COMPARISON OF CALIBRATION FACTORS OF THE RADIATION SURVEY METERS

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ABSTRACT.

Reltech Lab Sdn Bhd has observed the calibration factors that influence their users when selecting survey meters. The purpose of calibration is to ensure the survey meter are working properly under a controlled set of standard conditions. There are various types of survey meter are available for certain groups, which are Medical, Non-Destructive Testing (NDT), Industrial Application, Law Enforcement, Research and Education Institute. The categories are organised based on the need and preference for their use. The data will be collected from 1st January 2021 to 31st December 2021.The data come from the receiving of the survey meter to the laboratory and sorted by the survey meter model. The calibration was done to ensure the linearity of the survey meter scale and the response to the reference radiation energy. For linearity, the unit calibrated use Cs-137 as a reference to 30%, 50% and 80% of the selectable range or every decade of the logarithmic scale for auto ranging model. The calibration method done by the laboratory using the standard method as published in IAEA Safety Report Series No.60 and Reference Radiation using the ISO Standard 4037-1. The comparison of the calibration factor using five model of survey meter that popular in the Malaysia market which are Monitor 4 (M4), RAD100, Inspector, ND 2000 and 450P. The purpose of this comparison has been conducted to help the new user to select which are the best model of the survey meter to optimize the investment made in this major instrument for Radiation Safety.

ABSTRAK

Reltech Lab Sdn Bhd telah memerhatikan faktor penentukuran yang mempengaruhi pengguna mereka apabila memilih meter tinjauan. Tujuan penentukuran adalah untuk memastikan meter tinjauan berfungsi dengan baik di bawah satu set keadaan standard yang terkawal. Terdapat pelbagai jenis meter tinjauan disediakan untuk kumpulan tertentu, iaitu Ujian Perubatan, Tidak Merosakkan (NDT), Aplikasi Perindustrian, Penguatkuasaan Undang-undang, Institut Penyelidikan dan Pendidikan. Kategori disusun berdasarkan keperluan dan keutamaan untuk kegunaannya. Data akan dikumpul dari 1 Januari 2021 hingga 31 Disember 2021.Data ini datang daripada penerimaan meter ukur ke makmal dan disusun mengikut model meter tinjauan. Penentukuran dilakukan untuk memastikan lineariti skala meter tinjauan dan tindak balas terhadap tenaga radiasi rujukan. Untuk lineariti, unit yang ditentukur menggunakan Cs-137 sebagai rujukan kepada 30%, 50% dan 80% daripada julat yang boleh dipilih atau setiap dekad skala logaritma untuk model auto pelbagai. Kaedah penentukuran yang dilakukan oleh makmal menggunakan kaedah standard seperti yang diterbitkan dalam Laporan Keselamatan IAEA Siri No.60 dan Sinaran Rujukan menggunakan Standard ISO 4037-1. Perbandingan faktor penentukuran menggunakan lima model meter ukur yang popular di pasaran Malaysia iaitu Monitor 4 (M4), RAD100, Inspektor, ND 2000 dan 450P. Tujuan perbandingan ini telah dijalankan untuk membantu pengguna baru untuk memilih yang merupakan *model terbaik meter tinjauan untuk mengoptimumkan pelaburan yang dibuat dalam instrumen utama ini untuk Keselamatan Radiasi.*

Keywords: survey meters, calibration factors, radiation safety

INTRODUCTION

In 2018, Reltech Lab Sdn Bhd opened a new calibration facility in Bandar Baru Bangi, Selangor. The laboratory is open with a capacity of 2 bunkers for the calibration of the photon (gamma and x-ray) measuring survey meter. The calibration is required by law and recommended to be done at least annually by the IAEA [1,2]. The main aim of the calibration is to ensure that an instrument is working properly and is suitable for its intended purpose of use. The calibration is done under a controlled set of standard conditions, the indication of an instrument is a function of the value measured. The reported calibration factor is given to correct the instrument reading to the actual reading of radiation exposure, or equivalent dose. Based on the record of calibration requests by the customer, various survey meters have been sent to the laboratory for calibration. These instruments are from various industries, which can easily be categorized into three main group; Medical, Non-Destructive Testing (NDT) and Industrial application. These three categories are divided based on the needs and preferences of their respective applications. While the law enforcement, research, and education institute will have their own requirements, they usually use the same model as the industrial model instrument.

