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Y-12
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# Dosimetry Quality Assurance in Martin Marietta Energy Systems' Centralized External Dosimetry System


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# Dosimetry Quality Assurance in Martin Marietta Energy Systems' Centralized External Dosimetry System

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Martin Marietta Energy Systems, Inc. manages three Department of Energy (DOE) facilities in Oak Ridge, Tennessee, one DOE facility in Paducah, Kentucky, and one DOE facility in Portsmouth, Ohio. The facilities in Oak Ridge, Tennessee are the K-25 Site, the Oak Ridge Y-12 Plant, and the Oak Ridge National Laboratory (ORNL); the facility in Paducah, Kentucky is the Paducah Gaseous Diffusion Plant (PGDP), and the facility in Portsmouth, Ohio is the Portsmouth Gaseous Diffusion Plant. This paper will address the external dosimetry Quality Assurance programs at the Oak Ridge and Paducah facilities, which are served by one external dosimetry program. External dosimetry at the Portsmouth facility, which is performed under a separate program, will not be addressed.

The three facilities in Oak Ridge were built in the 1940's as part of the Manhattan Project. The K-25 Site, formerly known as the Oak Ridge Gaseous Diffusion Plant (ORGDP) began its operation as the world's first gaseous diffusion facility with its initial goal to support national defense programs. The ORGDP evolved into a center for uranium production and technology development until it was placed on standby status in 1985. In 1987 the plant was removed from standby status and phased out of production entirely. The K-25 Site now performs several work-for-others projects and is involved in waste treatment technology and remedial action programs.

The Oak Ridge Y-12 Plant was originally built to separate uranium by electromagnetic separation for the war effort. Since World War II the plant's mission has consisted primarily of manufacturing and development designed to produce nuclear weapons components and support DOE's weapons design laboratories. Other areas of the plant's mission have been to process source and special nuclear materials and provide support for other DOE facilities. With the changing world political climate of the 1990's the plant's mission has evolved to an emphasis on weapons disassembly , environmental restoration, and future decommissioning

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and decontamination.

The Oak Ridge National Laboratory was originally commissioned for the purpose of the production and chemical separation of the world's first gram quantities of plutonium. The plutonium was manufactured using the Graphite Reactor at ORNL. Today, ORNL is a multi-faceted research center with a reputation as one the most distinguished research facilities in the world.

The Paducah Gaseous Diffusion Plant was begun in 1950 to produce U-235 by the gaseous diffusion process. The PGDP today performs the initial enrichment of uranium (up to 2% U-235) for use in the nuclear power industry.

External dosimetry needs at these four Martin Marietta Energy Systems ("Energy Systems") facilities are served by Energy Systems Centralized External Dosimetry System (CEDS). The CEDS is a four plant program with four dosimeter distribution centers and two dosimeter processing centers. Each plant has its own distribution center, while processing centers are located at ORNL and the Y-12 Plant. The program has been granted accreditation by the Department of Energy Laboratory Accreditation Program (DOELAP).

The CEDS is a TLD based system which is responsible for whole-body beta-gamma, neutron, and extremity monitoring. Beta-gamma monitoring is performed using the Harshaw/Solon Technologies model 8805 dosimeter. The configuration of this dosimeter is shown in figure 1. Effective October 1, 1992 the standard silver mylar has been replaced with an Avery mylar foil blackened on the underside with ink. This was done in an effort to reduce the number of light induced suspect readings. At this time we have little operational experience with the new blackened mylars.The CEDS neutron dosimeter is the Harshaw model 8806B. This card/holder configuration contains two TLD-600/TLD-700 chip pairs; one pair is located beneath a cadmium filter and one pair is located beneath a plastic filter as shown in figure 2. In routine personnel monitoring the CEDS neutron dosimeter is always paired with a CEDS beta-gamma dosimeter.The CEDS extremity dosimeter is composed of a Harshaw thin (0.0036 inch) TLD-700 dosiclip placed inside a Teledyne RB-4 finger sachet. The finger sachet provides approximately 7 mg/cm^2 filtration over the chip. A teflon ring surrounds the dosiclip to help prevent tearing of the vinyl sachet (see figure 3).

Dosimeters are read in the Harshaw model 8800 TLD readers. These readers are standard production models which have been modified to include additional radio frequency interference shielding. Additionally, the machines do not include internal irradiators.

The Centralized External Dosimetry System Quality Assurance program covers beta-gamma, neutron, and extremity monitoring programs. Dosimetry QA encompasses such activities as acceptance testing of materials, training of personnel,daily front-line quality assurance programs, and intercomparison/confirmation programs; procedurized methods are in place for handling anomalous operational dosimetry results.

QA program requirements for the program are specified in the CEDS Quality Assurance Plan. The plan addresses both the CEDS processing and distribution centers. The CEDS QA plan complies with DOE Order 5700.6 "Quality Assurance", and the requirements of DOE/EH-0026 have been integrated into the plan. The plan is organized along the eighteen elements of ANSI/ASME NQA-1. Specific operational requirements of the program are found in the CEDS Standard Operating Procedures Manual. The manual contains eighty procedures specific to the program and addresses all aspects of dosimeter distribution and processing. Additionally, preparation of a CEDS self-assessment plan is underway. This plan will provide guidance for self-directed internal assessments and audits of the program. Routine audits are conducted on a regular basis by Energy Systems Quality Assurance personnel.

