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NNR: NO No.:	DOSIMETRY QUALITY CONTROL PROGRAMME			PAGE 1

KORC	ACCESS	IMPORTANCE CATEGORY	NEXT REVIEW DATE	DATE AUTHORISED
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S TAFENI	N MASHAO	T KARSTEN
SENIIOR SUPERVISOR	RADIATION PROTECTION PHYSICIST	CHIEF ADVISOR
DATE 2022-03-01	**DATE** 2022-03-01	**DATE** 2022-03-01

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CATEGORY 3 – PROCEDURE FOR REFERENCE

FCA	ALARA REVIEW	SUPERSEDES
PROTECTION	NO	KWH-B-014, Rev 9 dd. 2021-11-23 PARTIAL REVIEW

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1.0 PURPOSE

1.1 To describe the external dosimetry quality control programme.

2.0 SCOPE

2.1 Applicable to:

- Daily, weekly, monthly and other routine quality control
- Quarterly quality control
- 6-monthly quality control
- Annual quality control
- Performance tests
- TLD element correction factors

3.0 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

3.1.1 **Dose and Dose Rate Effectiveness Factor** – A postulated phenomenon where, at low dose rates, repair mechanisms within the body will reduce cancer risk.

3.1.2 **Dosemeter** – An instrument or device designed to measure the radiation dose received by an individual. The dosemeter may either be a direct reading type, e.g. electronic dosemeter or an indirect reading type, e.g. thermoluminescent dosemeter.

3.1.3 **Environmental TLD** – A dosemeter placed in the environment for the purpose of measuring direct radiation.

3.1.4 **Incandescence** – "Peak 3" produced in the glow-curve due to very high temperature of element heating. (Caused by heat, not trapped electrons).

3.1.5 **Legal or Principal Dosemeter** – A dosemeter used for assessing a person's legal dose which will be recorded on the Radiation Workers Dose Register. The legal dosemeter at Koeberg is the thermoluminescent dosemeter (TLD).

3.1.6 **Percentage Coefficient of Variation (% CV)** – The Standard deviation to the arithmetic mean of a set of measurements expressed as a percentage used to compare element readings of identical elements receiving the same dose.

$$\% \text{ CV} = \frac{100 \times \text{stdev (E1, E2, E3, E4)}}{\text{Avg (E1, E2, E3, E4)}}$$

3.1.7 **Percentage Difference** – In the context of this procedure, the difference between the actual reading and the true value expressed as a percentage of the true value.

3.1.8 **Thermal Noise** – Incadescence that occurs in the dose region of the glow-curve.

3.1.9 **TLD** – A passive device for measuring ionising radiation, consisting of a sealed holder together with a quantity of special material. This material, when subjected to controlled heating after exposure to radiation, releases measurable quantities of light proportional to the quantity of radiation absorbed.

3.2 Abbreviations

3.2.1 **CTS** – Counts

3.2.2 **CV** – Coefficient of Variation

3.2.3 **DDREF** – Dose and Dose Rate Effectiveness Factor

3.2.4 **DosiGui** – Dosiserv Global User Interface

3.2.5 **ECF** – Element Correction Factor

3.2.6 **EPD** – Electronic Personal Dosemeter

3.2.7 **ESL** – Environmental Survey Laboratory

3.2.8 **H** – TLD Response for Performance Index Test

3.2.9 **Hi** – Known Exposure for Performance Index Test

3.2.10 **mR** – milliRoentgen

3.2.11 **mSv** – milliSievert

3.2.12 **NMISA** – National Metrology Institute of South Africa

3.2.13 **NNR** – National Nuclear Regulator

3.2.14 **PC** – Personal Computer

3.2.15 **Pi** – Performance Index

3.2.16 **QA** – Quality Assurance

3.2.17 **QC** – Quality Control

3.2.18 **QFD** – Quartz Fibre Dosemeter – A direct reading personal dosemetric device

3.2.19 **R** – Roentgen

3.2.20 **RADPRO** – Radiation Protection Dose Management Computer System

3.2.21 **SI** – International System

3.2.22 **Stdev** – Standard Deviation

3.2.23 **TLD** – Thermoluminescent Dosemeter

4.0 REFERENCES

4.1 Referenced Documents

4.1.1 238-48, Rev 0b: Thermoluminescence Dosimetry Requirements

4.1.2 238-54, Rev 0b: Radiological Protection Licensing Requirements for Koeberg Nuclear Power Station

4.1.3 335-2, Rev 5: Koeberg Nuclear Power Station Management Manual

4.1.4 KAA-500, Rev 13: The Process for Controlled Documents

4.1.5 KSA-011, Rev 14: The Requirements for Controlled Documents

4.1.6 KSH-001, Rev 10: The Administration and Quality Control of Radiation Dosimetry

4.1.7 KWH-I-065, Rev 7: The use of the NE 2670 Farmer Dosemeter, UNIDOS webline and the Williston Ellin Panoramic Irradiator

4.2 Applicable Documents

4.2.1 K-5179-E: 1985 Submission to the AEC for the Approval of the Thermoluminescent Dosimetry System at Koeberg Nuclear Power Station for the Purpose of Assessing the Dose to Individuals arising from External Irradiations

4.2.2 KFH-HP-029: Batch Homogeneity Report 802 TLDs and 809 TLDs

4.2.3 KFH-HP-067 Dose Evaluation Test

4.2.4 KFH-HP-083: TLD Reader Calibration Check Record

4.2.5 KFH-HP-084: Panasonic Performance Index (Overall Batch Response)

4.2.6 KFH-HP-085: Panasonic Repeatability Test

4.2.7 KFH-HP-086: Panasonic Stability of Stored Information Test

4.2.8 KSH-008: Radiation Protection Records, Data and Information Management

4.2.9 KWH-I-068: Operation, Calibration and use of the Panasonic TLD Readers

5.0 PREREQUISITES

5.1 Dosimetry staff must be authorised to conduct the tests and checks.

6.0 PRECAUTIONS AND LIMITATIONS

6.1 TLD Readers operate in non-SI units, therefore all exposures are done in mR and R.

6.2 QFDs read in exposure, i.e. milliSievert (mSv). R

6.3 Any equipment that has an out of tolerance condition must be clearly signposted or tagged as DO NOT USE to prevent operation.

6.4 All TLDs are read using the UD-7900M PANASONIC TLD Readers and procedure KWH-I-068.

7.0 PROCEDURE

The quality control tests and checks are listed in terms of their frequency.

7.1 Daily, Weekly and Monthly (as required)

7.1.1 Daily Parameter Checks

Frequency: Before reading out TLDs for Legal Dose Assessment e.g. Neutron TLDs, Extremity TLDs, Emergency processing of Personnel TLDs and Environmental TLDs.

7.1.1.1 Ensure that the Reference light check value is > 0,99 before reading out TLDs. If this is not the case then the reader must be cleaned before any reading is done.

7.1.1.2 Ensure that the Reader is set to read out all four TLD elements.

NOTE: *Various other parameter checks are carried out automatically by the Reader before reading out.*

7.1.1.3 Before reading out badges for Legal Dose Assessment read one QC TLD exposed to 250 mR and one QC TLD exposed to 2000 mR.

Calculate the percentage difference from the delivered dose for elements 2 and 3 as follows:

$$\% \text{ difference} = \frac{A - B}{B} \times 100$$

Where:

A = Reading of Elements

B = Delivered Dose

7.1.1.4 The percentage difference between the reading and the delivered dose for both elements 2 and 3 must be within ± 15% of the delivered dose value. (An Excel Spreadsheet is available on the TLD reader PC for these calculations). If the reader fails this check no further reading on the reader is allowed until the necessary corrective actions have been done. This can include but is not limited to repeating the test, re exposing the QC TLDs, assigning new ECFs to the QC TLDs or recalibrating the reader.

7.1.2 Parameter Dump (Frequency: At Least Weekly)

7.1.2.1 Check the Reader parameters against the previous parameter dump.

7.1.2.2 Report any changes to the Dosimetry Supervisor.

7.1.2.3 Keep the parameter dump printout in the TLD Daily Logbook until the next calibration of the Panasonic UD 7900M TLD reader is done.

NOTE: *The Panasonic UD 7900M TLD reader software automatically stores all the parameters used with each file read.*

7.1.2.4 Log all events in the TLD Reader Daily Logbook.

7.1.3 QC Checks – Before Reading of Wearing Period TLDs

7.1.3.1 If the secondary standard is not available, or suspicious, during use of the panoramic exposure jig, another instrument, suitable for the exposure, and directly traceable to the National Standard, may be used for QC purposes, following review by a Senior Physicist.

7.1.3.2 Anneal the QC dosemeters and expose the 2 groups on the TLD jig in N040 to 250 mR and 2000 mR using Cs-137. The Secondary Standard is used to ensure traceability to the National Primary Standard, or alternatively use the WE2001 irradiator and reference TLD's to determine the exposure times for 250 mR and 2000 mR. If TLD jig exposures cannot be performed then 50 reference TLD's may be exposed to 250 mR and 2000 mR using the WE2001 irradiator. Calculate the average dose for elements 2 and 3. This is done using RADPRO and System Admin TLD File Processing Application. The calculated average reading must be used as the delivered dose reading. Expose the QC dosemeters in the WE2001 irradiator using the same time setting as that selected for the reference TLDs.

