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Testing of a new directional gamma survey meter

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Defence R&D Canada – Ottawa

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Abstract

In an effort to improve upon basic gamma radiation survey meters, DRDC Ottawa and Bubble Technology Industries developed a gamma radiation survey meter that adds a directional element to facilitate source localization. This Directional Survey Meter (which is also being called the Rad Compass) is based on the directional sensor of the previously-developed Directional Gamma Ray Probe, which was also co-developed by DRDC Ottawa and BTI. DRDC Ottawa carried out detailed testing of the prototype device based on a subset of the ANSI 42.33 gamma survey meter testing specifications. This report describes the testing carried out on the prototype device by DRDC Ottawa.

Résumé

Dans un effort d'améliorer les gammamètres élémentaires, RDDC Ottawa et Bubble Technology Industries (BTI) a développé un gammamètre qui ajoute aussi de capacité directionnel pour faciliter la localisation des sources radioactive. Cette Radiamètre Directionnel (qui est aussi appelé la Rad Compass) est basé sur le détecteur directionnel de rayonnement gamma, le DGRP, qui a également été co-développé précédemment par RDDC Ottawa et BTI. RDDC Ottawa a effectué des tests détaillés de l'instrument prototype basé sur un sous-ensemble des normes ANSI 42,33 pour tester des gammamètres. Ce rapport décrit les tests effectués sur le prototype par RDDC Ottawa.

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Executive summary

Testing of a new directional gamma survey meter:

Carey L. Larsson, Trevor Jones; DRDC Ottawa TM 2013-086; Defence R&D Canada – Ottawa; October 2012.

Introduction or background: In an effort to improve upon basic gamma radiation survey meters, DRDC Ottawa and Bubble Technology Industries developed a gamma radiation survey meter that adds a directional element to facilitate source localization. This Directional Survey Meter (which is also being called the Rad Compass) is based on the directional sensor of the previously-developed Directional Gamma Ray Probe, which was also co-developed by DRDC Ottawa and BTI. DRDC Ottawa carried out detailed testing of the prototype device based on ANSI 42.33 gamma survey meter testing specifications. This document describes the results of those tests.

Results: Tests of the Directional Survey Meter were very promising, highlighting only a few areas for further improvement. The general tests of the device suggested a few items that should be included in the user manual for the device for easy reference by end users. The readability of the LCD display in different lighting conditions is not ideal given the lack of a backlight option. In addition, the battery life of the detector is rather short when the device is in a low radiation field due to the power draw of the LEDs. Radiological tests showed accuracy of ±30% within the dose rate range of approximately 10 μSv/h up to 1 mSv/h for ^{137}Cs, with a much smaller range for ^{60}Co. The response time and angular response of the instrument were good, as was the directional indication.

Significance: The Directional Survey Meter is a very promising new gamma survey meter that provides the added directional capability not available in comparable handheld detectors. A preliminary market survey, performed by BTI, indicates that there are no existing commercially-available devices that have comparable capabilities. Target markets for the DSM include military and law enforcement CBRN responders, nuclear regulatory agencies, and decommissioning applications.

Future plans: Recommendations from these tests will be provided to BTI for consideration. Implementation of any necessary engineering improvements to the design will follow. Additional testing and/or certifications may be required in order to facilitate sales in certain countries. BTI will then undertake an aggressive strategy to rapidly commercialize the device. DRDC Ottawa also has plans to use the DSM in several research and development projects related to military priorities for radiation detection.

Sommaire

Testing of a new directional gamma survey meter:

Carey L. Larsson, Trevor Jones ; DRDC Ottawa TM 2013-086 ; R & D pour la défense Canada – Ottawa; octobre 2012.

Introduction ou contexte : Dans un effort d'améliorer les gammamètres élémentaires, RDDC Ottawa et Bubble Technology Industries (BTI) a développé un gammamètre qui ajoute aussi de capacité directionnel pour faciliter la localisation des sources radioactive. Cette Radiamètre Directionnel (qui est aussi appelé la Rad Compass) est basé sur le détecteur directionnel de rayonnement gamma, le DGRP, qui a également été co-développé précédemment par RDDC Ottawa et BTI. RDDC Ottawa a effectué des tests détaillés de l'instrument prototype basé sur un sous-ensemble des normes ANSI 42,33 pour tester des gammamètres. Ce rapport décrit les tests effectués sur le prototype par RDDC Ottawa.