A quality dosimetry program is built upon high quality material and well-trained personnel. Therefore, the issues of material acceptance testing and training are of importance to the CEDS.

New material introduced into the system is required to undergo initial acceptance testing before being used. Procedurized acceptance tests are in place for the evaluation of new TLD cards, holders, and readers. For new beta-gamma and neutron cards there are four acceptance tests each card must pass. The first of these tests is a physical inspection for damage or gross abnormality. Each card is visually inspected to ensure that the chips and aluminum substrates are in good condition. The cards are then annealed in the reader to test the readability of the barcodes on them. The ASCII file which results from this anneal is checked against the CEDS mainframe database of existing dosimeter numbers to ensure that the dosimeters being tested have unique barcode numbers. The third test is the generation of element correction coefficients (ECC's). Each card has its four ECC's generated and evaluated against the mean ECC's of the calibration card population. Acceptable cards are those whose ECC's fall within +/- 30% of the mean ECC of the calibration card population. The fourth test of new neutron and HBG TLD cards is concerned with the neutron sensitivity of the neutron sensitive chips relative to that of the neutron insensitive chips. Acceptable cards are those in which the neutron sensitive chips are at least 30 times more sensitive to neutrons than the neutron insensitive chips.New extremity TLD chips are required to undergo the first three acceptance tests listed above. At present extremity neutron monitoring is not performed; therefore, the neutron sensitivity test is not necessary.

Acceptance tests for holders (beta-gamma, neutron, and extremity) consists only of physical testing. Holders are inspected visually for gross physical damage or major abnormality. Beta-gamma and neutron holders which pass the physical test are bar-coded and placed into inventory. Extremity holders (which are disposable) are not barcoded.

New readers purchased for the CEDS are required to undergo initial acceptance testing, follow-up acceptance testing, and a linearity check. The follow-up acceptance testing is also performed whenever the reader has undergone major maintenance. Additionally, the linearity check is performed annually. Initial acceptance testing consists of a general maintenance inspection, verification of heating cycles by use of the TLDREMS PHOTCAL option, verification of light intensity, testing of all alarms, testing of card orientation, and verification of proper data transfer from the reader to the workstation PC. Follow-up acceptance testing consists of five days of data acquisition through the TLDREMS electronics QC and calibrate reader options, as well as tests of the reader's card reading ability and the generation of reference light and QC card ranges. Each day electronics QC is performed twice and the reader is calibrated three times. The reader must pass both electronics QC's and exhibit stability in the reader calibration factors by meeting the following criteria: RCF's for each position must vary by no more than 5% from day to day and by no more than 3% within any one day, and the percent standard deviation must not exceed 5% for any position. In addition, QC card ranges are established on days one and two and tested on days three through five. Following the readings on day five reader calibration factors, PMT noise readings, and reference light readings are plotted and examined for trends. For the linearity test, cards are irradiated to Cs-137 to the amounts shown in table 1. The cards are read and a standard linear regression is performed on the data to verify the linearity of the reader response. Additionally it is required that, for dosimeters irradiated to 50 mR and above, the mean value for each position is within 5% or 5 mR of the delivered value (whichever is greater), and that no single value differs from the delivered value by more than 10%.

Training for CEDS technicians has been developed from job/task analysis. Initial training for processing center technicians consists of completing ten modules of computer assisted instruction in basic radiation physics, completing procedure use examinations (PUE) on nine procedures and undergoing on-the-job testing (OJT) on eight procedures. The procedures identified for PUE and OJT were identified as most critical by the formal job/task analysis, and include procedures for acceptance testing of materials and daily quality control. In addition to this initial training, annual requalification on these procedures is required. Furthermore, whenever any program procedure is revised all persons who perform the procedure are required to undergo documented retraining on the revised procedure within two weeks of the receipt of the procedure revision.

In addition to the initial quality assurance measures of acceptance testing and training there are a multitude of ongoing QA measures ranging from ongoing inspection of components to formal intercomparison programs.

Continuous effort is made to ensure the integrity of dosimetry results by inspection of dosimeters as they return from the field. Dosimeters are monitored for contamination and visually inspected for physical damage by the TLD distribution centers. Additionally, dosimeters are inspected for damage by the processing centers as they are disassembled. Damaged dosimeters are segregated, read, and removed from the inventory.

Another method used to ensure the integrity of CEDS dosimetry results is the constant monitoring of environmental conditions. CEDS dosimeter processing laboratories are climate controlled areas in which temperature and humidity are continuously monitored by means of a hygrothermograph. Background radiation levels are monitored by the use of area TLDs placed in dosimeter storage rooms. Each quarter three pairs of TLD's are mounted in each storage area. One pair is removed each month and the exposure rate is calculated in terms of microR per hour. Acceptable ranges are 0-30 microR/hr. Additionally, monthly smear samples are taken in all processing and distribution centers. To ensure against accidental exposure in shipping, control (or transit) dosimeters are included in each dosimeter shipment sent through external mail services.