Calibration laboratory is a unique place to observe, handle, and collect data for various models of instruments for various industries used by the radiation worker and protection officer. Based on our observations in handling and calibrating the survey meter, we can record data and give advice and recommendations on the selection of the survey meter. As such, the main objective of this exercise is to process the data of the received survey meter, its calibration data, and make a comparison of the calibration factor between the five models of survey meters popular in the Malaysian market. Hopefully the information shared in this analysis will help the future user select a suitable survey meter and provide a few ideas for the survey meter designer and developer in Malaysia.

MODEL OF SURVEY METER

Throughout the laboratory's five years of operation, various types of surveys have been calibrated. The large number of survey meter models due to the many different models is designed to accommodate the various needs of the different sectors using this kind of instrument. Some of the features include different types of display and secondary indication, different types and purposes of detectors, battery or rechargeable power sources and different physical and survey meter features to satisfy the needs of different industries. Some survey meters have a scalar counter, dose recorder, dose and dose rate alarms, various levels of ingress protection, and wireless or computer connectivity as their additional feature.

The difference in survey meter features and industry needs causes many manufacturers and industrial suppliers to create and sell many different models of survey meter. Some models of survey meter may have the same feature, function, and detector response, but the survey meter designer may have to choose the popular feature and the common detector so their produced survey meter will be marketable and attractive to the user.

Figure 1 shows various models of survey meters calibrated in the laboratory. The upper row of survey meters is famous for the industries that use the x-ray machine in their activities. The survey meter has a low range, and the design is mostly based on the Geiger-Muller (GM) tube detector. These survey meters also have the simple function of only giving the dose rate for a survey meter reading. The second row of instruments in Figure 1 are the survey meters with additional features for different industries. The additional functions include a scalar and integrated counter, water and dust ingress protection, connectivity to the computer, and an ambient dose filter.

The survey meter in the lowest row is in the shape of a probe and has an external probe connector for the survey meter. The probe survey meter has advantages as the user can point to the direction or surface of the radiation while still monitoring the radiation level, and it has a larger selection of detectors than the built-in detector. The various probes for survey meters include the scintillation detector, the high-dose GM detector, and the alpha-beta or alpha-only detector. The user usually selects their survey meter based on some of these features and their budget to maximize their investment in radiation protection.

Figure 1. Various model of survey meter.

METHOD

Model of received survey meter

For the purposes of this data analysis, the data from receiving requests over a one-year period were processed to identify the various model survey meters received by the laboratory. Because it is the most recently completed annual calibration cycle, the period from 1st January to 30th December 2021 was chosen. The receiving unit's data is sorted by instrument model. Some models will be grouped together for the analysis based on their design and feature similarities. The reason for this decision is that there are many instruments that are similar in design and features but have a different instrument model and are sold by many different cooperatives or through various minor upgrades or generations of the same design but with different model identification. The five-survey meter model most send to the laboratory will be compared using calibration data.

Calibration of survey meter

The calibration is done to ensure the linearity of the instrument scale and the response of the instrument to reference radiation energy. The reference energies available to the laboratory are 48 keV, 83 keV, 118 keV, 164 keV, 208 keV, and 662 keV. The energy is produced following ISO Standard 4037–1[3] by using an x-ray machine at 60–250 kV with different fillers and a Cesium-137 calibrated source. For linearity, the unit will be calibrated to CS-137 reference at 30%, 50%, and 80% of the selectable range, or every decade of the logarithmic scale for an auto-ranging model. The unit is only usable if it is linear at least twice on its logarithmic scale. The laboratory will use the response of instruments to different energies as the basis for comparison in this exercise. The energy response of a survey meter is typically linked to the instrument's design, detector selection and design, and filter. It may not be surprising if there is a similarity of response between different models of survey meters. The calibration method done by the laboratory is the standard method as published in IAEA Safety Report Series No. 16 and X-ray and gamma Reference radiation follows ISO Standard 4037-1.