Résultats : Tests de la Radiamètre directionnel ont été très prometteurs, soulignant que quelques articles nécessitant des améliorations supplémentaires. Les tests généraux du détecteur suggéré quelques éléments qui devraient être inclus dans le manuel d'utilisation de l'appareil pour faciliter la consultation par les utilisateurs finaux. La lisibilité de l'écran LCD dans différentes conditions d'éclairage n'est pas idéal étant donné l'absence d'une option de rétro-éclairage. En outre, la durée de vie des piles du détecteur est plutôt courte lorsque l'appareil détecte rayonnement dû à la consommation électrique des LED. Des examens radiologiques ont montré une précision de ± 30% dans l'intervalle de débit de dose d'environ 10 µSv / h à 1 mSv / h pour le ^{137}Cs, avec une gamme beaucoup plus faible pour le ^{60}Co. Le temps de réponse et la réponse angulaire de l'instrument étaient bien, tout comme l'indication directionnelle.

Importance : Le Radiamètre directionnel est un compteur gamma très prometteuse qui offre la capacité supplémentaire de direction pas disponible dans les détecteurs portables comparables. Une étude de marché préliminaire, réalisée par BTI, indique qu'il n'y a pas déjà disponibles dans le commerce des dispositifs qui ont des capacités comparables. Les marchés cibles pour le Radiamètre directionnel comprennent militaires et policières d'application intervenants CBRN, les organismes de réglementation nucléaire et des applications de déclassement.

Perspectives : Les recommandations de ces tests seront fournis au BTI pour examen. La mise en œuvre de toutes les améliorations techniques nécessaires au design suivront. Tests supplémentaires et / ou certifications peuvent être nécessaires en vue de faciliter les ventes dans certains pays. BTI fera ensuite une stratégie agressive de commercialiser rapidement l'instrument. RDDC Ottawa a aussi l'intention d'utiliser le Radiamètre directionnel dans plusieurs projets de développement liés aux priorités militaires pour la détection des radiations.

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Acknowledgements

The authors would like to thank Bubble Technology Industries for their efforts in the rapid development of this compact, easy-to-use, and fully integrated directional survey meter.

1 Introduction

DRDC Ottawa and Bubble Technology Industries (BTI) collaborated in the development of two novel portable directional radiation spectrometers, the Directional Gamma Ray Probe (DGRP) and the Sensitive Directional Gamma Ray Probe (SDGRP). These detectors have demonstrated a significant advantage over conventional (non-directional) detectors via the inclusion of a directional indicator in addition to the standard dose rate and spectroscopic capability of conventional low-resolution gamma spectrometers. However, while the spectroscopic capability included in these devices offers useful isotope identification information, it also drives cost and weight of the units up significantly. In addition, many responder communities are simply not able to effectively use spectroscopic detectors due to the high knowledge/training burden required to interpret spectra. This fact is evidenced by the detector deployment strategy used during the V2010 and G8/G20 deployments, wherein law enforcement officers used basic gamma survey meters to detect the presence of radiation and then called specialized teams to carry out more detailed spectroscopic analysis. Even these specialized teams reached back to scientific support for interpretation of the spectra.

In an effort to improve upon basic gamma survey meters, DRDC Ottawa and BTI proposed adding a directional element to facilitate source localization. Tests of the DGRP and SDGRP showed that the directional indication provided by these detectors decreased source localization time by a factor of 2 to 10 in various circumstances. By removing the more sophisticated spectroscopic component of the DGRPs, and simplifying and integrating the design, a low-cost hand-held directional survey meter has been developed. This Directional Survey Meter (whose commercial name will be the Rad Compass) is based on the directional sensor of the previously-developed Directional Gamma Ray Probe. DRDC Ottawa has carried out detailed testing of the prototype device based on a subset of the ANSI 42.33 gamma survey meter testing specifications. This report describes the testing carried out on the prototype device by DRDC Ottawa

2 Scope

Tests performed on the Directional Survey Meter, shown in Figure 1, were based on a subset of the IEEE American National Standards Institute (ANSI) American National Standard for Portable Radiation Detection Instrumentation for Homeland Security, ANSI 42.33-2006 [1]. The tests selected from the standard included a series of general tests and radiological tests.

