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Early Electroscopes at the National Bureau of Standards

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NIST Special Publication
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Abstract

This report describes the use of five electroscopes used as national standards for radioactivity for the United States during the early 20th century. This set of instruments were used for the calibration of thousands of radium-226 sources used in medical therapy in the US from 1913 to 1989. The provenance of these instruments is recorded here to aid historians and curators in preservation of knowledge and artifacts of early radioactivity measurements in the United States.

Keywords

Beta particle; electroscope; emanation; gamma rays; museum collections; radium; radon.

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Foreword

Anyone with responsibility for accepting donations of artifacts for a museum collection will likely relate to a situation similar to this: An artifact is brought to you for consideration and the donor tells you: “This has been kept in my laboratory/business/family for many years because it was important. But we no longer know what it is. Do you want it?” Museums cannot keep a collection of unknown objects, and you have no documentation to help identify the artifact, so you must decline the offer knowing that a possibly significant piece of history has now been lost.

In the case of important scientific instruments, they would ideally be given over to the care of a relevant museum in a timely manner. But in reality, instruments can often remain in-use in a laboratory for decades, or there is a desire to maintain the instrument in the lab for demonstration or instruction to new employees and visitors. For radiological devices, they may need to be stored in a proper environment until contamination hazards subside. Eventually the individuals who know about the instrument move on, broad laboratory knowledge of the instrument slips away over the years, and the device finds its way to a museum as an ‘important but unknown’ artifact.

With this report, the authors are commended for recognizing the need to formally document the notable historical instruments under their care. This report will be of immense value to future museum curators and historians, and functions as a guarantee against loss of knowledge over time. I strongly encourage others to take the same time and care in documenting instruments and artifacts they currently have responsibility for.

Keith Martin
Supervisory Librarian, NIST Museum and Archives
April 2024

Acknowledgments

The authors gratefully acknowledge our colleagues Ronald Collé, Keith Martin, Edward Landa, Joel Lubenau and David Allard for their helpful discussions, comments, and references to enhance this account.

1. Introduction

This report describes the history of the early electroscopes used for radioactivity measurements at the National Bureau of Standards (NBS) (after 1987 the National Institute of Standards and Technology) in the first half of the 20th century[1]. Five of the electroscopes used for radioactivity measurements still exist: two in the Radiation Physics Division in Gaithersburg, Maryland and two in the collection of the Museum of Radiation and Radioactivity at the Oak Ridge Associated Universities [1]. Yet another early electroscope is now in the museum collection at the California Institute of Technology [2]. The electroscopes used to measure radioactivity depend on the ionization of air from the high energy alpha, beta, and gamma radiation from radioactive decay of nuclides such as uranium-238, thorium-232 and radium-226. Further descriptions are given in references [2 - 4] and in Appendix A by NBS physicist Ernest Noah Dorsey [4].

[1] NIST property records indicate the purchase of two Hensen quartz-fiber electroscopes by George Singer in the dosimetry section of the Optics Division of NBS in 1944. These instruments have not been located and were likely used for radiation worker protection purposes during WWII.

2. The Early Electroscopes (1913 – 1920)

The beginning of the US radiation standards at the Bureau of Standards has been described by Coursey and Martin [3]. In 1913, Noah Ernest Dorsey mentioned to Bertram Boltwood, the chemist at Yale, several electroscopes but did not publish any details. On December 1, 1913, Dorsey wrote “We have built a few emanation electroscopes, and have a complete Rutherford setup…. I am rather pleased with the Rutherford method”. In response, on December 13, 1913, Boltwood described the instruments used in Vienna by Meyer and Hess, in Manchester by Rutherford and Chadwick, and in Paris by Curie and Debierne. Boltwood offered that Stefan Meyer in Vienna would build an instrument for the Bureau for about $150 (about $4000 USD in 2024). Dorsey did not describe the electroscope until he published his textbook on radioactivity in 1921 [4].

Although there are no records in the archives of the electroscopes that Dorsey purchased or constructed, there is a photograph from a newspaper in 1924 that shows Mary Brower Harrington (at NBS from 1921-1929; 1943-1954) using a gold-leaf electroscope to measure gamma rays from a radium source [5].

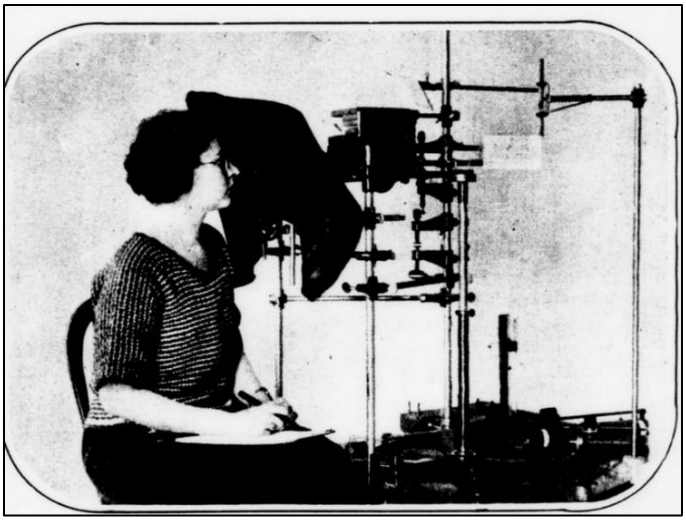

Figure 1. “Miss Mary Brower of the bureau of standards, an expert who measured four million dollars worth of radium recently. The photograph shows the method of measurement” [5].

There are other photographs in the NIST archives showing Brower’s colleague Constance Torrey who worked in the radium calibration laboratories from 1921 until her death in 1950. Both Figures 2 and 3 show Torrey posing with the electroscope, but in both there is a black cloth covering the electroscope obscuring any details about the instrument she is using.

Figure 2. Constance Torrey with stopwatch and gamma-ray electroscope. (NIST archives)

Figure 3. Constance Torrey in a formal portrait with electroscope in early 1920s. (NIST archives)

Leon Francis Curtiss came to the Bureau in 1926 following a four-year fellowship at the Cavendish Laboratory in Cambridge under the guidance of Ernest Rutherford [6]. Curtiss designed and constructed a projection electroscope that allowed the operator to be some distance from the radium source under measurement. There are three photographs in the NIST archives that show a "projection electroscope". Constance Torrey is shown with the earliest version in Figure 4.

