OPERATING INSTRUCTIONS
for Counter Tube Type FSZ

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ALPHAiX
with Counter Tube Type FSZ

Immersion counter tube for measurement of BETA and GAMMA radiation. Designed for measurements on bulk solid materials and liquids. Also suitable for contamination measurements on food with high liquid content (meat). Particularly recommended for mobile use. Dose rate measurements are also possible.

OPERATING INSTRUCTIONS
for Counter Tube Type FSZ

1. Dose rate measurement with type FSZ Counter Tube

Counter tube type FSZ is a counter tube which can be used in various fields of application. When using counter tube type FSZ for dose rate measurements, the protective cover of the counter tube (which it removed for contamination measurements) must remain in position on the counter tube, in order to shield the BETA radiation, Dose rate measurements are measurements of GAMMA radiation (high energy electromagnetic waves), and it is necessary here to shield the ALPHA + BETA radiation (particle radiation), which often occurs simultaneously.

The radiation dose is given in REM, and more recently in Sievert (Sv), whereby

100 Rem = 1 Sv or 1 Rem 0.01 Sv

For counter tube type FSZ:

17 impulses per minute (Ipm) = 120 mrem/a (Millirem per year)

This means: 120 mrem/a : 17 = 7

i.e. 1 Ipm for counter tube FSZ corresponds to 7 mrem/a

In order to calculate the radiation dose in millirem per year the counted impulses per minute must be multiplied by the factor 7. 10 calculate the dose for 1 hour the yearly dose value must be divided by 8500. In radiation measuring technique the yearly hour basis is taken as 8500 and not 8640 or 8760 hours, which is found by more exact calculation.

EXAMPLE

During a 10 minute measurement 800 impulses are counted. This corresponds to 80 impulses for 1 minute.

80 Ipm x factor 7	=	560 mrem/a
or 5.5 mSv/a	=	56 µSv/a
560 mrem : 8500	=	0.066 mrem/hr
or 0.00056 mSv/hr	=	0.66 µSv/hr

Since 120 mrem/a corresponds to the normal background radiation (Federal Republic of Germany) the radiation contamination is thus 5 times higher than the normal value. If the radioactive radiation is more than 40 times higher, protective clothing is normally recommended. It should be considered that injury through exposure to radiation becomes progressively worse as the period of exposure increases. Thus in the case of continuous exposure, a relatively low dose can still cause injury.

2. Statistical measurement error

120 mrem/a or 1.2 mSv/a is the normal background radiation (solar and earth radiation), although this can vary considerably in different regions. The normal background radiation of a particular region or measuring place can be determined by allowing the radiation measuring device to run for 2 hours with no radioactive emitters in the vicinity. The registered impulse count is converted to a basis of 1 minute. This value (Ipm) is then the so called zero (background) rate. When taking measurements, only measured values which are above the zero rate give an indication that there may be radioactive contamination in the area.

All measurements are subject to a statistical measurement error. This is due to the fact that radioactive radiation is not constant with respect to time and space, but occurs at different intervals.

The measurement error can be calculated from the root of the counted impulses:

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

(N = total counted impulses)

This means that the measurement error decreases with increasing impulse number. In other words, the longer the measurement the more accurate it becomes. Thus, for example, a series of measurements of 100 impulses has a measurement error of 10 %, whereas for 1000 impulses the error is only 3.2 % and for 10,000 impulses as little as 1 %.

When testing food a minimum measuring period of 10 minutes is always to be recommended. Experience has shown that for 10 minute measurements and a zero rate of 17 Ipm, the tolerance value is 21 Ipm (17 + 4), i.e. only the impulses above 21 per minute result from additional radiation contamination. If the determined zero rate is not 17 but, for example, 15, the tolerance value is then 19 (15 + 4) - see section on detection limit.