The general tests consisted of a documentation check, details on the manufacturer, model and serial number of the instrument, information on the type of radiation detectors used, the overall mass, the presence of reference point markings and the exposure rate range of the device, an assessment of the device functionality in terms of readability of the display and operation of the detector, and an assessment of the batteries used and their lifetime during operation.

The radiological tests consisted of an assessment of the detectors accuracy over the effective range of exposure rates, the photon energy response, the response time, the angular response, the over-range response, and a test of the direction indicator. The last item was not included in the ANSI N42.33 standard since most portable radiation detectors do not have a directional indicator. Instead, DRDC Ottawa added this test specifically for the DSM assessment.

Certain limitations of the instrument and documentation provided led to the need for some deviation from the original test plan. The deviations are described in the description of the actual tests performed.

Figure 1: The Directional Survey Meter or Rad Compass prototype.

3 General tests

3.1 Documentation check

ANSI N42.33 requires that manufacturers provide instructions to verify proper operation of the instrument. For the DSM, the manufacturer provided a user guide [2] that contains an operational summary of the device. While the documentation was very brief, it did outline the necessary operational guidelines.

3.2 Manufacturer, Model and Serial Number

This test requires that the following shall be recorded: manufacturer's name along with the model, serial number, and firmware number of the instrument and detector, if separate. The DSM that was tested did name the manufacturer, however given that it was a prototype device, the model, serial number, and firmware number were not listed.

3.3 Type of Radiation Detector

The testing criteria require that the type of radiation detector used in the device (e.g., NaI, CsI, GM) be identified and recorded. The user manual does not specify the type of detectors used in the device; however, BTI has prepared an information sheet on the device [3], which clearly specifies that the DSM utilizes an array of four Geiger Mueller tubes.

3.4 Exposure Rate Range

ANSI N42.33 requires that the instrument have an operating range from 0.01 μGy/h to at least 0.1 mGy/h. Reported technical specifications (from the BTI RAD COMPASS information sheet [3]) of the DSM claim a linear response up to 10 mSv/h. However, testing of the DSM exhibited a dose rate range of approximately 5.5 μSv/h up to 1 mSv/h, which does not meet the minimum dose rate requirement of 0.01 μGy/h and does not reach the upper limit quoted in the devices technical specifications (although it does exceed the ANSI 42.33 requirement). This testing will be elaborated on further in the radiation testing section.

3.5 Functionality Test

ANSI N42.33 has a list of functionality tests to be performed on gamma survey meters, including checks that the instrument has:

a. A display that is easily readable under different lighting conditions

b. Controls that are user-friendly for routine operation

c. A menu structure that is simple and easy to be followed intuitively

d. The capability of operation if the user is wearing gloves

e. A display that provides the user with an instantly recognizable indication of the fact that the magnitude of radiation present has increased and/or exceeded the alarm set point

In response to the first point, the display of the DSM utilizes an LCD which currently has no backlight capabilities, therefore the display is not visible in the dark. When looking from the top or bottom of the LCD the viewing angle is limited to approximately 30º. When looking from the sides the viewing angle is mechanically limited to about 60º.

For the next three items, the DSM controls were simple to use and understand, the device does not utilize a menu structure, and the control buttons are large enough to easily allow operation using gloves.

In response to the last point, the DSM does provide an indication of a high, medium, and low radiation field, however, this is displayed on the LCD display in small font and thus is very easy to overlook. Nonetheless, the LEDs which indicate directionality will also give the user an immediate indication that dose rate levels are increasing based on their illumination pattern.

3.6 Mass

ANSI 42.33 requires that instruments shall be less than 3.0 kg (6.6 lb). The DSM weight with battery is 0.95 kg.

