Dose Reproducibility Assessment
for Thomson Nielsen Electronic Dosimetry Systems

Introduction

Thomson and Nielsen electronic dosimetry systems have been reviewed and cleared by the US-FDA for marketing in the USA for two applications, (a) measurement of absorbed dose to blood products during irradiation (TN-ID-50) and, (b) the verification of patient doses during radiation therapy (TN-RD-50). The nature of the MOSFET dosimeter is new to most members of the two markets served. The technology allows dosimetric information to be stored indefinitely in the dosimeter, so that it can, like film, be read many times. In this sense the MOSFET behaves as a passive dosimeter. Its dose information, although fundamentally electronic, need not be monitored continuously as is the case with ion chambers and diode detection systems. This leads to considerable instrument design flexibility since the dosimeter itself can be exposed remotely from its reader and dose information read immediately upon completion of the irradiation. The reader measures electronic, rather than radiation quantities and is calibrated to read absorbed dose. There is therefore no ambiguity in the data and no requirement for interpretation or correction.

The MOSFET is engineered like a film dosimeter to be used within a specific dose range over which its response to radiation is linear, reproducible and suitably accurate. The dosimetric information is accumulated in the MOSFET structure until the upper limit of the dose range has been reached, at which time the dosimeter is disposed of. In other circumstances the dosimeter may be used until a particular prescribed dose has been absorbed, at which time the dosimeter may be archived. It is not practical to calibrate every sensor. Instead sampling techniques are used and the MOSFET specifications are predicated on results of sampling statistics. It is the purpose of this note to describe the sampling and testing process so that users can know what to expect from these devices.

MOSFET Manufacture

MOSFETS are manufactured in large batches, typically 100,000 at a time. All aspects of the manufacturing meet the requirements of FDA medical device GMP. The manufacturing process is carefully controlled and each member of the batch has very nearly identical characteristics. At this stage, the MOSFET is a bare semiconductor transistor with dimensions 0.2 mm by 0.2 mm by 1 mm thick. This transistor must now be assembled into a package that allows it to be used by the practicing dosimetrist. Many packages are possible. In the case of the TN-ID-50 the package looks like a standard IC assembly known as a “plastic dual in-line eight pin package”. Such devices are fabricated in batches of 2000.

The package for the TN-RD-50 is quite different. The transistor is encapsulated in epoxy and mounted on a durable, flexible polymer cable. In contrast to the MOSFET batches, the dosimeter packaging is done in small batches, typically a few hundred at a time, and from these batches of assembled dosimeters, 5% are taken for characterization of dosimetric response, reproducibility, stability and linearity. Both packages are used in the dose range from a nominal zero to a full burden of 200Gy (20krad). The nominal zero is 0.01Gy (1rad) in the case of the RD-50, and 2Gy (200rad) for the ID-50. Dose calibration is performed at the Canadian Radiation Standards Laboratory located at the National Research Council Canada, using an internationally recognized cobalt 60 radiation standard from which known tissue equivalent doses are generated. Standard doses are measured using a calibrated Farmer Ion Chamber.

Tests Performed

Performance verification tests are carried out on a routine basis. The results of two such tests are reproduced here as examples of the performance of the TN-RD-50 sensor. These results are typical of those that a TN-RD-50 user will obtain. The calibration procedure recommended in the instrument manual (TN-RD-50) was followed. Seventeen dosimeters were irradiated in two sets of five and one set of seven. The field size was 100mm by 100mm and the source to surface distance was 1000mm. Full dose build up was achieved using 7mm of acrylic.

Each sensor was given three irradiations of 197cGy (197rad). The results of these irradiations were averaged, see column CAL in TABLE 1, and a calibration factor calculated for the sensor by dividing (CAL / 197). Subsequently the sensor was exposed to seven additional 197cGy doses. Each indicated result was then divided by the calibration factor to convert the indicated dose to actual dose. Reproducibility testing was also performed for nominal doses of 20cGy using a sample of 39 dosimeters.