3. Contamination Measurements

For contamination measurements counter tubes must be able to detect BETA radiation. In order to guarantee the necessary detection sensitivity, counter tube FSZ should be used without the protective cover for contamination measurements. The counter tubes can be washed, but please do not crush them since the metal casing is only 1/10 mm thick. Contamination is measured in Becquerel (activity) and not in Rem or Sievert (energy of the radiation).
For surface measurements counter tubes with a sensitive end window are preferred. However, if measurement of the ALPHA radiation is not essential, immersion counter tubes should be used, since these are more robust, easier to handle and better results with respect to sensitivity can be achieved.
For food controls we recommend, in addition to 10 minute measurements, that counter tube FSZ is used as an immersion counter tube, since this enables a higher count yield to be achieved through the geometry factor (all-round pick up of radiation). The sample to be tested should be ground and dried to give 100 grams of dried material. Drying can be carried out in a baking oven or microwave overt. Before drying, the sample should be weighed, since the measured radiation should be related to the normal weight.
As already mentioned the tolerance value for a 10 minute measurement is 21 Ipm. This means that if a maximum of 210 impulses is indicated during a 10 minute measurement. the value is still within the permissible tolerance. If the number of impulses measured is above 210 impulses after 10 minutes, then every additional impuls corresponds to 10 Bq/kg.
(* taking into consideration the next paragraph).
This calculation is a rule of thumb, which can vary by max. ± 30%, depending on the nuclide.
The determined value is based on the normal weight of the sample if the sample has been artificially dried. If the food is dry bulk meterial e.g. coffee, tea, cocoa, drugs of any kind, milk powder etc, the measured value is always related to 1 kg. The counter tube only detects radiation at a distance of max. 1 - 2 cm anyway, no matter whether it is placed in a 100 liter drum or in a 100 gram container.
EXAMPLE:

> In a 10 minute measurement 250 impulses are counted. The zero (background) rate is 17 Ipm, so that, for a 10 minute measurement 210 impulses are still within the tolerance. Every impulse above this value represents
>
> > 10 Bq of unnatural radiation contamination.
> > 250 impulses - 210 tolerance value = 40 impulses
> > 40 impulses x 10 Bq = 400 Bq/kg additional radiation

These 400 Bq should be considered as the minimum value of radioactive contamination, since the tolerance range (110 - 210 impulses for a 10 minute measurement) also includes a proportion of radiation contamination which cannot be determined accurately, however, since it is outside the detection limit. Therefore the radiation contamination is really between 400 and 800 Bq/kg, whereby the 400 Bq can be taken as a reliable lower value.

4. Detection limit (DL)

The detection limit of a radiation measuring device is calculated as follows :

$$DL = 3 \sqrt{\text{zero rate}}$$

For counter tube FSZ the detection limit for a measurement of 1 minute is 17 impulses, so that the tolerance value would he 29.5 impulses

$$3 \times \sqrt{17} = 4.123 \times 3 = 12.369 \text{ impulses (DL)}$$

$$17 + 12.5 = 29.5 \text{ Ipm tolerance value}$$

For a 10 minute measurement the detection limit decreases:

17 impulses zero rate x 10 minutes = 170 impulses

$$3 \times \sqrt{170} = 3 \times 13.04 = 39.1$$

39.1 : 10 minutes = 3.9 impulses (Ipm) DL

170 + 39 = 209 impulses or 17 + 3.9 = 20.9 Ipm (DL)

As can be seen from this example the measuring accuracy increases with measuring time. The measuring time may have to be increased if the result after a 10 minute measurement is not satisfactory.

Using the measuring table in the APPENDIX the following points must be taken into account

1. The calculation is for Cs-137
2. When using counter tube FSZ as an immersion counter tube, the value in the measuring table must be multiplied by the factor 10.
3. The sample is 100 g dry bulk material - if necessary the samples should be suitably dried and ground.

523 Ipm (52.3 x 10) correspond to = 100 Bq Cs-137

Therefore 12.5 Ipm (DL) correspond to

100 Bq : 523 x 12.5 = 2.39 Bq Cs-137

For a 10 minute measurement the DL is 3.9 Ipm using the measuring table (Cs-137) this gives:

100 Bq : 523 x 3.9 = 0.75 Bq Cs-137

In other words, when used as an immersion counter tube and with a measuring time of 1 minute, counter tube FSZ can detect contamination values as from 3 Bq Cs-137. For a measuring time of 10 minutes this is possible as from the even lower value of 1 Bq. In order to estimate the result for 1 kg, these values must be multiplied by the factor 40, since the immersion counter tube only detects radiation at a distance of 1 - 2 cm, which generally corresponds to 20 - 30 grams.

In estimating the result for 1 kg the exact value (0.75 Bq) should be used, and not the rounded up measured value (1 Bq).

5. Measurements in liquids

For measurements in liquids other laws apply, since liquids (or the water contained to a more or less extent in the sample) shield (absorb) the radiation. The counter tube can therefore only partially detect this radiation (if this is possible at all).

By highly concentrating the sample (evaporation of the water), the measured results are improved. Basically it should be assumed that in water, or similar liquids, only 10 % of the actual radiation can be determined.

Counter tube FSZ can be used for liquid measurements. The flexible cord is also waterproof and washable, the immersion depth being 1 meter.