RESULT AND DISCUSSION

Number and model of received survey meter

More than 600 units of survey meters were recorded for 2021 by Reltech Lab Sdn Bhd. The figure may not accurately reflect the number of units in the Malaysian market, as Agensi Nuklear Malaysia's Secondary Standard Dosimetry Laboratory and two other laboratories offer similar services. The number of survey meters calibrated is affected by the pandemic state in 2020-2022 as not all survey meters were in operation during the strict Movement Control Order (MCO) and the ease of regulation by AELB during the period. However, the data still show the same pattern of survey meter sales and use in Malaysia as in the last 2 years.

As seen in Figure 2, the highest model of survey meter sent to the laboratory is Monitor 4 from SE International. This model has been on the market for a long time and has several variants. As the model is a very basic unit with an analogue display, the price of the unit is very attractive compared to another model. The second-highest model is in the RAD100 family. This family of survey meters is produced by several cooperatives under many different names. However, the unit's user interface, control, and construction are the same. Its ease of use, clear digital LCD, secondary indication, and solid construction have made it a very desirable unit to be sold in the market.

Next model is Inspector and Ranger family of survey meter which has the familiarity of the RAD100 model but using build-in pancake detector. The pancake detector makes the unit more multipurpose survey meter compare to the GM tube detector but make the unit cost more. These three models are the main model used by the Industrial user due to their ease of use and cheaper price compare to another model.

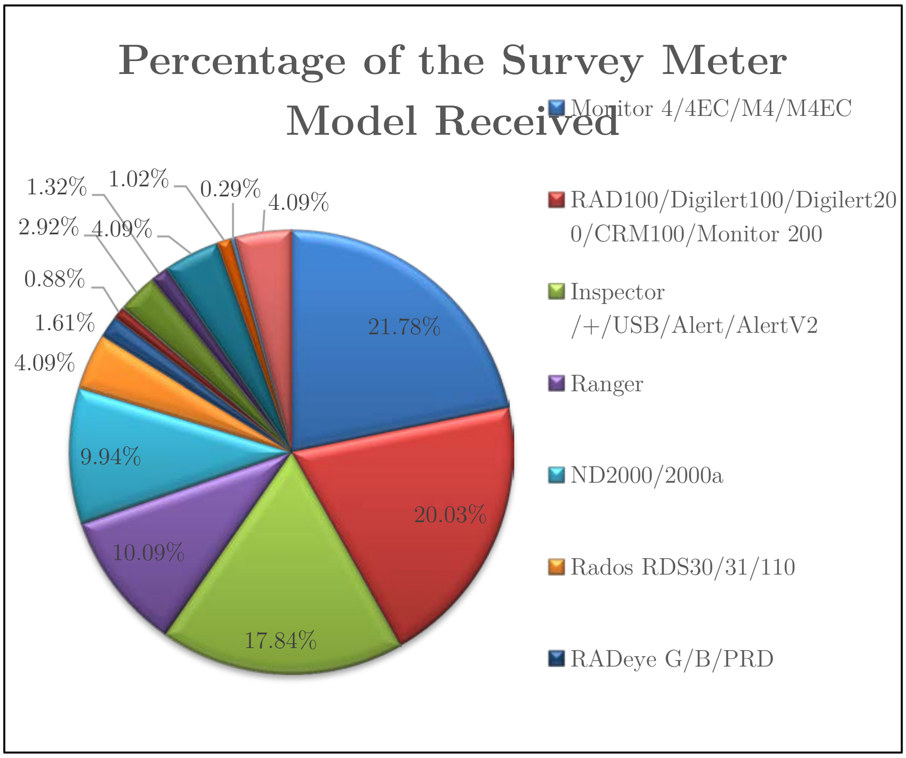

Figure 2. The percentage of the survey meter model received by Reltech Lab during 2021 annual period.

The following model is the ND2000 family of survey meter. This model is a very common model used by the field radiographers. The unit is a very robust and easily maintain on the field due to solid construction and gasket surrounding the unit display and open part. Last unit selected for the comparison is fluke 450P family of survey meter. The model is popular uses by medical industry due to its stable reading and ability to freeze the maximum reading of the survey meter. This model is the only unit used by the Medical industry as well as the only ionization chamber detector survey meter. Other model of survey meter received by the laboratory in the period can be seen in Figure 2.

