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Testing of the Siemens EPD MK2 Final Report of Tasking W28476KR00X (DSSPM)

D.S. Haslip, T. Cousins, D. Estan, J.R. Brisson,
B.E. Hoffarth and T.A. Jones
Defence Research Establishment Ottawa

DEFENCE RESEARCH ESTABLISHMENT OTTAWA

TECHNICAL MEMORANDUM
DREO TM 2000-034
April 2000

National Defence Défense nationale

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DEFENCE DÉFENSE

Testing of the Siemens EPD MK2 Final Report of Tasking W28476KR00X (DSSPM)

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Radiation Effects Group
Space Systems and Technology Section

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Project
DSP00002199

ABSTRACT

Defence Services Procurement Project 00002199 tasked DREO to test the new Siemens EPD Mk2 (an electronic personal dosimeter) at DREO's various irradiation facilities. The dependence of the response on dose rate, energy, and temperature were all studied. This dosimeter was found to be comparable to the DMC 2000S electronic dosimeter produced by Merlin-Guerin Products (MGP), although each has some particular advantages over the other. This dosimeter is an appropriate product for use as an electronic dosimeter by the Canadian Forces in a wide variety of radiation fields.

RÉSUMÉ

Le Projet de Procurement de Services pour la Défense 00002199, a fait la demande à CRDO d'évaluer les dosimètres personnels électroniques Siemens EPD Mk2. La réaction des EPD en ce qui concerne la dépendance sur le débit de dose, l'énergie de rayonnement et la température a été évaluée. La performance de ces dosimètres est comparable aux dosimètres électroniques DMC 2000S, fabriqué par Merlin-Guerin Products (MGP). Cependant, chacun possède quelques avantages particuliers par rapport à l'autre. Le dosimètre Siemens EPD Mk2 est un produit bien adapté pour l'usage comme dosimètre électronique par les forces canadiennes dans une grande variété de champs de rayonnement.

EXECUTIVE SUMMARY

Background: DREO continues to provide scientific and technical services to Defence Services Procurement Project 00002199. The project recently received three of Siemens new EPD Mk2 electronic personal dosimeters for test and evaluation purposes, and tasked DREO to perform this evaluation. This report describes the results of this work.

Results: The dose-rate and energy dependencies of the response of this dosimeter were tested extensively at DREO's irradiation facilities. This investigation has shown that the response is sensitive to both dose and energy; this is not desirable, but is within the tolerance of this project's requirements. The dosimeter is sensitive to gamma radiation below 20 keV, a property not always found in electronic dosimetry.

The dosimeter's response falls steadily with increasing temperature, at a rate of about 0.12% per degree Celsius. This also is undesirable but is tolerable for the project. Apart from the change in response, the device's performance at low temperature is impressive, demonstrating full functionality down to –40°C.

Significance and Future Plans: The Siemens product is an electronic dosimeter that is appropriate for use by the Canadian Forces in the electronic dosimetry role, but not as a reconnaissance meter. It is largely equivalent to the MGP DMC 2000S tested previously at DREO, although each meter has advantages over the other.

Haslip D. S., Cousins T., Estan D., Brisson J.-R., Hoffarth B. E., and Jones T. A., Testing of the Siemens EPD Mk2: Final Report of Tasking W28476KR00X (U), Defence Research Establishment Ottawa, DREO TM 2000-034. April 2000.

SOMMAIRE

Étude Préliminaire: CRDO continue à fournir des services techniques et scientifiques au Projet de Procurement de Services pour la Défense 00002199. Le projet a dernièrement reçu trois dosimètres personnels électroniques Siemens EPD Mk2 afin d'effectuer une évaluation. Ce travail à été délégué à CRDO. Ce rapport décrit en détail les résultats de ce travail.

Résultats: La réaction de ces dosimètres en ce qui concerne la dépendance sur l'énergie de rayonnement et le débit de dose a été étudiée en profondeur en utilisant l'équipement de rayonnement disponible à CRDO. Les deux résultats en question démontrent un comportement non-linéaire. Ceci n'est pas souhaitable mais peut par contre être facilitées. Le dosimètre est sensible au rayonnement gamma en-dessous de 20 keV, un atout qu'on retrouve rarement en dosimétrie électronique.

