SUBJECT: Instrument Calibration

OBJECTIVE: To obtain accurate and reproducible results from nuclear instrumentation.

RESPONSIBILITY: Site Radiation Safety Officer

SCHEDULE: As specified in this Standard Operating Procedure

PROCEDURE:

A. Portable G.M. Survey Meters and Radiation Monitors:

1. These instruments are calibrated yearly and after repair.

2. The calibrations are performed by the instrument manufacturers or a licensed, certified individual or company registered with the NRC or applicable state agency.

   a. Service will be performed by one of the following companies (or other comparable firm, licensed to perform these calibrations):

      1. Mallinckrodt, Inc.
         2703 Wagner Place
         Maryland Heights, Missouri 63043
         (314) 344-3800
         License #24-04206-01 (NRC)

      2. Eberline Instrument Corporation
         P.O. Box 2108
         Sante Fe, New Mexico 87501
         (505) 471-3232
         License #NM-EBE-BL-21 (New Mexico)

      3. Dosimeter Corporation
         6106 Interstate Circle
         Cincinnati, Ohio 45242
         (513) 489-5100
         License #34-13477-01 (NRC)

      4. Nuclear Medicine Associates
         9700 Garfield Blvd.
         Cleveland, OH 44125
         (216) 641-5799
         License #34-1672-01 (NRC)

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b. At minimum, the procedures followed by the company providing this service should correspond to the following NRC requirements:

1. Calibration will be performed with radionuclide sources at distances sufficient to approximate point sources.
2. These sources will be of sufficient activity to act as point sources (Cs-137:85mCi, Co-60:21mCi, or Ra-226:34mCi).
3. Instruments will be calibrated on every scale or range that the instrument offers, up to 1 Roentgen/hr.
4. Survey instruments will be adjusted to provide readings on all calibrated scales or ranges within ± 10% of true value (or ± 20%, provided that a calibration chart or graph is prepared and attached to the instruments).

3. The instruments should be calibrated on a rotating basis to ensure proper health physics coverage of the lab.

4. Records of calibrations will be kept for a minimum of 2 years.

B. Multichannel Analyzer:

1. Determine energy response on a daily (workday) basis using a long lived isotope (such as Cs-137).
2. Determine efficiency on a quarterly basis and after machine repair or malfunction.

C. Calibration of the Dose Calibrator:

All radiopharmceuticals must be assayed for activity to an accuracy of ±10% The most common instrument for accomplishing this is an ionization-type dose calibrator. The instrument must be checked for accurate operation at the time of installation and periodically thereafter. Test for the following:

1. Instrument constancy (daily).
2. Instrument accuracy (installation and annually).
3. Instrument linearity (installation and quarterly).
4. Geometrical variation (installation).
5. After repair or adjustment of the dose calibrator, repeat the appropriate tests above.

SUBJECT: Instrument Calibration - Calibration of the Dose Calibrator

Instrument Constancy: A long-lived standard radionuclide such as Cs-137 or Co-57 should be assayed using a reproducible geometry at least once each working day.

a. Assay the reference source using the appropriate instrument setting.

b. Measure the background at the same setting, and subtract or confirm the proper operation of the automatic background subtract circuit if it is used.

c. For the source used, either plot on graph paper or log in a book the net activity of the source.

d. Indicate the predicted activity of the source based on decay calculations and ± 5% limits.

e. Variations greater than ± 5% from the predicted activity indicate the need for instrument repair or adjustment.

f. Using one of the sources listed above, repeat the measurement procedure for all commonly used radioisotope settings. Plot or log results.

g. Higher than normal background levels should be investigated to determine origin and eliminated if possible by decontamination, relocation, etc.

Instrument Accuracy: Check the accuracy of the dose calibrator for several radionuclides, including Cs-137, Co-57, Ba-133, using appropriate reference standards whose activities have been calibrated by comparisons with standard sources that have been assayed by NBS and documented.

a. On an annual basis or after repair, assay the reference standard in the dose calibrator at the appropriate setting, and subtract the background level to obtain net activity.
b. Repeat step (a) for total of three determinations and average results.
c. The average activity from step (b) should agree with the certified activity of the reference source within ± 5% after decay corrections.
d. Repeat the procedure for the other calibrated reference sources.
e. Keep a log of these calibration checks.
f. Calibration checks that do not agree within ± 5% indicate that the instrument should be repaired or adjusted. If this is not possible, a calibration factor should be calculated for use during routine assays of radionuclides.

