Operating Instructions for Counter Tube Type A

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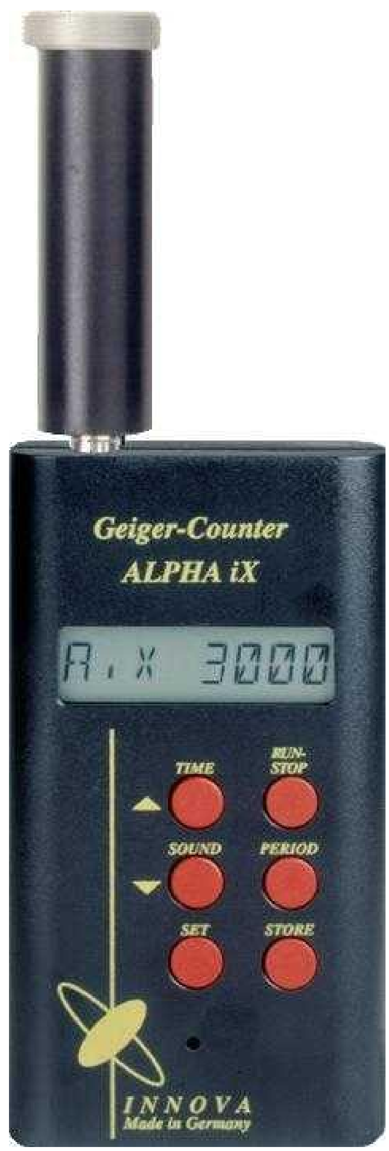

Operating Instructions for Counter Tube Type A

1. Dose rate measurement with counter tube A

The type A Geiger counter is actually used for contamination measurement at the surface of an object but can also be used for dose rate measurement. When the type A Geiger counter is used for dose rate measurement the protective end window cover of the tube for screening ALPHA and BETA radiation must remain on the radiation detection tube. Dose rate measurements are GAMMA ray (high energy electromagnetic waves) measurements in which the often concurrent particulate radiation (ALPHA + BETA radiation) must be suppressed as they would otherwise lead to the wrong results.
The radiation dose is expressed in sievert (Sv) (formerly rem) where

100 rem = 1 Sv or 1 rem = 0.01 Sv

In the counter tube A

20 impulses per minute (Ipm) = 120 mrem/a (millirems per annum)

That means: 120 mrem/a : 20 = 6

i.e. 1 Ipm in the type A Geiger counter corresponds to 6 mrem/a

The counted impulses per minute must be multiplied by the factor 6 in order to determine the radiation dose in millirems per year. For reduction to 1 hour the annual dose must be divided by 8,500.

In radiation measurement 8,500 hours represents the annual hourly basis and not 8640 or 8760 which can be determined from more accurate calculations.

EXAMPLE:

800 impulses were counted during a 10 minute test.
Reduced to 1 minute this corresponds to 80 impulses.
80 Ipm x factor 6 = 480 mrem/a or 4.8 mSv/a
480 mrem : 8,500 = 0.056 mrem/h or 0.00056 mSv/h

As 120 mrem/a corresponds to the customary background radiation (Federal Republic of Germany), the radiation exposure is therefore 4 times as high as the normal value. Suitable protective clothing is recommended for safety purposes if the radiation exposure exceeds 40 times that value.

2. Statistical Error of Measurement

120 mrem/a or 1.2 mSv/a is the customary background radiation (solar and earth radiation) which may however show considerable local variation. The customary background radiation of a location or test location can be determined if the radiation detection instrument is left running for 2 hours without the presence of a radioactive radiation source in its vicinity. The recorded number of impulses is reduced to a value per minute. This value (Ipm) is then the so called background frequency. During measurement, only values measured above the background frequency indicate the presence of radioactive exposure.

All measurements are subjected to a statistical error of measurement. This is due to the fact that radioactive radiation does not occur constantly in time and space but at varying intervals.