The most frequently used QA methods at CEDS facilities are the daily operational quality control checks. Each day that the reader is used the TLDREMS software's electronics QC is performed. Failure to pass the EQC disqualifies the reader from being used that day until the reason for failure can be resolved.

It is required that the readers be calibrated before any operations are performed with field dosimeters. Calibrations are performed using 10 calibration cards irradiated to 500 mR Cs-137. Acceptance criteria for reader calibration factors are that the calibration factors for each positions are within +/- 10% of the calibration factors of the day before. Additionally, it is required that the percent standard deviations of the ten calibration card readings do not exceed 10%.

During an occasion of reading cards for dose there are three on-line quality control checks that are performed: quality control cards are placed every 25 field cards to measure reader stability, and PMT noise and reference light readings are taken every 10 cards.

Quality control cards are representative cards taken from the field card population and identified as QC cards by the TLDREMS software. These cards are irradiated to 250 mR Cs-137 each week. A strict schedule of use is observed to ensure that the fading on these cards is kept uniform. Typically cards are used 5-9 days post exposure. QC card ranges are established for each reader during initial acceptance testing and are reevaluated and reestablished following any major repairs. The QC card range is based on +/- 10% of the mean of 50 QC cards read over a two day period. If a QC card fails to read within the specified range and the reader automatically shuts down, the read may be restarted by inserting three new QC cards into the rack. If all three of these QC cards pass the read may be restarted. Failure of a second QC card requires the operator to investigate. Typically he/she will perform electronics QC and recalibrate the reader to verify the reader's condition.

Reference light ranges are also based upon +/- 10% of a mean established during acceptance testing. Failure of reference light reading requires investigation. Similarly, a PMT noise reading outside the range of 1 to 500 pC will require investigation.

One quality control check that was very welcome to the CEDS organization was the new date/time verification introduced in

TLDREMS version 16. The unexplained tendency of the 8800 reader's internal clock to change years had caused us much trouble with our data. The new TLDREMS will shut down the reader if the host clock and the reader PC clock differ by five minutes or more.

Several methods are used to provide trending of the reader performance. Each day at the Y-12 Plant data acquired during the reader calibration is plotted on statistical trend charts. This data consists of the reader calibration factor, the average PMT noise during the calibration run, and the average reference light reading during the calibration. Although the decision whether or not to accept daily calibration factors is based upon the criterion of percent change from the day before and therefore the charts are not used to make acceptance decisions on the daily calibration data, they provide useful insight into trends in reader behavior. Examples of these charts are shown in figures 4-6.

Periodically the reader PMT noise, reference light, and QC card databases are exported and the data plotted on similar control charts. These plots provide insight into reader stability and data trending as the reader operates throughout the day.

The log database is also an excellent source of data for performance trending. Whenever the reader stops for any reason the reader operator enters a comment into the log database. Periodically these log databases are exported and problems summarized in reader shutdown charts. These reader shutdown charts provide insight into the mechanical as well as electronic performance of the readers.

Three quality assurance programs exist which are external to the CEDS processing centers. These are the blind audit program, the external confirmation program, and the irradiation facility confirmation program ( dosimeter irradiations for the CEDS are performed by the Radiation Standards and Calibration Laboratory (RaSCaL) at ORNL).

The blind audit program is a quarterly program in which CEDS distribution centers assign TLD's to inactive employee numbers, arrange to have these dosimeters exposed to known doses at RaSCaL, and send them to the processing centers disguised as routine dosimeters for processing. Each quarter 10 dosimeters are exposed to each of two categories chosen from among those listed in table 2. In addition, ten dosimeters are included as blanks. These blind audit dosimeters are exposed to computer generated random doses and mixed in with the routine dosimeters returned to be processed. At the end of the quarter reports are sent to the processing centers summarizing their performance for the quarter.

The external confirmation program allows CEDS processing centers to verify their calibration factors by using a facility (other than RaSCaL) that maintains NIST traceable standards. Each quarter fifteen dosimeters are exposed to each of five rotating categories from among those chosen in table 3. The irradiated dosimeters are then sent to the processing centers for a single-blind test. After the dosimeters have been read the results are reported to the testing facility which then generates performance reports for review.

The irradiation facility confirmation program is a biannual program designed to provide a statistical comparison between the RaSCaL facility and the independent facility used for the external confirmation program. Every six months thirty TLD's are irradiated to each category in table 4. These dosimeters are then divided between the two facilities for irradiation, read, and a statistical comparison of the results performed.

One of the more common activities of operational dosimetry is the resolution of suspect personnel dose data. In the CEDS program a majority of this suspect data is identified as suspect based upon the shape (or lack thereof) of the glow curve.

