DOSE CALIBRATOR EXPERIMENT

CENTER FOR MEDICAL AND RADIATION PHYSICS

AIM

To Perform a Quality Assurance Test of the Dose Calibrator.

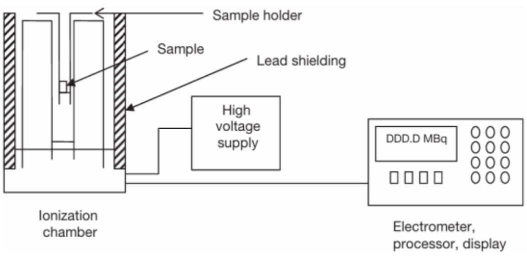
Equipment Required:

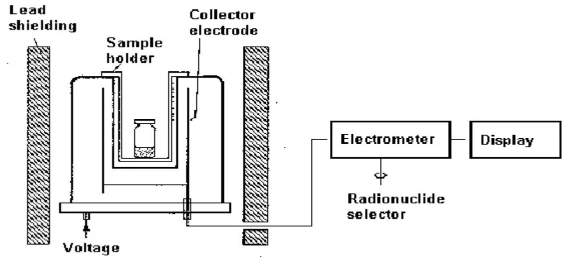
- Dose calibrator
- Check source
- Canister
- Source holder

Theory:

The dose calibrator is one of the most essential instruments in nuclear medicine for measuring and verifying the radioactivity of radiopharmaceuticals before administration to patients. A typical radioisotope calibrator contains an ionization chamber, a high-voltage power supply, an electronic amplifier, and a display unit to select the radioisotope to be calibrated.

The ionization chamber used for the dose calibrator is generally cylindrical well type in shape and contains Argon gas under high pressure like 20-30atm. The geometric goal to make it well-typed is to simulate the ideal 4Π(4pi) geometry, and the highly pressurized gas creates a favourable environment for higher ionization effects, resulting in a high detector efficiency. The calibrator has two coaxial cylindrical electrodes maintained at a voltage difference from a suitable supply.





In the associated electrometer, the ionization current is processed and displayed in units of activity, commonly in digital form. Lead shielding around the ionization chamber protects personnel against radiation hazards and reduces the background contribution on measurement. A sample holder and a removable liner that can be easily cleaned in case of radioactive contamination of the chamber well are usually provided.

Radioactive decay can produce high-energy photons or charged particles that interact with and deposit their energy in the surrounding gas medium. When the vial or syringe containing the radionuclide is placed into the dose calibrator, the Argon gas gets ionized, the ion pairs migrate toward the anode and cathode and an electric current flows between them. This current is proportional to the activity of the measured radioisotope. The magnitude of this current is usually very small (μA); hence, a highly sensitive electrometer is required. The output is displayed either in mCi or MBq.

Tests to be performed:

Accuracy Test:

An accuracy test signifies how closely an instrument's measurement matches with a known value. This test is designed to show whether the calibrator gives correct readings for a standard radioactive source. The standard radioactive source would have a labelled activity at a specific calibration time and date. This data calculates the decay corrected activity at the time of measurement. The standard is then measured in the dose calibrator. Then the calculated and measured values are compared. Measured values should be within ± 5% of the standard value. This test needs to be done daily.

Constancy Test:

A Constancy test is a routine quality control test to ensure the equipment's performance. This test measures the precision and reproducibility of the instrument. In this test, a long-lived radioactive standard source (e.g. Cs137) is used, and its activity given by the dose calibrator is checked multiple times (5-10 times). The deviation between subsequent values should be minimal, and the activity measured each time should be within ± 2% of the standard value.

Linearity Test:

In our case, we check whether the measured activity follows a linear relation with the predicted activity in the µCi to mCi range. A given activity of $Tc99^m$ or F-18-FDG source (>1 mCi) is measured at T_0 and predetermined time intervals, like every 15 minutes, until activity reaches approximately 30 µCi. This can take more than 24 hours, depending upon initial activity. Usually, a short half-life source is preferred for this QA to achieve the desired minimum activity.

Geometry Test

This test is performed to check the variation of measured activity varies with the geometry of the source. It is performed by keeping the source inside a vial or taking it in a syringe. The effect of sample geometry on the dose calibrator reading can be checked by taking a known amount of radioisotope (Any radioisotope like Tc^{99m}) and then measuring the change in activity by increasing the dilution of the solution. The dilution is made by adding a known amount of saline so that the volume of the measured sample increases. This increase in volume results in a change in sample geometry from the initial condition. If the instrument's response is geometry-independent, we should get the same reading or activity every time. Repeat the same process multiple times to check its accuracy.

Procedure:

Accuracy Test:

- Measure the background activity without any source in the calibrator.
- Place the Cs^{137} standard gel source in the dose calibrator.
- Wait for some time to obtain a stable reading on the display unit.
- For the Constancy test, repeat the above procedure around 10 times.