NOTE: *The reference TLD's provide traceability to the National Primary Standard.*

7.1.3.3 Store these exposed QC TLDs for short-term fading (± 24 hours) in the safe located in RP Dosimetry.

7.1.3.4 Before reading out the monthly badges, read ten QC TLDs exposed to 250 mR and 10 TLDs exposed to 2000 mR.

7.1.3.5 ECF correct the readings and calculate the average values for elements 2 and 3 for the two groups of TLDs and record the results on TLD Reader Calibration Check Record form (KFH-HP-083).

7.1.3.6 Calculate the percentage difference from the delivered dose for elements 2 and 3 as follows:

$$\% \text{ difference} = \frac{A - B}{B} \times 100$$

Where:

A = Average Reading of Elements

B = Delivered Dose

Record results on TLD Reader Calibration Check Record form (KFH-HP-083).

7.1.3.7 The percentage difference between the average reading and the delivered dose for both elements 2 and 3 must be within ± 15% of the delivered dose value. Record values on TLD Reader Calibration Check Record form (KFH-HP-083).

7.1.3.8 Calculate the % CV from the mean for elements 2 and 3 and record values on TLD Reader Calibration Check Record form (KFH-HP-083). The % CV should be less than or equal to 10%. (An Excel Spreadsheet is available on the TLD reader PC for these calculations). R

7.1.3.9 If the % CV of the set of quality control dosimeters is less or equal to 5% then the test is acceptable. In a case where the % CV is between 5% and 10%, the dosimeters causing the large variation must be investigated upon the completion of the quality control test and necessary corrective actions must be applied on the dosimeters (for example ECF correction). Processing may continue if the % Difference of the mean to the true exposure is within 15%. If the % CV is above 10% then remove the suspect dosimeters and repeat the test. R

7.1.3.10 If the Reader passes the QC tests, reading out of personnel badges may proceed. If the Reader fails any of the QC tests no further processing is allowed until the necessary corrective actions have been done. This can include, but is not limited to, repeating the tests with a new set of QC TLDs, re-exposing the QC TLDs, assigning new ECFs to the QC TLDs or recalibrating the reader (Refer to the TLD reader maintenance plan).

7.1.3.11 Clean the reader and repeat the QC checks before reading out every batch of 500 TLDs and after all the badges have been read.

7.1.4 QC Checks – After reading of TLDs

7.1.4.1 This check must be performed after the reading of any TLDs used for legal dose purposes i.e. wearing period TLDs, neutron TLDs, Extremity TLDs.

7.1.4.2 When any reading or annealing is completed a screen will appear to allow reading of the read results (Figure 1).

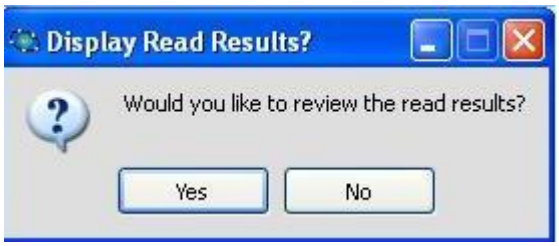

Figure 1

7.1.4.3 Click on Yes and verify all TLDs were read / annealed by viewing the Magazine Slot Map and the Total Badges Read indicated on the bottom of the report.
A @ sign indicates a slot containing a badge. A – sign indicates a badge not in the slot or not read i.e. skipped.

7.1.4.4 Alternatively, select Panasonic > Database Maintenance > Operator from the main screen of the UD-7900 Reader Control Software. (Figure 2)

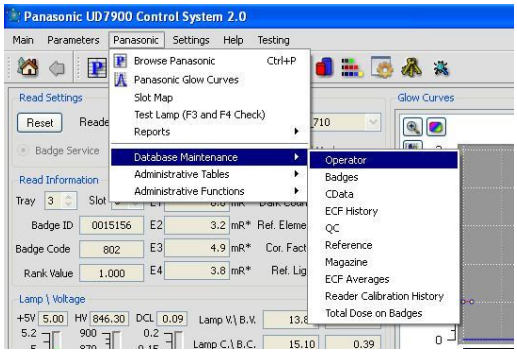

Figure 2

Or Select Panasonic > Browse Panasonic.

7.1.4.5 In the Search Value field (Figure 3) enter the File name / batch_name of the file(s) to be viewed or leave as All to view all files. (See Figure 4)

Figure 3

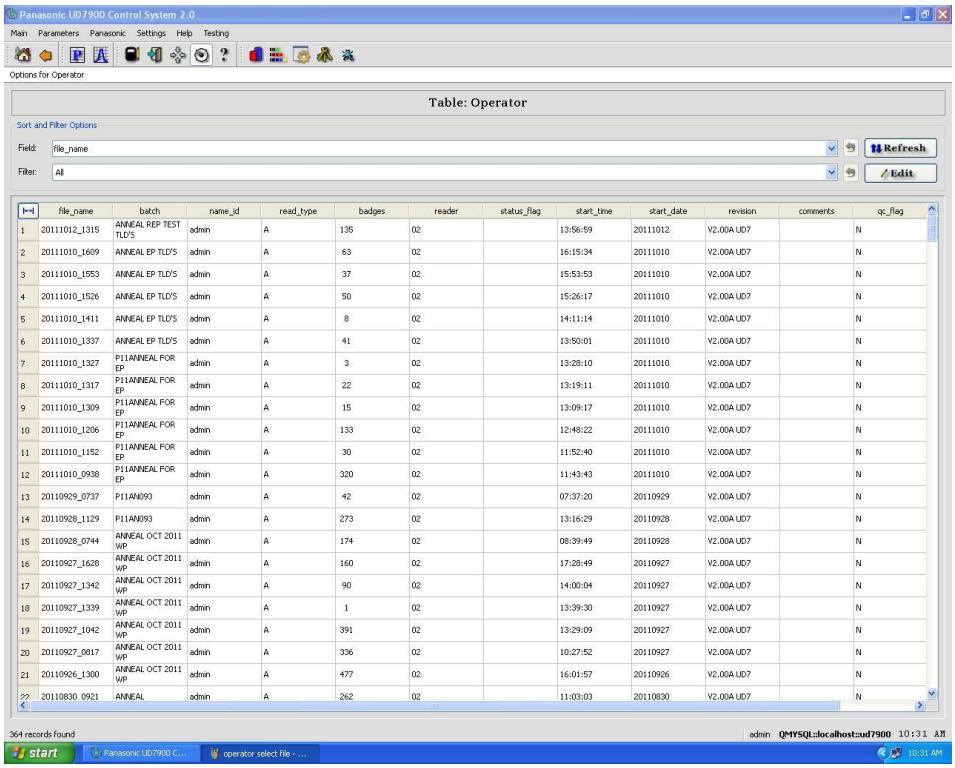

Figure 4

7.1.4.6 Double click on the file to view the detail. (Figure 5)

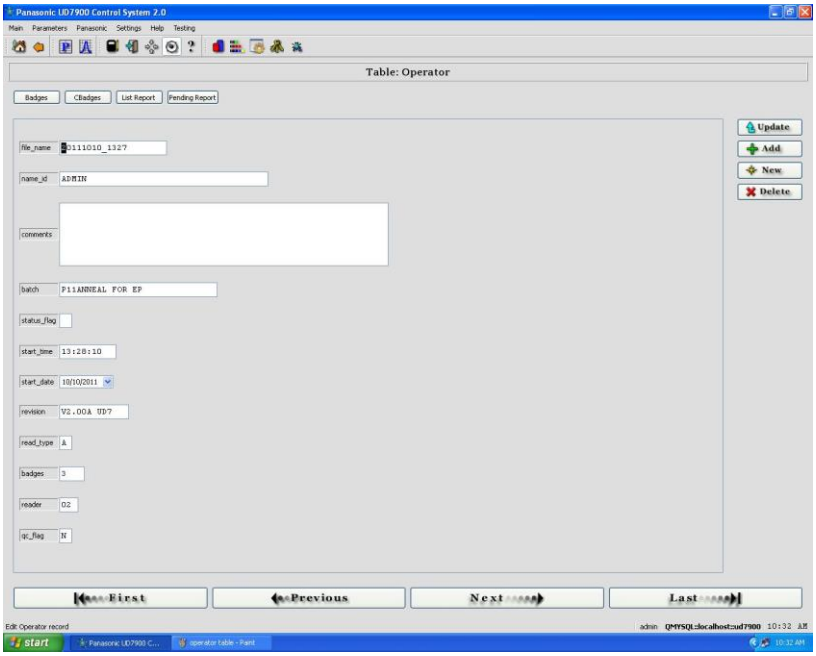

Figure 5

7.1.4.7 Click on the List Report button to view the read results report.

7.1.4.8 Double click on the file and verify all TLDs were read/annealed using the View Text Tab. View the magazine slot map at the end of the file.