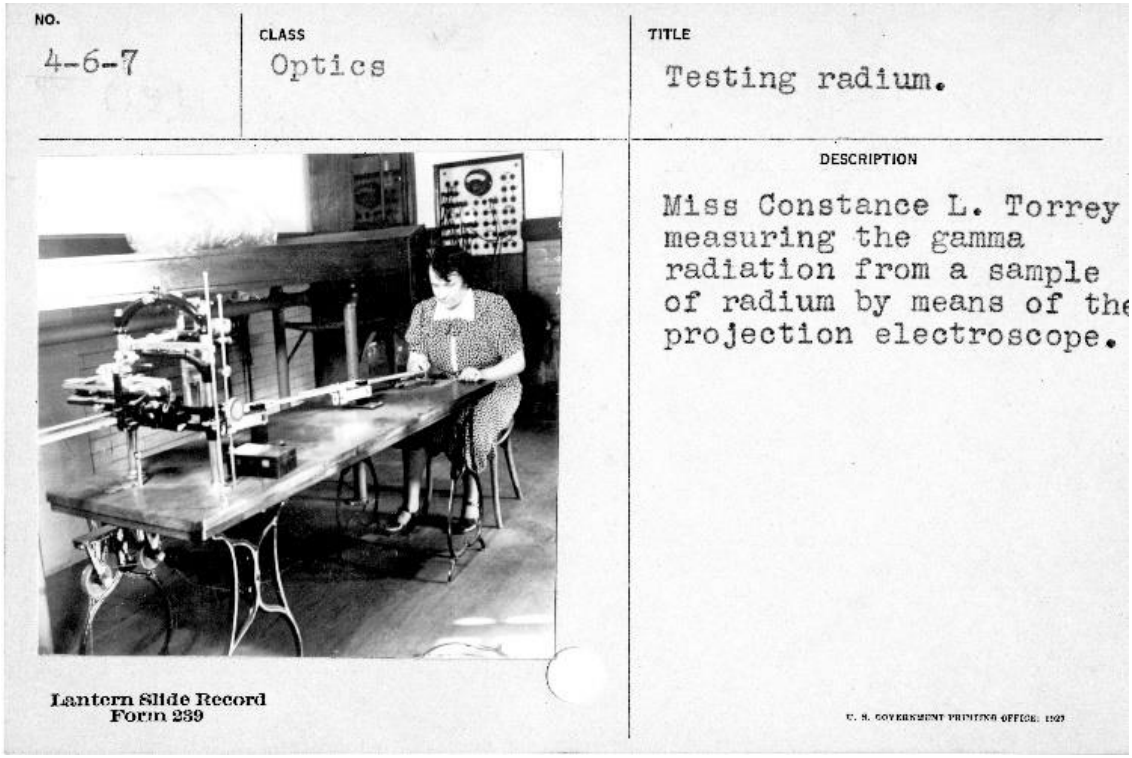

Figure 4. Constance Torrey with projection electroscope in the 1920s. (NIST archives)

3. Standard Electroscope for Radium Source Calibrations

At some time in the late 1920s, the gold-leaf electroscope was placed inside a shielded trough in the East Building. Leon Curtiss is shown with a different version in Figure 5. The setup looks slightly different in Curtiss's paper [7] in 1928 (Figure 6). The projector box in Figure 5 is on a wooden table and the projector box in Figure 6 is mounted on metal plumbing fixtures.

Figure 5. Leon F. Curtiss with projection electroscope in the 1920s or early 1930s. (NIST archives)

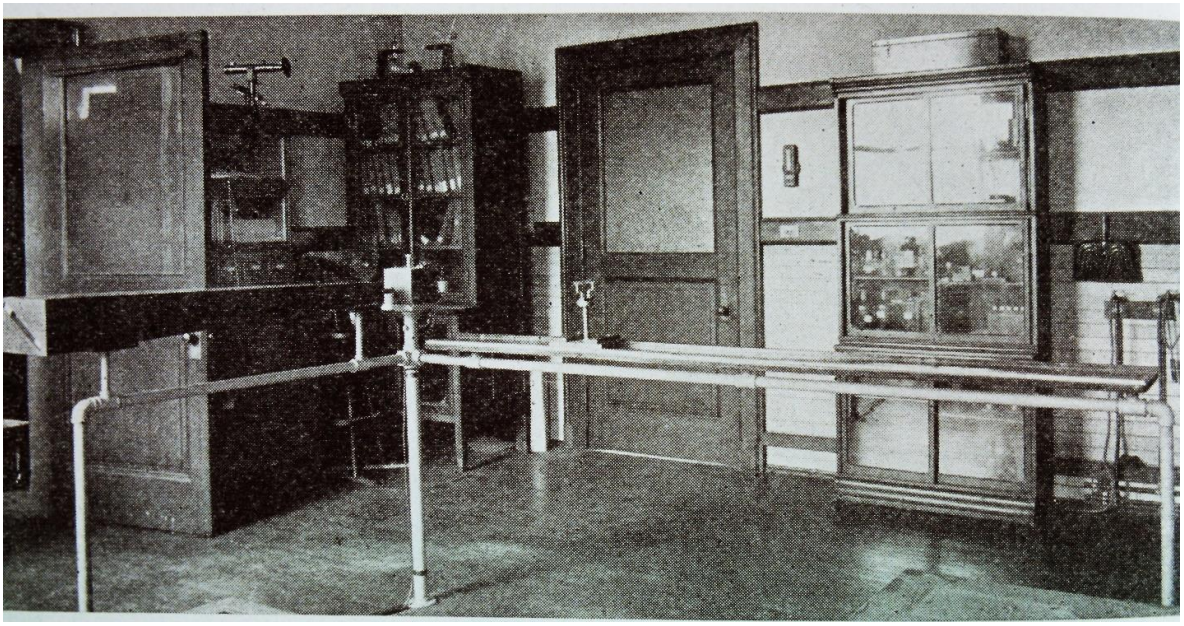

Figure 6. Projection electroscope in the East Building laboratory circa 1927 [6].