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Instrument Linearity: Linearity means that the calibrator is able to indicate the correct activity over the range of use of that calibrator. This test will utilize a syringe or vial of Tc-99m whose activity is at least as large as the maximum activity in prepared radiopharmaceutical kits or bulk dose (whichever is larger).

a. Assay the Tc-99m vial in the dose calibrator and subtract background level to obtain net activity in millicuries. Record the date, time and activity of the source.
b. Repeat step (a) a minimum of six times over the next 48 hours after the initial assay.
c. Using the 30 hour calibration of the source, calculate the expected activities at the times the readings were taken.
d. Compare the measured net activity for each time interval versus the decay predicted activity on log or graph.
e. The net activities should be within ± 5% of the decay predicted curve if the instrument is linear and functioning properly. Errors greater than ± 5% indicate the need for repair or adjustment of the instrument.
f. If instrument linearity cannot be corrected, it will be necessary in routine assays to use either (1) an aliquot of the elvate that can be accurately measured or (2) determine a correction factor to relate measured activities to true activities.
g. A set of "sleeves" of various thickness may also be used to test instrument linearity. The manufacturer's calibration instructions shall be followed and a log book will be kept of all linearity tests.

Geometrical Variation: There may be a significant geometrical variation in activity measured as a function of sample volume or configuration, depending on the volume and size of the ionization chamber used in the dose calibrator. The extent of geometrical variation should be ascertained for commonly used radionuclides and appropriate correction factors computed if variations are significant (i.e. greater than ± 2%). The test should be performed using a vial similar in size, shape and construction to the radiopharmaceutical kit or generator elution vials used in pharmacy dispensing.

To measure variation with liquid volume, a vial containing approximately 2mCi of Tc-99m in a volume of 1 ml will be used.

a. Assay the vial at the appropriate instrument setting and subtract background level to obtain net activity.
b. Increase the volume of liquid in the vial in steps to 2,4,8,10,20, and 25 ml by adding the appropriate amount of water or saline. After each addition, gently shake vial to mix contents and assay as in Step (a).
c. Select one volume as a standard (such as the volume of the reference standard used in performing the test for instrument accuracy), and calculate the ratio of measured activity for each volume to the reference volume activity. This represents the volume correction factor (CF).

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Example: If activities of 2.04, 2.02, and 2.00 mCi are measured for 4, 8, and 10 ml volumes and 10 ml is selected for the reference volume:

$$4 \text{ ml Volume CF} = \frac{2.00}{2.04} = 0.98$$

d. If any correction factors are greater than 1.05 or less than 0.95, it will be necessary to make a correction table or graph that will allow you to convert from "indicated activity" to true activity". Graph should be labeled as "vial or syringe geometry" whichever is appropriate, and should include the date of the test, model, and serial numbers of the calibrator.

e. The true activity of a sample is calculated as follows:
True activity = Measured activity X Correction factor
(Where the CF used is for the same volume and geometrical configuration as the sample measured)

f. Vial/Syringe Comparison

This test is designed to note differences between activities measured in glass vials versus plastic syringes. This test was performed by assaying the stock vial before and after filling a syringe. The activity in the syringe should be the difference in the two readings (with a volume correction, if significant).

D. Calibration of the Pocket Dosimeters:

The Dosimeter Calibrator contains a hermetically-sealed Cesium-137 source (90 uCi) located between the black lines on the top of the block.

1. These instruments are calibrated annually.

2. To get the maximum reading on a dosimeter, locate the most sensitive portion of the chamber. On most chambers it is either 1-1/4" or 1/2" from the charging end. To locate this area, simply place the dosimeter in the groove of the Calibrator so that the source is adjacent to a point 1" from the charging end. Using a timer, find the total dosage. Usually a 15-minute exposure is sufficient. Repeat this procedure at other distances until a maximum reading is obtained.

3. Make a mark on the dosimeter to show the exact position to be used for future checks.

4. Cesium-137 has a half-life of 30 years. The output of the source decreases by approximately 2% per year. To obtain reading of a similar magnitude after an appreciable period of time, it may be desirable to increase the exposure time to compensate for this decay.

5. The Dosimeter Calibrator is not an absolute calibration device. It may be used on a routine basis to determine whether your dosimeter is functioning properly. Typically, a 15-minute exposure of a properly calibrated 200mR dosimeter will yield readings from 35mR to 45mR.