Portable radiation dosimeter

KO Lam, FHKCR, FHKAM (Radiology)
Member, Educational and Research Committee, Hong Kong Museum of Medical Sciences Society

https://doi.org/10.12809/hkmj-hkmms202204

Radiation has been present since the beginning of time, but modern understanding of radiation took a leap forward when Wilhelm Conrad Roentgen discovered X-rays in 1895 in Wurzburg, Germany. The discovery led to Roentgen becoming the inaugural laureate of the Nobel Prize in Physics 1901.[1] In the early days, the potential health hazards of radiation exposure were not well understood. Indeed, calibration of X-ray tubes at that time was based on the amount of skin erythema (as known as "erythema dose") produced when the operator placed a hand directly in the X-ray beam! It is not surprising to learn that some radiation workers in those days hurt their hands or even lost fingers, as their hands commonly received exceptionally high doses of radiation. Numerous unexpected radiation injuries were reported in patients, doctors, and scientists,[2] including those at the cutting edge of research, such as the three well-known winners of the 1903 Nobel Prize in Physics. Antoine Henri Becquerel noted skin erythema under his waistcoat in proximity to a radiation source in his pocket. Pierre Curie wounded himself after intentional exposure of his arm to a radiation source for 10 hours.[3] And most famously, Marie Curie, who was also awarded the 1911 Nobel Prize in Chemistry for discovering the radioactive elements radium and polonium, ultimately died as a result of radiation exposure. There were unfortunately many more pioneers in radiation research who sacrificed themselves to their dedicated work! There was a strong call for radiation safety in the field and Arthur Mutscheller was the first to propose a "tolerance" dose for radiation workers at the meeting of the American Roentgen Ray Society in 1924. Without a proper device to measure radiation dose, his proposed "tolerance" dose was based on the primitive "erythema dose", which was the common, albeit inconsistent and hazardous, standard of measurement at that time.[2]

The ability to measure radiation dose—dosimetry—is an essential component in radiation safety. Otto Glasser, a German physicist, was a notable pioneer in dosimetry. He developed an electrometer dosimeter with Hugo Fricke, Valentine Seitz, and UV Portmann in 1925. The dosimeter was manufactured by the Victoreen Instrument Company and marketed as the "Condenser r-Meter". The model was a great success and Victoreen became a leader in the field radiation measurement equipment. Owing to its expertise in radiation detection, Victoreen was contracted by the Manhattan Project in 1944 to manufacture portable radiation devices as part of Operation Peppermint. In return, the company devised modifications for the Condenser r-Meter so that it could be used to detect any potential radioactive poison used by the German army to disrupt the Normandy landings. It was reported that the company continued to provide 95% of the instrumentation for nuclear testing in the Marshall Islands after World War II.[4]

The Victoreen Model 570 Condenser r-Meter is an instrument for the measurement of total X-ray dosage in international roentgens (Fig 1). The Condenser r-Meter consists of an ionisation chamber, a complete dust-tight electrometer with its viewing microscope systems, and a lighting system for the microscope in a metal case. It came with a nicely crafted carrying case that also included storage space for six extra ionisation chambers, spare fuses and lamps, a desiccator, and an instrument manual. The Condenser r-Meter works on the principle that X-rays can liberate charges in air, and these charges can be collected by producing an electric field across the volume of air. By placing the thimble portion of the ionisation chamber in the radiation field, the ionisation will produce a potential difference which can be measured by the electrometer. To cover a broad range of energy and total dose conditions, a number of other chambers

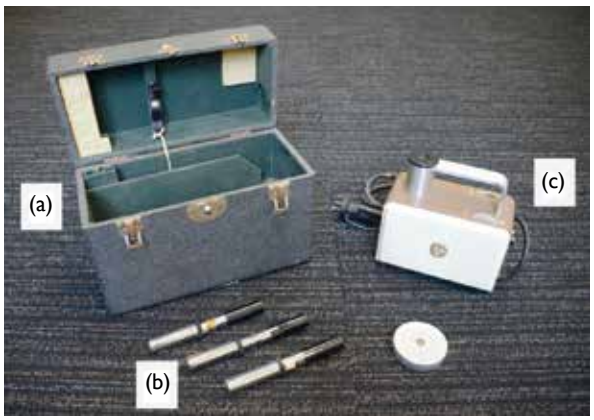
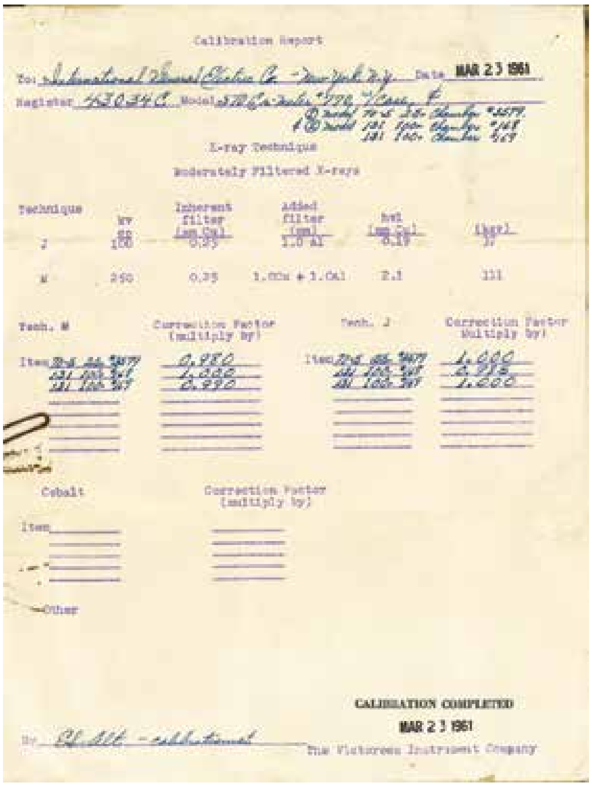