Results

Data from a set of 17 production dosimeters processed on March 17, 1995 is shown in TABLE 1. From TABLE 1, the following observations can be made:

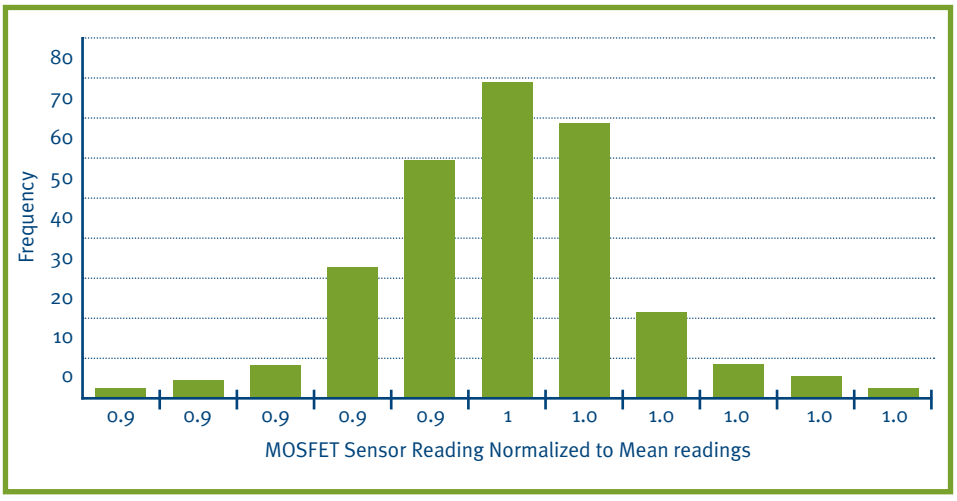
(a) The S.D. of the CAL values for all 17 dosimeters, 3.4 cGy is essentially the same as the overall S.D. of the 119 calibrated doses, 3.1cGy, indicating that sensor to sensor reproducibility is the same as the dose to dose reproducibility for a given sensor.

(b) The standard deviations of the dose to dose responses for the dosimeters in this sample are shown in FIGURE 1 where the normal distribution of the data is illustrated. From an analysis of the probability data we conclude that the response of a particular sensor will be within 1.5% of the target dose with a 68% confidence limit, within 3% of target dose with a 96.5% confidence limit, and within 4.5% of the target dose with a 99.7% confidence limit.