Les données de débits de dose du dosimètre diminuent de façon constante en augmentant la température ambiante. Ceci représente un facteur d'environ 0,12% par degré Celsius. Ce comportement est également indésirable mais peut tout-de-même être facilité. Malgré ce changement dans les données de débits de dose, la performance du dosimètre à températures basses est impressionnante, démontrant un fonctionnement presque impeccable jusqu' à -40°C.

Importance et Futurs Projets: Le produit de Siemens est un dosimètre électronique qui est bien adapté à l'usage des forces canadiennes dans le rôle de dosimétrie électronique, mais pas cependant comme indicateur dans un rôle de reconnaissance. Il est en grande partie équivalent au MGP DMC 2000S évalué précédemment à CRDO, bien que chaque dosimètre possède quelques avantages particuliers par rapport à l'autre.

Haslip D. S., Cousins T., Estan D., Brisson J.-R., Hoffarth B. E., et Jones T. A., Évaluation des dosimètres Siemens EPD Mk2: Rapport Final du Travail W28476KR00X(U), Le Centre de recherches pour la défense Ottawa, DREO TM 2000-034, Avril 2000. (en anglais)

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1 INTRODUCTION

The "Low-Level Radiation" threat is becoming increasingly more important to militaries around the world. This threat comprises a number of scenarios, such as radiological dispersal devices and sabotaged nuclear reactors. Recent events in the Former Soviet Union [1], Kosovo [2], and Thailand [3] demonstrate that armed forces must be prepared to confront the radiation hazard.

Defence Services Procurement Project 00002199 [4] is set to procure a variety of radiation detection, identification, and dosimetry devices to meet modern demands. Electronic dosimeters (EDs) are one of the equipment suites to be purchased. In the project's Concept of Use, electronic dosimeters will be issued to groups of two to sixty personnel, acting as both an in-theatre record of radiation exposure and as a "tripwire", alarming when certain dose rates are exceeded. Aside from thermoluminescent dosimeters, this will be the most broadly distributed piece of equipment acquired by the project. As such, it must be rugged, easy to use, and reliable.

Siemens recently loaned several EPD Mk2 personal dosimeters [5] to the project for evaluation purposes. The project in turn has tasked DREO with evaluating this dosimeter in a manner similar to that used to evaluate several other dosimeters in 1999 [6]. This document is a final report on this work.

2 THE DOSIMETER

The Siemens EPD Mk2 (Figure 1) is the latest in Siemens' line of personal dosimetry. Considerably slimmer and lighter than its earlier models (such as the EPD-2E procured by DND under the Radiation Safety Project), its performance specifications are largely unchanged from previous versions. It is sensitive to doses down to 1 μSv and dose rates down to 1 μSv/h, although fluctuations at these rates will be significant. It has both dose and dose-rate alarms, and measures both deep and shallow doses. It has a dose profile history capability that will store up to 579 dose records of up to 127 μSv. It is powered by a single AA battery, and can accommodate either a 1.5-Volt alkaline cell or a 3.6-Volt lithium cell. Siemens has also attempted to address the hypersensitivity of this dosimeter to electromagnetic fields (such as radars and cellular phones) [7].

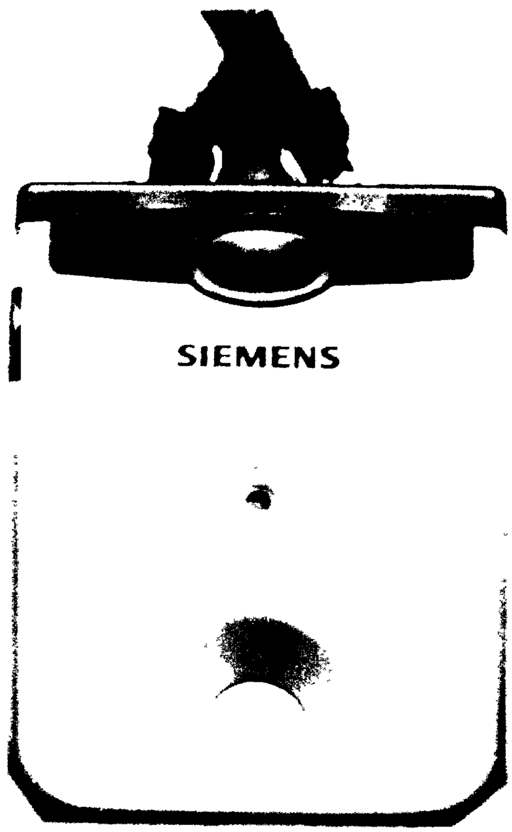

Figure 1: The Siemens EPD Mk2.