All dosimeters read for dose have their glow curves visually inspected. Those dosimeters whose glow curves reveal abnormal shapes are segregated and identified as suspect. In general, only those dosimeters with positive dose are marked as suspect; dosimeters reading below the lower limit of the system are not marked.

Those dosimeters identified as suspect are segregated for further study. The history of the dosimeter is reviewed to check for the tendency to read high. In addition, after 30-45 days of storage in a shielded environment the dosimeter is read to investigate if it has a tendency to read unusually high. This reread data is then used qualitatively to suggest whether or not a false positive reading may have occurred. This suggestion is then offered to the distribution center for consideration as they perform their dose estimates. The final dose for the individual is determined by the distribution center as they perform a dose estimate using a combination of dose-estimate techniques based on data from sources other than the suspect TLD (time-motion data, working group average doses, etc.). Several different methods for determining dose from bad glow curves have been explored, including methods based upon the concepts of peak ratios and residual readings. None of these, however, have been implemented in practice.

**Table 1**
**Reader Linearity Test Exposure Levels**

| Exposure | Number of Cards |
|---|---|
| Controls | 5 |
| 10 mR | 5 |
| 50 mR | 5 |
| 100 mR | 5 |
| 500 mR | 5 |
| 1000 mR | 5 |
| 5000 mR | 5 |
| 10000 mR | 2 |
| 50000 mR | 2 |

**Table 2.**
**Blind Audit Exposure Categories**

| Category | Definition |
|---|---|
| 05 | High Energy Photons (Cs-137) |
| 6A | Beta Particles (Tl-204) |
| 6B | Beta Particles (Sr/Y-90) |
| 07 | Beta Particles ( U slab) |
| 13 | Mixture 05,07 |
| 16 | Blanks (HBG) |
| 17 | Mixture 05,6A |
| 18 | Mixture 05,6B |

**Table 3**
**External Confirmation Program Test Categories**

| Category | Definition |
|---|---|
| IIIA | Low Energy Photons General (X-ray) |
| IIIB | Low Energy Photons - Plutonium Environment |
| IV | High Energy Photons (Cs-137) |
| VA | Beta Particles - General (Point) |
| VB | Beta Particles - Special (Slab) |
| VI | Neutron |
| VII | Mixture Categories |
| | III & IV |
| | III & V |
| | IV & V |
| | III & VI |
| | IV & VI |

**Table 4**
**RaSCaL Irradiation Confirmation Program Test Categories**

| Category | Dose Equivalent Level (mrem) |
|---|---|
| Cs-137 | 500 deep |
| Uranium | 500 shallow |
| Sr/Y-90 | 500 shallow |
| Tl-204 | 200 shallow |
| Mixture (Cs-137 and SR/Y-90) | 500 deep and 500 shallow |