Two closeup photographs of the electroscope are in the NIST Digital Archives (Figures 7 and 8). The shielding bricks on the wall are different in these two photos indicating that there were two locations for the electroscope at the NBS site in Washington, DC. Figure 7 shows the instrument installed in 1950 (Figure 50 in NBS Special Publication 625). Lauriston S. Taylor [8] said that it had been in use since 1925. The setup shown in Figure 8 was in the Materials Testing Laboratory in 1954. This building was constructed in 1943 with some of the construction funds ($600,000) provided in support of the war effort [9]. This electroscope was used for routine comparisons of radium sources with the United States 15.44 mg radium standard provided by the International Radium Standards Commission in December 1913 [3].

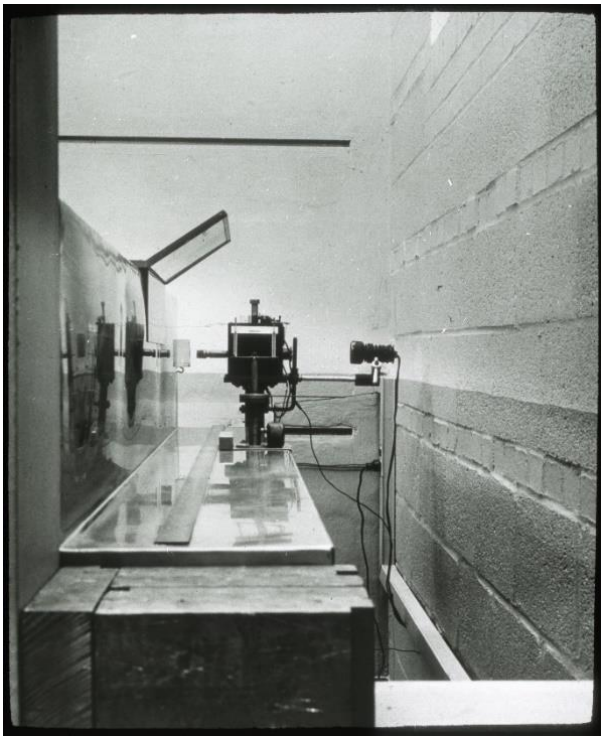

Figure 7. Electroscope probably in the East Building in 1950; Figure 50 in NBS Special Publication 625 [8]. (NIST archives)

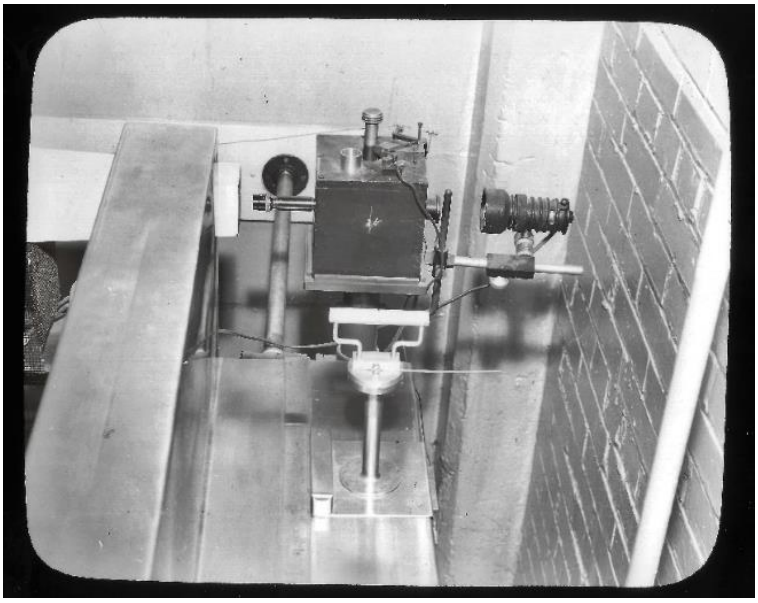

Figure 8. Electroscope in a shielded trough in the Materials Testing Laboratory in 1953. (NIST archives)

The best details on the electroscope itself are provided by Curtiss [7] and Davenport et al [10]. "The NBS standard electroscope and measuring system were used, without modification, for this comparison of four national radium standards. The ionization chamber consists of a 10 cm cube free-air volume, with walls made of 1 cm of lead and a 0.5 cm aluminum inner lining. A gold leaf is suspended near the center of the chamber. A 10 μ quartz fiber at the free end of the leaf provides a fine line for projection. The fiber image is magnified approximately 100 times and projected onto a metric scale. The discharge of the electroscope is measured by timing the transit of the image between two fixed points on the scale 6 cm apart." [10]. Curtiss describes the procedure for affixing the fine quartz fiber to the gold leaf [7].

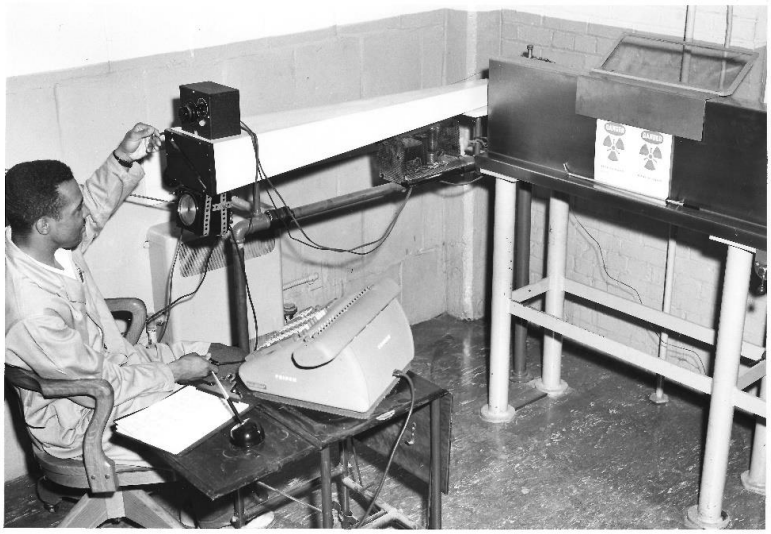

Figure 9. Carl C. McCraven with electroscope in 1953. (NIST archives)

Figure 9 shows NBS physicist Carl McCraven during the experiments in which NBS used the electroscope to compare national radium standards of the US, Germany, and Canada [10]. A close inspection of Figures 8 and 9 reveal that this is the same setup of the electroscope. The projection piece in the top left of Figure 7 is the end of the tapered viewing chamber shown in Figure 8. The reticle shown on the right in Figures 8 and 9 is a gun sight with markings that allowed the operator to quantify the rate of change in the leaf in divisions per minute (hence the use of the stopwatch in Figure 2). Figure 10 shows McCraven in the foreground in a large bay in the Radioactivity Section in the same period (circa 1953). The projection electroscope viewed by an unidentified worker can be seen in the far-left corner of the laboratory. Framed copies of the Curie/Hönigschmid standards [3] are hung on the right wall.