3 TEST RESULTS – RADIATION DETECTION

3.1 EPD Mk2 Dose-Rate Response

The objective of the first series of tests was to determine the linearity of the dose rate response for the EPDs. The first test was performed with ^{60}Co as a radiation source with dose rates ranging from 0.963 μSv/h to 10.2 Sv/h. Three different ^{60}Co sources were used: two calibrated sources (500 Ci and 10 Ci), and a pellet source (~ 1 mCi). For all measurements with the pellet source, a Microspec-2 gamma spectroscopy system [8] was used as a reference.

Figure 2 depicts the relative response of the EPDs in the ^{60}Co fields, as a function of dose rate. Included for each data point is an error bar, which represents the maximum deviation in the dose rate response between the three dosimeters being tested. The dose measurement in this and subsequent exposures is the deep dose (Hp(10)); the shallow dose is of lesser interest to the project and was not tested in this work. The dose rate was determined based on the activity of the calibrated source or on the reference measurements, as appropriate.

The response changes substantially over the device's operating range. There is a significant decrease in response around 10 Sv/h, but it should be noted that this is beyond the manufacturer's specification of 2 Sv/h. More important is the dip in response between 0.01 mSv/h and 10 mSv/h. In this regime, the relative response falls by as much as 20% from its response at higher and lower doses. This was also observed in a number

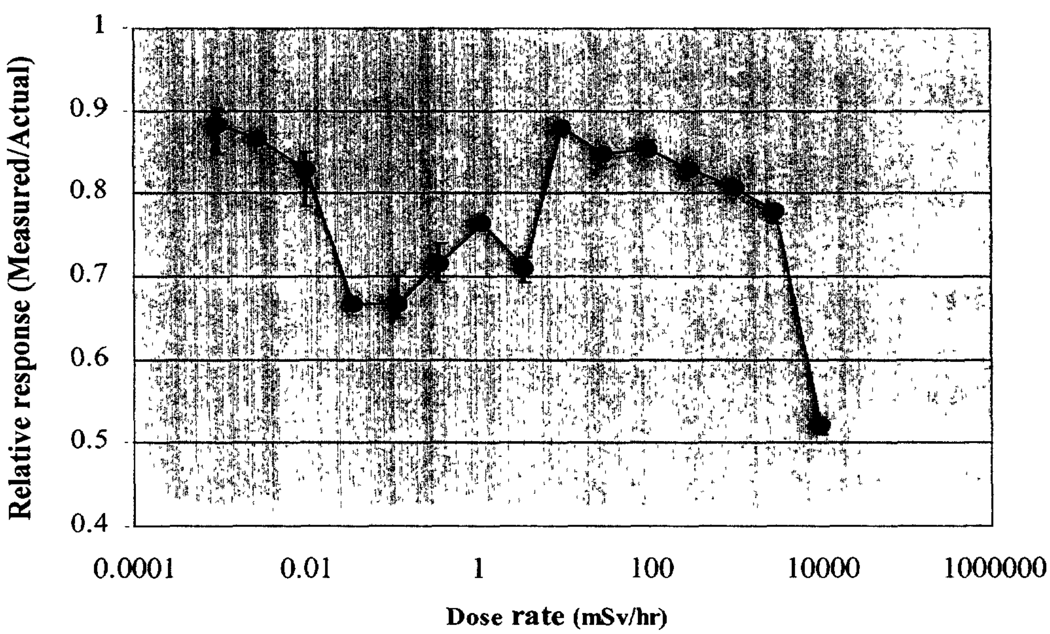

Figure 2: Ratio of measured dose rate to actual dose rate, as a function of actual dose rate for ^{60}Co gamma fields.

of Siemens dosimeters during the TTCP dosimeter intercomparison [9]. While this is not a monumental problem, it is important to note that such variations in response exist.

The response between EPDs was very consistent, even at low dose rates. The worst case deviation in the dose rate response between EPDs was 8%. On more than one occasion, all three EPDs gave exactly the same answer. Such reproducibility in response is obviously a very desirable feature in a dosimeter for the field.

The response of the dosimeters to gamma radiation from Cesium-137 was then investigated. For this investigation, DREO's UDM-1A Cesium-137 source (originally 120 Ci) was used. The response of the EPDs is shown in Figure 3. It is much flatter in this case. The worst case deviation is 20% occurring at over 3 Sv/h, once again beyond the manufacturer's specifications. This kind of response is more than satisfactory for this project, and even meets the stringent requirements of NATO Triptych D/104 [10]. The degree of consistency between EPDs, represented by the error bar associated with each data point, is high, with a worst case deviation no larger than 2%.