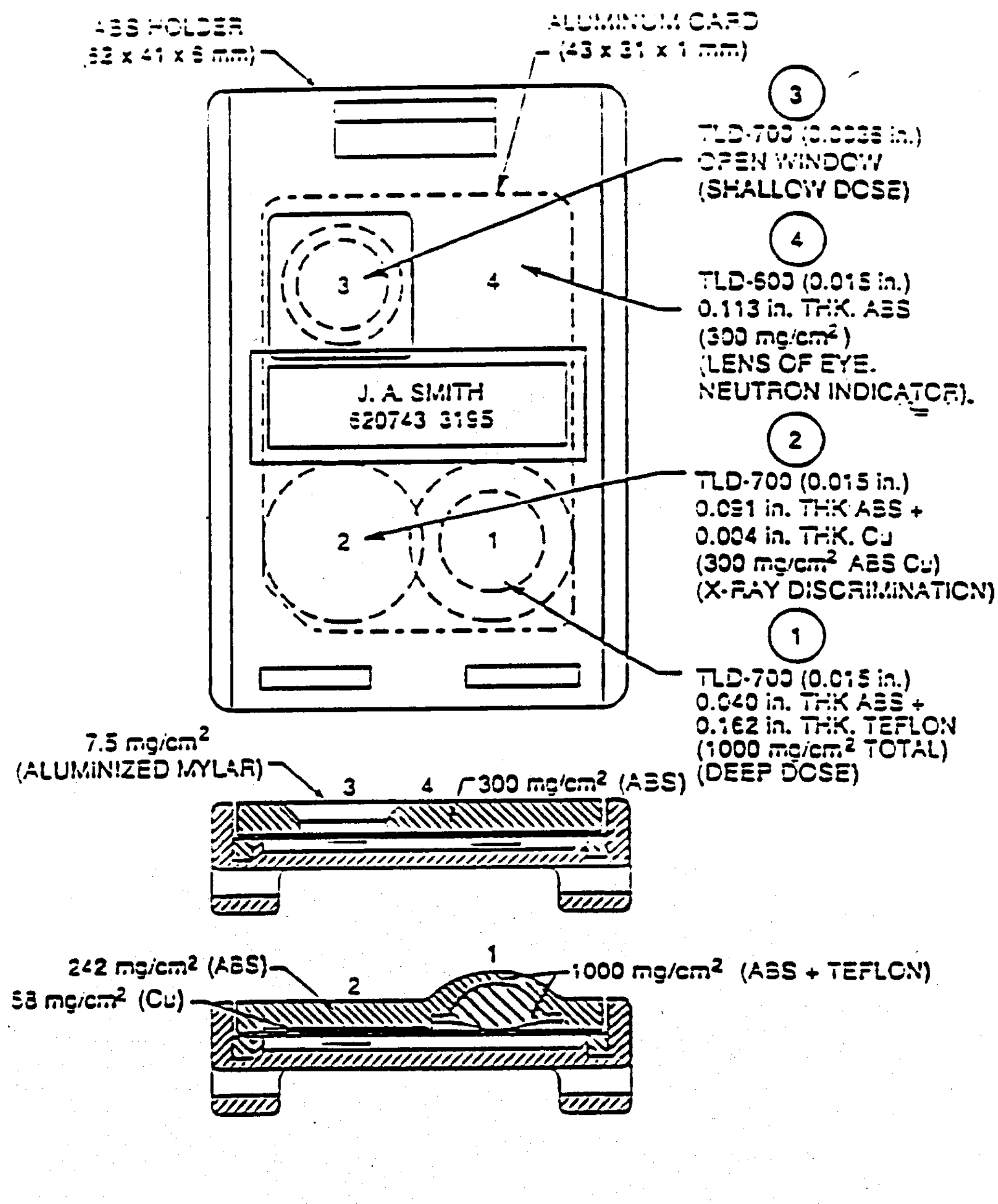


**Figure 1.**
**Harshaw Model 8805 Beta-Gamma Dosimeter Used by the CEDS**

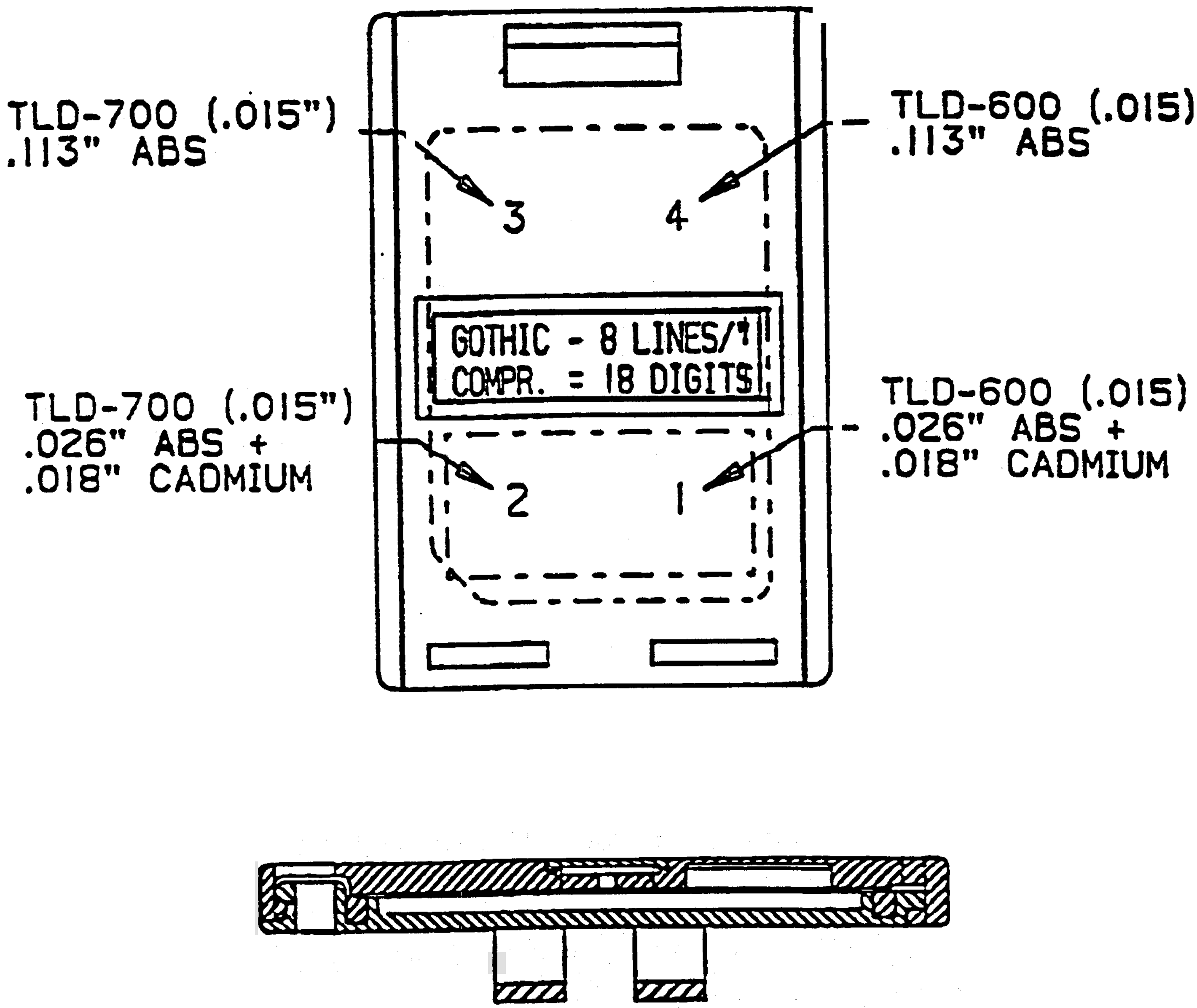