Comparison of Survey Meter

Calibration factor. Calibration factor is defined as the conventional true value of the quantity the instrument is intended to measure (reference value, h) divided by the indicated value (measured value, m) given by the instrument. The value is mainly used to correct the reading of the survey meter to the actual value of the exposed radiation.

$$Calibration\ factor, CF = \frac{Reference\ value, h}{Measured\ value, m} \quad \text{Eq. 1}$$

The perfectly accurate instrument should have a calibration factor of 1. For most instruments, the survey meter reading is calibrated to the radiation field of Caesium 137, Cs-137 which produces a gamma ray with a mean energy of 662keV. As most detectors have different responses at different levels of energy, the calibration factor also changes to reflect the response of the detector. Only the ionisation chamber detector has almost the same response to a large range of energy; however, its reading is affected by changes in environmental temperature and pressure.

For the data analysis, the 10-unit survey meters data for each of the five models is extracted from the calibration record. The laboratory required to hold these data for 6-year record as per SAMM requirement and the data is strictly confidential. Due to data confidentiality, the laboratory will only use the calibration data and release the average calibration factor of the units for this exercise upon the notification and agreed the laboratory customer. The average for the calibration factor is shown in Table 1. The unit is calibrated to six energy qualities, which are produced using Cesium-137 and an x-ray machine.

Table 1. The average calibration factor for 5 model of survey meter

Energy Quality	**Mean Energy, keV**	**Average calibration factor**				
		Monitor 4	**RAD100**	**Inspector**	**ND2000**	**450P**
60kV	47	0.1250	0.1240	0.1880	1.0300	1.6420
100kV	84	0.1040	0.1070	0.2540	0.5925	1.4290
150kV	121	0.2090	0.2070	0.4170	0.5750	1.3900
200kV	171	0.3990	0.3900	0.6730	0.5175	1.3820
250kV	218	0.5760	0.5820	0.8680	0.6475	1.3870
Caesium-137	662	0.9139	0.9374	1.0549	0.9917	1.5396

Comparison of Survey Meter response.

The survey meter response to different energy shows the characteristic of survey meter for use in different kind of energy. The response of the survey meter can be calculated by inversing the value of the calibration factor [2]., which is the quotient is the indicated value, m and the conventional value of the radiation measured, h.

$$Response, R = \frac{1}{Calibration\ factor, CF} = \frac{Measured\ value, m}{Reference\ value, h}, \quad \text{Eq. 2}$$

The response of the survey can indicate the type of detector use and the design of the survey meter. Depending on the survey meter application, the survey meter can be selected based on the response to low energy radiation (x-ray, low energy gamma source), high energy radiation (high energy gamma source, particle accelerator), or a flat response to a large spectrum of energy. To achieve a flat energy response, the survey meter designer would use an ionization chamber or an energy compensated GM detector, or include an energy filter in the instrument's construction or design. Using the data in Table 1, the energy response for the five models is calculated, and the data is plotted in the graph as shown in Figure 3.