Figure 10. Workers in the Radioactivity Section of the Radiation Physics Laboratory circa 1953. (NIST Archives)

The electroscope was moved to Gaithersburg in 1966 and installed in a brachytherapy calibration laboratory, Room B145 in the Radiation Physics Building (Building 245) [11]. Thomas Loftus was the principal investigator on the brachytherapy calibrations and was assisted by James T. Weaver.

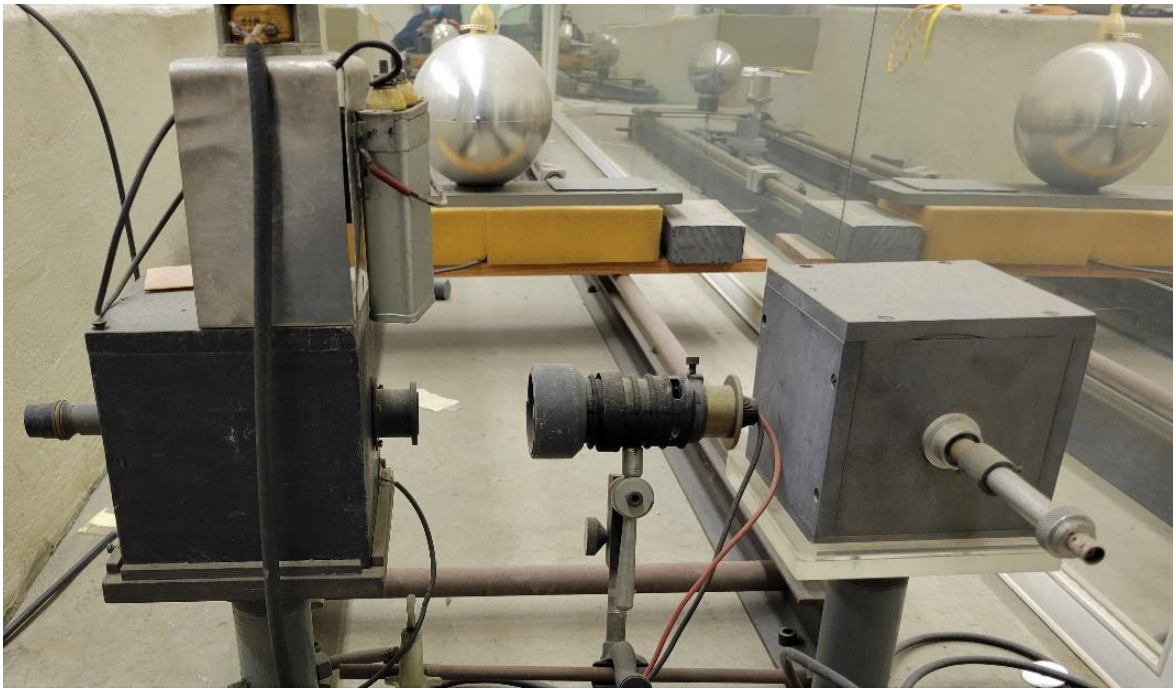

Figure 11. Gold-leaf electroscope (left) and ionization chamber (right) installed in B145 in 2020. (NIST archives, 2021)

The purpose of the electronics package on the top of the electroscope is unknown. The ionization chamber on the right (a 13 cm lead cube) was constructed by Lee and Loftus [12] such that one could record the reading from the electroscope and the current from the ionization chamber for the same source at the same distance simultaneously.

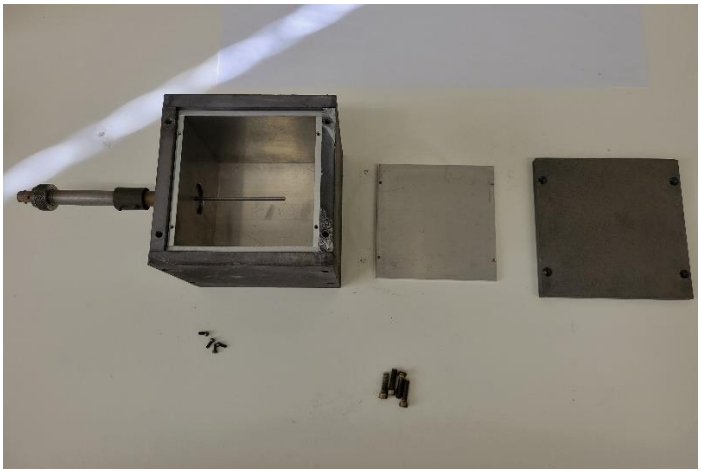

Figure 12. Transfer ionization chamber used by Lee and Loftus [8]. (NIST archives, 2021)

Weaver and Loftus were the last to use the electroscope for calibrating radium sources in the 1980s. In 1988 Coursey replaced Robert Loevinger as Group Leader for the Radiation Interactions and Dosimetry Group. The following year, 1989, NIST announced that calibration services for radium-226 would be terminated. This decision was made because there were

higher priority brachytherapy projects (iridium-192, iodine-125 and palladium-103) and radium-226 brachytherapy sources were no longer used in medical practice. There were no measurements with the electroscope over the next 32 years, although the calibration range was still used to calibrate iridium-192 and other brachytherapy sources.

In late 2021, Coursey and Mitch disassembled the calibration range and identified some of the paraphernalia that had been used to shape the leaves along with a small amount of gold leaf and quartz fiber. These are not contaminated and are stored for historical purposes.

Figure 13. Glass bottle holding suspended leaf, and wooden blocks for shaping the leaves to give the right curvature for viewing thru the eyepiece. (NIST archives)

The electroscope itself was found to have a low-level of radium-226 contamination which could not be removed [13] (Appendix B).