**Figure 2.**
**Harshaw Model 8806B Neutron Dosimeter Used by the CEDS**

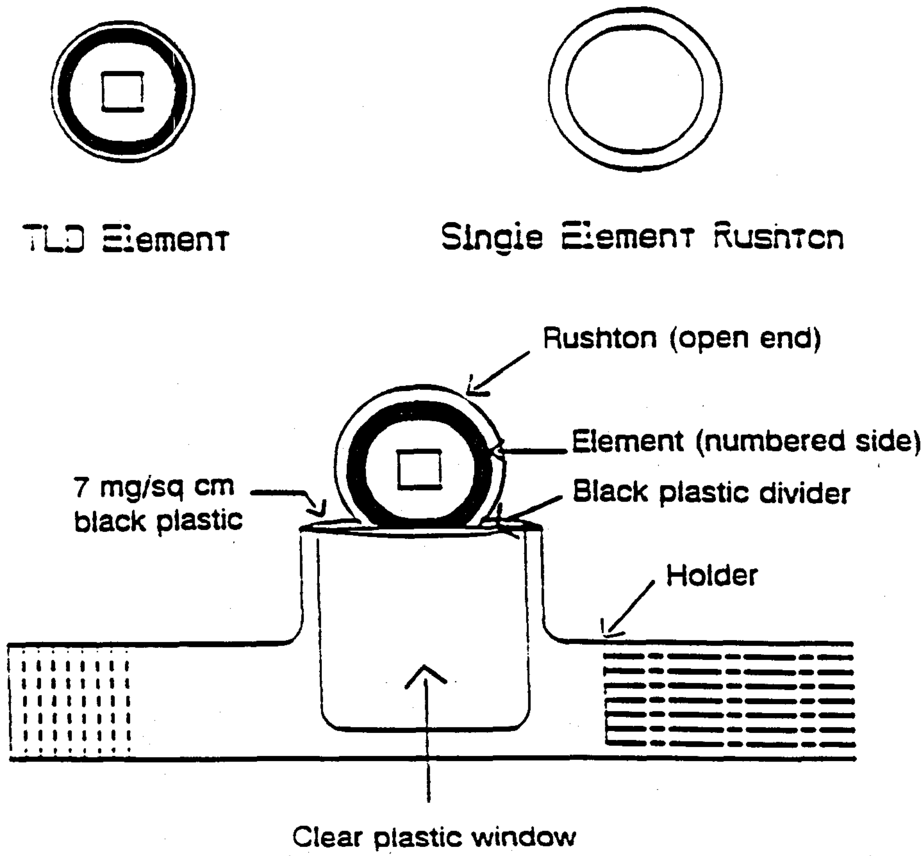


**Figure 3.**
**Extremity Dosimeter Used by the CEDS**

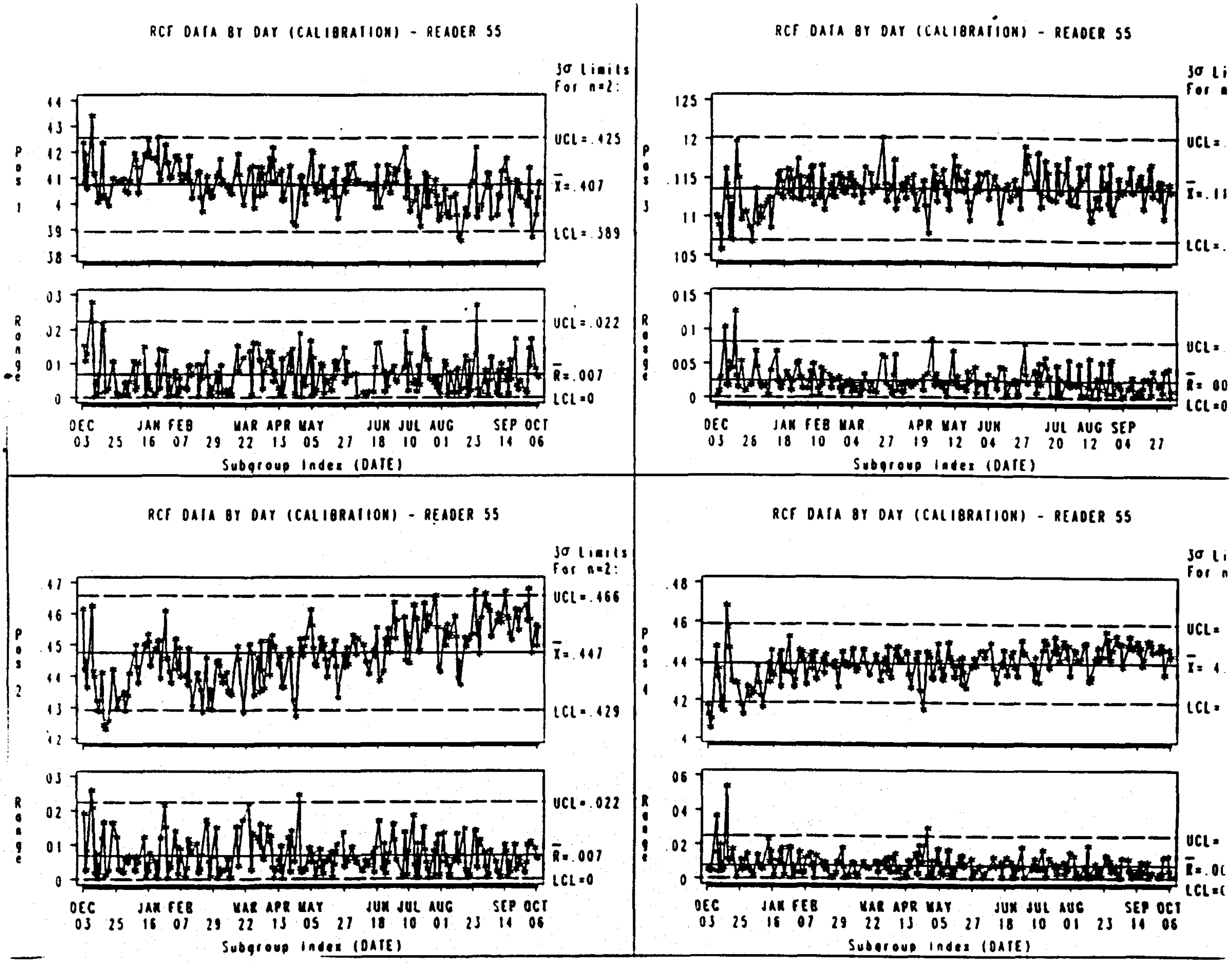