The error of measurement is calculated from the root of the counted impulses:

$$\text{Error of measurement in \%} = \frac{100}{\sqrt{N}}$$

(N = total counted impulses)

This means the error of measurement reduces with an increasing number of impulses. In other words, the longer the measurement, the more accurate the measurement. A series of measurements of, for example, 100 impulses has an error of measurement of 10 %, at 1.000 impulses only 3.2 % and at 10,000 impulses 1 %.

For food inspection purposes a minimum duration of 10 minutes is recommended for measurement. Experience shows that the tolerance value for 10 minute measurements at a background frequency of 20 Ipm is at 25 Ipm (20 + 5), i.e. only the impulses in excess of 25 per minute are the result of additional radiation exposure. If a series of measurements is very close to the tolerance value, the series must be repeated for a longer measuring period or using a more sensitive counter tube (type G).

3. Contamination Measurements

For contamination measurements Geiger counters must be able to detect BETA radiation and, if necessary, ALPHA radiation as well. To ensure the required detection sensitivity, Geiger counter A must be used without a protective cover for contamination measurements, i.e. measurements are carried out with the end window open. Contamination is measured in becquerel (radiation activity per second) and not in rem or sievert (radiation dose).

The sample to be tested should be pulverized and dried. Approximately 10 gram dry mass is sufficient for Geiger counter A as the end window of this counter is relatively small. The drying process can be carried out in a baking or microwave oven. The sample must be weighed before drying as the measured radiation must be related to the normal sample weight.

The open end window should he located as close as possible to the sample. A minimum safety distance of 5 mm must however be observed to avoid contamination of the end window due to contact. The end window of the type A Geiger counter is sunk by approx. 5 mm so that the metal bezel of the end window can be put on flat surfaces. For loose material a stand is required to ensure a constant distance for 10 minutes.

As already stated the tolerance value for a 10 minute measurement is 25 Ipm, i.e. it maximum 250 impulses are indicated during a 10 minute measurement the value is still within the tolerance value. If more than 255 impulses are measured after 10 minutes it can be assumed there is a minimum contamination of at least 600 Bq/kg on the tolerance value being exceeded. The detection limit of the type A Geiger counter at a distance of 0.5 cm and a measuring time of 10 minutes is approximately 3 Bq. When the 10 gram sample is converted to one kg (3 Bq x 100), the value is already 300 Bq/kg. This inaccurate result shows that Geiger counter A must really only be used for food inspection purposes in exceptional cases. More accurate results can he achieved by longer measuring periods or more sensitive probes such as type G Geiger counter – see MEASURING TABLE in the APPENDIX.

The calculated value relates to the normal sample weight insofar as the sample has been artificially dried. If dry samples are involved – such as coffee, tea, all types of drugs, milk powder, minerals, sand, building materials, scrap, etc. – the calculated value must be extrapolated to 1 kg as comparative values are usually given in kg. The conversion will give an inaccurate result but it will certainly be possible to determine whether contamination in excess of 600 Bq/kg is present.

4. Detection Limit (DL)

The detection limit (DL) of an instrument is calculated as follows:

$$DL = 3 \times \sqrt{\text{background frequency}}$$

For Geiger counter A the detection limit for a 1 minute measurement is 13.5 impulses and the tolerance value would therefore be 33.5 impulses:

$$3 \times \sqrt{20} = 4.473 \times 3 = 13.42 \text{ impulses (DL) or approx. } 13.5 \text{ DL}$$

20 (background frequency) + 13.5 = 33.5 impulses per minute (upper) tolerance value

The detection limit decreases for a 10 minute measurement:
20 impulses background frequency x 10 minutes = 200 impulses

$$3 \times \sqrt{200} = 3 \times 14.14 = 42.4/10 \text{ minutes} = 4.24 \text{ Ipm (DL)}$$

$$200 + 42.4 = 242.4 \text{ impulses or } 20 + 4.42 = 24.24 \text{ Ipm}$$

As the examples show, the accuracy of the measurement increases with its duration. If necessary, the duration of measurement must be extended if a 10 minute measurement does not show satisfactory results. As you can see, we have rounded up in the calculation of the tolerance value. Needless to say, you can work with the more accurate values.

