# RADIATION SURVEY INSTRUMENT CALIBRATION AND MAINTENANCE PROCEDURES
# TEXAS DEPARTMENT OF STATE HEALTH SERVICES

## BACKGROUND

Calibration of portable radiation survey instruments is a process which may be conducted with varying degrees of accuracy and precision. Both are a function of the facilities and equipment, time, personnel and financial resources available to perform the calibration. The object of calibrating an instrument intended for routine use is to ensure that its accuracy is adequate under the conditions in which it is used (ICRU 1976). The following set of procedures has been written in order to document the conditions under which portable survey instruments are currently being calibrated at the Texas Department of State Health Services, and to establish the procedures for users of portable survey instruments which assure that a minimum set of precautions are observed in the field to verify that the instruments function properly and that the calibration is valid.

Proper care of radiation detection and measuring equipment, as with all equipment, is the primary mechanism for insuring its proper functioning. Each individual to whom an instrument is assigned also has assigned the responsibility to perform frequent checks on the equipment to assure its proper functioning and to report immediately any problem which, based on their experience and familiarity with their survey instrumentation indicates a particular instrument is not functioning reliably. Further discussion of these responsibilities will be presented later in the text.

In order to facilitate communications regarding any problems encountered with portable radiation detection and measuring equipment, when practicable, a copy of the manufacturer's manual for each instrument and detector commonly used will be included as part of this manual. Additionally, familiarity with the operational characteristics of each instrument an inspector uses should enhance his abilities to perform surveys. Whenever possible, the manufacturer's calibration procedures will be followed. Significant deviations from manufacturer's suggested procedures will be verified with the manufacturer, prior to implementation or have a rationale developed and in both cases documented in the manual.

## CONSTANCY CHECKS AND MAINTENANCE

As soon after calibration as possible each inspector should check his/her instrument against a small check source, such as those provided in the check source kits. One should use the same source each time the instrument is checked and one should also be sure to position the source at the same location on or near the detector.

This check should be made on all detectors, not just those that are calibrated as a means of assuring oneself that the operating characteristics of the detectors and the rate meter have not changed. The GM detectors should be checked daily, since they are used routinely to determine compliance. Other detectors may be checked less frequently. Each region should have an appropriate source of radiation for each of the common types of radiation except, of course, neutrons.

Sodium iodide detectors should be checked regularly for changes in response in established radiation fields. Crystals which have been fractured or which have begun to swell and discolor (they will become yellow as iodine is released) will demonstrate significantly lower count rates than normal. Although less frequent a problem photomultiplier tubes may also go bad. Generally, a bad photomultiplier tube will be manifested by a sudden rise in count rate with no apparent cause. A damaged photomultiplier tube, however, might demonstrate a decreased count rate if one of the dynodes were displaced.

As well as checking the detectors frequently, each inspector should also check batteries and battery contacts frequently. Also if the instrument is to be stored for more than thirty days the batteries should be removed[1]. In humid climates the indicator/desiccant should be checked every month at a minimum and dried as described in "Preparation for Calibration" when necessary. Cleaning battery contacts every three months will also prevent unexpected losses of power and provide an opportunity to check the condition of the batteries periodically[2].

One should be mindful that the calibration of an instrument takes place under a fairly stringently defined set of conditions. Although one would like for these conditions to match those encountered in the field, they rarely do. When making measurements to determine compliance one should to the degree possible use the detector or instrument in the same orientation to the source of radiation as it had during calibration. One should be aware of significant differences in the energy or distribution of energies of the radiations which he is measuring compared to those used during calibration. Note should be made of whether radiation is being measured under broad or narrow beam conditions and whether or not other types of radiation may be present which might interfere with the measurement.

## PREPARATION FOR CALIBRATION

Prior to bringing a survey instrument in for calibration each inspector should determine that the batteries are good or, if necessary, replace them. Additionally, in the case of ionization chamber instruments each inspector shall make sure that the indicator/desiccant is dry. If not it may be dried by pouring it into a dish and heating it in a microwave oven until it turns dark blue or by placing it in a conventional oven and heating it for twelve hours at 250°F or one hour at 400°F[3]. Always allow sufficient time for the indicator/desiccant to cool before replacing it in its holder.

## CALIBRATION PROCEDURES

### CALIBRATION FACILITIES

At present all portable survey instruments, except the MDH's are calibrated at the Radiation Controls calibration range. The calibration range is located at the Health and Human Services Warehouse on Technology Blvd in Austin. The range is in a 40ft by 40ft room off the main

[1] Ludlum Measurements, Instruction Manual Model 12s Miro R Meter, Section 6- Maintenance, 1999

[2] Eberline, RO-20 Ion chamber Technical Manual, Section 4- Maintenance, 1995

[3] Eberline, RO-20 Ion chamber Technical Manual, Section 4- Maintenance, 1995

warehouse floor and currently implements the use of two J.L. Shepherd model 28-6A collimated beam calibrators.