FIG 1. Photograph of the Victoreen Model 570 Condenser r-Meter showing (a) the carrying case; (b) three different air chambers with caps; and (c) the electrometer in metal case



Calibration Report

To: International General Electric Co - New York N.Y. Date MAR 23 1961

X-ray Technique

Moderately Filtered X-rays

Technique	kv	Inherent filter (mm Cu)	Added filter (mm)	hvl (mm Cu)	(kev)
J	100	0.25	1.0 Al	0.19	37
M	250	0.25	1.0Cu + 1.0Al	2.1	111

Tech. M Correction Factor (multiply by): 0.980, 1.000, 0.990

Tech. J Correction Factor (multiply by): 1.000

Cobalt Correction Factor (multiply by)

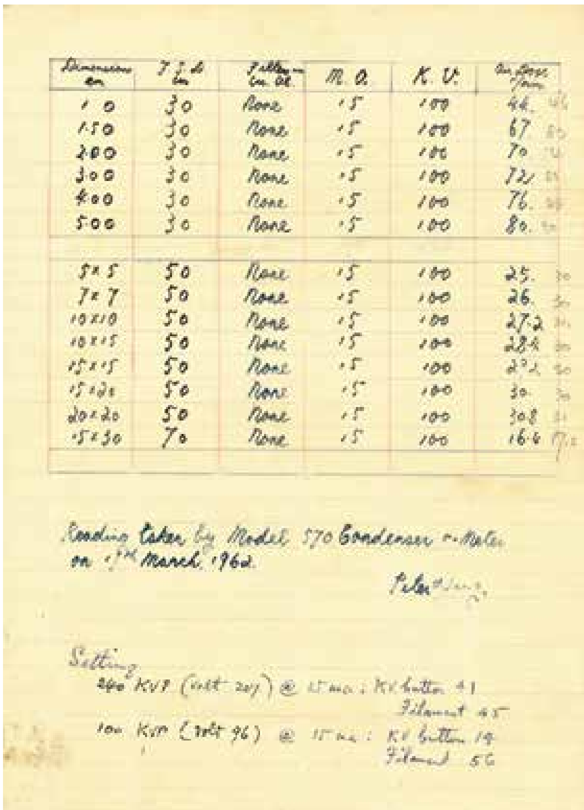
Item

Other

CALIBRATION COMPLETED MAR 23 1961

The Victoreen Instrument Company

FIG 2. Calibration report of the Victoreen Model 570 Condenser r-Meter



			M.A.	K.V.	
1 0	30	None	·5	100	46.
1·50	30	None	·5	100	67
2·00	30	None	·5	100	70
3·00	30	None	·5	100	72
4·00	30	None	·5	100	76.
5·00	30	None	·5	100	80.
5×5	50	None	·5	100	25.
7×7	50	None	·5	100	26.
10×10	50	None	·5	100	27·2
10×15	50	None	·5	100	28·4
15×15	50	None	·5	100	29·2
15×20	50	None	·5	100	30.
20×20	50	None	·5	100	30·8
15×30	70	None	·5	100	16·6

Reading taken by Model 570 Condenser r-Meter on 19th March 1962.

Setting

FIG 3. Victoreen Model 570 Condenser r-Meter reading table

with different specifications can be interchanged to fit in the model.[5] The machine required regular maintenance, as shown in calibration reports issued by The Victoreen Instrument Company to the International General Electric Company on the 23 March 1961 (Fig 2) and a table of meter reading under different settings on the 19 March 1962 (Fig 3). The Condenser r-Meter was mainly used for calibration of radiotherapy doses, measurement of radioisotope radioactivity, and detection of radiation leakage from the 1960s to the 1990s. This Condenser r-Meter was donated to the Hong Kong Museum of Medical Sciences by the Hong Kong Sanatorium & Hospital in November 2002.

Today, technology for radiation measurement has evolved dramatically. Fluorescent screens, photographic plates, gold-lead electroscopes, and Geiger counters are among the different types of radiation detection methods available. Ionisation chambers are still commonly applied in calibration of radiotherapy doses, measurement of radiation leakages, and detection of scatter around diagnostic X-ray and radiotherapy machines. However, they are now more portable, automated, and user-friendly than the original Victoreen model, without the hassle of referring to the correction chart. Radiation measurement tools continue to save the lives (and hands!) of many radiation workers.

References

1. The Nobel Prize. Wilhelm Conrad Röntgen: facts. Available from: https://www.nobelprize.org/prizes/physics/1901/rontgen/facts. Accessed 2 Mar 2022.
2. Meinhold CB, Taschner JC. Radiation and risk—a hard look at the data. Los Alamos Science 1995;23:116-23.
3. Flakus FN. Detecting and measuring ionizing radiation—a short history. IAEA Bulletin 1981;23:31-6.
4. Case Western Reserve University. Dosimeter: Victoreen condenser R-Meter, 1928. Available from: https://artsci.case.edu/dittrick/online-exhibits/explore-the-artifacts/dosimeter-victoreen-condenser-r-meter-1928/. Accessed 1 Mar 2020.
5. Victoreen Model 570 Condenser r-Meter instruction manual.