3.2 Energy Dependence

It is already evident from the previous section that the response of this detector varies with gamma-ray energy (relative response is as much as 20% smaller for Cobalt-60). Since the Canadian Forces might encounter sources with a broad range of gamma-ray energies, it is important to establish the response as a function of energy.

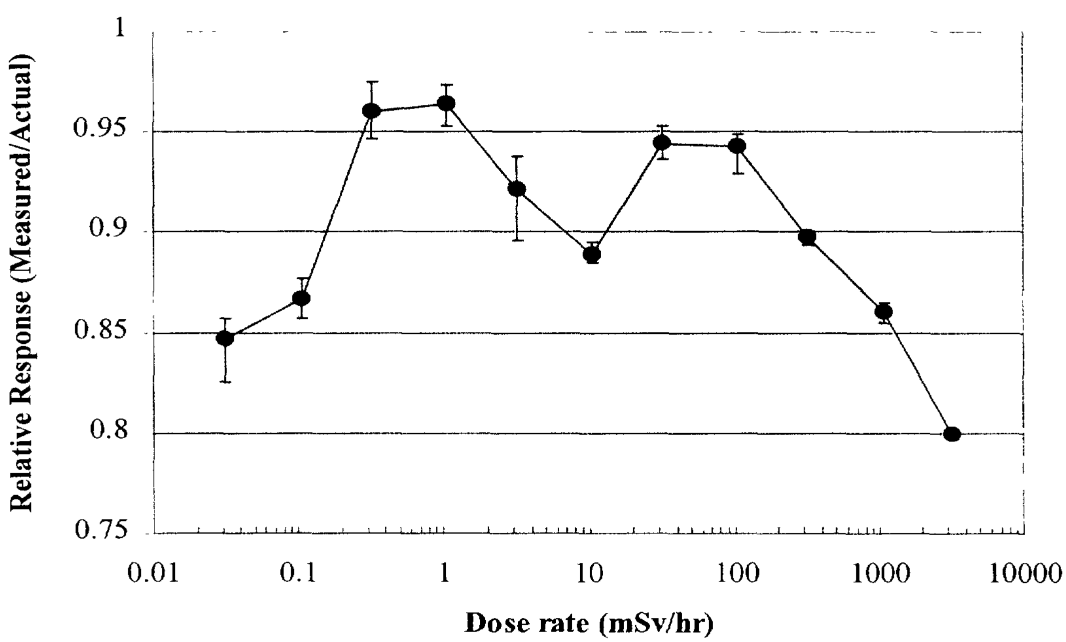

Figure 3: Ratio of measured dose rate for the EPD Mk2 to actual dose rate as a function of actual dose rate for ^{137}Cs gamma fields.

Table 1: Gamma-ray energies and associated sources studied as well as the references used for spectroscopy and dosimetry for the purpose of characterising the energy dependence of the EPDs. Details on X-ray machine set up can be seen in [11].

Energy (keV)	Source	Reference Spectroscopy	Reference Dosimetry
20	X-ray machine [0.2" Cu; V_{app} = 30 keV]	Microspec	Microspec
30	X-ray machine [0.2" Cu; V_{app} = 54 keV]	Microspec	Microspec
40	X-ray machine [0.063" Cu; V_{app} = 47 keV]	Microspec	Microspec
60	X-ray machine [0.126" Cu; V_{app} = 71 keV]	Microspec	Microspec
75	X-ray machine [0.2" Cu; V_{app} = 88 keV]	Microspec	Microspec
101	X-ray machine [0.5" Cu; V_{app} = 120 keV]	CdTe	CdTe
275	Mercury-203	Microspec	Microspec
662	Cesium-137		Calibrated Source
1253	Cobalt-60		Calibrated Source
1339	Van de Graaff [$d(d,n)^3He$, 1.0 MeV]	BGO	BGO
3124	Plutonium-Beryllium	BGO	BGO
4628	Van de Graaff [$^{19}F(p,\alpha)^{16}O$, 1.5 MeV]	BGO	BGO
5088	Van de Graaff [$^{19}F(p,\alpha)^{16}O$, 2.2 MeV]	BGO	BGO

The energy response of the EPDs was determined by exposure to a variety of gamma-ray sources. Table 1 lists all of the radiation sources used and their associated energies. To the greatest extent possible, tests were done at common dose rates to eliminate changes due to this variable. A few of the sources used are not mono-energetic and/or emit more than one significant gamma ray. In such cases, a mean energy is shown. The mean energy is a weighted average and is intended to serve as an approximation.