3.7 Batteries and Battery Lifetime

The requirements state that batteries used in the instrument shall be widely available, shall not be unique to the instrument, and shall be replaceable in the field without the use of special tools. In addition, the batteries shall be capable of powering the instrument for 16 h in a non-alarm state, and the instrument shall have a low battery indicator. To perform this test, the instrument shall be exposed to an exposure rate of 1 μGy/h for 16 h. The low battery indicator shall not come on during the 16 h.

The DSM uses a standard 9 VDC battery, readily available from multiple sources. The battery is easily changed in the field using a coin or other small straight edged instrument to unscrew the bottom battery cap of the unit.

Unfortunately, the battery lifetime is non-compliant with the desired 16 h given the following measurements:

- At background levels the unit lasted ~ 17 hrs
- At high dose rates where only one LED is active ~ 5 hrs
- At low dose rates where more than one LED is active < 1.5 hrs

4 Radiological Tests

4.1 Accuracy

The ANSI 42.33 test for accuracy states that the relative error of indication of the instrument shall not exceed ±30% over the entire effective range of exposure rates. To test this, the instrument was to be exposed to a ^{137}Cs source at dose rates of 1 μGy/h, 50 μGy/h, and 80% of the manufacturer's stated maximum response, with the reference point of the instrument orientated with respect to the radiation source. However, since the operational range of the instrument was not known at the time of testing, the dose rates used for this testing were modified somewhat.

The DSM utilizes two measurement modes for dose rate: Short and Long integration time. The short integration time is approximately 3 seconds, whereas the Long integration time is 15 seconds. The longer integration time is intended to provide better reading stability.

The DSM was exposed to ^{137}Cs from dose rates of approximately 4 to 2500 μSv/h using both the short and long integration times. Figure 2 shows the measured versus actual rate using the short integration time of the DSM, while Figure 3 shows the same but for the long integration time. The red lines represent the 30% upper and lower limits. The measured dose rate was determined from readout of the LCD on the DSM. The fluctuation in dose rate was observed for approximately 30 seconds and the higher and lower dose rate boundaries were recorded for each applied dose rate point. An average of the higher and lower dose rates was then calculated. Table 1 summarizes the data displayed in Figure 2 and Figure 3. The fluctuation in readings is increasingly pronounced at lower dose rates, although this is much improved in the long integration mode.

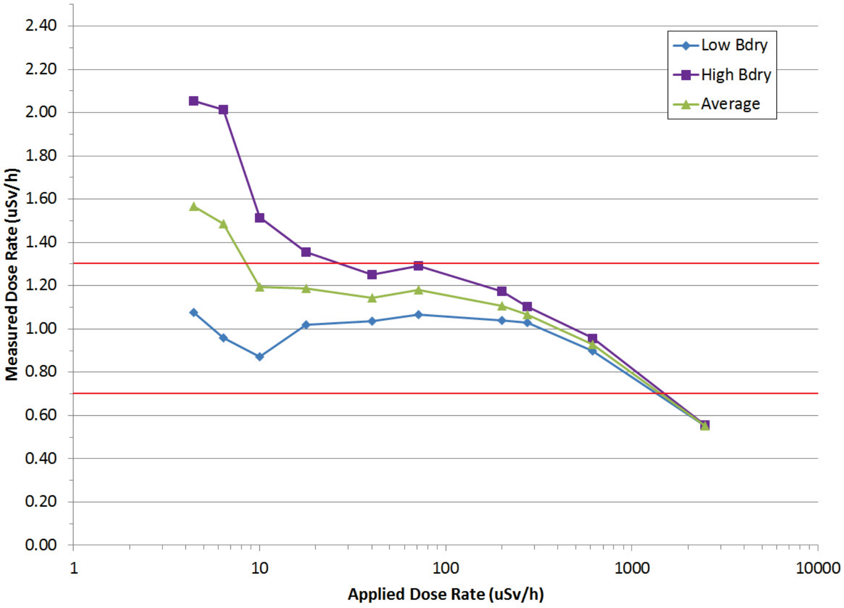

Figure 2: DSM short integration time response to ^{137}Cs exposures.

