OPERATING INSTRUCTIONS
for Counter Tube Type G

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ALPHAiX
with Counter Tube Type G

End window counter tube for measurement of ALPHA, BETA and GAMMA radiation. Laboratory counter tube for surface measurement. Suitable for contamination measurements

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1. Dose Rate Measurement with Type G Counter Tube

The Type G end window counter tube is a pure contamination counter tube and not suitable for dose rate measurement. Simply because of its very high sensitivity, this counter tube becomes saturated relatively fast in cases of intense radiation which often arise in dose rate measurements. Its longer dead time leads to coincidence losses at a higher impulse density. Moreover, the all round radiation detection of the counter tube is not symmetrical due to the relatively large end window, so different results would be obtained at different angles to a specific radiation source. For dose rate measurement with ALPHAiX we recommend the Type A or B counter tube. The fluctuations in background radiation can be calculated in millirem per year (mrem/a) by multiplying the impulses by a factor of 4 and converting to 1 minute.

2. Statistical Error of Measurement

120 mrem/a or 1.2 mSv/a is the usual background radiation (solar and earth radiation) which can, however, show considerable local variation. The usual background radiation of a location or test location can be determined if the radiation detection instrument is left running for 2 hours with no radioactive radiation source present in its vicinity. The recorded number of impulses is converted to a value per minute. This value (Ipm) is then the so-called background count. In measurement, only measured values above the background count indicate the presence of radioactive exposure.

All measurements are subject 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 declines as the number of impulses increases. In other words, the longer the measurement, the more accurate the measurement. Thus a series of measurements of, say, 100 impulses has an error of measurement of 10% but only 3.2% at 1,000 impulses and 1% at 10,000 impulses.

For food inspections a minimum measurement duration of 10 minutes is recommended. Experience shows that the tolerance value for 10 minute measurements at background counts of 30 Ipm is at 35 Ipm (30 + 5), i.e. only the impulses in excess of 35 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.

3. Contamination Measurements

For contamination measurements counter tubes must be able to detect BETA radiation and possibly ALPHA radiation as well. To ensure the required detection sensitivity, the counter tube must always be used without a protective cover for contamination measurements, i.e. with the end window open.

Contamination is measured in becquerel (radiation activity) and not in rem or sievert (radiation energy).

The sample to be tested should be pulverized and dried, approx. 20 gram dry mass is sufficient for counter tube G 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 be 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. For accurate measurements a stand is required to ensure a constant distance for 10 minutes
As already mentioned, the tolerance value for a 10 minute measurement is 35 Ipm – i.e. if a maximum of 350 impulses are indicated during a 10 minute measurement the value is still within the tolerance value. If more than 350 impulses are measured after 10 minutes it can be assumed that there is already a contamination of at least 50 Bq/kg on exceeding the tolerance value.

The detection limit of the Type G counter tube at a distance of 0.5 cm and a measuring time of 10 minutes is approx. 1 Bq. When the 20 gram sample is converted to one kg (1 Bq x 50), the value is 50 Bq/kg.

The calculated value refers 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 because comparative values are usually given in kg. But extrapolation is at the expense of an exact result (± 20%).

4. Detection Limit (DL)

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

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

For counter tube G (background counts = 30) the detection limit for a 1 minute measurement is 16.5 impulses and the tolerance value would therefore be 46.5 impulses:

$$3 \times \sqrt{30} = 5.478 \times 3 = 16.434 \text{ impulses (DL)}$$
$$30 + 16.5 = 46.5 \text{ Ipm tolerance value}$$

The detection limit decreases for a 10 minute measurement:

$$30 \text{ impulses background counts} \times 10 \text{ minutes} = 300 \text{ impulses}$$
$$3 \times \sqrt{300} = 3 \times 17.32 = 51.96$$
$$51.96 : 10 \text{ minutes} = 5.19 \text{ Ipm (DL)}$$
$$300 + 52 = 352 \text{ impulses or } 30 + 5.2 = 35.2 \text{ Ipm (DL)}$$

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 G counter tube (background counts 30 Ipm) applied to the measuring table to Cs-137, for example, gives the following result:

143 Ipm correspond to = 100 Bq Cs-137
16.5 Ipm DL therefore correspond to
100 Bq / 143 Ipm = 0.7
0.7 x 16.5 = 11.5 Bq Cs-137

After a 10 minute measurement the detection limit is 5.2 Ipm.
Applied to the measuring table (Cs-137) this gives

(100 Bq / 143 Ipm) = 0.7
0.7 x 5.2 = 3.6 Bq Cs-137

This means that a counter tube G can detect Cs-137 only from 12 Bq in a 1 minute measurement but already from 4 Bq in a 10 minute measurement.