Figure 4 displays the response of the EPDs (averaged over the three dosimeters) as a function of energy. This response follows the same general trends of increase and decrease as claimed by the manufacturer [5], but the degree of change observed in this work is considerably greater. The dosimeter over-responds at very low energies (20-30keV), but significantly under-responds at around 60keV. The response then levels off and is relatively flat out to around 1200 keV, at which point it rises sharply. On the whole, the response above 100 keV is more or less the same as that of the MGP DMC 2000S dosimeter, and significantly better below (more constant and extending to lower energies) [6].

3.3 Dose Rate Fluctuations

Project 00002199 plans to deploy a large number of personal dosimeters and a relatively small number of reconnaissance and survey meters. Thus, there is a significant advantage to procuring a dosimeter that can carry out some of the roles of a reconnaissance meter (determining gamma-ray dose rates, locating sources). The chief

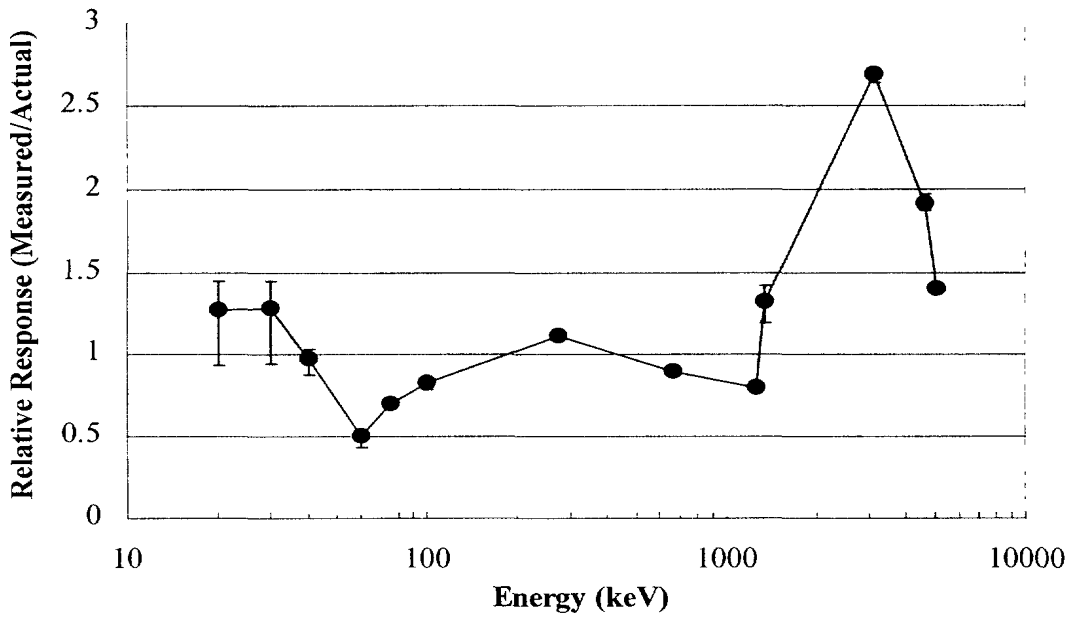

Figure 4: Relative response of the dosimeters as a function of gamma-ray energy.

factor mitigating against such a use is the sensitivity of the dosimeter. Dosimeters normally employ small radiation sensors; while these are sufficient for the purposes of dosimetry, they are often sufficiently insensitive to result in substantial fluctuations in measured dose rate at low rates.

Figure 5 shows the EPD's relative response to Cesium-137 as a function of dose rate (the same data as in Figure 3). The new element in this figure is the error bars, which represent the magnitude of the fluctuations of the dose rate display on the EPDs (worst case between three EPDs), as observed over a period of two to three minutes. There is no obvious trend in the size of these error bars; they are remarkably constant (±10-20%) over a large range of dose rates. This is in marked contrast to the dose rate fluctuations of the MGP DMC 2000S [6], which showed steadily larger error bars with decreasing dose rate, reaching ±30% at 0.1 mSv/h. This implies that the algorithm for displaying and updating the display of this dosimeter is substantially different from that used in the MGP dosimeter. That is, it seems likely that the Siemens dosimeter averages the displayed dose rate over a fixed number of counts. This will result in a relatively constant relative uncertainty in dose rate, but also a slow response time at low rates. The MGP dosimeter, on the other hand, likely recalculates the dose rate on a more regular basis, resulting in steadily growing uncertainties with decreasing dose rate. While there are pros and cons to both systems, since the inherent sensitivities (counts per millisievert) are the same for the two dosimeters, the fact remains that neither is suitable for a reconnaissance role.