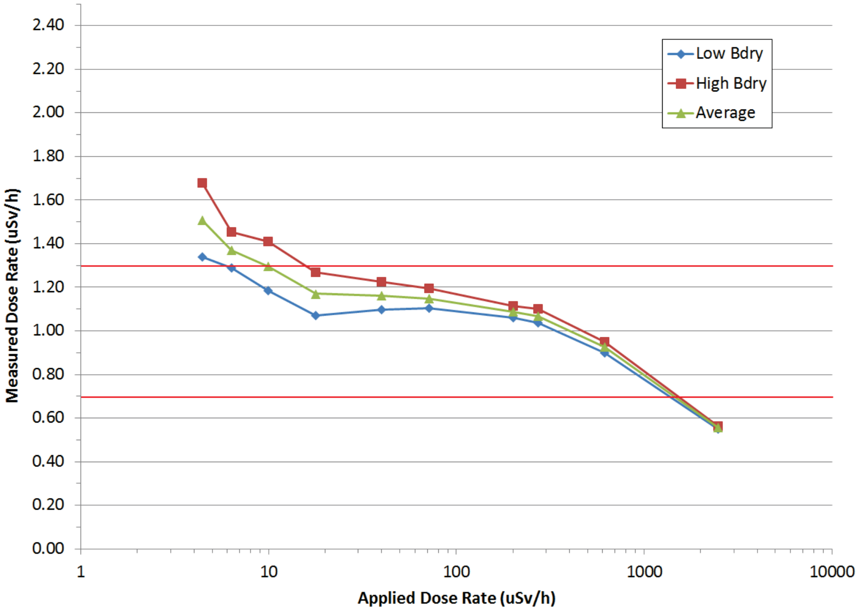

Figure 3: DSM long integration time response to ^{137}Cs exposures.

Table 1: Summary of DSM dose rate response to ^{137}Cs exposures for both short and long integration times.

Applied Dose Rate (µSv/h)	Mean Ratio to Applied Short Sample Time	Mean Ratio to Applied Long Sample Time
4.41	1.57	1.51
6.36	1.49	1.37
9.96	1.19	1.30
17.74	1.19	1.17
40.00	1.14	1.16
71.17	1.18	1.15
200.09	1.11	1.09
272.77	1.07	1.07
616.22	0.93	0.93
2474.83	0.55	0.56

4.2 Photon energy response

The instrument testing also should include a comparison of response to other photon radiation with energies between 60 keV and 1.33 MeV. The response shall be within ±50% of the applied exposure rate normalized to ^{137}Cs. Given the time limits on testing, only a comparison to ^{60}Co was performed.

The DSM was also exposed to ^{60}Co from dose rates of approximately 4 to 3500 µSv/h, using both the short and long integration times. Figure 4 shows the measured versus actual rate using the short integration time of the DSM, while Figure 5 shows the same but for the long integration time. The red lines represent the 30% upper and lower limits. The measured dose rate was determined from readout of the LCD on the DSM. The fluctuation in dose rate was observed for approximately 30 seconds and the higher and lower dose rate boundaries were recorded for each applied dose rate point. An average of the higher and lower dose rates was then calculated. Table 2 summarizes the data displayed in Figure 4 and Figure 5.