5. KC1 Standard Compound

Experience shows that Geiger-Müller counter tubes have a service life of about 10 years. The service life is reduced in the event of continuous use at intense radiation because the quenching gas in the tube is used up faster.

It is expedient after many years of use to be able to check the operability of the radiation detection tubes. 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 89.33% 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 counter tube with the end window of the tube held directly on the tablet surface. In the counter tube A, the metal bezel can be put on the tablet as the end window itself is sunk but in counter tube G a distance of approx. 3 mm must be observed. In an operational counter tube the net impulse value indicated (after deduction of the background counts) after 10 minutes must be for

Type G:	1054 impulses ± 41

The check values for

Type A counter tube:	205 impulses ± 24
Type B counter tube:	434 impulses ± 26
Type FSZ counter tube:	792 impulses ± 35

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

6. Differentiation of Radiation Types

Differentiation of ALPHA, BETA and GAMMA radiation is relatively easy with regard to ALPHA radiation. ALPHA radiation involves helium nuclei with two positive charges which themselves have a short range even in air – max. 10 cm and usually not more than 5 cm.

The ALPHA component of radiation can be determined by 2 measurements using the end window counter tubes (A or G) in which one measurement is carried out with open end window and the other measurement with an open window which is however covered by a thin transparent film. The thin transparent film shields against ALPHA particles, so the ALPHA radiation component follows from the difference between the two measurements. If ALPHA radiation is present the first measurement without transparent film must be correspondingly higher. The distance for these measurements should be 5 mm.

Separating the BETA radiation from the GAMMA radiation is not so simple because complete shielding against BETA radiation already absorbs part of the GAMMA radiation even at the higher energy levels. The BETA radiation up to roughly 1.5 MeV can be shielded by Plexiglass or plastic plate with a thickness of 4 mm or aluminum with a thickness of 2 mm. A thick ruler is usually sufficient. For counter tube A this shielding is carried out with an aluminum cover. So a 3rd measurement shielded with 4 mm Plexiglass or plastic plate – produces a difference to the 2nd measurement corresponding to the BETA component in the radiation.

7. Some more theory

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

MEGA = 1,000,000 = 10^6 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 = 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 rises with the sensitivity of a Geiger-Müller counter tube. 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). This also applies to the detection limit (DL) which refers to the 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 show the radiation in sievert (Sv) or rem. Contamination measuring instruments must be much more sensitive. They must allow measurement of BETA and possibly also ALPHA radiation.

The specifications of radiation detection tubes also always state the radiation energy required so the tube can detect the radiation (quality characteristic). The end window tubes A and G can detect

e.g. ALPHA radiation from 1.9 MeV
BETA radiation from 0.09 MeV
and GAMMA radiation from 0.01 MeV

Immersion probes B and FSZ can detect no ALPHA radiation and 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 surface of the probe receiving radiation is larger than in surface measurements. In surface measurements the counter tube absorbs the radiation from one side only and even the smallest distance results in scatter losses.

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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.

	Impulses per minute Ipm			
NUCLIDE	END WINDOW COUNTER TUBES –		IMMERSION COUNTER TUBES	
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

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Explanatory Notes on Using the Measuring Table

As can be seen, the relationship between the impulses of the counter tubes is proportionate to the becquerel values - in other words, the higher impulse rates mean correspondingly higher becquerel values. Conclusions for other measurements are thus possible.

If, for example, a specific object contaminated by caesium-137 *** must be examined, 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 G counter tube 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 counts (30 Ipm) a net impulse rate of 20 Ipm is left.

The column in the measuring table for a counter tube G shows under 100 Bq Cs-137: 143 Ipm. Consequently, 20 Ipm corresponds to

100 Bq / 143 x 20 = 14 Bq

If the sample weight is, for example, 20 gram this value must be extrapolated to 1 kg

(14 Bq x 50 = 700 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 counter 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 715 Ipm would correspond to (143 x 5) 100 Bq.
Converted to the above 30 Ipm, that would be

(100 / 715 x 20) only 2.8 Bq Cs-137

The immersion counter 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 be multiplied by the high factor of 10 in this case. This means that 100 Bq Cs-137 would correspond to 1430 Ipm (143 x 10) for a counter tube type G.

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