7.1.4.9 For annealing, also verify that all TLD readings are satisfactory, as per 7.1.4.12.

7.1.4.10 Export the file to Xcell by selecting Options for Badges > Administrative Functions > Export query set to CSV (Figure 6). All the information listed in the table on the screen will be exported to Xcell.

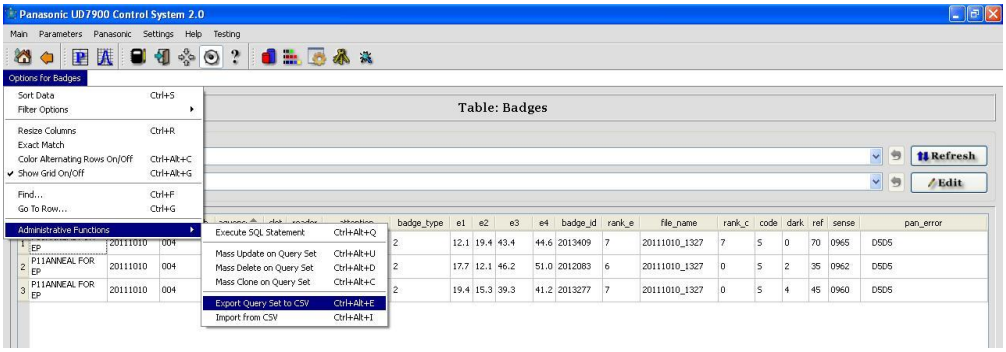

Figure 6

The Xcell file can be found in the UD7900 Export > Badges folder on the desktop.

7.1.4.11 Filter for unsatisfactory readings as follows:

(1) Delete all unwanted columns, keeping Batch, magazine number, slot, Filename, Reader, TLD number (badge_id), E1, E2, E3 and E4 columns.

(2) Highlight all data and click on Filter to add automatic filters.

(3) Filter for E1, E2, E3 and E4 readings to highlight readings not meeting requirements in 7.1.4.12.

7.1.4.12 Badges must be re-annealed under the following circumstances:

(1) When a TLD was skipped.

(2) When a D5 error is displayed.

(3) When the residual readings for elements 1 and 2 are above 10 mR.

(4) When the residual readings for elements 3 and 4 are above 5 mR for 802 TLDs.

(5) When the residual readings for elements 3 and 4 are above 10 mR for 809 TLDs.

(6) When the residual readings for elements 1, 2, 3 and 4 are above 0.3 mR for 812AR TLDs.

NOTE 1: *Badges that fail the residual readings criteria must be removed from service.*

NOTE 2: *Personnel badges that fail the residual readings criteria must be removed from service and if assigned to an individual a new TLD must be assigned to the individual.*

NOTE 3: *It is recommended that for reader calibration and experimental work, the residual readings should be of the order of 5-6 mR for elements 1 and 2, and less than 0,3 mR for elements 3 and 4.*

7.2 Quarterly Quality Control

7.2.1 Glow Curve Verification

NOTE 1: *Glow curves must be obtained for Li2B4O7 and CaSO4.*

NOTE 2: *The new advance TLD Reader UD-7900M software stores all glow-curves of all types of TLD's processed.*

7.2.1.1 Obtain the glow-curves from the file of the latest QC test that was carried out.

7.2.1.2 Study the shape and position of the glow-curve. Pay particular attention to the position of the dose peak in relation to TIC marks 2 and 3.

7.2.1.3 Compare the glow-curves with that of the latest (valid) calibration glow-curves.

7.2.1.4 If no significant shift or shape distortion has taken place, print the glow-curves and file it in the QC records file.

7.2.1.5 If in doubt or the glow-curve has changed, carry out a short-term fade and thermal noise test as described in KWH-I-068.

NOTE 1: *Low short-term fading and low thermal noise indicates good heating parameters.*

NOTE 2: *Peak 3 of the glow-curve is produced primarily from incadescence caused by heating the element to very high temperatures and not from trapped electrons.*

NOTE 3: *High thermal noise will increase the detection threshold of the element.*

7.2.2 Performance Index (Overall Batch Response) Pi = (H – Hi) /Hi

Performance Index is performed to monitor any long term variations in the response characteristics of the system.

7.2.2.1 Select a random sample of 200 personnel badges. (Badges which are in regular use).

7.2.2.2 Anneal the badges and expose them on the TLD jig in N040 to 500 mR using Cs-137. If TLD jig exposures cannot be performed then 50 reference TLD's may be exposed to 500 mR using the WE2001 irradiator. Calculate the average dose for elements 2 and 4. (Hi) This is done using RADPRO and System Admin TLD File Processing Application. Expose the 200 personnel badges in the WE2001 irradiator using the same time setting as that selected for the reference TLDs.

NOTE: *The reference TLD's provide traceability to the National Primary Standard.*

7.2.2.3 Allow for short-term fading (± 24 hours) and read. Process the readings using RADPRO and System Admin TLD File Processing Application.

For manual processing follow steps 7.2.2.4 – 7.2.2.5

7.2.2.4 Correct the readings with ECFs.

7.2.2.5 Calculate Pi = [(H – Hi) / Hi] x100

For elements 2 and 4 and record on Panasonic Performance Index form (KFH-HP-084). (Elements 2 and 4 are used since these elements are used to calculate deep dose equivalent).

NOTE: *Pi = Performance Index*
H = Average TLD Response
Hi = Known Exposure (Dose)

7.2.2.6 Plot for both elements 2 and 4 on linear graph paper as a check on the system's long term response (Panasonic Performance Index form (KFH-HP-084). (RADPRO generated printout and an Excel Graph is acceptable).

7.2.2.7 A result exceeding ± 15% of the delivered dose must be investigated. No further reading is allowed on this reader until the necessary corrective actions have been done. This can include, but is not limited to, repeating the test with a new set of personnel badges, assigning new ECFs to the TLDs or recalibrating the reader.

7.2.2.8 Retain the graphs near the Reader.

7.3 Six-monthly Quality Control

7.3.1 TLD Reader Calibration

7.3.1.1 As described in KWH-I-068 for the Panasonic UD-7900M TLD Readers.

7.3.2 Quartz Fibre Dosemeters

QFDs must be drift and response tested 6 monthly ± 1 month.

7.3.2.1 QFDs are distributed to various locations as part of the Emergency plan. A record is kept of their specific location on RADPRO.

The QFDs to be tested are collected by Emergency plan staff and delivered to RP Dosimetry for testing.

7.3.2.2 Drift Check

The drift check will determine the electrical charge leakage of the individual QFDs. The maximum allowable leakage over 24 hour period is 5% of the scale.

(1) Once the QFDs have been collected from the various locations, they must be zeroed and stored in a low background area for ± 24 hours.

(2) After ± 24 hours read the QFDs and set aside as unserviceable any that exceed the limit of drift.

(3) Update the RADPRO system with the results as follows:

- Log onto the RADPRO system and onto the DosiGui Application;
- Select Equipment from Equipment menu in the Configuration submenu in the navigation panel;
- Type the QFD number in the filter row Equipment Name column;
- Double click on the line to open the Equipment Details screen;
- Enter the date of the drift test in the Drift test do date field. The system will automatically calculate the Drift test expiry date. If the QFD has failed this test change the Drift test expiry date to be the same date as the Drift test do date and mark the QFD as Failed in the Location box and set aside;
- Click the √ box on the control bar to save the information.

7.3.2.3 Response Test

The response test determines whether the individual QFDs respond acceptably to a known radiation exposure. The QFDs must respond to within 15% of the exposure it was subjected to.

(1) Zero the QFDs and expose them on the TLD/QFD jig in N040 using Cs-137.

(2) Expose the QFDs to an exposure reading of mid to three-quarter scale:

- 150 mR for a 0-200 mR QFD
- 300 mR for a 0-500 mR QFD
- 3 R for a 0-5 R QFD
- 30 R for a 0-50 R QFD

(3) Read the QFDs and set aside as unserviceable any that do not read within 15% of the exposure.

(4) Update the RADPRO system with the results as described in 7.3.2.2(3) but update the Response test do date. If the QFD has failed this test change the Response test expiry date to be the same as the Response test do date and mark the QFD as Failed in the Location box and set aside.

(5) After all QFDs have been updated manually on the equipments screen in Dosigui, generate an updated printout of all QFDs in date order and file together with the exposure printouts in the QFD file to be sent to Documentation.

(6) All QFDs that have passed the drift and response tests can be redistributed to their respective locations by Emergency plan staff. Replace QFDs where necessary and ensure that the QFD locations are updated on the RADPRO system.

7.4 Annual (± 3 Months) Quality Control

NOTE 1: *The processing of the annual QC tests is done using RADPRO and System Admin TLD File Processing Application.*

NOTE 2: *A RADPRO generated report is acceptable in the place of Appendix 3-4.*

7.4.1 Batch Homogeneity Test

Batch Homogeneity is carried out to prove all dosemeters have an individual element response of within ± 15% of the mean batch response for that element.