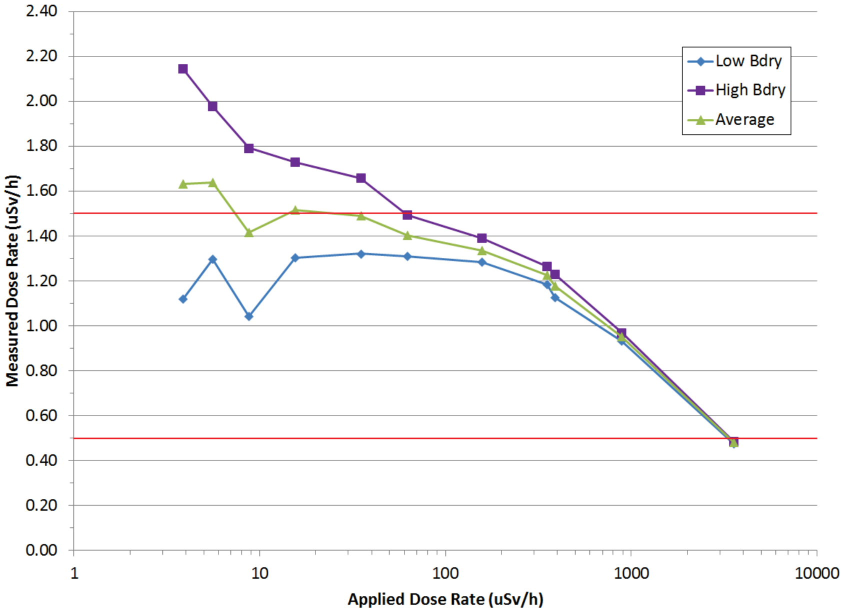

Figure 4: DSM short integration time response to ^{60}Co exposures.

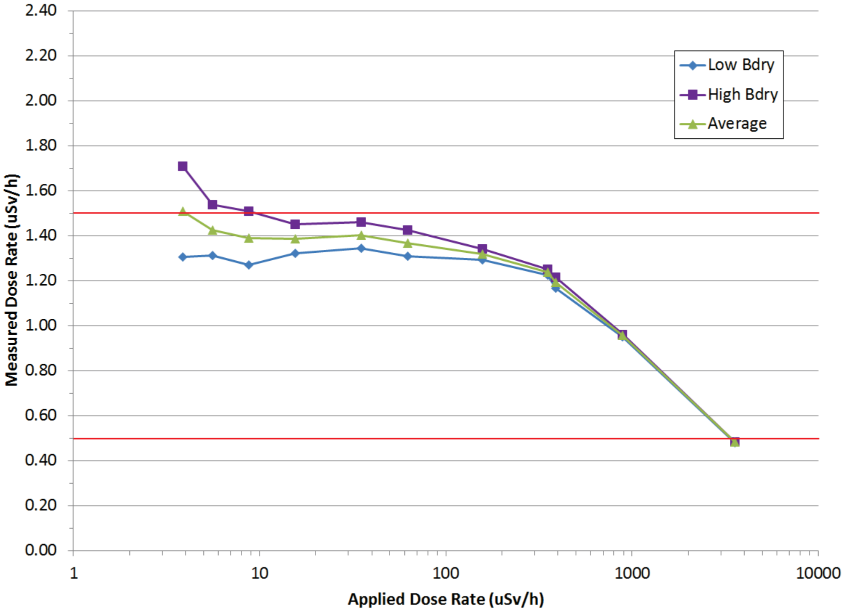

Figure 5: DSM long integration time response to ^{60}Co exposures.

Table 2: Summary of DSM dose rate response to ^{60}Co exposures for both short and long integration times.

Applied Dose Rate (µSv/h)	Mean Ratio to Applied Short Sample Time	Mean Ratio to Applied Long Sample Time
3.85	1.63	1.51
5.56	1.64	1.42
8.70	1.42	1.39
15.50	1.52	1.39
34.94	1.49	1.40
62.18	1.40	1.37
156.56	1.34	1.32
352.33	1.23	1.24
390.00	1.18	1.19
890.00	0.95	0.96
3560.00	0.49	0.48

In addition to the above tests, the instrument was exposed to a range of given dose rates and a set of 10 readings was taken every 10 seconds apart and recorded. The lower dose limit as defined by the ANSI standard (0.1 µSv/h) could not be used due to the lower working boundary of the DSM. Instead, the lower dose limit used for this test was 10 µSv/h. Table 3 provides a summary of these results, showing that the overall average dose rate is not affected by the sample time. However, the standard deviation in the readings is a factor of approximately 2-3 less for the long integration time mode.

Table 3: Summary of dose rate variance for ^{137}Cs and ^{60}Co exposures.