TABLE 1 - SUMMARY OF 17 PRODUCTION DOSIMETERS TESTED AT 197cGy

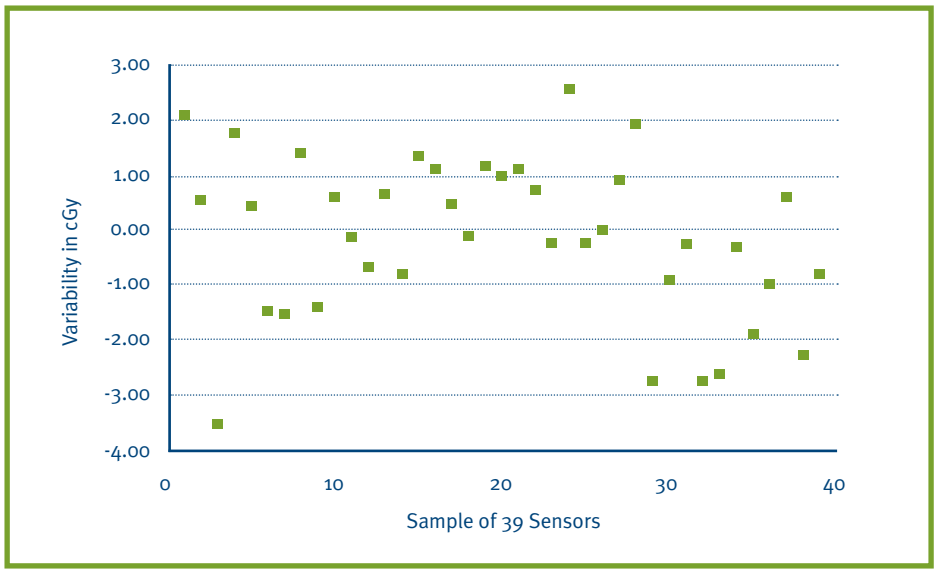
Sensor Number	Cal.	Cal. Factor	Calibrated Readings							Mean	SD
1	187.00	0.95	192	193	192	197	197	197	196	195	2.54
2	188.67	0.96	199	192	198	195	195	196	202	197	3.12
3	193.33	0.98	197	200	195	199	207	202	199	200	3.92
4	198.33	1.01	196	197	192	194	199	196	193	195	2.41
5	200.00	1.02	194	190	193	197	200	196	193	195	3.20
6	196.67	1.00	199	195	201	197	199	196	198	198	2.04
7	195.00	0.99	200	197	200	202	201	193	201	199	3.16
8	196.67	1.00	202	193	196	195	201	198	197	198	3.21
9	198.33	1.01	196	200	193	200	196	197	193	196	2.86
10	197.67	1.00	197	198	195	199	196	198	196	197	1.41
11	192.67	0.98	200	201	200	202	202	198	201	201	1.43
12	197.00	1.00	198	189	195	197	195	191	190	194	3.55
13	196.00	0.99	197	194	197	196	195	192	197	195	1.91
14	194.33	0.99	196	196	196	198	199	200	193	197	2.37
15	194.33	0.99	193	197	196	196	198	196	198	196	1.73
16	192.33	0.98	197	196	199	195	198	198	195	197	1.61
17	194.67	0.99	199	200	194	197	196	199	199	198	2.16
AV. CAL	**194.88**										
S.D.	**3.40**		**AVERAGE OF 119 CALIBRATED READINGS**							**199.85**	
			STANDARD DEVIATION OF 119 CALIBRATED READINGS								**3.14**

FIG. 1. DISTRIBUTION OF MOSFET SENSOR READINGS AT STANDARD DOSES OF 197 cGY



Similar tests were performed on a second set of 39 dosimeters using 20cGy doses. Doses of this magnitude result from scattered dose measurements and special procedures. These results are shown in FIGURE 2. The standard deviation was found to be 1.5 units. Each point is the difference between two doses applied to the same sensor.

FIGURE 2. DISTRIBUTION OF THE REPRODUCIBILITY OF 39 SENSORS



Conclusions

The MOSFET data show that these dosimeters have a dose-to-dose reproducibility of about 1.5% (1 S.D.) at typical treatment doses and that the sensor to sensor dose reproducibility is essentially the same. The data also show that 20cGy doses will be replicated to limits of +/-7% (1 S.D.). Comparison with diode data is worthwhile. Consider for example the study by Lee et al in International Journal of Radiation Oncology 29 (5) 1994 1175 1182. In this study, diode dose reproducibility was found to be within 0.2% (1 SD) in tests in phantom and within +/- 7% in tests performed on patients. In this work the degradation in reproducibility when the diodes were placed on patients was attributed to day to day variations in patient set up and diode placement and it was noted that the -7% lower bound corresponded to the limit at which changes in tumor control may result.

Our findings for 200cGy doses may also be compared with TLD results. For example, consider the work of Kirby et al in Medical Physics 19 (6) 1992 1427, 1433. In their study, the estimated uncertainty in powder TLD samples was +/-5.8% at 95% confidence. The standard doses used were higher than those used here so it is clear that MOSFET represents an improved choice over TLD.

From our test data, we conclude that MOSFET dosimeters would be able to verify patient doses with improved certainty compared to TLD and that with attention to proper set up procedures, MOSFET would be an adequate substitute for diodes especially where large numbers of dosimeters were required for the treatment. Where physical constraints, concerns over shadowing, or issues of scattered doses are important, then MOSFET dosimeters have clear advantages over both diodes and TLD.