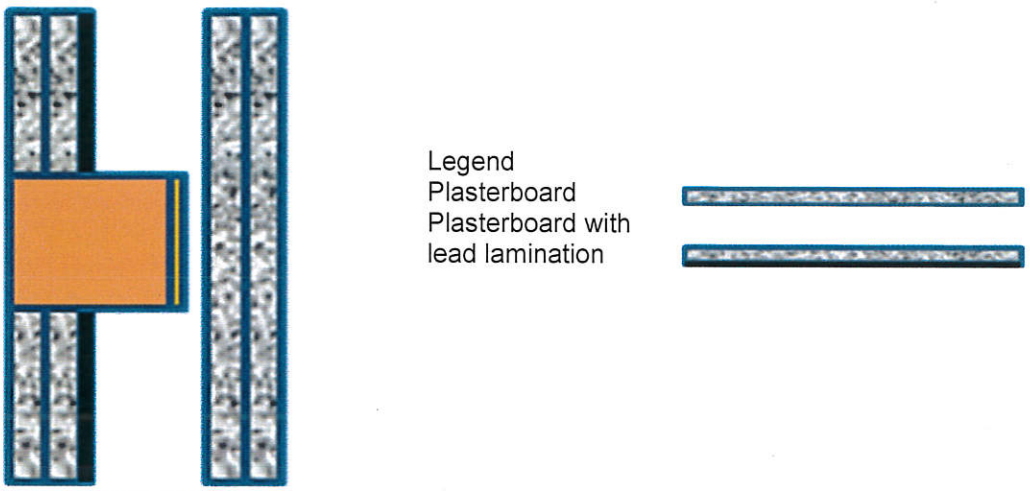

Figure 2 Wall construction

Of the three built-in cavity wall boxes, two cable feed-throughs were cut in the two outer ones. This structure corresponds to a conventional radiation protection wall and an electrical installation.

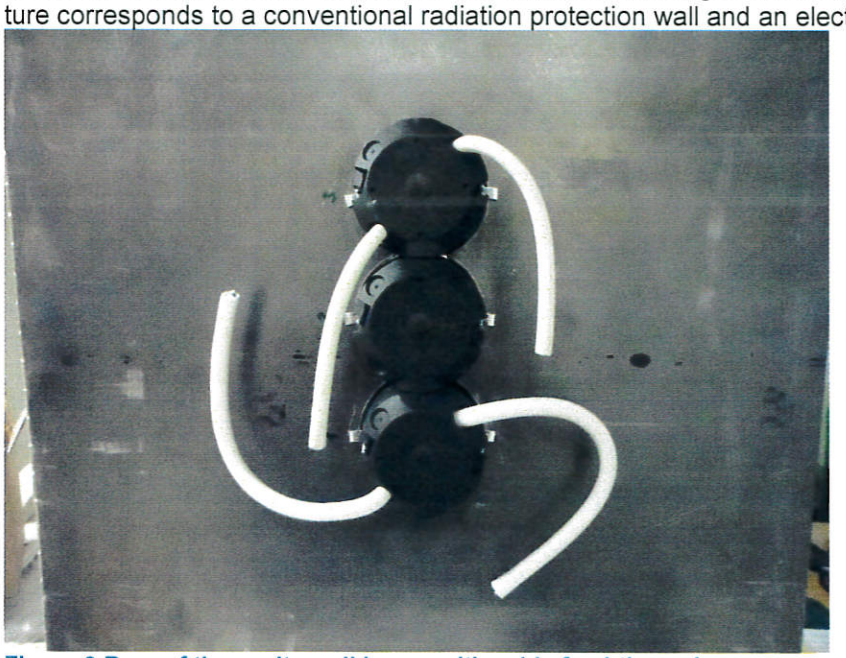

Figure 3 Rear of the cavity wall boxes with cable feed-throughs

The structural openings and the gaps of unknown geometry remaining in the installation were taken into account by averaging the measured dose over 100 cm². A dosimeter with a flat chamber BV 120 was used to measure the dose and dose rate. This ionisation chamber has a flat, disk-shaped geometry 14 mm thick and 160 mm in diameter with a chamber volume of 112 cm³. Since the averaging area is larger than the 100 cm² provided for in DIN IEC 60601-1-3, the entrance area was reduced by placing four shielding strips of lead in such a way that 100 cm² is not exceeded.
The requirements of the X-ray Ordinance must be taken into account in order to evaluate the cavity wall box under test. Both the whole body exposure and the partial body exposure limits must be respected. Partial body exposures arise as a result of the openings in the radiation protection wall. For the partial body dose, the X-ray Ordinance specifies a limit value for non-occupationally exposed persons of 50 mSv

or 15 mSv per year. The 15 mSv limit represents the most stringent requirement and is therefore used as the basis here. The minimum radiation attenuation to be achieved under measurement may therefore be 15 times lower than the attenuation factors specified in DIN 6812 where the limit value of the partial body dose is 15 mSv / year.