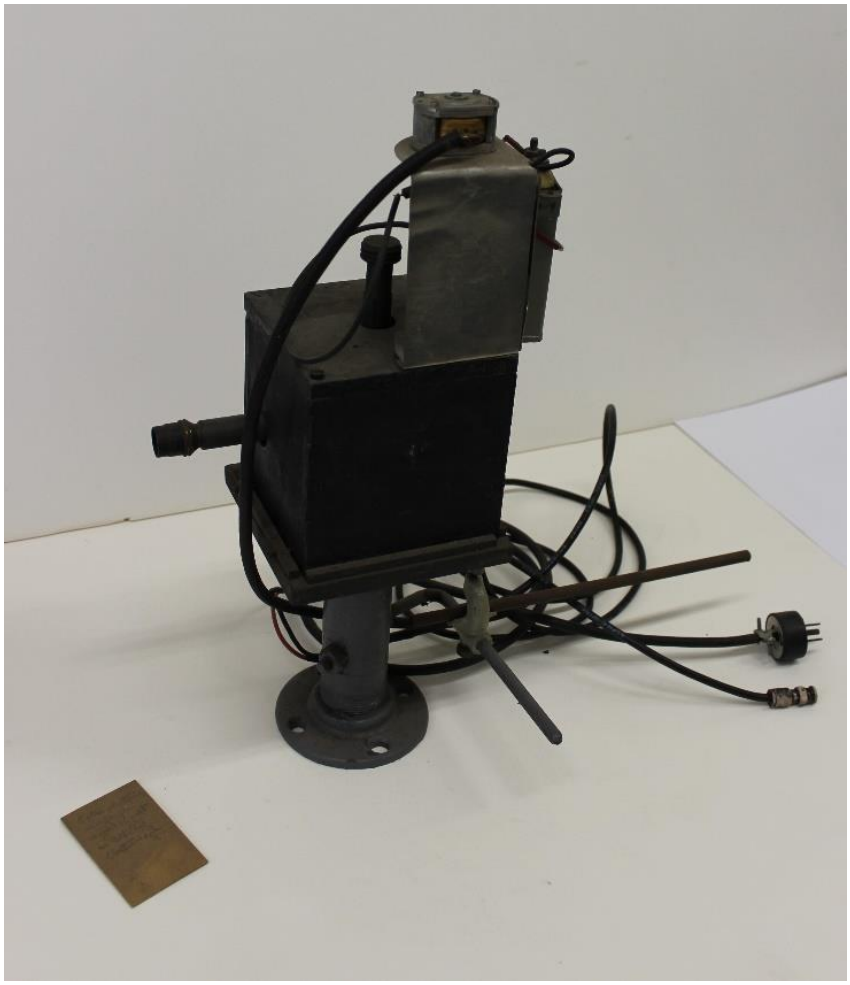

Figure 14. Original gold-leaf electroscope in 2021 (NIST archives. 2021).

4. Lind Electroscope for Radon-222

There is no information in the NIST archives describing the instruments used for the early emanation (radon-222) measurements, although such measurements were being made in 1914 according to the Dorsey – Boltwood correspondence [3] and the NBS Director's Annual Report [14] of June 30, 1914.

In July 2021, during the clean-out of old storage areas in the C Wing attic of Building 245, Coursey and Zimmerman spotted an interesting piece of equipment that turned out to be a Lind emanation electroscope [15, 16, 17].

Figure 15. Lind electroscope in 2024. (NIST archives)

This instrument is most likely the one referred to in 1928 by Elizabeth Hughes [18] who reported that she had used it in 1919 under the direction of N.E. Dorsey when she was in the NBS Radium Section. In addition to Lind's original papers, there are good descriptions of the different versions of Lind's electroscope collected by Frame in exhibits of the Oak Ridge Associated Universities Museum of Radiation and Radioactivity [1].

Figures from the ORAU website are shown here for comparison. The same gold-leaf, or aluminum-leaf, apparatus can be used with interchangeable chambers designed to accommodate ore or mineral samples. The Denver Fire Clay Company provided chemicals, supplies and instruments for use in the Colorado mining industry [19]. Frame has suggested that Lind was probably inspired by a very similar design developed by Cheneveau and Laborde [20] sometime around 1908.

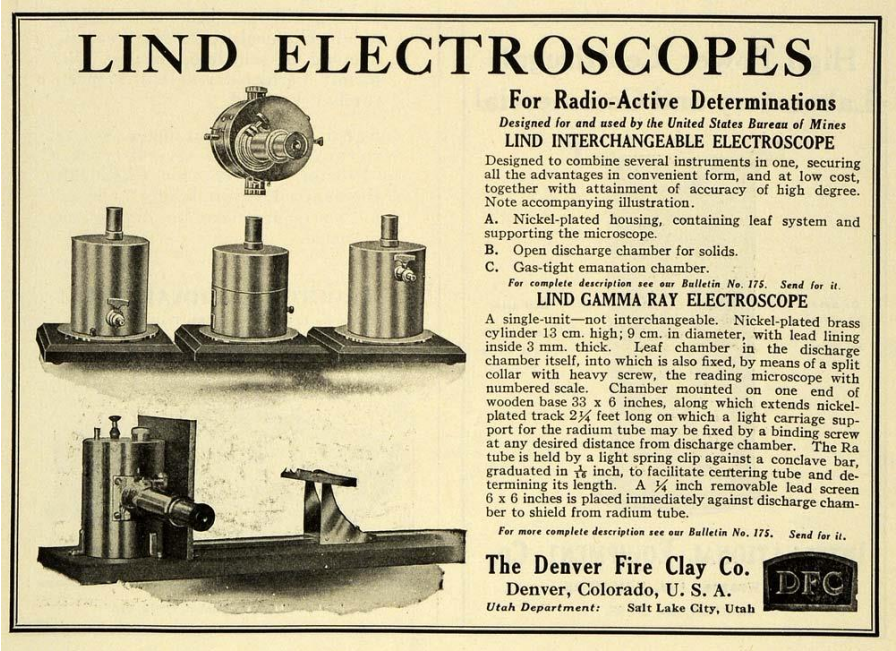

Figure 16. Advertisements for different versions of the Lind Electroscope. (Credit, Denver Fire Clay Co.)