One calibrator originally contained a Cesium-137 source of 120 mCi (4.44 GBq). Source output was verified by the manufacturer to be 40.9 mR $hr^{-1}$ (1.055E-5 C $kg^{-1}hr^{-1}$) on August 31, 1989 utilizing the 45° collimator. This reading was taken using an MDH Industries model 2025 X-ray Monitor, calibrated by National Institute of Standards and Technology (NIST), report no. DG8640/87. This is in close agreement (3.2%) with a calculated exposure rate of 39.6 mR $hr^{-1}$ (1.022E-5 C $kg^{-1}hr^{-1}$) from a 120 mCi source.

Subsequent measurements made by the DSHS's personnel on October 3, 1991, using Victoreen R chambers (traceable to NIST test no DG8953/89), produced an average, measured exposure rate 37.9 mR $hr^{-1}$ (9.78E-6 C $kg^{-1}hr^{-1}$) with the 45° collimator. The calculated field based on the activity of source as of 10/8/91 would be 37.72 mR $hr^{-1}$ (9.73E-6 C $kg^{-1}hr^{-1}$). The difference between the calculated and measured numbers is 0.5%.

The other calibrator originally contained a Cesium-137 source of 1.2 Ci (44.4 GBq). Source output was verified by the manufacturer to be 312 mR $hr^{-1}$ (8.05 C $kg^{-1}hr^{-1}$) on December 6, 1998, utilizing the 30° collimator. This reading was taken using an MDH Industries model 2025 X-ray Monitor, calibrated by NIST, report no. DB917/114. This is in agreement with a calculated exposure rate of 396 mR $hr^{-1}$ (1.022E-4 C $kg^{-1}hr^{-1}$) from a 1.2 Ci source. Since the source is 10 times stronger than the previous source the beam edges for the 10 and 30 degree collimators are marked on the floor.

Also available for calibration is a CDV-784 calibrator that originally contained a Cesium-137 source of 130 Ci. Source output was verified by Civil Defense program to be 130 Ci on October 25, 1983.

**CALIBRATION PERSONNEL**

The individual who will supervise the instrument calibration will have experience in general Health physics, the handling of sealed sources, operation of calibrators, and the use and maintenance of the survey meters to be calibrated.

**CONDITIONS OF CALIBRATION**

Calibrations may be carried out in several ways:

(1) By national standards laboratories using calibration standards of the highest possible accuracy.
(2) By major government, academic, research or industrial laboratories using institutional standards established by careful comparison with a national standard.
(3) By other groups using working standards (reference instruments) of lesser accuracy that are periodically calibrated by comparison with one of the above-mentioned national or institutional standards (ICRU 1976).

The calibration method described in this procedure falls into the third category.

All calibrations will be conducted within the temperature range 25±10°C(ANSI 1978). Additionally, no correction will be made for temperature or air pressure when calibrating ionization chamber instruments which operate at atmospheric pressure. The temperature and air pressure at the time of calibration will be noted on each calibration record and can be used by the inspectors in order to determine actual exposure rates when making measurements in the field (see attached air density correction table). Each inspector may apply this correction factor to normalize the reading to the standard conditions of calibration, then apply the correction factor appropriate for the temperature and air pressure to the corrected reading obtained at the time and date of his survey in order to obtain a more accurate measurement. Or the inspector may choose to apply the actual reading without making adjustments for variations over a reasonable range in temperature and air pressure.

Although “free space geometry should be achieved for photon... instrument calibration”(ANSI 1978), some contribution from scatter will occur due to the physical constraints imposed by available facilities and equipment. Tests have been conducted at DSHS in order to ascertain the effects of scatter from collimation, surrounding surfaces and supporting materials. No discernible effects were noted[4].
The current activity of the source is calculated as a minimum semiannually. Using the inverse square relationship distances are then calculated in order to obtain a one quarter and three quarter scale reading on each scale of each instrument. Some scales may not be calibrated or may only have a single calibration point. The calibration reports will be annotated accordingly[5].

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[4] Meyer, R. 2nd Correction to Memo re: Estimate of Error for Calibration Procedures, Internal Memo from Russ Meyer to Richard Ratliff, Texas Department of Health, Bureau of Radiation Control, dated November 20, 1991

[5] Texas Department of Heath, Bureau of Radiation Control. Regulatory Guide 5.2, Guide for the Preparation of Survey Instrument Calibration Applications, 1982

Remote GM detectors will be calibrated with the long axis of the detector perpendicular to the central axis of the beam.

If the detector has a window, the window will be closed during calibration. Other GM detectors such as end window or pancake types will not routinely be calibrated for photon radiation fields. Instruments with internal detectors or chambers will be calibrated with the instrument facing the source of radiation, and the chamber's or detector's center at the distance from the source designated as the calibration point and with the center of the detector or chamber within a few centimeters of the central axis of the beam in the vertical and horizontal planes. In all cases calibrations will be performed in such a manner that the sensitive volume of the detector or chamber is fully encompassed by the beam[6].