Tabulation for accuracy test:

Source- Cs^{137} gel source

Initial Activity	Decay corrected activity	Background (BKG)	Measured Activity (A)	Net Activity (A-BKG)	% deviation from true value	Tolerance
0.211mCi (18/02/2018)	180.3µCi	2µCi	185µCi	183µCi	1.5%	± 5%

Tabulation for constancy test:

Source- Cs^{137} gel source

Initial activity measured= 185µCi

Number of Repetition	Activity Measured (µCi)	Deviation (%)	Tolerance
1	185	0	± 2%
2	184	0.54	
3	185	0	
4	185	0	
5	185	0	
6	185	0	
7	184	0.54	
8	185	0	
9	185	0	
10	185	0	

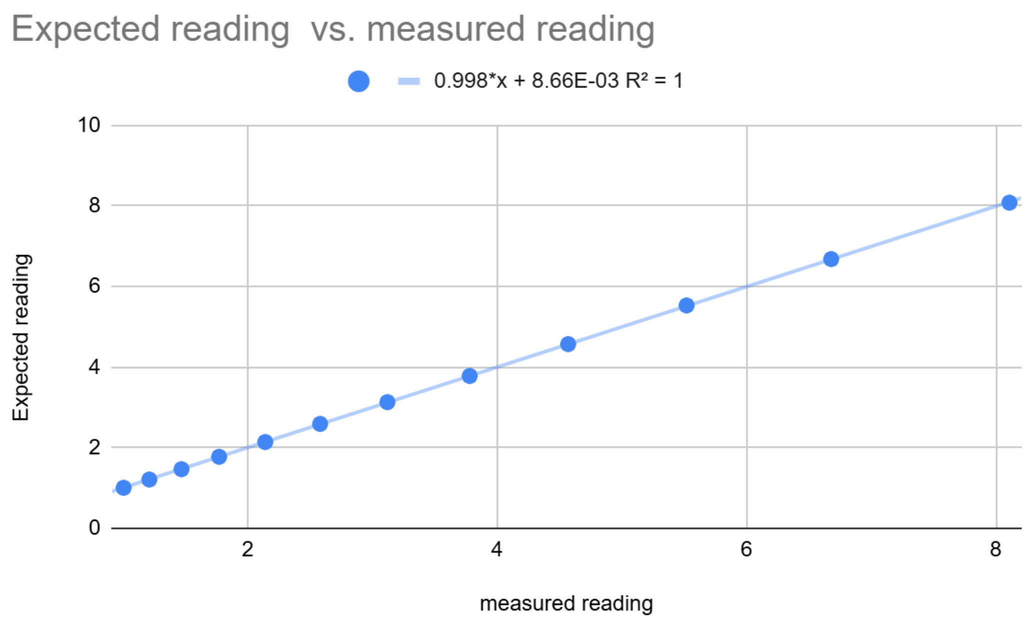
Linearity Test:

- Take a syringe or vial containing a radioisotope sample having the activity normally used in daily practice and place it in the radionuclide activity calibrator.
- After each 15-minute interval, check the reading.
- Calculate the decay corrected activity from the initial activity value measured for the first time for each interval. This will be the expected value.
- Tabulate the data as shown below and plot the graph between the Measured value vs the expected value. It should be linear.

Tabulation for linearity test:

Source: F^{18} FDG, Time interval taken=30 mins.

Time Elapsed (in Minutes)	Expected Value (mCi)	Measured Value (mCi)	% Deviation
30	8.08	8.11	0.4
60	6.68	6.68	0.0
90	5.53	5.52	0.1
120	4.57	4.57	0.1
150	3.78	3.78	0.1
180	3.13	3.12	0.3
210	2.59	2.58	0.2
240	2.14	2.14	0.4
270	1.774	1.77	0.2
300	1.467	1.468	0.0
330	1.21	1.21	0.0
360	1.005	1.004	0.0
390	0.831	0.831	0.1
420	0.688	0.687	0.1
450	0.569	0.569	0.0
480	0.471	0.471	0.0



Geometry Test:

- Take 20 ml of the vial. Measure the background by placing this empty vial in the calibrator.
- Remove it from the calibrator and add 1.0 ml of Tc99m in it with the help of a syringe to measure the activity.
- Dilute the activity with saline to 2.0 ml, 3.0 ml, 4.0 ml, 5.0 m, etc, up to 10 ml. And take the measurement after each 1 ml dilution.
- Evaluate the data to determine the effect of sample geometry on the dose calibrator reading.

Tabulation for geometry test:

Source - Tc^{99m}

Sample Volume	Sample activity	Mean Activity after dilution
0 ml Saline	4.41 mCi	4.41 mCi
1 ml Saline	4.38 mCi	
2 ml Saline	4.39 mCi	
3 ml Saline	4.41 mCi	
4 ml Saline	4.43 mCi	
5 ml Saline	4.42 mCi	

Result:

Conclusion:

Precaution:

- Wear gloves while handling radiopharmaceuticals and dose calibrator to prevent radioactive contamination.
- Carefully place the source vial or syringe into the calibrator.
- Use an L-bench to fill liquid radioisotope or radiopharmaceutical into the syringe or vial.
- Wash your hands with soap and water after finishing the experiment.
- Always hold the source vial with forceps or holding tongs.
- Switch on the fume hood while handling any pharmaceuticals that are evaporating in nature.

References:

- Dose Calibrator operation and quality control PDF
- CRC®-55t (R/PET/W) Radioisotope Dose Calibrator - Owner's Manual