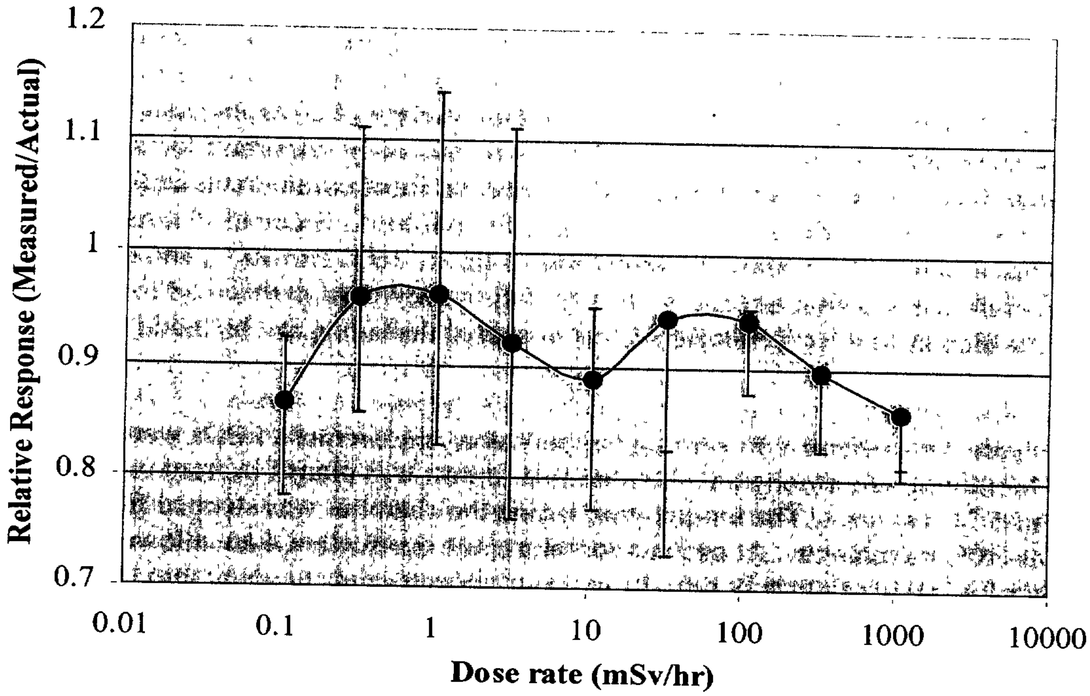

Figure 5: Fluctuations in the reported dose rate from the EPDs for ^{137}Cs exposures. The error bars indicate the range of dose rates observed over a period of two to three minutes.

3.4 Neutron Sensitivity

The sensitivity of the Siemens EPDs to neutrons was evaluated at the same time as the energy response testing was performed at the Van de Graaff accelerator. The experiment in which 1.0 MeV deuterons are directed onto a deuterium target produces 3.91 MeV neutrons where the dosimeters were placed. The dosimeters were exposed to over 1500 μSv of neutron dose (just over 200 μGy), at the same time as approximately 13.4 μSv of gamma dose from neutron activation. The dosimeters registered between 16 and 19 μSv, which we assume to be entirely due to gamma exposure with a slight over-response. It is possible that the 4 μSv of over-response is due to neutron dose, but even if this is the case, the dosimeters still under-respond to neutrons by a factor of almost 400.

Also, in the Van de Graaff run with 2.2. MeV protons impinging on a LiF target, 0.42 MeV neutrons are produced at the dosimeter positions. The dosimeters were exposed to almost 1200 μSv of neutrons, in addition to the 100 μSv of gamma dose. In this case, the dosimeters recorded just over 140 μSv, a significant over-response. However, given that the dosimeters over-responded to an even greater extent during the run with 1.5 MeV protons (in which there is no neutron production, but similar gamma production), it is likely that this response is due entirely to gamma exposure, and that the 1 mSv neutron dose was not detected.