A calibration shall consist of a comparison of the instrument's response to a known radiation field at two points on each scale. If an adjustment to the instrument is needed, it will only be made at one of these points. Should the instrument not respond to within ±10% of the second reading on that scale when checked in the appropriate radiation field, it will be replaced and scheduled for maintenance and/or repair. It should be noted that the error in the reading only relates to the error allowed between the calculated radiation field and the response of the instrument. It does not include the error in the calculation, the error in measurement of the distance, the error in any instrument used to measure the exposure rate or the error in the primary standard. If care is taken, however, the sum of these "unexpressed" errors should not exceed 10% (IAEA 1971).

The high voltage will not be checked; modern power supplies should generally be capable of providing stable high voltages to within a few per cent or better (IAEA 1971). Nor will an electronic calibration (a check of the linearity of the scale of the rate meter) be performed as part of routine calibration procedures. If an instrument cannot be calibrated within specification in the appropriate radiation fields, then in will be replaced and sent for maintenance and/or repair.

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[6] Texas Department of Heath, Bureau of Radiation Control, Regulatory Guide 5.2, Guide for the Preparation of Survey Instrument Calibration Applications, 1982

## PROCEDURES FOR SPECIFIC INSTRUMENTS

### LUDLUM MODEL 14-C GEIGER COUNTER

This instrument will be calibrated only with the remote GM detector Models 44-6 or 44-38 series. The calibration will be carried out in the manner specified in the general section entitled Conditions of Calibration. Only one point will be checked on the x0.1 and x1000 (internal detector) scales. Ludlum model 14Cs currently in use by the Bureau come with three different meter faces. Meter faces can be distinguished by the location of the x100 scale in comparison with the other two scales. There are two Calibration Record sheets available to document the calibration of the instrument, one sheet is use if the x100 scale is in the middle of the face plate and the second is used otherwise.

### LUDLUM MODEL 12S or 19 MICRO METER

This instruments calibration will be carried out in the manner specified in the general section entitled Conditions of Calibration. Contrary to recommendations by the manufacturer no attempt will be made during **routine** calibration procedures to calibrate each range with a pulser or establish a voltage plateau.

### LUDLUM MODEL 2241 SCALER AND RATEMETER

This instrument will be calibrated with the remote GM detector Models 44-38 series. The calibration will be carried out in the manner specified in the general section entitled Conditions of Calibration. A minimum of three decades will be checked covering a range of 5 to 500 Roentgens per hour. The high range detector will be calibrated over a range of 3 decades and will have at lease one of the reading be greater than one Roentgen per hour. The 1x1 sodium iodide detector will be calibrated at a minimum of three points over a range of 20 to 2000 micro-Roentgens per hour.

### RADeCO MODEL H809VI LOW VOLUME AIR SAMPLERS

Calibration only occurs at a flow rate of two cubic feet per minute. All samples will be collected at this flow rate. The instruments used to calibrate the RADeCO model H809VI air samplers are either the RADeCO model 812 or 828 calibrators. These are returned to the manufacturer once a year for calibration.

### RADeCO MODEL H810 LOW VOLUME AIR SAMPLERS

Routine calibration verifies a flow rate of two to four cubic feet per minute. If routine calibration is not with ten percent of the calibrators value the sampler with be calibrated in accordance with technical manual to low value of up to one cubic foot per minute and a high value not to exceed ten cubic feet per minute. The instruments used to calibrate the RADeCO model H810 air samplers are either the RADeCO model 812 or 828 calibrators. These are returned to the manufacturer once a year for calibration.

### LUDLUM MODEL 77-3

This instruments calibration will be carried out in the manner specified in the general section entitled Conditions of Calibration. During calibration the detector should be removed from the telescope by removing four screws that hold it to the telescope. Only one point will be checked on the x10, x100, and x1000 R $hr^{-1}$ scales. These last three scales are calibrated in the CDV-784 calibrator by feeding the detector though the back of the calibrator into a custom detector holder. Radiation field produce in calibrator should be 20-80% of meter scale.

**EBERLINE RO-20 & RO-2**

Calibration and maintenance of the Eberline Ion chambers should be performed as outline in the instruments Technical manual with the exception that two points will be check on each scale when possible.

**ASP-2 WITH SPA-8 PROBE**

The ASP-2 is entirely controlled by its microprocessor, its probe voltage and detection thresholds are directly set by output of the processor chip. Calibrating and configuring this instrument is accomplished from a program which runs on a host computer and communicates with the ASP-2 via a serial data link. Refer to the technical manuals supplied with the host program and instrument for detailed information on calibration.

American National Standard Institute(ANSI), Radiation Protection Instrumentation Test and Calibration, ANSI N323-1978, The Institute of Electrical and Electronics Engineers , Inc., New York, NY, 1978

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Knoll, G. F., Radiation Detection and Measurement, 2nd edition, Wiley, New York, NY, 1989