7.4.1.1 This test must be carried out on all personnel and neutron TLDs.

IMPORTANT: *DO NOT COMBINE 802 PERSONNEL BADGES WITH 809 NEUTRON BADGES WHEN PERFORMING THIS TEST.*

7.4.1.2 The badges are divided into batches as they become available for the test (the number of badges used at any single time will depend on the availability of the TLDs).

7.4.1.3 Anneal the TLDs and expose them to approximately 200 mR in the WE2001 irradiator.

7.4.1.4 Store the TLDs in a low background area for for short term fading (± 24 hours).

7.4.1.5 Read the exposed TLDs.

7.4.1.6 When all the TLDs are read combine the read files. Process the readings using RADPRO and System Admin TLD File Processing Application.

For manual processing follow steps 7.4.1.7 – 7.4.1.9

7.4.1.7 Correct the readings with ECFs and calculate the mean batch response for each of the four elements. Calculate the ± 15% value (minimum and maximum value) of the mean value for each of the four elements.

7.4.1.8 Record the mean, minimum and maximum values for all four elements.

7.4.1.9 Highlight all individual element readings that fall outside ± 15% of the mean.

7.4.1.10 Complete Batch Homogeneity Report (KFH-HP-029) for 802 TLDs or 809 Neutron TLDs as appropriate.

7.4.1.11 All TLDs that have failed the homogeneity test must be prioritised for ECF correction prior to the next TLD processing for wearing period dose assignment. R

7.4.2 Repeatability Test

The repeatability test is carried out to prove that the standard deviation on response of each dosemeter and all dosemeters collectively does not exceed 7.5%.

7.4.2.1 Select a random sample of 200 personnel badges from the TLD stock (badges that are in regular use).

7.4.2.2 Anneal the badges and expose them to approximately 200 mR in the WE2001 irradiator.

7.4.2.3 Allow for short term fading (± 24) hrs and read.

7.4.2.4 Repeat steps 7.4.2.2 to 7.4.2.3 a total of ten times, making sure that the exposure time selected for each exposure is identical.

7.4.2.5 When all the TLDs are read combine the read files. Process the readings using RADPRO and System Admin TLD File Processing Application.
For manual processing follow steps 7.4.2.6 – 7.4.2.11

7.4.2.6 Correct the readings with ECFs.

7.4.2.7 Calculate the mean read-out value r and standard deviation S_1 for each element of each badge over the ten exposures and record it on Panasonic Repeatability form (KFH-HP-085) in groups of 50 TLDs.

7.4.2.8 Calculate $\left(\frac{S_1}{r}\right)$ for each element of each badge and record it on Panasonic Repeatability form (KFH-HP-085).

7.4.2.9 Calculate $\overline{\left(\frac{S_1}{r}\right)}$ and standard deviation S_2 of $\overline{\left(\frac{S_1}{r}\right)}$ and record it.

7.4.2.10 Calculate $\overline{\left(\frac{S_1}{r}\right)} + 0{,}139.S_2$ and record it.

7.4.2.11 Show that $\overline{\left(\frac{S_1}{r}\right)} + 0{,}139.S_2 < 0{,}075$.

NOTE: *$\overline{\left(\frac{S_1}{r}\right)}$ is the average of $\left(\frac{S_1}{r}\right)$ over the 200 TLDs, and S_2 is the standard deviation of $\overline{\left(\frac{S_1}{r}\right)}$.*

7.4.2.12 If the TLDs fail this test collectively then the test must be repeated. If the test fails again a check of the reader calibration must be carried out and any faults rectified. The heating lamp or a major heat sink is often the most probable cause for concern. The reader must be recalibrated if any changes were made to the heating of the reader. The reader must not be used for any further reading and must be tagged with a Do Not Use sign until this test passes the criteria. If single dosemeters fail the test then the failed TLDs must be removed from service. New ECF's must be assigned to the failed TLDs. The test must be repeated for the failed TLDs before placing them back in service.

7.4.2.13 All processed results must be retained for record purposes.

7.4.3 Stability of Stored Information Test

The evaluated value of dosemeters irradiated to a known dose equivalent shall not alter by more than 5% for 30 days storage. If this value cannot be met the effects of fading over the wearing period must be corrected for. This is done with the Dose assessment algorithm at Koeberg.

7.4.3.1 Select a random sample of 150 regularly worn personnel badges.

7.4.3.2 Anneal the badges and expose 100 TLDs to approximately 200 mR in the WE2001 irradiator.

NOTE: *The sample size must be 100 badges.*

7.4.3.3 Store both the irradiated and unirradiated TLDs in the safe in RP Dosimetry for 30 days.

7.4.3.4 After 30 days read out the 50 unirradiated TLDs and the 100 irradiated TLDs to two separate files on the PC and identify the groups as follows:

(1) Unirradiated Group (50 TLDs) – $\mathbf{r_0}$

(2) Group irradiated 30 days earlier (100 TLDs) – $\mathbf{r_{30}}$

7.3.4.5 Re-anneal the r_{30} group and expose it 200 mR in the TLD irradiator using the same time setting as that selected in 7.4.3.2. (The exposure must be exactly the same as in 7.4.3.2).

7.3.4.6 Store the TLDs for 24 hours in the safe in RP Dosimetry and read them out to a new file. This group is called $\mathbf{r_1}$ (100 TLDs).

7.3.4.7 Process the readings using RADPRO and System Admin TLD File Processing Application.
For manual processing follow steps 7.4.3.8 – 7.4.3.12

7.3.4.8 ECF correct all readings.

7.3.4.9 Calculate the mean background (r0) for each of the four elements of group r0 and record it on Panasonic Stability of Stored Information Test form (KFH-HP-086).

7.4.3.10 Calculate the value of P for each element of each TLD where:

$P = \frac{r_1 - (r_{30} - r_0)}{r_1}$ and record it on Panasonic Stability of Stored Information Test form (KFH-HP-086).

7.4.3.11 Compute $\bar{P}$ (mean) and standard deviation (S) of P for each element and record it.

7.4.3.12 Compute the average fading over 30 days for each element as follows:

(1) Fading = $\bar{P}$ + 0,199.S (NB. 95% confident value).

(2) Record the values on Panasonic Stability of Stored Information Test form (KFH-HP-086).

7.4.3.13 Should the fading results vary substantially from previous tests, then the fading correction factors in the algorithm must be adjusted.

NOTE: *Fading results are halved because it cannot be determined when, over a 30 day period, dose was accrued. The middle of the month is thus used as a central figure (i.e. divide 30 days by 2). The 30-day storage results are therefore divided by 2.*

7.4.3.14 All processed results must be retained for record purposes.

7.4.4 Dose Evaluation Test

This test is done to demonstrate system accuracy with exposures done independently.

7.4.4.1 Select a sample of 16 UD-802 TLDs.

7.4.4.2 The irradiations are performed at NMISA or any other accredited laboratory approved by the NNR.

7.4.4.3 Specify that the badges must be irradiated with Cs-137 to the following:

- 8 badges must be irradiated to below the Reader cross-over point less than 10 mSv (< 1000 mR).
- 8 badges must be irradiated to above the Reader cross-over point greater than 20 mSv (> 2000 mR).

NOTE: *TLDs must be irradiated to a dose below 10 mSv and above 20 mSv to ensure the reader is using the correct counter and is not within the uncertainty area associated with the cross over point.*

7.4.4.4 Anneal the 16 TLDs as well as the two background TLDs. (Label the TLDs from 1 – 16 for easy grouping). Place the badges inside the TLD holders and pack them in the box to be forwarded to NMISA. Enclose a letter stating all details and requirements. See template Appendix 1.

7.4.4.5 Once the badges have been returned, read the TLDs to two separate files.

Group 1-8 TLDs (numbered 1-8) exposed to < 10 mSv

Group 2-8 TLDs (numbered 9-16) exposed to > 20 mSv

Include background TLDs

Process the readings using RADPRO and System Admin TLD File Processing Application.
For manual processing follow steps 7.4.4.6 – 7.4.4.7

7.4.4.6 Obtain a printout of the readings.

7.4.4.7 On the printout, ECF correct all the readings and obtain the average of the two background badges and then process through the dose assessment algorithm. (Manual calculation) Calculate the average of E3 for the 8 low exposures and the 8 high exposures.

7.4.4.8 Fill in the results on the Dose Evaluation Test form (KFH-HP-067)

7.4.4.9 The average E3 readings must fall within ± 15% of the irradiated dose for both groups. If this criteria is not met the test must be repeated. If the test fails again investigate in conjunction with service provider.