4 TEST RESULTS – LOW TEMPERATURE PERFORMANCE

Canadian Forces personnel may operate in a wide variety of environments, with temperatures ranging from –50°C to +50°C. It is obviously important for their equipment to operate under these conditions as well. However, most commercial equipment is not designed to operate under such a wide range of conditions. Siemens claims that their dosimeter will operate in ambient temperatures from –10°C to +40°C, and other manufacturers make similar claims. It is therefore important to discover the extent of any failure at high or low temperatures so that doctrinal decisions can be made regarding their use.

To evaluate their response to varying temperatures, the Siemens EPDs were placed in an 8 ft^3 Thermotron environmental chamber that in turn was placed in front of a 500 Ci calibrated ^{60}Co source. The temperature inside the chamber was stepped from –50°C to 50°C in 10°C increments. At each temperature, the dosimeters were allowed to sit in the chamber for 30-60 minutes before the exposure began, so as to come into thermal equilibrium with their surroundings. All exposure rates and times were identical.

Figure 6 depicts the measured dose rate of the three EPDs as a function of the temperature inside the chamber. The graph clearly depicts that the response of the dosimeters decreases with increasing temperature. The average rate of change in response is approximately –0.12% / °C, and approximately 12% over the range of temperatures studied. Exactly why this occurs is not known. It was not observed in the irradiation of the MGP dosimeters, which employ a very similar technology. It is consistent, however, with previous type testing of the Siemens dosimeter [12].

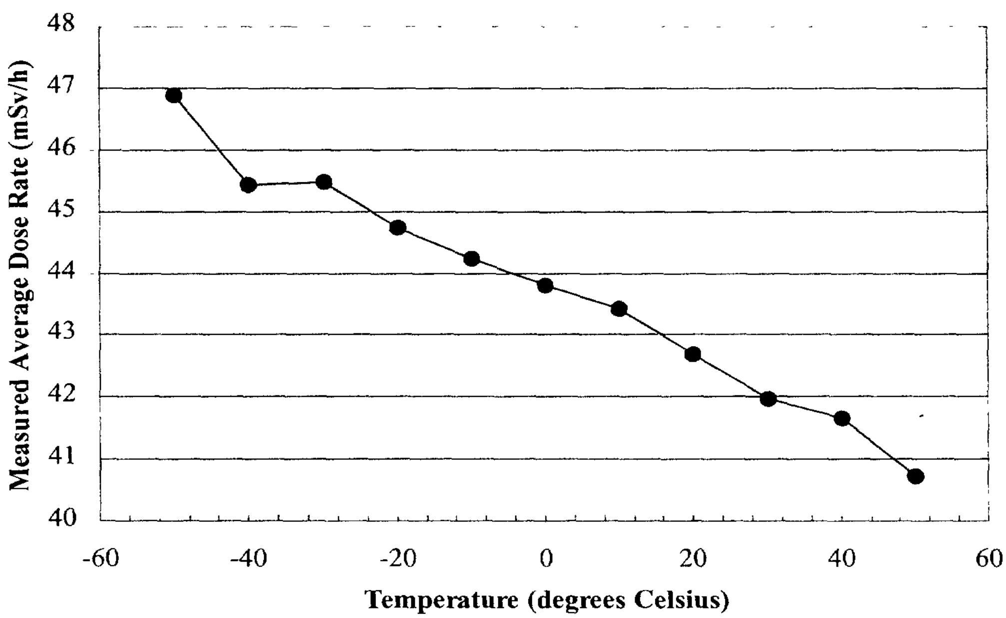

Figure 6: Measured average dose rate for the three EPD Mk2s in a ^{60}Co field as a function of ambient temperature.

As far as functionality at low temperatures is concerned, the Siemens EPDs faired quite admirably. The aspects in performance that were evaluated were

- the toggling of the LCD display in response to a button push, and
- the performance of the LCD display

Delays in toggling between display settings began to appear at -10°C where a slight (less than 0.5 s) delay was noted. At -20 °C, a 0.75 s delay was noted, at -30°C a 1.5 s delay was observed while at -40 °C, the delay exhibited was approximately 4-5 s. At all of these temperatures, the correct dose reading was perfectly legible.