Forimmersion counter tube FSZ the detection limit in 100 ml of unconcentrated liquid with caesium-137 is:

for a measuring time of 10 minutes - 63 Bq Caesium-137 and
for a measuring time of 20 minutes - 46 Bq Caesium-137

This corresponds to 630 and 460 Bq respectively for 1 liter. It is thus possible to test liquids for impermissible contamination. In the EC contamination with Cs-137 up to 600 Bq per liter is considered to be completely harmless. For children's food the value is 300 Bq/ltr. Apart from this there are some special regional regulations, but here the permitted limit values are usually considerably higher than 600 Bq/ltr. If lower values are detected, the samples are highly concentrated by drying, particularly in the case of Cs-137 the contamination adheres to the material.

6. Measurement of potassium-40 in coffee, tea, cocoa etc.

When carrying out measurements or coffee, tea, cocoa, tobacco (i.e. mainly with all industrially cultivated products) using counter tube FSZ as an immersion counter tube, an increase in radiation will be found. This radiation is due to the natural radionuclide, potassium-40.
32.5 Bq are emitted per gram of potassium, as follows:

BETA radiation at max. 1.312 keV, amounting to 89.3 %
and
GAMMA radiation at 1.461 keV, amounting to 10.7 %

Caesium-137 releases, for example,
BETA radiation at 514 keV and GAMMA radiation at 662 keV

Potassium is contained in fertilizers up to about 20 %, and it is therefore also stored in the plants to a corresponding extent. According to medical opinion and the responsible authorities this is not dangerous, since excess potassium in the body is broken down again and excreted within a short period.

Counter tube FSZ used as an immersion counter tube indicates the radiation to be 1.5 Ipm per 100 Bq (10 minute measurement)

If coffee powder is measured, for example, and 230 impulses are found after 10 minutes, with a zero rate of 17 Ipm (x 10 minutes = 170), then 60 impulses are too high, and are also significantly above the tolerance threshold of 21 and 210 impulses respectively.

If 1.5 Ipm or 15 impulses in 10 minutes correspond to 100 Bq K-40
then 60 impulses correspond to

(60 : 15 = 4 x 100) = 400 Bq K-40

In freeze-dried coffee extract the radiation contamination found is considerably higher than 1000 Bq. This is also the case in certain cocoa types - the more this is deoiled the lower is the radiation.
The stored potasaium is water soluble. If you are in doubt as to whether the existing radiation actually comes from K-40 or not, then boil the coffee powder (or tea) and measure the residue of coffee, tea or whatever else it might be. This must, of course, first be dried, so that is has about the same consistency as the coffee powder or tea before boiling.
You will now find that no more radiation is registered in the coffee or tea residue. If there is any radiation, then this is not from K-4O

7. Some more theory

In atomic physics radioactive radiation sources are called NUCLIDES. The radiation energy is measured in mega-electron-volts 1Mev) or in kilo-electron-volts keV

MEGA = 1,000,000 or 10^6
KILO = 1.000 or 10^3

Basically it can be said that the count yield is increased for measurements carried out with the sensitivity of a Geiger–Müller counter tube. However, this is always true only for a certain RADIO-NUCLIDE, or its radiation energy. The penetrating power (range) of any type of radiation can be derived from the radiation energy. It is the radiation energy which determines whether the radiation can be detected by a Geiger–Müller counter tube and is therefore measurable.

The radiation energy of a RADIO-NUCLIDE has nothing to do with its activity (disintegration per second), which is measured in Becquerel (Bq). This applies also to the detection limit (DL), which is related to the necessary minimum activity (Bq) of a radiation source. Radiation energy keV or MeV) and its activity (Bq) are two different factors which, together with the type of radiation (ALPHA, BETA, GAMMA), determine the effect of the radiation.

In the technical data for counter tubes the radiation energy which is necessary so that the counter tube can register the radiation is indicated in each case. For each type of radiation there is a different energy threshold.

Window counter tubes, type A and G, can, for example, register ALPHA radiation from 1.9 MeV BETA radiation from 0.09 MeV and GAMMA radiation from 0.01 MeV. Immersion counter tubes, type B and FSZ, can generally measure no ALPHA rays, BETA rays from 0.2 MeV and GAMMA rays from 0.02 MeV.

The energy sensitivity of a counter tube is an important quality characteristic. Large radiation measuring devices have a high count yield owing to their size. However, it is the energy sensitivity of a counter tube, and not its size, which determines whether a NUCLIDE can be measured at all.