7.5 2-yearly (± 3 months) Quality Control

NOTE 1: *Applicable to all dosemeters used for the purpose of environmental monitoring.*

NOTE 2: *All calculations are done using spreadsheet ESL QC MASTER new on TLD PC in computer room.*

7.5.1 Reproducibility (ESL)

7.5.1.1 This test must be performed on ALL dosemeters used for the purpose of environmental monitoring.

7.5.1.2 Anneal the badges and expose them on the TLD jig in N040 to approximately 20 mR using Cs-137.

7.5.1.3 Store the TLDs in a low background area for ± 24 hours for short term fading.

7.5.1.4 Read out and determine the ECF corrected value for each element of each dosemeter.

7.5.1.5 Calculate the average value E_{avg} for each dosemeter (average of four elements).

NOTE: *Apply % CV to the ECF corrected values to identify incorrect element readings.*

7.5.1.6 Repeat steps 7.5.1.2 – 7.5.1.5 three more times to have four sets of data.

7.5.1.7 For each of the four irradiations, calculate the mean $\bar{E}_{avg}$ (irr) and the standard deviation $S_{\bar{E}avg}$ (irr). Where $\bar{E}_{avg}$ (irr) is the mean value for the total number of dosemeters in each irradiation, i.e. the mean of the average values E_{avg} for each irradiation.

7.5.1.8 Show that for each of the four irradiations: $\dfrac{S_{\bar{E}avg}(irr) + I(irr)}{\left(\dfrac{\sum_{i=1}^{4} \bar{E}avg}{4}\right)} \leq 0{,}075$ where

$I(irr)(n) = t_n \sqrt{\dfrac{0{,}5}{n-1}} \cdot S_{\bar{E}avg}$, t_n is the student's t factor and n=number of dosemeters.

7.5.1.9 For each of the dosemeters, determine the mean value $\bar{E}$ (TLD) and the standard deviation $S_{\bar{E}}$ (TLD), where $\bar{E}$ (TLD) is the mean value for the total number of element readings over the four irradiations, for each dosemeter, i.e. mean value for 16 readings from each TLD.

NOTE: *If incorrect element readings were detected they must be exclude from the calculations, hence there will be less than 16 readings.*

7.5.1.10 Show that for each of the dosemeters: $\frac{S_{\bar{E}}(TLD) + I(TLD)}{\bar{E}(TLD)} \leq 0{,}075$, where

$I(TLD) = t_n \sqrt{\frac{0{,}5}{n-1}} \cdot S_{\bar{E}(TLD)}$, t_n is the student's t factor and n=number of element readings.

7.5.1.11 If the TLDs fail this test collectively then the test must be repeated. If the test fails again a check of the reader calibration must be carried out and any faults rectified. The heating lamp or a major heat sink is often the most probable cause for concern. The reader must be recalibrated if any changes were made to the heating of the reader. The reader must not be used for any further reading and must be tagged with a Do Not Use sign until this test passes the criteria. If single dosemeters fail the test then the failed TLDs must be removed from service. New ECF's must be assigned to the failed TLDs. The test must be repeated for the failed TLDs before placing them back in service.

7.5.2 Batch Homogeneity Test (ESL Badges)

7.5.2.1 Combine with REPRODUCIBILITY TEST by using one set of data from REPRODUCIBILITY TEST to perform BATCH HOMOGENEITY TEST.

7.5.2.2 This test must be performed on ALL dosemeters used for the purpose of environmental monitoring.

7.5.2.3 Anneal and irradiate all dosemeters in the batch on the TLD jig in N040 to approximately 20 mR using Cs-137.

7.5.2.4 Store the TLDs in a low background area for ± 24 hours for short term fading.

7.5.2.5 Read out and determine the ECF corrected value for each element of each dosemeter.

7.5.2.6 Calculate the average value E_{avg} for each dosemeter (average of four elements).

NOTE: *Apply % CV to the ECF corrected values to identify incorrect element readings.*

7.5.2.7 Identify the elements with the maximum and minimum ECF corrected values, E_{max} and E_{min} respectively.

7.5.2.8 Show that:

$$\frac{E_{max} - E_{min}}{E_{min}} \leq 0{,}3$$

$|E - C| \leq (30\ \mu Sv)\ 3\ mrem$ for each element of each dosemeter

(15% of 20 mrem = 3 mrem).

7.5.2.9 Identify the dosemeters with the maximum and minimum average values, E_{avgmax} and E_{avgmin} respectively.

7.5.2.10 Show that:

Eavgmax

$$\frac{E_{avg\max} - E_{avg\min}}{E_{avg\min}} \leq 0{,}3$$

7.5.2.11 If the above criteria are not met, new ECFs must be assigned.

7.5.3 Detection Threshold (ESL)

7.5.3.1 This test must be performed on ALL dosemeters used for the purpose of environmental monitoring.

7.5.3.2 Anneal and read out all dosemeters.

7.5.3.3 Determine the ECF corrected value for each element of each (unirradiated) dosemeter and the average value E_{avg} for each dosemeter (average of four elements).

7.5.3.4 Calculate the mean of the evaluated values $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for all n dosemeters.

7.5.3.5 Show that: $t_n \cdot s_{\bar{E}avg} \leq H$, where H=30 μSv (3 mrem) and t_n is the student's t factor for the number of TLDs in the batch.

n	t_n
5	2,78
10	2,26
15	2,15
20	2,09
50	2,01

7.5.3.6 If the TLDs fail this test then the test must be repeated. If the test fails again a check of the reader calibration must be carried out and any faults rectified. The heating lamp or a major heat sink is often the most probable cause for concern. The reader must be recalibrated if any changes were made to the heating of the reader. The reader must not be used for any further reading and must be tagged with a Do Not Use sign until this test passes the criteria. If single dosemeters fail the test then the failed TLDs must be removed from service. New ECF's must be assigned to the failed TLDs. The test must be repeated for the failed TLDs before placing them back in service.

7.6 Performance Tests for Legal Dosemeters

(1) The following tests shall be carried out on all new types of TLDs, i.e. all TLDs other than UD-802s if used as legal monthly worn TLDs. All test criteria must be met before being commissioned.

(2) All new batches of UD-802 TLDs shall be subjected to tests 7.6.1 to 7.6.5. If any of these tests fail the new batch of UD-802 TLDs must not be placed in service. The tests must be repeated. If the tests still fail the new TLDs must be investigated or returned to the manufacturer.

7.6.1 Batch Homogeneity Test

In accordance with section 7.4.1.

7.6.2 Repeatability Test

In accordance with section 7.4.2.

7.6.3 Stability of Stored Information Test

In accordance with section 7.4.3.

7.6.4 Stability of Zero Point

After a storage period of 30 days the zero point shall not exceed 0.5 mSv for element 1 and 0.1mSv for elements 2 and 4.

7.6.4.1 Anneal 50 TLDs twice, in order to achieve residual readings.

7.6.4.2 Read the 50 TLDs (d0).

7.6.4.3 Store the TLDs in a low background area for 30 days.

7.6.4.4 Read the 50 TLDs (d30).

Process the readings using RADPRO and System Admin TLD File Processing Application.
For manual processing follow steps 7.6.4.5 – 7.6.4.6

7.6.4.5 ECF correct all readings. Calculate d30-d0 for each TLD element and obtain the mean $\bar{d}$ and standard deviation, S, for the group.

7.6.4.6 Show that:

$\bar{d} + 0{,}287.S \leq 0.5$ mSv (50 mR) for element 1

$\bar{d} + 0{,}287.S \leq 0.1$ mSv (10 mR) for elements 2 and 4, and

7.6.4.7 Retain all processed results for record purposes.

7.6.5 Detection Threshold

The detection threshold shall not exceed 0.5 mSv for element 1 and 0.1 mSv for elements 2 and 4.

7.6.5.1 Anneal 50 TLDs twice, in order to achieve residual readings.

7.6.5.2 Read out the 50 TLDs (d0).

Process the readings using RADPRO and System Admin TLD File Processing Application.
For manual processing follow steps 7.6.5.3 – 7.6.5.4

7.6.5.3 ECF correct all readings. Calculate the mean ($\bar{d}$) and standard deviation (S) for the group.

7.6.5.4 Show that:

$2{,}01.S \leq 0.5$ mSv (50 mR) for element 1, and

$2{,}01.S \leq 0.1$ mSv (10 mR) for elements 2 and 4

7.6.5.5 Retain all processed results for record purposes.

7.6.6 Linearity

This indicates that the element response at any exposure level will not differ by more than 5% to the element response at 1 Rad.

(1) Anneal 50 TLDs, irradiate and process them successively to exposures of 40 mR, 100 mR, 1R, 3R and 10R.

(2) Do ECF corrections for all elements at the various exposure levels.

(3) Calculate the ratio R = (Ni - N1)/N1 where:

- Ni is the response of the element at exposure i
- N1 is the response of the element at 1R

(4) Calculate the mean $\bar{R}$ and standard deviation S for each group of elements at the various exposures.

(5) Show that $\bar{R} + 0{,}287\ S \leq 0{,}05$.

7.6.7 Dose Range

This is to show that the evaluated dose shall be an increasing function of dose up to at least 1000 R.

NOTE: *These TLDs cannot be used again for operational purposes.*

(1) Anneal four TLDs, irradiate and process them successively to exposures of 10 Rad, 100 Rad, 500 Rad and 1000 Rad.

(2) Do ECF corrections for each exposure level, 10R, 100R, 500R and 1000R.

(3) Show that 10R < 100R < 500R < 1000R.

7.6.8 Effect to Exposure to Light

(1) Anneal 20 TLDs and divide them into two equal groups.