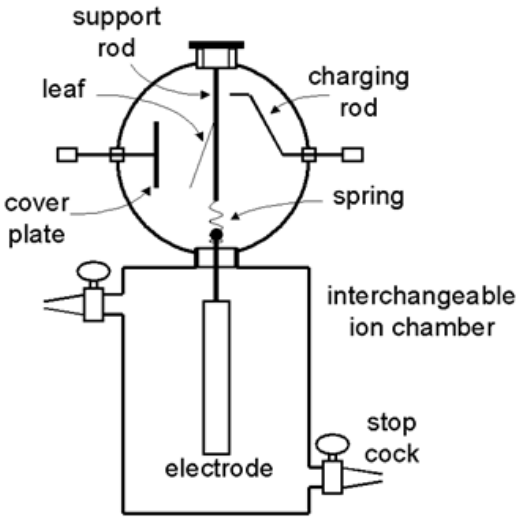

Figure 17. Diagram of the Lind Electroscope from ORAU [1].

The NIST Lind electroscope is missing some pieces. It contains residual radium-226 contamination, mainly on one of the stopcocks [21]. This was suspected considering operational procedures during the years the instrument was used. Partial decontamination and measurements were made by Ben Estes in the Radiation Safety Division in July 2021 (Appendix C).

5. Wilfrid Basil Mann Electroscopes

Wilfrid Mann was recruited to the NBS in 1951 by Lauriston Taylor to head the Radioactivity Section [20]. Mann brought with him three electroscopes that he had used at the National Research Council, Chalk River, Canada in the 1940s. During the Cuban Missile crisis, Mann became concerned that the NBS might be destroyed in an atomic attack on Washington. To preserve the NBS's capability to make radioactivity measurements, Mann calibrated these electroscopes against the NBS primary standards of radium-226. The electroscopes were then sent to the NBS laboratories in Boulder, Colorado. Had Washington and the NBS been destroyed, these electroscopes would have become the nation's primary standard instruments for radioactivity.

These three electroscopes were donated to the ORAU Museum in the 1990s. The electroscope shown in Figure 17 was designed for measuring gamma-emitting samples. The latter were inserted into the vertical tube next to the spherical chamber. This ensured that samples were always counted in the same position with respect to the chamber.

Figure 18. The Mann Gamma-Ray Electroscope in the ORAU Collection [1]. https://www.orau.org/health-physics-museum/collection/electroscopes/radioactivity/mann.html

The electroscope shown in Figure 19 was used to measure beta-emitting samples. The latter were inserted into the hemispherical chamber via the sliding drawer (projecting to the left in the photograph).

Figure 19. The Mann Beta-Particle Electroscope in the ORAU Collection [1]. https://www.orau.org/health-physics-museum/collection/electroscopes/radioactivity/mann.html

Another type of beta-particle electroscope was described by Hunter and Mann in a Chalk River internal report in 1948 [22]. In that report they describe use of the electroscope to measure the beta-particle activity of carbon-14 labelled sodium carbonate. Mann was a gifted artist and the report cited included a perspective of the electroscope shown in Figure 19. This is a modified version of a Lauritsen electroscope. The latter was developed by Millikan's student Charles Lauritsen at CalTech. The instrument shown in Figure 21 is now in the museum archives of the California Institute of Technology [2].

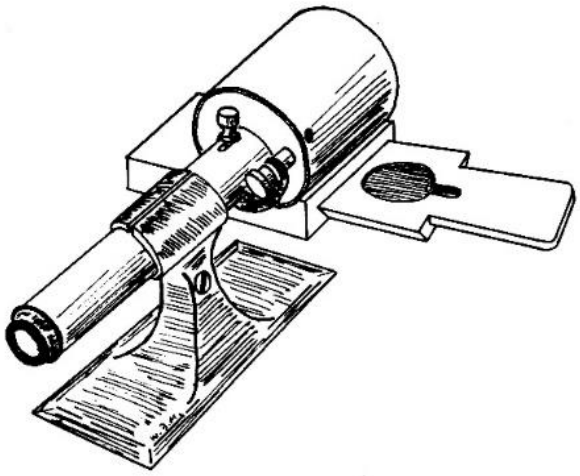

Figure 20. Hand drawn (by Mann) version of the Canadian electroscope [21].

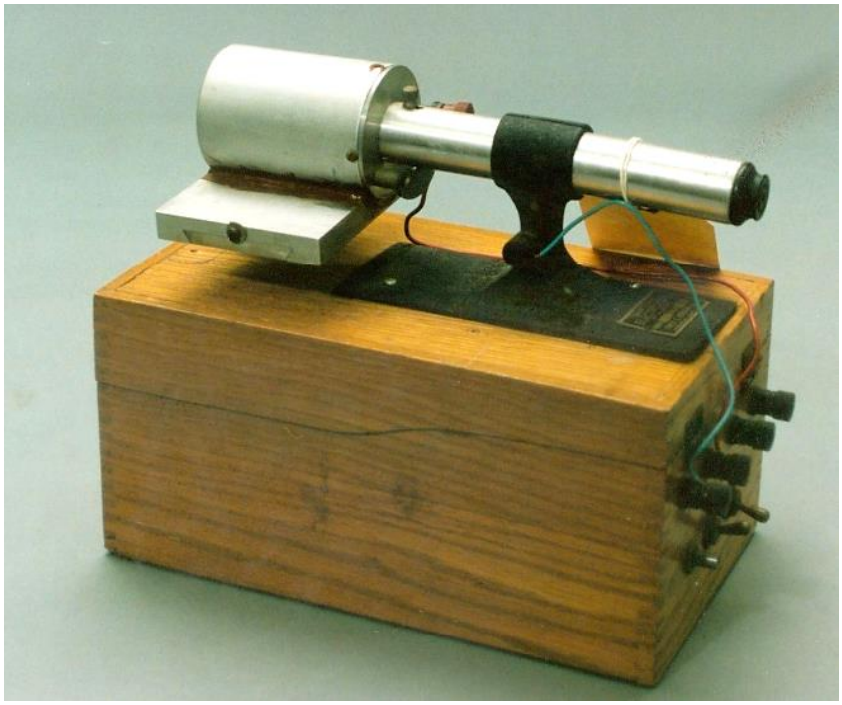

Figure 21. Modified Lauritsen electroscope brought to the NBS from Chalk River Laboratories by Wilfrid Mann [2]. (Credit CalTech Archives and Special Collections).
https://calisphere.org/item/b26608be6f5cbf03e99d0162748896c5/

The original property tag for the Chalk River gamma-ray electroscope is shown in Figure 22. The NBS property number, scratched on the bottom, is barely legible.