**Figure 4.**
**Reader Calibration Factor Statistical Control Charts**

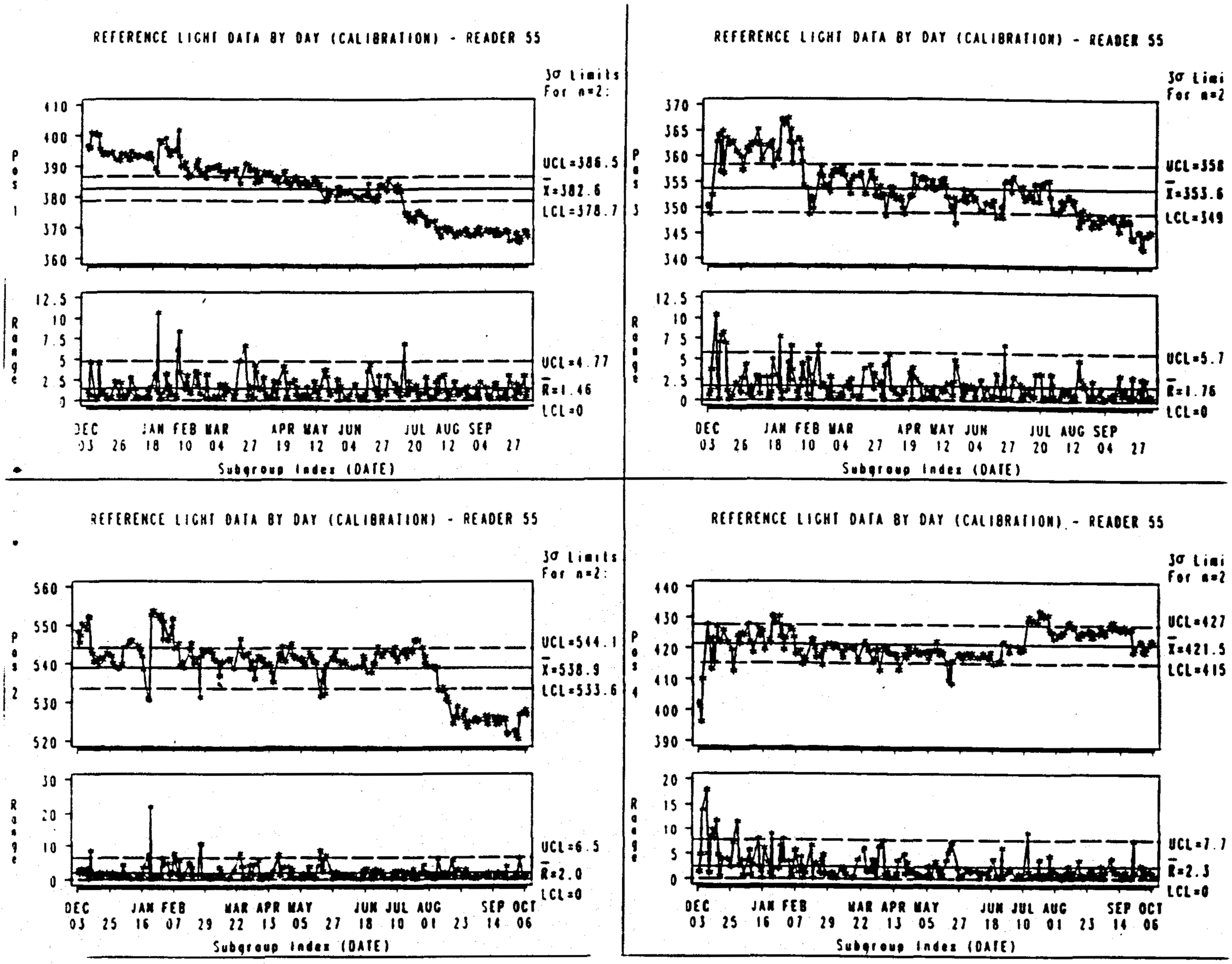


**Figure 5.**
**Reader Reference Light Statistical