(2) Expose one group to the following conditions:

- One week to 10,000 lux from a daylight fluorescent lamp
- Temperature shall be $\leq$ 40°C

NOTE: *Expose the group inside the holders.*

(3) Store the second group in a dark place at a temperature of approximately 5°C from that of the first group.

(4) Process both groups after one week and calculate the means, M_1 and M_2 (for all elements).

(5) Show that:

- $M_2 - M_1 \leq 50$ mrad for element 1
- $M_2 - M_1 \leq 10$ mrad for elements 2 and 4.

7.6.9 Spectral Response

(1) Anneal 80 TLDs and have them exposed on a phantom by NMISA or any other suitably accredited laboratory approved by the NNR to a dose of 1 Rad to the following:

Photons: 10 dosemeters to 15.8 keV x-rays
10 dosemeters to 30-40 keV x-rays
10 dosemeters to 80-100 keV x-rays
10 dosemeters to 662 keV from Cs-137
10 dosemeters to Co-60

Betas: 10 dosemeters to Sr 90 / Y-90 betas
10 dosemeters to TI-204 betas
10 background dosemeters

(2) Process the TLDs, do ECF and background corrections and show that:

Photons: Response is between 0,7 and 1,3 for elements 1 and 2.

Betas: Response is between 0,7 and 1,3 for element 1.

NOTE: *Failure to comply with these criteria must be corrected for in the dose assessment algorithms.*

7.6.10 Isotropy

7.6.10.1 Photons

(1) Anneal 20 TLDs and have them exposed on a phantom by NMISA or any other suitably accredited laboratory approved by the NNR to a dose of 1 Rad from 40 keV ± 20 keV at the following angles of incidence:

10 TLDs at normal incident
10 TLDs at 20°
10 TLDs at 40°
10 TLDs at 60°

(2) Process the TLDs and do ECF corrections.

(3) Show that all the average responses are within 10% of that at normal incidence.

NOTE: *These tests are normally done by the manufacturer for high energy gammas, i.e. Co-60.*

7.6.10.2 Betas

(1) Anneal 20 TLDs and have them exposed on a phantom NMISA or any other suitably accredited laboratory approved by the NNR to.

1 Rad from Sr-90 / Y-90 betas, under the following:

10 TLDs at normal incident
10 TLDs at 45° to normal incidence.

(2) Process the TLDs and do ECF corrections.

(3) Show that the average response at 45° is within 30% of that at normal incidence.

7.6.11 Remanance (Memory)

(1) Anneal 10 TLDs. Read out the TLDs and record the residual readings, R_0.

(2) Irradiate the TLDs to approximately 10 Rads.

(3) Read out the TLDs and ECF correct the readings, R_1.

(4) Read it out again, R_2.

(5) Calculate the ratios $\frac{R_0 - R_2}{R_1}$ and the mean ratios $\overline{r_m}$ and standard deviation, S_m.

(6) Show that $\overline{r_m} + 1{,}5\ S_m \leq 0{,}001$ (0,1%).

NOTE: *If this test fails, then minimum criteria for annealed TLDs must be established, i.e. maximum residual readings that are allowed before issue.*

7.6.12 Effect to Climatic Changes

7.6.12.1 Dry Heat

(1) Anneal 20 TLDs and expose them to approximately 1 Rad.

(2) Store the TLDs in a low background area for one day.

(3) After one day, remove 10 TLDs and do the following:

Place the TLDs in a chamber where the humidity is 65%.
Raise the temperature to 50°C over a period of 30 minutes.
Maintain this temperature for 30 days.
Reduce the temperature to 20°C over 30 minutes.

(4) Process all 20 TLDs.

(5) Calculate the mean read-out values for both groups, T_{50} (those exposed to 50°C) and T_N (normal temperature).

(6) Show that $T_{50}/T_N \geq 0,8$.

7.6.12.2 Humidity

(1) Anneal 20 TLDs and expose them to approximately 1 Rad.

(2) Keep 10 TLDs in a low background area and 10 TLDs under the following conditions:

(a) Place the TLDs in a chamber at 20°C ± 2°C and relative humidity of 90%.

(b) After 30 days, process the two groups, T_{90} and T_N, and calculate the mean read-out values.

(c) Show that $\frac{T_N - T_{90}}{T_N} \leq 0,2$.

NOTE: *The ESL can conduct these tests.*

7.7 Performance Tests for Environmental Dosemeters

7.7.1 The following tests shall be carried out on all new types of TLDs other than UD-812s if used for environmental monitoring. All test criteria must be met before being commissioned.

7.7.2 All new batches of UD-812 TLDs shall be subjected to tests 7.7.3 to 7.7.7. If any of these tests fail the new batch of UD-812 TLDs must not be placed in service. The tests must be repeated. If the tests still fail the new TLDs must be investigated or returned to the manufacturer.

7.7.3 Reproducibility

In accordance with section 7.5.2.

7.7.4 Detection Threshold

In accordance with section 7.5.3.

7.7.5 Stability of Dosemeters under Various Climatic Conditions

(1) Prepare two groups of five dosemeters each.

(2) Store both groups for 24 hours under standard conditions.

(3) Irradiate group 1 to approximately 1R, using the Cs-137 source and exposure jig.

(4) Store both groups of dosemeters in a climatic chamber in which standard test conditions prevail.

(5) After a continuous period of 30 days, remove both groups of dosemeters from the climatic chamber. Irradiate group 2 to approximately 1R, using the Cs-137 source and exposure jig.

(6) Store both groups for 24 hours under standard test conditions.

(7) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) after stripping the overexposure factor from all four elements.

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(8) Calculate the mean of the average values, $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for each of the two groups.

(9) Show that for each group: $\frac{\bar{E}_{avg}}{C} \pm 1{,}24.S_{\bar{E}_{avg}} \leq 1{,}05$, where

$I = \frac{t_n \cdot S_{\bar{E}avg}}{\sqrt{n}}$ and t_n is the student's t factor.

n	t_n
5	2,78
10	2,26
15	2,15
20	2,09
50	2,01

(10) Repeat the test for a storage period of 90 days.

(11) Show that: $0{,}90 \leq \frac{\bar{E}_{avg}}{C} \pm I \leq 1{,}10$, where I is calculated as above.

NOTE: *The following steps are only applicable as type tests.*

(12) Repeat the test for a storage period of 30 days but store in a climatic chamber in which the temperature is 50°C ± 2°C and the relative humidity are about 65%.

(13) Show that: $0{,}80 \le \frac{\bar{E}_{avg}}{C} \pm I \le 1{,}20$, where I is calculated as above.

(14) Repeat the test for a storage period of 30 days but store in a climatic chamber in which the temperature is 20°C ± 2°C and the relative humidity is 90%.

(15) Show that: $0{,}80 \le \frac{\bar{E}_{avg}}{C} \pm I \le 1{,}20$, where I is calculated as above.

7.7.6 Self-irradiation

(1) Anneal 10 dosemeters.

(2) Store for 30 days in a location where the background dose rate stays constant together with three EPDs to determine background irradiation.

(3) Read out dosemeters and determine the ECF corrected values for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements).

(4) Calculate the mean of the average values $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for the 10 dosemeter.

(5) Use the average EPD readings to determine the background (C_b) irradiation during storage.

(6) Show that: $(\bar{E}_{avg} + 0{,}715 \,.\, S_{\bar{E}_{avg}}) - C_b \le 30$ mSv (3 mrem) .

7.7.7 Effect of Light Exposure on the Dosemeters

<u>Effect on zero point</u>

(1) Anneal two groups of 20 dosemeters each.

(2) Expose group 1 to 1000 $W.m^{-2}$ of light for 24 hours (dosemeter temperature maintained at less than 40°C).

(3) Store the group 2 dosemeters in the dark in an otherwise identical environment. (Ensure that the temperature of the two groups of dosemeters is within ± 15°C of one another).

(4) After one day, read out all dosemeters and determine the ECF corrected values for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements).

(5) Calculate the mean of the average values $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for each of the two groups.

(6) Show that: $[\bar{E}_{avg}(group1) - \bar{E}_{avg}(group2)] \pm I \leq 30mSv(3mrem)$, where $I = \sqrt{I_1^2 + I_2^2}$ for $I_i = 0{,}467.S_i$; i=1,2.

Effect on response

(1) Anneal two groups of 20 dosemeters each.

(2) Irradiate to approximately 1R, using the Cs-137 source and exposure jig.

(3) Expose and store both groups as in above.

(4) After 168 hours (7 days), read out all dosemeters and determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) after stripping the overexposure factor.

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(5) Calculate the mean of the average values, $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for each of the two groups.

(6) Show that: $0{,}90 \leq \frac{\bar{E}_{avg}(group1)}{\bar{E}_{avg}(group2)} \pm I \leq 1{,}10$, where $I = \frac{\bar{E}_1}{\bar{E}_2}\sqrt{\left(\frac{I_1}{\bar{E}_1}\right)^2 + \left(\frac{I_2}{\bar{E}_2}\right)^2}$ for $I_i = 0{,}467.S_i$; i=1,2.

7.7.8 Linearity

(1) Anneal, irradiate and read out five groups of 10 dosemeters.