Qualification of the test setup

The reproducibility of the X-ray equipment and of the dosimeter was better than 5%. The correctness of the X-ray tube voltage was checked at regular intervals as part of quality assurance for the X-ray machine. In order to reduce the influence of the multiple scattered photons during measurement, the dose measurement behind the test object was carried out in a shielding box. The geometry ensures that the active volume of the measuring chamber used is not additionally affected by stray radiation.

The nominal attenuation factors for 3 mm lead for X-rays in the range 90 to 150 kV exceed the measuring range of a single dosimeter. An extension of the measuring range due to the change of the ionisation chamber is ruled out due to the given geometry. For this reason the dose rate of the X-ray machine was changed with the help of the X-ray tube current and adjusted to the attenuation to be measured. Since the limits of the measuring device had almost been reached, comparative measurements were carried out with a further calibrated and standardised measuring device to detect any nonlinearities in the X-ray device and the measuring device used, correcting them if necessary. The deviations that were found were 2% below the ideal value and were therefore not corrected. The dependence of the test equipment on the radiation energy was less than 5% between 90 kV and 150 kV. The requirements of DIN IEC 61331-1 were thus met.

Measuring equipment used:

PTW NOMEX QA No. 230204 with measuring chamber BV 120
PTW Diados E No. 00955.
40-160 kV X-ray device

Attenuation measurement

The attenuation measurement on the wall structure was carried out in the X-ray room of the Technical Centre at TÜV NORD in Hanover. The wall structure was irradiated with X-ray radiation at an X-ray tube voltage of 90 to 150 kV from a distance of 150 cm.

The attenuation of the specimen is calculated from the dose without specimen divided by the dose with specimen. The cavity wall box is deemed suitable if the attenuation factor in the measurement is greater than the value required in DIN 6812, corrected by the relationship between the limit values of the partial body dose to the effective dose. The calculated attenuation factor is compared with the required attenuation according to DIN 6812. Linear interpolation between the attenuation values of lead tabulated in DIN 6812:2012 gives a design value for the cavity wall box. This design value indicates the maximum lead equivalent value from the radiation protection plan in DIN 6812 with which the hollow wall boxes can be used.

Measurement result

X-ray tube voltage [kV]	Attenuation factors for 15 mSv partial body dose			Design value
	Cavity wall box	2.75 mm lead	3.0 mm lead	mm lead
90	1463	1407	2667	2.8
100	1161	747	1373	2.9
110	969	600	1107	2.9
120	864	507	933	3.0
130	760	443	800	3.0
140	663	387	713	3.0
150	583	343	640	3.0

Table 1 Cavity wall box without opening

X-ray tube voltage [kV]	Attenuation factors for 15 mSv partial body dose			Design value
	Cavity wall box	2.5 mm lead	2.75 mm lead	mm lead
90	754	740	1407	2.5
100	606	403	747	2.6
110	512	327	600	2.7
120	445	275	507	2.7
130	393	240	443	2.7
140	343	210	387	2.7
150	304	186	343	2.7

Table 2 Cavity wall box with opening

X-ray tube voltage [kV]	Attenuation factors for 15 mSv partial body dose			Design value
	Cavity wall box	2.75 mm lead	3.0 mm lead	mm lead
90	1624	1407	2667	2.8
100	1218	747	1373	2.9
110	1005	600	1107	2.9
120	855	507	933	3.0
130	738	443	800	3.0
140	658	387	713	3.0
150	578	343	640	2.9

Table 3 Angled radiation

Evaluation

It can be confirmed that the cavity wall boxes tested offer sufficient radiation protection for the application of 90 kV to 150 kV X-ray tube voltages up to a planned lead equivalent of at least of 2.5 mm lead. When installing the boxes in the base, this can be extended to at least 2.8 mm due to the oblique radiation normally present.

The radiation protection box type 9074-03 manufactured by Kaiser GmbH & Co. KG, Schalksmühle facilitates the construction of radiation protection walls for X-ray rooms with X-ray devices classified in DIN 6812 with tube voltages in the range 90 to 150 kV.

Making the conservative assumption that the attenuation factor at the lower X-ray tube voltages may not drop below the minimum value specified in Tables 1 to 3 at an X-ray tube voltage of 90 kV, these boxes can also be used for X-ray tube voltages below 90 kV. The attenuation factors required of the radiation protection plan must be observed for the partial body dose.

The wall construction shown by way of an example (Figure 2 Wall construction Construction) describes the number and position of the lightweight building panels to be used and the lead layer for compliance with the lead equivalents required in the plan according to DIN 6812. The number and position of the lead-free lightweight panels used in conjunction with the electrical installation box ensure that the limit values are complied with in accordance with the X-ray Ordinance without requiring additional shielding measures (e.g. lead enclosures) in the installation area.

The electrical installation boxes can be used both as a single box and in multiple combinations using a connection piece type 9060-88. Installation is possible on the one side as well as on the opposite side. If the boxes are placed opposite one another, an offset cable entry should be made in order to avoid continuous openings. The installation must be carried out in accordance with DIN 18015-3.

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