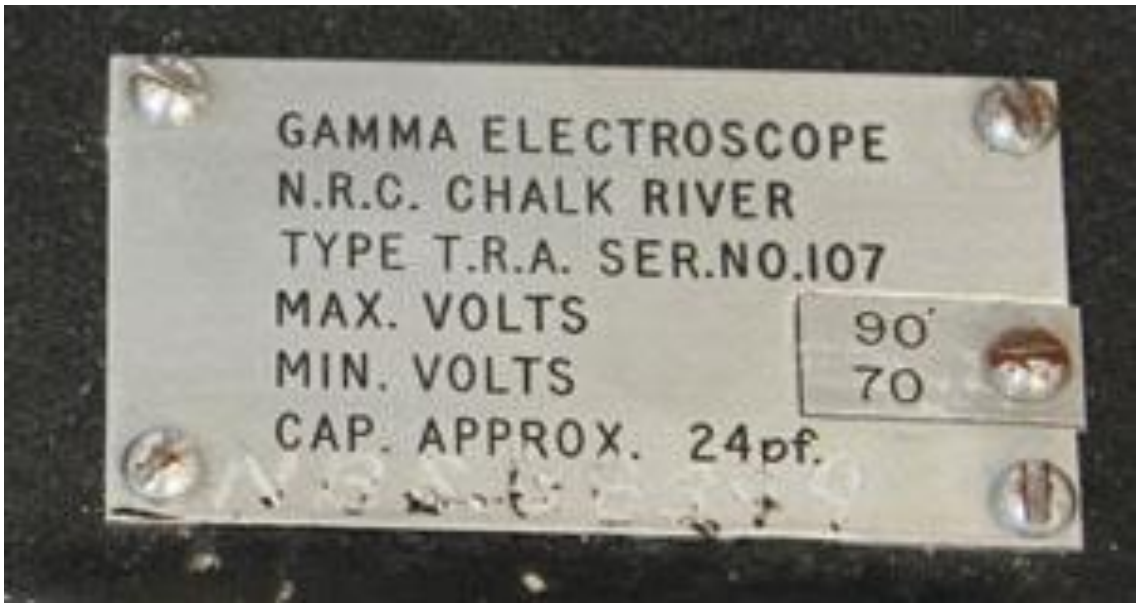

Figure 22. Property tag for the Chalk River gamma-ray electroscope [1].

6. Summary

The five electroscopes described here played important roles in the NBS radioactivity calibrations during the first half of the 20th century. The details of their provenance provided here is intended to allow historians and curators to maintain these instruments in museum collections, and to provide perspectives for future researchers who would seek to understand the role these instruments played in standards for radioactivity in the United States.

7. References

[1] ORAU Web site (2024) https://orau.org/health-physics-museum/collection/electroscopes/index.html
[2] CalTech Archives and Special Collections (2024). https://calisphere.org/item/b26608be6f5cbf03e99d0162748896c5/
[3] Coursey BM, Martin KR (2023) *Standards and Measurements of Ionizing Radiations in the 20th Century at the National Bureau of Standards/National Institute of Standards and Technology Chapter 1: 1901 – 1921,* NIST Special Publication 1298. https://doi.org/10.6028/NIST.SP.1298
[4] Dorsey NE (1921) *Physics of Radioactivity,* Williams and Wilkens, Baltimore.
[5] Washington Evening Star, Jun 8, 1924.
[6] Biography of Leon F. Curtiss (2009, updated 2016) https://www.nist.gov/pml/marie-curie-and-nbs-radium-standards/marie-curie-and-nbs-radium-standards-biographies-1
[7] Curtiss LF (1928) *A Projection Electroscope for Standardizing Radium Preparations,* Journal of Amer. Opt. Soc., 16, 363.
[8] Taylor LS (1981) *X-Ray Measurements and Protection: 1913 – 1964,* NBS Special Publication 625, National Bureau of Standards, Washington, DC. https://www.nist.gov/publications/x-ray-measurements-and-protection-1913-1964
[9] Cochrane RC (1966) *Measures for Progress: A History of the National Bureau of Standards,* U.S. Department of Commerce, Washington, DC. https://nistdigitalarchives.contentdm.oclc.org/digital/collection/p15421coll1/id/9100/
[10] Davenport TI, Mann WB, McCraven CC, Smith CC (1954) *Comparison of Four National Radium Standards, Part 1. Experimental Procedures and Results. Part 2, Statistical Procedures and Survey,* Conner WS and Youden WJ, Research Paper 2544, NBS J. Res., 53, 267. https://nvlpubs.nist.gov/nistpubs/jres/53/jresv53n5p267_A1b.pdf
[11] Weaver JT, Loftus TP, Loevinger R (1989) Calibration of Gamma-Ray-Emitting Brachytherapy Sources, NBS Special Publication 250-19, Department of Commerce, Washington, DC. https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nbsspecialpublication250-19.pdf
[12] Lee RM, Loftus TP (1962) *Correction factors for the calibration of encapsulated radium sources,* NBS J. Res. http://dx.doi.org/10.6028/jres.066A.011
[13] Verow S (2022) Radiation Safety Division email March 23, 2022. (Appendix 3)
[14] NBS Director's Annual report, June 30, 1914.
[15] Lind SC (1915) *Practical methods for the determination of radium: I. Interchangeable electroscope and its use,* Jour. of Industrial and Engineering Chemistry, 7, 406-410.
[16] Lind SC (1915) *Practical methods for the determination of radium: II. The Emanation Method,* Jour. of Industrial and Engineering Chemistry, 7, 1024-1029.
[17] Parsons, CL, Moore, RB, Lind, SC, Schaefer, OC (1915), *Extraction and recovery of radium, uranium and vanadium from carnotite,* US Bureau of Mines Bulletin 104, Mineral Technology 12, Washington, U.S. Govt Printing Office (1915).