(2) The exposure for each group shall be 3 mR, 10 mR; 0,1 R; 1 R and 10 R, using the Cs-137 source.

(3) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) (after stripping the overexposure factor for jig exposures).

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(4) Calculate the mean of the average values, $\bar{\bar{E}}_{avg}$ at each irradiation level and its standard deviation $S_{\bar{\bar{E}}avg}$, where $\bar{\bar{E}}_{avg}$ is the mean value for the total number of dosemeters in each irradiation level.

NOTE: *If incorrect element readings were detected they must be excluded from the calculations.*

(5) Show that at each irradiation level: $0{,}9 \leq \dfrac{\bar{\bar{E}}_{avg} \pm 0{,}715.S_{\bar{\bar{E}}_{avg}}}{C} \leq 1{,}10$.

7.7.9 Residual Signal

Effect on detection threshold

(1) Anneal, irradiate and read out 10 of the dosemeters used for the detection threshold test.

(2) The exposure shall be approximately 1R, using the Cs-137 source and exposure jig.

(3) Using same dosemeters repeat the test for detection threshold.

Effect on response

(1) Anneal, irradiate and read out 10 of the dosemeters used for the detection threshold test.

(2) The exposure shall be approximately 20 mR, using the Cs-137 source and exposure jig.

(3) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements).

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(4) Calculate the mean of the average values $\bar{\bar{E}}_{avg}$ and standard deviation $S_{\bar{\bar{E}}avg}$ for the 10 dosemeter.

(5) Show that: $0{,}90 \leq \dfrac{\bar{\bar{E}}_{avg} \pm 0{,}715.S_{\bar{\bar{E}}_{avg}}}{C} \leq 1{,}10$.

7.7.10 Energy Response (Photons)

(1) Anneal, irradiate and read out three groups of 5 dosemeters each.

(2) The exposure value shall be approximately 1R using the following radiations:

Group 1: reference radiation in range 30-40 keV
Group 2: reference radiation in range 80-100 keV
Group 3: ^{137}Cs

(3) Group 1 and Group 2 must be sent to NMISA for exposure. Group 3 is exposed using the Cs-13,7 source and exposure jig.

(4) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) after stripping the overexposure factor (Group 3 only).

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(5) Calculate the mean of the average values, $\bar{E}_{avg}$ and standard deviation $S_{\bar{E}avg}$ for each of the three groups.

(6) For Group 1 show that: $\dfrac{\bar{E}_{avg} + 1{,}24.S_{\bar{E}_{avg}}}{C} \leq 2$

(7) For Groups 2 and 3 show that: $0{,}7 \leq \dfrac{\bar{E}_{avg_i} \pm 1{,}24.S_{\bar{E}_{avg_i}} \leq 1{,}3 \quad (i = 2, 3)}{C}$

7.7.11 Isotropy (Photons)

(1) Anneal, irradiate and read out three groups of 5 dosemeters each.

(2) The exposure value shall be approximately 1 R using the Cs-137 source and exposure jig.

(3) During irradiation, each dosemeter in each group shall be rotated around one of three perpendicular axes using the centre of the dosemeter as the centre of rotation.

(4) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) after stripping the overexposure factor.

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(5) Calculate the mean of the average values, $\bar{\bar{E}}_{avg}$ and standard deviation $S_{\bar{\bar{E}}avg}$ for each of the three groups.

(6) Show that, for each group: $0{,}85 \leq \dfrac{\bar{\bar{E}}_{avg} \pm 1{,}24 S_{\bar{\bar{E}}_{avg}}}{C} \leq 1{,}15$

7.7.12 Dropping Effect on Dosemeter

(1) Anneal and irradiate two groups of 5 dosemeters each.

(2) The exposure value shall be approximately 1 R, using the Cs-137 source and exposure jig.

(3) Read out the dosemeters under the following conditions:

Group 1: normal operation
Group 2: after dropping the dosemeters 1 m onto a concrete surface.

(4) Determine the ECF corrected value for each element of each dosemeter and the average value E_{avg} for each dosemeter (average of four elements) after stripping the overexposure factor.

NOTE: *Apply % CV to evaluated values to identify incorrect element readings.*

(5) Calculate the mean of the average values, $\bar{\bar{E}}_{avg}$ and standard deviation $S_{\bar{\bar{E}}avg}$ for each group.

(6) Show that:

$$0{,}90 \leq \frac{\bar{\bar{E}}_{avg(group1)}}{\bar{\bar{E}}_{avg}(group2)} \pm I \leq 1{,}10, \text{ where } I = \frac{\bar{\bar{E}}_1}{\bar{\bar{E}}_2}\sqrt{\left(\frac{I_1}{E_1}\right)^2 + \left(\frac{I_2}{E_2}\right)^2} \text{ for}$$

$$I_i = 1{,}24.S_{\bar{\bar{E}}_{avg}}; \quad i = 1{,}2$$

7.8 Performance Tests for Neutron Dosemeters

7.8.1 The following type tests shall be performed on new types of TLDs other than UD-809 if used for neutron measurements. All test criteria must be met before being commissioned.

7.8.2 All new batches of UD-809 TLDs (new production) that Koeberg purchase for use as neutron TLDs shall be subjected to test 7.8.5. If this test fails the new batch of UD-809 TLDs must not be placed in service. The test must be repeated. If the test still fails the new TLDs must be investigated or returned to the manufacturer.

7.8.3 Energy Response to Neutrons

(1) Anneal, irradiate and read out four groups of 10 dosemeters each using the following radiations:

Group 1: Neutron energy range up to 10 keV
Group 2: keV neutron energy range > 10 keV
Group 3: D20-Moderated Californium-252
Group 4: Am-Be fast neutrons

(2) Exposure for group 1 to 3 must be performed by off site irradiation facilities.

(3) Read and determine the ECF corrected value E for each element of each dosemeter.

(4) Determine for each element $\frac{E_i}{C}$, where C = exposure value and i = 1, 2, 3, 4.

(5) These response values will be used in the dose assessment algorithms.

7.8.4 Energy Response to Photons

(1) Anneal and irradiate 10 dosemeters to approximately 5 mSv (500 mrem) on the TLD jig in N040 using Cs-137.

(2) The Secondary Standard must be used to determine the true exposure value (C).

(3) Store the TLDs in a low background area for ± 24 hours for short term fading.

(4) Read and determine the ECF corrected value E for each element of each dosemeter.

(5) Calculate the mean of the ECF corrected values, $\bar{E}_i$ for each element and the standard deviation $S_{\bar{E}i}$ for each element.

(6) Show that: $0{,}7 \leq \frac{\bar{E}_i \pm 0{,}715.S_{\bar{E}_i}}{C} \leq 1{,}3$, (i=1, 2, 3, 4).

NOTE: *Failure to comply with these criteria must be corrected for in the dose assessment algorithms.*

7.8.5 Detection Threshold

(1) Anneal and read out 10 dosemeters.

(2) Determine the ECF corrected value for each element of each (unirradiated) dosemeter.

(3) Calculate the mean of the ECF corrected values, $\bar{E}_i$ for each element and the standard deviation $S_{\bar{E}i}$ for each element.

(4) Show that: $2{,}26 \cdot S_{\bar{E}_i} \leq H$, where i=1, 2, 3, 4 and H=100 μSv (10 mrem).

7.9 TLD Element Correction Factors (ECFs)

(1) Element Correction Factors are applied to all type 802, 809, and 812 dosemeters used at Koeberg. ECFs are determined by exposing the TLDs to the same dose, four consecutive times in order to obtain acceptable statistics.

(2) Any dose can be selected to produce ECFs as long as all the TLDs including the reference badges, if used, are exposed to the same dose. Approximately 250 mR is normally used.

7.9.1 Determining Reference Badges

7.9.1.1 Anneal the batch of TLDs (ideally approximately 500 badges).

7.9.1.2 Irradiate the TLDs in the WE2001 irradiator to approximately 250 mR. Allow for fading (± 24 hours) and read.

7.9.1.3 Repeat 7.9.1.1 and 7.9.1.2 three more times. Read the badges to a new file each time.

7.9.1.4 Transfer one file for the normal TLD processing routine (TLD type).

7.9.1.5 Transfer one file to RADPRO sysadmin for the **Process ECF routine** (ECR type).

7.9.1.6 Transfer all four to RADPRO sysadmin for the **Process ECF routine** (ECE type) with the same group number as the file in 7.9.1.4.

7.9.1.7 Process the readings using RADPRO and System Admin TLD File Processing Application to determine the average of the readings and the standard deviation. The standard deviation must demonstrate a uniform response for the batch of TLDs and should ideally be below 20%.

***NOTE**: Update TLD information in DosiGui prior to performing processing in System Admin and ensure and ECF of 1 has been assigned.*

7.9.1.8 Use the **Process ECF** routine, which will generate a report that flags TLDs exceeding the criteria (>5% percentage difference) with a * to make selection of exactly 50 TLDs easier (delete the others from the file). This will ensure a batch of TLDs is selected with an ECF sufficiently close to 1 to not need changing. This batch then provides an accurate average reading to determine temporary ECF's for the remainder of the TLDs in the batch.