The calculated detection limit for the type A Geiger counter (background frequency 20 Ipm) applied to the measuring table to Cs-137, for example, gives the following result:

35.6 Ipm correspond to = 100 Bq Cs-137
13.4 Ipm DL therefore correspond to
(100 Bq / 35.6 Ipm) x 13.4 = 2.81 x 13.4 = 37.65 Bq Cs-137

After a 10 minute measurement the detection limit is 4.24 Ipm. Applied to the measuring table (Cs-137) this gives
(100 Bq / 35.6 Ipm) x 4.24 = 2.81 x 4.24 = 11.92 Bq Cs-137

This means that a counter tube A can detect Cs-137 only from 38 Bq in a 1 minute measurement but already from 12 Bq in a 10 minute measurement.

5. KC1 Standard Compound

Experience shows that Geiger-Müller radiation detection tubes have a service life of about 10 years. The service life may be reduced if it is continuously used at intense radiation.

After many years of use, being able to check the operability of the radiation detection tubes is expedient. We therefore offer a standard compound which emits 12 Bq ± 1 on one surface. This is a KC1 tablet (5 gram) in which a natural radioactivity (K-40) of 85 Bq is embedded - of which, however, only 12 Bq emerges at a surface because the bulk of the BETA radiation remains in the tablet due to self-shielding.

The decay of potassium-40 releases up to 89. 3,1% BETA radiation with a maximum energy of 1,312 keV and up to 10.67 % GAMMA radiation of 1,461 keV.

Check measurement is carried out with opened covers both at the tablet and the radiation detection tube while the end window of the tube is held directly on the tablet surface. In the Geiger counter A, the metal bezel can be put on the tablet - as the end window itself is sunk. An operational Geiger counter the net impulse value indicated (after deduction of the background frequency) after 10 minutes must be for

Type A: 205 impulses ± 24

The check values for

Type B radiation detection tube:	434 impulses ± 26
Type G radiation detection tube:	1054 impulses ± 41
Type FSZ radiation detection tube:	792 impulses ± 35

With a probability of 65% all measured impulse frequencies will be within the above bandwidth around the check value. A pre-requisite is accurate enough determination of the background frequency to be deducted from the total number of impulses for calculating the net impulse frequency. Experience shows that the background frequency of radiation detection tubes increases with age.

6. Some more theory

Radioactive radiation sources are called RADIONUCLIDES in nuclear physics. The radiation energy is measured in mega-electronvolt (MeV) or kilo-electronvolt (keV):

$$\text{MEGA} = 1.000.000 = 10^6 \text{ or Kilo} = 1.000 = 10^3$$

Where this radiation arrives it is measured in sievert (Sv) or rem, where

100 rem = 1 Sv or 1 rem = 0.01 Sv

0.1 rem = 1 mSv or 0.1 mrem = 1 μSv

Normal background radiation: 120 mrem/a

120 mrem/a = 1.2 mSv/a = 0.015 mrem/h = 0.15 μSv/h

In principle it can be said that the counting efficiency of a measurement increases with the sensitivity of a Geiger-Müller counter. But that always applies only to one specific RADIONUCLIDE or its radiation energy. The penetration capacity (range) of radiation can be derived from the radiation energy. Whether the radiation can be detected by a Geiger counter and can therefore be measured depends on the radiation energy of the RADIONUCLIDE and the transparency/sensitivity of the counter.

The radiation energy of a NUCLIDE has nothing to do with its activity (decay per second), which is measured in becquerel (Bq). That also applies to the detection limit (DL) which relates to a minimum activity (Bq) of the radiation source required to allow its measurement. The radiation energy (keV) and its activity (Bq) are two different factors which, together with the type of radiation (ALPHA, BETA and GAMMA radiation) cause the radiation exposure.