At the extreme low temperature of -50°C, the display was frozen so that the correct dose reading was not displayed and the display would not change in response to button toggling. Furthermore, two out of the three EPDs displayed low battery warnings. After approximately 1-2 minutes at room temperature, the correct dose reading appeared on the LCD display despite some condensation. However, at this point, the display still failed to respond to a button push. After 3~4 minutes of acclimation at room temperature, the display did respond to a button push with a 1.5 s delay.

These results are very impressive, in that they suggest that these dosimeters could be used under a wide variety of temperatures, even wider than the manufacturer suggests. The temperature-dependence of the response is also valuable to know, just as the energy dependence is worth knowing. It should be noted that all of these tests were performed with lithium batteries in the dosimeters (as supplied by Siemens). Performance with an alkaline battery would surely be much worse at low temperatures. However, given the lifetime advantages of using lithium versus alkaline batteries (manufacturer claims 5 months versus 2 months), it is suspected that DND will use the lithium batteries in these dosimeters.

5 CONCLUSIONS AND RECOMMENDATIONS

This report has described some very thorough testing of the Siemens EPD Mk2 dosimeter. The dosimeter itself is very capable and a suitable candidate for Project 00002199. Its most serious shortcomings are in the variation of its response with dose rate, energy, and temperature, but these factors are all relatively minor (although they are important to keep in mind).

This dosimeter is most comparable to the new MGP DMC and SOR dosimeters that have also been tested by DREO. By way of conclusion, the results of the tests of these two dosimeters will be compared below.

5.1 Response Dependence on Dose Rate and Energy

Both the Siemens and MGP dosimeters were tested over a wide range of dose rates with both Cobalt-60 and Cesium-137 sources. The MGP dosimeter's response was relatively flat over the testing range, whereas the Siemens product showed varying response depending on dose rate, with relative response varying by as much as 20% in front of a Cobalt-60 source. The MGP dosimeter also measures dose rates accurately up to 10 Sv/h, while the Siemens dosimeter's response falls off sharply beyond a few sieverts per hour. The MGP product is, therefore, superior in both respects.

Siemens, however, has a distinct advantage in terms of energy response. As discussed previously, the response of the Siemens and MGP products above 100 keV are essentially the same. Below 100 keV, they are very different. The MGP dosimeter response rises to 1.5 at 60-80 keV, and then falls rapidly to zero. The Siemens dosimeter response falls to 0.5 at 60 keV, but then climbs again, remaining around 1.3 down to 20 keV. While both systems have their shortcomings below 100 keV, the Siemens dosimeter has the advantage of non-zero response to much lower energies.

The two dosimeters are equally sensitive to radiation, but clearly have different algorithms for calculating dose rates. As a result, the Siemens product shows much less fluctuation at low dose rates, likely at the expense of longer response times.

5.2 Dosimeter-Reader Communication

Both dosimeters are used in concert with a reader. The MGP dosimeter uses a low-frequency magnetic coupling to allow the two devices to communicate, while the Siemens product uses an infrared wand. Neither method is perfect. The MGP system was prone to error, meaning that dosimeters would sometimes have to be read several times to transfer data. Similarly, we have observed that writing information to the Siemens dosimeter does not always work on the first try. The MGP system does have the advantage of greater range, although we observed during previous work that turning up the range of the reader resulted in anomalous behaviour of the dosimeter when it was brought too close to the reader. Overall, the advantage goes to the Siemens system. The

Siemens system also has the edge in terms of dose management software, where their system has been developed to a far greater extent.

5.3 Low- and High-Temperature Performance

Neither dosimeter was adversely affected by temperatures up to 50°C. However, based on DREO test results, the Siemens dosimeter is a much better system in terms of low-temperature performance. Testing of the MGP product showed that it was not reliable below –20°C, whereas this work has demonstrated that the Siemens dosimeter performs well down to –40°C. This is not to say that a different doctrinal approach could not overcome this difference in performance. It should also be noted that MGP has since developed a product with a higher-performance battery that is meant to improve the dosimeter's performance at low temperatures.

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Defence Services Procurement Project 00002199 tasked DREO to test the new Siemens EPD Mk2 (an electronic personal dosimeter) at DREO's various irradiation facilities. The dependence of the response on dose rate, energy, and temperature were all studied This dosimeter was found to be comparable to the DMC 2000S electronic dosimeter produced by Merlin-Guerin Products (MGP), although each has some particular advantages over the other This dosimeter is an appropriate product for use as an electronic dosimeter by the Canadian Forces in a wide variety of radiation fields.

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
electronic dosimeter

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