A further important feature is the geometry factor, i.e. the distance and position of the radiation absorbing surface in relation to the radiation source. End window counter tubes can generally be used only for surface measurements, in which case direct contact with the radiation source should be avoided. In surface measurements the counter tube absorbs radiation only from one side, and the distance from the source causes losses through scattering.

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The advantage of immersion counter tubes is that the radiation is picked up on all sides without losses through scattering. These are therefore considerably more sensitive than end window counter tubes. Furthermore these counter tubes are simpler to handle, particularly for mobile use.

Radiation energy is measured in MeV or keV, but at the position where the radiation is picked up this is measured in Sievert (Sv) or in Rem whereby

100 Rem = 1 Sv or 1 Rem = 0.01 Sv

or

0.1 Rem = 1 mSv or 0.1 mRem = 1 μSv

OPERATING INSTRUCTIONS
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APPENDIX

Measuring Table

In this measuring table reference emitters of 6 different nuclides, which can be released during possible disturbances or accidents in nuclear power stations, have been used. These reference emitters correspond to 100 Bq and 1000 Bq. From the measuring time of 10 minutes the impulses per minute were indicated, after the determined zero rate of the counter tubes had been subtracted. The values given are thus net impulse rates (without background radiation). For this measurement a distance of 30 mm was chosen. Smaller distances result in a higher impulse rate, and therefore greater distances give a correspondingly lower count yield.

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

OPERATING INSTRUCTIONS
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APPENDIX

Using the Measuring Table

As can be seen, the impulses of the counter tubes are proportional to the Becquerel values - in other words, the higher impulse rates indicate correspondingly high Becquerel values. Consequently conclusions can be drawn from comparative measurements.

For example, if a certain object is to be tested for contamination with caesium-137*** the measurement should be carried out for 10 minutes at a distance of 30 mm from the sample. The result calculated for 1 minute should then be applied using the measuring table.

EXAMPLE

> A 10 minute measurement carried out on a sample containing caesium-137, using counter tube type FSZ, gives a measured value of 500 impulses at the end of the measuring time.
> After converting to 1 minute (500 : 10 = 50 Ipm) and subtracting the zero (background) rate (17 Ipm) a net impulse rate of 33 Ipm remains.
> In the measuring table a value of 52,3 Ipm is given for 100 Bq Cs-137 in the column for counter tube type FSZ.
> Therefore 33 Ipm corresponds to
>
> (100 Bq : 52.3) x 33 = 63 Bq
>
> If the sample weighs, for example, 5 grams, this value must be estimated for 1 kg
>
> 63 Bq x 200 = 12,600 Bq/kg

Experience has shown that the measurement conditions often do not agree with those assumed in the measuring table. For surface measurements with the end window counter tubes, type A and G a smaller distance is frequently selected, usually 5 mm. At a distance of 5 mm the number of impulses is 5 times higher than that given in the measuring table, i.e. before conversion the corresponding value in the measuring table must be multiplied by the factor 5.

Thus 261 Ipm (52.3 x 5) would correspond to 100 Bq. Calculated on the basis of the above 33 Ipm this would then only be (100 : 261) x 33 = 12.64 Bq Cs-137

Immersion counter tubes are not generally used for surface measurements. These are much more efficient as immersion devices. In order to obtain comparable results, in this case the value in the measuring table has to be multiplied by the higher factor 10. i.e. the 100 Bq Cs-137 would correspond to 523 Ipm (52.3 x 10) for counter tube FSZ.

*** It can be assumed that existing contamination in Europe as a result of the Tschernobyl catastrophe is due almost entirely to the nuclide caesium-137.

Instructions for Handling the Measuring Probes B and FSZ for Environmental/Mobile Measurements

The measurement table (p. 8) was drawn up to determine whether the counter tubes can be gauged/calibrated. In mobile applications outside of the laboratory, such pure nuclides are hardly ever encountered. The measurement table is intended more for teaching purposes at secondary school or university, where these kinds of nuclide are used. Unmixed or shielded nuclides are in fact very rare in nature (the environment).

For this reason we have commissioned studies in which measurements were conducted which better equate with the reality of mobile applications. A test arrangement was set up in which the submersible counter tube types B and FSZ were used as area counter tubes (surface measurements) and as submersible probes.