[18] Coursey BM (2021) *The National Bureau of Standards and the Radium Dial Painters,* Jour of Res of the National Institute of Standards and Technology. https://doi.org/10.6028/jres.126.051
[19] Landa, ER (2024), Private communication.
[20] Cheneveau C, Laborde A (1908) *Appareils pour la Mesure de la Radioactivite, d'apres la Methode Electroscopique.* Bulletin des Seances de la Société Francais de Physique, pp. 262-275.
[21] Estes B (2021) Radiation Safety Division email July 15, 2021. (Appendix 2)
[22] Mann WB (1982) Was *there a Fifth Man? Quintessential Recollections*, Pergamon Press, Oxford.
[23] Hunter RF, Mann WB (1948) A Modified Lauritsen Electroscope for Measurement of Carbon-14 Activities, CRM-409, National Research Council of Canada, Atomic Energy Project, Division of Research, Chalk River, September 30.

Additional references to standard instruments in use in Vienna (Radium Research Institute).

[24] Hess VF (1913) Űber Neuerungen und Erfahrungen an den Radiummessungen nach der γ-*Strahlenmethode: I. Eine modification des Wulfschen Strahlungsapparates*, Physikalisch Zeitschrift, 14, 1135.
[25] Meyer S, Hess VF (1912) Mitteilungen des Institutes für Radiumforschung XVII, Zur Definition der Wiener Radiumstandardpräparate, Academy der Wissenschaften in Wien, math. -naturw. Klasse.
[26] Wulf T (1907, 1909) Ein neues Elektrometer für statische Ladungen*. Physikalisch Zeitschrift*, 8, 246 (1907); 10, 211 (1909).

Additional references to standard instruments in use in Paris (Curie Laboratory)

[27] Curie M (1912) *Les mesures en radioactivité et l'étalon du radium*, J. Phys. Theor. Appl., 2 (1), 795-826. https://hal.archives-ouvertes.fr/jpa-00241800

Additional references to standard instruments in use Manchester (Manchester University)

[28] Rutherford E (1912) *The International Radium Standard*, Nature, 89, 115.
[29] Rutherford E, Chadwick J (1912) *A balance method for comparing quantities of radium and some of its applications*, Proceedings of the Physical Society, 24, 141.

Appendix A. Description from Dorsey 1921 textbook [4].

“The simple electroscope consists of a metal case within which, and near its center, is supported in a vertical position a well-insulated metal strip to the top of which is attached a narrow strip of thin foil, preferably of gold leaf. This strip of foil is usually spoken of as the leaf. The strip of metal and the leaf constitute the insulated system of the electroscope. When the insulated system is electrically charged by a suitable switch passing through the wall of the case, the leaf is repelled by the strip, and is deflected from its normal, vertical position. In opposite sides of the case are windows through which the position of the leaf can be observed. Such observation is usually made by means of a microscope having in its eyepiece a ruled scale.

When intended for gamma ray measurements, the electroscope should be carefully screened on all sides except one with lead at least one inch thick, so that the air in the electroscope will be protected from scattered radiations that would otherwise enter it. For the same reason, the windows should be as small as is conveniently possible. The ionizing radiation of which the intensity is to be measured enters the electroscope through the unscreened side. In order to minimize the effect of the absorption of the radiation by the wall of the container and by the salt itself, the measurements should be based upon the hard, penetrating radiation emitted by radium-C. For this reason it is desirable that the radiations entering the electroscope be filtered through lead at least 15 mm thick so that very little of the soft gamma radiation from radium-B enters the electroscope.

When everything is ready, all radium preparations are placed at such distances and so screened that they produce as small an ionization in the electroscope as possible – the preparations to be compared must be so placed that they produce only a negligible ionization. The insulated system is then charged and insulated, and the time required for the image of the leaf to move over a few divisions near the middle of the scale in the microscope is determined. From this, the rate of drift of the leaf, in divisions per second, when there is no radium near the electroscope, is determined. This is called the natural, or the blank, drift. It results from imperfect insulation and slight residual ionization of the air.

Then the tube under test is placed in a suitable position, and the time required for the leaf to drift over a certain portion of the scale is determined. If the blank drift is subtracted from the rate of drift observed when the tube under test is in position, the difference will be the rate of drift due to the radiation from the tube; this is known as the corrected drift.

The tube under test is now removed to its former position where it does not affect the electroscope, and the standard tube is placed in exactly the same position previously occupied by the tube under test. Its corrected drift is determined in exactly the same way as was that for the tube under test.

The ratio of the two corrected drifts is equal to the ratio of the intensities of the two radiations; which, in turn, is equal to the ratio of the amounts of radium-C that are contained in the two tubes, provided that the absorption of the radiations by the walls of the two tubes is the same in both cases. Knowing the amount of radium-C in the standard, the amount in the tube under test can now be computed at once.” (N.E. Dorsey, 1921)

Appendix B. E-mail from Shain Verow, March 23, 2022

Hi Bert,

The decontamination of the electroscope has been successfully completed in so far that recent smears on the items are showing no detectable removable contamination. Please be aware, the components are still radioactive and have contamination that can be liberated through rough handling or abrasion. The fixed levels on the items have been reduced to about 10 % of their initial levels. I am finishing up the packaging presently and the items will be in H104 for you to pick up when it is convenient for you. If it is easier, I can deliver them to a lab for you, provided I have access to the room.

Beyond my initial expectations, I was able to decontaminate the lamp from the electroscope along with the main body and stand. The other items have been disposed of as radiological waste.

Best,
Shain Verow
March 23, 2022

Appendix C. E-mail from Ben Estes, July 15, 2021

Hi Bert,

Based on our conversation this morning, I surveyed the electroscope to find where the activity was located. It looks like most of it is on the handles of the stopcocks (~ 1 kcpm) and the thumbscrew on the side. Paper swipes at those locations indicate that the contamination there is fixed, as no activity transferred to the swipe.

If you intend on decontaminating this, we can work with you directly or we can give you a bottle of decon-gel if you'd like to do it yourself. (it works like using wood glue on records to remove dust)

I've put a tag on it indicating "Do not send to waste" just to make sure it doesn't accidentally go down that pathway.

Either way please let us know.

Thank you, Ben Estes, July 15, 2021