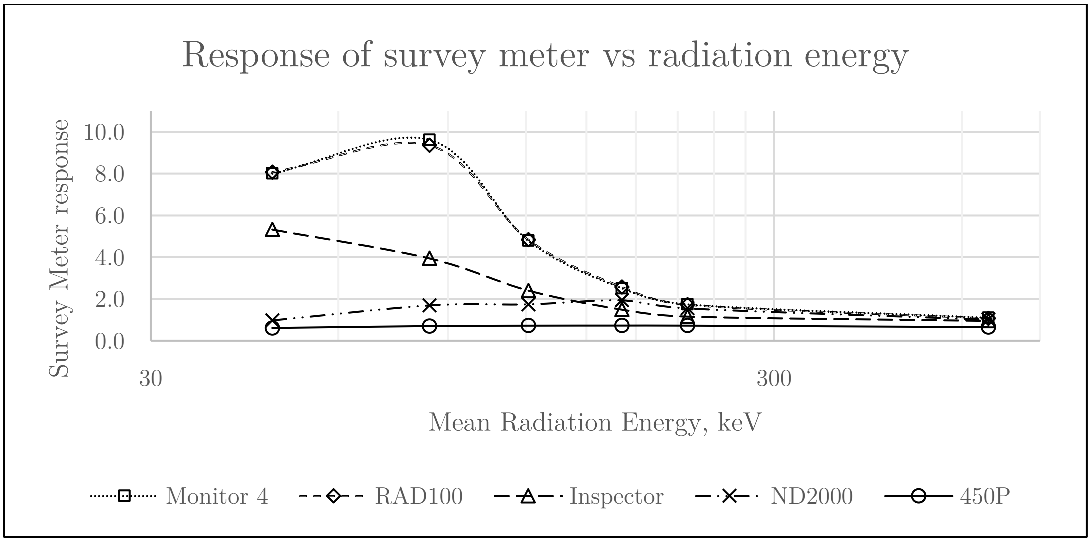

Figure 3. Response of Survey Meter against Radiation Energy.

Based on the Figure 3, we can say that the monitor 4 and RAD100 survey meter have the same or similar energy response, where their energy response curves are almost overlapping each other. This is due to both units using the same detector and filter construction, as both survey meter use the LND712 detector [4] when each instrument is opened and the detector model is inspected. Based on the calibration record and our observations, the LND712 is the most used detector in the Malaysian survey meter market, as it is very compact and relatively cheap compared to other LND detector offerings. This also makes the repair of both survey meter easy as the detector is interchangeable. All GM tube-based survey meter have a high response for low energy x-ray. The addition of an energy filter to the detector or survey meter can reduce the response to low radiation energy and give the survey meter a flatter overall energy response. While this will produce a better survey meter response, the additional part of its construction will increase the cost of the unit and make it less attractive to many budget sensitive users. This is evident in the ND2000 survey meter response, which is constructed with a compact GM tube and an energy filter surrounding the detector body and has a flatter energy curve than the other three models.

The Inspector features a lower response to low energy radiation than Monitor 4 and RAD100 survey. The difference in energy response is due to the Inspector use a different detector than these two models. The inspector uses a pancake-shaped detector, which has a large mica window in its construction. The mica window is a thin layer of mica that encloses the open part of the GM tube. The purpose of the mica window is to allow the detection of alpha and beta particles, which are blocked by the metal body of the GM tube. While this allows the survey meter using this detector to detect alpha, beta, gamma, and x-ray radiation, the detector cannot distinguish between each type of radiation. This makes Inspector almost a “universal” survey meter. While the pancake GM detector makes Inspector a good detector for almost all radiation sources, the large mica window also makes the survey meter easy to break due to the fact that the mica window can burst due to a change in pressure and the punctures on the mica window. The pancake GM price is also much higher than the GM tube price, making the Inspector price higher than the RAD100 survey meter which has the same survey meter function and features.

The 450P family survey meter has the flattest response due it the only survey meter using an ionization chamber in the group. This response makes the survey meter reading linear across a large range of radiation energy. The ion chamber and the complicated circuit designed to support the detector make the unit more expensive. The ionization chamber itself needs to be pressurized at 8 atm for it to function [6]. While the features make it better, the pressurized chamber makes it harder to transport and requires the gas pressure to be checked so the unit may work within the specifications provided by the manufacturer. As a result, the survey meter only suitable for indoor use or in controlled environments. As a result, only hospitals, healthcare facilities, and medical laboratories use this model. The model also has a higher selling price and requires access to manufacturer or seller support, repair, and maintenance to maintain the gas pressure in the ionization chamber, making it less attractive to most industries outside of healthcare.

CONCLUSION

Most users would select the cheaper survey meter for their use as the instrument is quite expensive compared to other protection instruments. However, there are numerous factors to consider when selecting a survey meter for personal use. The survey meter should be able to read the radiation reading accurately based on the radiation it needs to detect. The energy response of the survey meter should inform the user of the suitability of the survey meter to the type of radiation and its response that it needs to measure. The energy response also highlights a few insights from the survey meter construction and shows how much it costs to acquire and maintain a working survey meter. The energy response of the survey meter and other survey meter features may affect the use and application of the unit for selecting a suitable level of radiation protection. Hopefully, this comparison will help the future user select the best model to optimize their investment in this major instrument in radiation safety.

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