Control Charts**

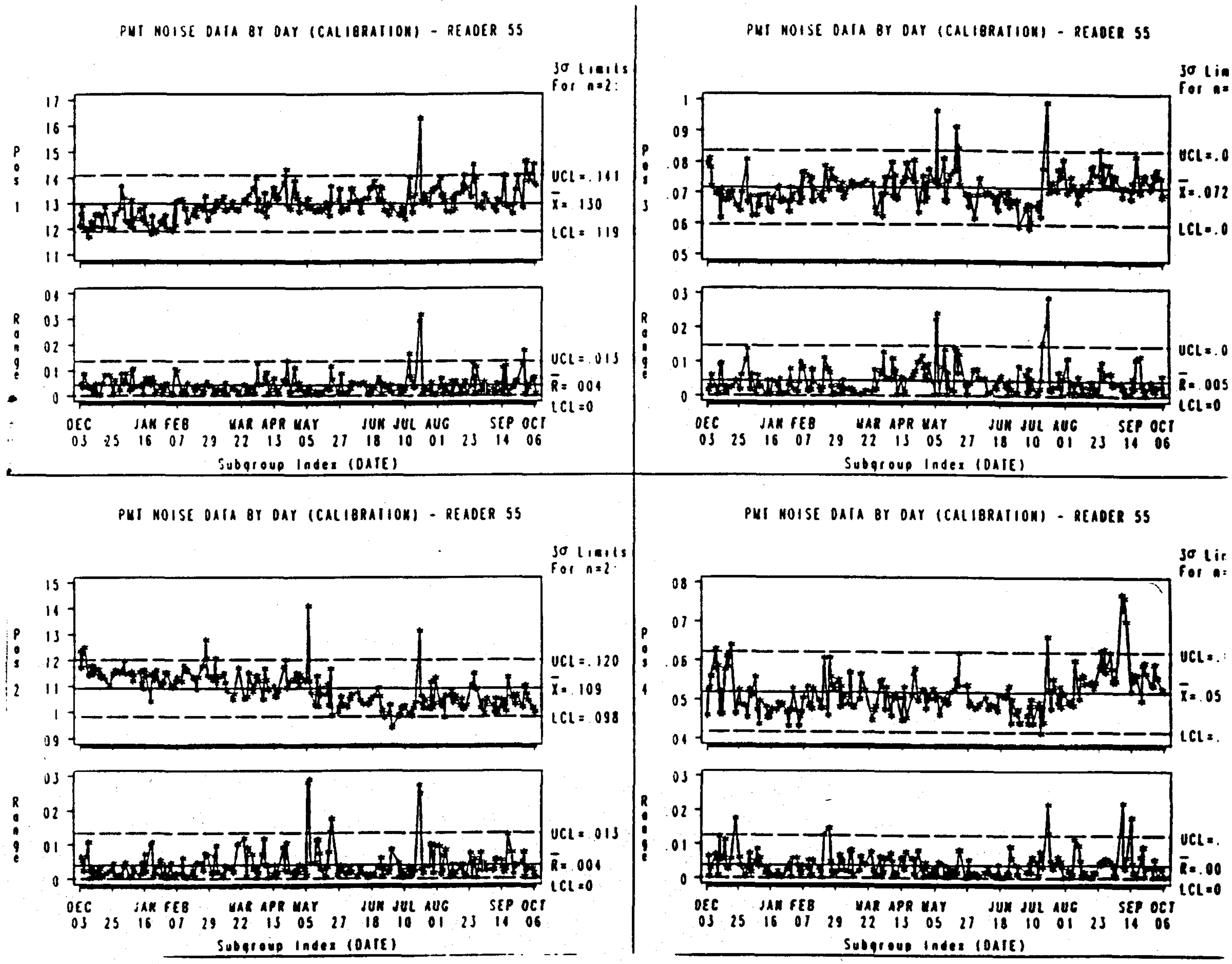


**Figure 6.**
**Reader PMT Noise Statistical Control Charts**

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