1. The test object was tea that had been contaminated with caesium 137 and caesium 134. First, it was determined what quantity of tea could be measured via the submersible probe, e.g. to which a contamination could be attributed.
It was shown that **35.5 g** tea was the optimum amount. With larger quantities of tea, radiation measurements using the submersible probe were no longer possible. That is important for extrapolation up to 1 kg. This means that the measured value of radiation must be multiplied by **28** to obtain the result for 1 kg.
This extrapolation is normal and necessary for all commercial devices for making mobile radiation measurements, because the reference values refer to activity relating to **mass per kg**. The 35.5 g tea sample was contaminated with 749.9 becquerels Cs 137 and with 87.4 becquerels Cs 134; giving a total activity of 837.3 becquerels.
Whilst using counter tubes B and FSZ as submersible probes the following net pulse rates (**without null rate**) were measured in the contaminated tea with counter tubes B and FSZ:

Type B = 92.2 ppm +/- 2.5 **Type FSZ = 176.2 ppm +/- 3.4**

ppm = pulse per minute:
For counter tube B this came to 1 ppm (837.3 **:** 92.2) **9 becquerels**
Extrapolated to 1 kg that equals (9 x 28) **252 becquerels**

For the FSZ counter tube this came to 1 ppm (837. **:** 176.2) **4.75 becquerels**
Extrapolated to 1 kg that equals (4.75 x 28) **133 becquerels**

This is also the measuring limit for this measuring probe when used as a submersible probe!

2. A further test arrangement was set up for measurements in liquid using the two submersible probes. Caesium 137 was dissolved in a **50 ml** solution, marked with 55,500 becquerels (1.5 µCi). Measurements were made by placing the measuring probe in the contaminated liquid.

Using the **counter tube B** a net pulse rate of **1,591.7 ppm** was measured. With respect to the 55,500 total activity that equates to **34.86 Bq per ppm** (55,000 : 1,591.7). Extrapolated to one litre (x 20) that gives **697 Bq/litre.**

Instructions for Handling the Measuring Probes B and FSZ

Using the **counter tube FSZ** a net pulse rate of **3,297.2 ppm** was measured. With respect to the 55,500 total activity that equates to **16.83 Bq per ppm** (55,000 : 1,591.7). Extrapolated to one litre (x 20) that gives **336 Bq/litre.**

Such measurements are of particular significance for food consumables containing high quantities of liquids. The values can differ depending on the consistency of the measuring sample (different liquid quantities). Lower liquid quantities lead to a lower measuring limit. Liquids have a particularly high shielding property for radiation (self-absorption). The measurement values using the FSZ counter tube could lay anywhere between 4.45 Bq per ppm (dry goods) and 16.8 Bq per ppm (pure liquid).

Anomalous measurements could also be caused by fluctuations in the background radiation, which themselves are caused by variation in the given weather conditions (wind direction). An uncertainty of ±20 % is to be expected for measurements of radiation in mobile applications, independent of type of construction of the measuring device.

We should point out that assessments of these measurement values have been conducted and documented by the Institute for Nuclear Physics at the Technical University of Darmstadt. For the measurements, preparations used to contaminate the samples were provided by the Physikalisch-Technische Bundesanstalt in Braunschweig.

3. In another test arrangement, the two measurement probes were used for making surface measurements; once at a distance of 3 cm and again in another experiment where the probes were placed directly on the contaminated tea sample. The same contaminated tea sample was used as in Point 1 as well as a further tea sample measuring 4.53 g that was spread widely. This smaller sample was contaminated with 94.4 Bq Cs 137 and 12.5 Bq Cs 134, giving a total of 106.9 Bq.

3.1 The following net pulse rates were measured using the **counter tubes**:

a) Small tea sample (4.53 g):	**Net pulse rate direct on the surface**	**18.1 ppm +/- 1.1**
Measuring probe B	**Net pulse rate at 3 cm distance**	**2.9 ppm +/- 0-6**
b) Large tea sample (35.5 g):	**Net pulse rate direct on the surface**	**39.3 ppm +/- 1.6**
Measuring probe B	**Net pulse rate at 3 cm distance**	**13.9 ppm +/- 1.5**
a) Small tea sample (4.53 g):	**Net pulse rate direct on the surface**	**31.4 ppm +/-1.4**
Measuring probe FSZ	**Net pulse rate at 3 cm distance**	**6.2 ppm +/- 0.9**
b) Large tea sample (35.5 g):	**Net pulse rate direct on the surface**	**69.5 ppm +/- 2.1**
Measuring probe FSZ	**Net pulse rate at 3 cm distance**	**28.6 ppm +/-1.6**

The significantly lower values (sensitivity) of the surface measurements demonstrate that the measuring probes B and FSZ are better suited for use as submersible probes. With increased distance from the source of radiation, the magnitude of the values measured (sensitivity) drops significantly.
Rule of thumb: with increasing distance, the amount of radiation measured drops by the square of distance from the source of radiation.