Isotope	Applied Dose Rate (µSv/h)	Short Integration		Long Integration	
		Ratio of Average to Applied Dose Rate (%)	Standard Deviation of 10 Readings (%)	Ratio of Average to Applied Dose Rate (%)	Standard Deviation of 10 Readings (%)
^{137}Cs	10	34.0	12.4	26.0	6.3
^{137}Cs	50	17.1	4.7	16.3	2.1
^{137}Cs	500	-4.3	1.4	-2.3	0.4
^{60}Co	10	48.3	8.7	42.2	3.5
^{60}Co	50	37.6	4.2	37.4	1.0
^{60}Co	500	11.7	1.6	12.4	0.8

4.3 Response time

To test the instrument response time, the instrument was subjected to an increase in exposure rate and the display was observed to assess whether it indicates the new exposure rate within five seconds of the change. The DSM response time to instant on/off source conditions appeared to be the same regardless of dose rate and isotope used (^{137}Cs or ^{60}Co, data not shown). In all cases, there was an immediate response to the increased dose rate, observable within 1 second. The time required for the displayed dose rate to reach 50% of the applied dose rate varied with the integration mode, as would be expected. In the short integration mode, the DSM measured dose rate reached 50% of the applied dose rate in approximately 2 to 3 seconds. In the long integration mode, the DSM measured dose rate reached 50% of the applied dose rate in approximately 7-8 seconds. This is as expected given that this mode integrates over 15 seconds to determine the displayed dose rate.

4.4 Angle of incidence

The instrument's response at angles of ±45° with respect to 0° incidence in the vertical orientation should agree to within ±30% of the response from 0° incidence. The DSM response was tested at three different angels of incidence for ^{137}Cs exposures at applied dose rates of 10, 50 and 500 μSv/h. Table 4 shows that the measured dose rate did not vary significantly with angle of incidence.

Table 4: Vertical angle of incidence response for ^{137}Cs exposures.

Angle of incidence (degrees)	Applied Dose Rate (μSv/h)	Measured dose rate (μSv/h)	Ratio measured to applied
0	10	12	1.20
0	50	58	1.16
0	500	485.5	0.97
+45	10	12.8	1.28
+45	50	52.7	1.05
+45	500	440	0.88
-45	10	12.5	1.25
-45	50	55.15	1.10
-45	500	487.5	0.975

4.5 Over-range response

To test the over-range response, the detector should be exposed to an exposure rate that is two times the maximum exposure rate specified by the manufacturer. In this situation, the indication of the instrument shall remain at the maximum of that range, and an overload indication shall be displayed for the duration of the exposure. For the DSM, as the unit received dose rates in excess of 600 μSv/h, the displayed dose rate began to decrease. At this point the LED response changed from a single LED being on, to several LEDs responding. When in a true over-response condition (i.e. > 2 mSv/h), the LEDs began to blink in a predetermined up/down pattern to indicate over-response. The instrument continued to display a dose rate.

4.6 Directionality response

To test the directionality response, the DSM was exposed to a variety of dose rates to determine the LED response indication to the direction of the radiation field. The instrument was oriented such that 0 degrees was pointed toward the source and the instrument was exposed to a range of 137Cs dose rates. A summary of the observations are given in Table 5.

Table 5: LED directionality response of the DSM to ^{137}Cs exposures.

Applied Dose Rate (µSv/h)	Short Sample Time LED Response	Long Sample Time LED Response
4.41	Random 1-6 LEDs, varied, mostly in the source direction	Mainly 3 LEDs, sometimes 4th on either side, in source direction
6.36	Random 1-6 LEDs, varied, mostly in the source direction	Mainly centre source direction LED but sometimes up to 4
9.96	Random 1-6 LEDs, varied, mostly in the source direction	Mainly centre source direction LED but sometimes up to 4
17.74	Random 1-6 LEDs, varied, mostly in the source direction	Mainly centre source direction LED but sometimes up to 3
40.00	Mainly centre LED in source direction but random centre 3	Centre LED source direction only
71.17	Mainly centre LED in source direction but random centre 3	Centre LED source direction only
200.09	Mainly centre LED in source direction but random centre 3	Centre LED source direction only
272.77	Mainly centre LED in source direction but random centre 3	Centre LED source direction only
616.22	Mainly centre LED in source direction but random centre 3	Mainly centre LED in source direction but random centre 3
2474.83	Mainly centre LED in source direction but random centre 3	Centre LED source direction only

5 Conclusions and recommendations

The DSM is a very promising new gamma survey meter that provides the added directional capability not available in comparable handheld gamma radiation detectors. The prototype device was tested against a subset of the ANSI N42.33 testing guidelines to assess its design and response.