NOTE: *The exposure value (average of the four elements) is obtained from step 7.9.1.7 above.*

7.9.1.9 Generate a print-out of these values, including a distribution summary.

7.9.1.10 Use the **Get average ECFs** routine to obtain a report of temporary ECFs for the remainder of the exposed TLDs in the batch of four exposure files. Then use the **Check TLDs** and **USE ECFs** routine and then print the report.

7.9.1.11 Manually select the TLDs with the smallest ECFs (closest to 1). For use as reference badges.

7.9.1.12 Anneal the selected Reference TLDs.

7.9.1.13 Expose the selected Reference TLDs, including the initially selected 50 TLDs on the TLD jig in N040 to 250 mR using Cs-137. Allow for fading (± 24 hours) and read.

7.9.1.14 Repeat 7.9.1.7 – 7.9.1.8 three more times. Read the badges to a new file each time and transfer to RADPRO for use with the **Reference** routine (type REF). R

7.9.1.15 ECFs are calculated by dividing each reading of each element by the delivered dose to obtain four sets of ECFs for each element of each TLD. The assigned ECF is the average of the four ECFs calculated for each element of each TLD. This is done on the RADPRO system and System Admin TLD File Processing Application.

NOTE: *The QC TLDs must also have their ECFs calculated using the above method.*

7.9.1.16 Transfer the new ECFs and ECF assignment date to Equipments in DosiGui. This is done on the RADPRO system, System Admin TLD File Processing Application.

7.9.2 Assigning Reference Badges

7.9.2.1 Renumber the TLDs as reference TLDs and QC TLDs in the DosiGui Application Equipments screen.

7.9.2.2 Change the identity code of the selected TLDs to reference TLDs and QC TLDs as appropriate. Label the TLDs accordingly.

7.9.3 Determining ECFs for UD-802 Dosemeters

7.9.3.1 Anneal ± 100 reference TLDs. Expose the reference TLDs on the TLD jig in N040 to 250 mR using Cs-137. Allow for fading (± 24 hours) and read.

7.9.3.2 Calculate the % difference from the delivered dose for each element of each TLD. This is done on the RADPRO system and System Admin TLD File Processing Application.

7.9.3.3 Select 50 Reference TLDs where all the elements responded within 5% of the exposed dose.

7.9.3.4 Anneal and irradiate the UD802 TLDs plus the 50 selected reference TLDs to approximately 250 mR using the WE2001 Irradiator.

7.9.3.5 Allow for fading (± 24 hours) and read.

7.9.3.6 Repeat from 7.9.8.3 to 7.9.8.4 three more times. Read the badges to a new file each time.

7.9.3.7 After completion, process the results on the RADPRO system and System Admin TLD File Processing Application.

7.9.3.8 The ECF of the UD-802 TLD is calculated by dividing each reading of each element of each TLD by the average element response of the reference badges for the corresponding element for each exposure to obtain four sets of ECFs for each element of each TLD. The assigned ECF is the average of the four ECFs calculated for each element of each TLD.

7.9.3.9 Generate a printout of the ECFs.

7.9.3.10 TLDs with ECFs less than 0,5 or greater than 1,5 must be removed from service. These TLDs must have their status changed on the database to non-operational in the Equipment's screen in DosiGui. R

7.9.3.11 Transfer new ECFs and ECF assignment date to Equipments in DosiGui. This is done on the RADPRO system and System Admin TLD File Processing Application.

7.9.4 Determining ECFs for UD-809 Neutron Dosemeters

NOTE: *All calculations are done using spreadsheet Neutron ECF Master 2015 on TLD PC in computer room.*

7.9.4.1 Anneal and irradiate the UD-809 TLDs on the TLD jig in N040 to 250 mR using Cs-137. Allow for fading (± 24 hours) and read.

7.9.4.2 Repeat 7.9.4.1 three more times. Read the badges to a new file each time.

7.9.4.3 Divide each reading of each element by the exposed dose to obtain four sets of ECFs for each element. Calculate the average ECF for each element to determine the assigned ECFs for that TLD. This is done using spreadsheet **Neutron ECF Master 2015** on TLD PC in computer room.

7.9.4.4 Make a printout of the Excel spreadsheet and file in the ECF file.

NOTE: *ECFs for Neutron TLDs must be verified as correct by RP Dosimetry Supervisor.*

7.9.4.5 Update the ECFs manually on the Equipment's screen in DosiGui. Select Equipment Type 809 TLD. By name field type in number of 809 TLD that must be updated. Select and double click for equipment detail screen.

7.9.4.6 TLDs with ECFs less than 0,6 or greater than 1,4 must be removed from service. These TLDs must have their status on the database changed to non-operational in the Equipment's screen in DosiGui.

7.9.5 Determining ECFs for UD-812 Environmental Dosemeters

NOTE: *All calculations are done using spreadsheet ESL QC MASTER new on TLD PC in computer room.*

7.9.5.1 Anneal and irradiate the UD-812 TLDs on the TLD jig in N040 to 20 mR using Cs-137.

7.9.5.2 Allow for fading (± 24 hours) and read.

7.9.5.3 Repeat three more times.

7.9.5.4 Divide each reading of each element by the exposed dose to obtain four sets of ECFs for each element. Calculate the average ECF for each element to determine the ECFs for that TLD. This is done using spreadsheet **ESL QC MASTER new** on TLD PC in computer room.

NOTE: *Element over responses are stripped out, using Excel.*

7.9.5.5 Make a printout of the Excel spreadsheet and file in the ECF file. Submit list of TLD numbers and new ECFs to ESL.

7.9.5.6 ECFs will be recalculated for badges not meeting the % CV and/or Batch Homogeneity criteria as applicable.

8.0 ACCEPTANCE CRITERIA

8.1 As described in body of procedure.

9.0 RECORDS

9.1 Records generated by this procedure:

TLD Reader Calibration Check Record (KFH-HP-083) (Permanent)

Panasonic Performance Index (KFH-HP-084) (Permanent)

Panasonic Repeatability Test (KFH-HP-085) (Permanent)

Panasonic Stability of Stored Information Test (KFH-HP-086) (Permanent)

Dose Evaluation Test (KFH-HP-067) (Permanent)

Batch Homogeneity Report 802 TLDs (KFH-HP-029) (Permanent)

QFD Drift and Response Check Report (Permanent)

Stability of Zero Point Report (Permanent)

Detection Threshold Report (Permanent)

Environmental TLD QC Tests (Permanent)

Environmental TLD Performance Tests on New Batches (Permanent)

Panasonic UD7900M TLD Reader Glow Curve (Permanent) Included with Panasonic Performance Index

9.2 These records must be handled in accordance with KSH-008 requirements

10.0 ATTACHMENTS

Appendix 1 – NMISA Dose Evaluation Test Letter Template

Appendix 2 – Justification

APPENDIX 1

NMISA DOSE EVALUATION TEST LETTER TEMPLATE

NMISA

FOR ATTENTION: TO WHOM IT MAY CONCERN

Date:

Enquiries:
Radiation Protection Dosimetry
☎ 550 4738
FAX: 550 4968

TLD EXPOSURES FOR DOSE EVALUATION TEST

Could you please perform the following service:

1. For our Dose Evaluation Test, TLD exposures in free air using Cs-137.
   TLD Nos 1-8: Exposed to a dose between 500mR and 1000mR (< 1000mR)
   TLD Nos 9-16: Exposed to a dose between 2000mR and 2500mR (> 2000mR)

Please enclose the exact exposures in a sealed envelope together with the TLDs once completed.

Also enclosed are 2 Background TLDs (green labels). There are for our purposes for background determination only and are not to be exposed, but must be stored with the other TLDs at all times.

The Order number for this service is XXXXXXXXXXXX.

Yours sincerely

HEAD OF RP DOSIMETRY
RADIATION PROTECTION

KWH-B014-APP9.PCX

APPENDIX 2

JUSTIFICATION

Revision 8

1. Full review.
2. Forms KFH-HP-029, KFH-HP-067, KFH-HP-083, KFH-HP-084, KFH-HP-085 and KFH-HP-086 removed as Attachments and added to Applicable Documents.

Revision 9

1. Full review to include the following paragraphs:
2. 3.1.7 – Definition for % difference included.
3. 5.1 – Dosimetry staff must be authorised to conduct the tests and checks,
4. 7.1.3.1 – If the secondary standard is not available, or suspicious, during use of the panoramic exposure jig, another instrument, suitable for the exposure, and directly traceable to the National Standard, may be used for QC purposes, following review by a Senior Physicist.
5. 7.9.1 – Changed to outline the method for determining reference badges.
6. CR 118973-011 GA – Review Dosimetry procedures for alignment with current practices.

Revision 9a

1. Partial review, updated sections listed below:
2. Page 7, paragraph 6.2.
3. Pages 9 and 10, paragraphs 7.1.3.8, 7.1.3.9.
4. Pages 18, paragraph 7.4.1.11.
5. Page 40, paragraph 7.9.3.10.