Dosimeters (energy dose) are designed for measuring GAMMA radiation. These indicate the radiation in sievert (Sv) or rem. Contamination measuring instruments must be much more sensitive. They must allow measurement of BETA and, if necessary, ALPHA radiation. The specifications of radiation detection tubes also always show the radiation energy required to allow the tube to detect the radiation (quality characteristic). The end window tubes A and G can detect

ALPHA radiation from 1.9 MeV
BETA radiation from 0.09 MeV and
GAMMA radiation from 0.01 MeV

Immersion probes B and FSZ cannot detect ALPHA radiation and can detect BETA radiation from 0.2 MeV and GAMMA radiation from 0.02 MeV. The immersion probes can compensate for this drawback by the geometry factor. In immersion the radiation receiving surface of the probe is larger than in surface measurements. In surface measurements the radiation detection tube absorbs the radiation from one side only and even the smallest distance results in scatter losses.

APPENDIX

Measuring Table

In this measuring table standard emitters are prepared for 6 different nuclides which can be released in any failures in nuclear power stations; these are standard emitters with 100 Bq and 1,000 Bq. The impulses per minute during the measuring time of 10 minutes were recorded with the calculated background count of the radiation detection tubes deducted. These are therefore the net impulse frequencies (without background radiation).
A distance of 30 mm was chosen for this measurement. Smaller distances give higher impulse frequencies and larger distances correspondingly lower counting efficiencies.

NUCLIDE	END WINDOW COUNTER TUBES		IMMERSION COUNTER TUBES	
		- ipm -		
100 Bq	Type A	Type G	Type B	Type FSZ
J-131	26.2	63	13.5	27.5
Cs-137	35.6	143	27.3	52.3
Sr-90	36.0	155	29.1	59.0
Sr-90 + Y-90	84.6	363	100.3	203.4
Uranium	15.9	64	28.9	57.0
Thorium	19.3	74	31.2	62.1

1000 Bq	Type A	Type G	Type B	Type FSZ
J-131	262	626	135	275
Cs-137	356	1431	273	523
Sr-90	360	1550	291	590
Sr-90 + Y-90	846	3630	1003	2034
Uranium	159	638	289	570
Thorium	193	744	312	621

APPENDIX

Explanatory Notes on the Use of the Measuring Table

As can be seen, the relationship between the impulses of the radiation detection tubes is proportional to the becquerel values, in other words the higher impulse rates mean correspondingly higher becquerel values. So conclusions for other measurements are possible.

If, for example, a specific object contaminated by caesium-137*** must be investigated, a 10 minute measurement at a distance of 30 mm from the sample should be carried out. The result reduced to 1 minute must then be used for the table.

EXAMPLE

> A 10 minute measurement on a sample with caesium-137 using a type A Geiger counter shows after the measuring time a measured value of 500 impulses.
> After reduction to 1 minute (500 : 10 = 50 Ipm) and after deduction of the background frequency (20 Ipm) a net impulse rate of 30 Ipm is left.
> The column in the measuring table for a type A Geiger counter shows under 100 Bq Cs-137: 35,6 Ipm. Consequently, 30 Ipm corresponds to

100 Bq : 35,6 x 30 = 84.3 Bq

If the sample weight is, for example, 5 gram this value must be extrapolated to 1 kg (84,3 Bq x 200 = 16,860 Bq/kg)

Experience shows that the pre-requisites often do not concur with those of the measuring table. A shorter distance, usually 5 mm, is often chosen for surface measurements using the type A or G end window radiation detection tubes. The number of impulses at a distance of 5 mm is 5 times as high as that shown in the table, i.e. the corresponding value in the measuring table must be multiplied by a factor of 5 before conversion.

Thus 178 Ipm would correspond to (35,6 x 5) 100 Bq. Reduced to the above 30 Ipm that would be (100 : 178 x 30) only 16,9 Bq Cs-137.

The immersion radiation detection tubes are not normally used for surface measurements. These are much more efficient as immersion probes. To obtain comparable results, the value in the measuring table must even be multiplied by a factor of 10 in this case. This means that 100 Bq Cs-137 would correspond to 356 Ipm (35,6 x 10) for a type A Geiger counter.

*** It must be assumed that, due to the Chernobyl disaster, the existing contamination in Europe must be attributed almost exclusively to the nuclide caesium-137.
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