The following points outline recommendations from the general tests of the device:

- The prototype device was not marked with the model, serial number or firmware number of the instrument. While firmware number is not entirely necessary, future devices should be marked in some way with the model and serial number for easy user reference, as well as with markings of the detector (GMT) reference points.
- The user manual should include basic information on the types of radiation detectors used in the device and the realistic exposure rate range.
- The existing LCD has very limited readability. A new type of LCD should be considered, with an increased viewing angle and backlight option. An alternate option would be to investigate the use of so-called e-paper displays such as those used in widely available e-readers, such as the Kobo or Kindle. Information on these displays can be found at http://www.pervasivedisplays.com/products/panels.
- While the detector does indicate when it is measuring high radiation fields, an audible alarm with at least 2 alarm levels might be considered for future models of the device.
- The battery lifetime was less than desired when the device was in a low radiation field. This is likely due to the power draw of the LEDs. Less power-intensive components should be considered.

The radiation tests of the DSM were largely successful, with only the operating range of the DSM falling slightly outside the ANSI standard requirements at the lower end. This seems to be due to large fluctuations in readings at low doses, particularly when in short integration mode. The DSM user manual (and other documentation) should quote an operating range of 5 µSv/h to 1 mSv/hr for ^{137}Cs. Also, improvements to the algorithm for determining dose rates below about 5 µSv/h should be considered to ensure a more consistent (i.e. less jumpy) estimation of dose rate is displayed.

No environmental testing was carried out on the DSM. Prior to widespread commercialization, the instrument should undergo temperature testing, including a temperature shock test and cold temperature start up test, and humidity testing as a minimum. Electrical, electromagnetic, and mechanical tests should also be considered since these are included in the ANSI N42.33 testing standard.

Data transmission via the USB connection should also be possible for future versions of the DSM.

References

[1] American National Standards Institute, National Committee on Radiation Instrumentation. American National Standard for Portable Radiation Detection Instrumentation for Homeland Security, Institute of Electrical and Electronics Engineers, Inc. January 2007.

[2] Bubble Technology Industries, Directional Survey Meter (DSM) User Guide, version 2.0. March 2012

[3] Bubble Technology Industries, Rad Compass Directional Radiation Survey Meter brochure. May 2012.

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In an effort to improve upon basic gamma radiation survey meters, DRDC Ottawa and Bubble Technology Industries developed a gamma radiation survey meter that adds a directional element to facilitate source localization. This Directional Survey Meter (which is also being called the Rad Compass) is based on the directional sensor of the previously-developed Directional Gamma Ray Probe, which was also co-developed by DRDC Ottawa and BTI. DRDC Ottawa carried out detailed testing of the prototype device based on a subset of the ANSI 42.33 gamma survey meter testing specifications. This report describes the testing carried out on the prototype device by DRDC Ottawa.

Dans un effort d'améliorer les gammamètres élémentaires, RDDC Ottawa et Bubble Technology Industries (BTI) a développé un gammamètre qui ajoute aussi de capacité directionnel pour faciliter la localisation des sources radioactive. Cette Radiamètre Directionnel (qui est aussi appelé la Rad Compass) est basé sur le détecteur directionnel de rayonnement gamma, le DGRP, qui a également été co-développé précédemment par RDDC Ottawa et BTI. RDDC Ottawa a effectué des tests détaillés de l'instrument prototype basé sur un sous-ensemble des normes ANSI 42,33 pour tester des gammamètres. Ce rapport décrit les tests effectués sur le prototype par RDDC Ottawa.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

radiation detection, gamma, survey meter, directional