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TM-1379
1183.000

THE FERMILAB NEUTRON THERAPY FACILITY:
PERFORMANCE OF THE AUTOMATIC PHOTON CALIBRATION
SYSTEM FOR IONIZATION CHAMBERS

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August 8, 1985

The Fermilab Neutron Therapy Facility:
Performance of the Automatic Photon Calibration
System for Ionization Chambers

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This previously described system¹ to calibrate ionization chambers (IC) has been in continuous use at various levels of sophistication since Sept. 1975.² Fundamentally, the calibration system consists of,

1. A 300 Ci ¹³⁷Cs source in a lead shield,⁴ having a geometry that permits positioning of EG&G³ and later on, FWT,⁴ model IC-17 ICs with high precision;
2. A thermocouple built into the lead shield of the ¹³⁷Cs source, with a thermocouple reader having a digital read-out;⁵
3. A digital barometer;⁶
4. A computer controlled system "home" built^{1,7,8} having an electrometer charge integrator, an ADC, a crystal controlled oscillator for timing, and a Motorola M6800 CPU integrated circuit.

This system calibrates the ICs using the following algorithm,

$$\dot{X}(0) * F * \int t = N_C * TPC * \Delta Q,$$

where,

- $\dot{X}(0)$ = initial decay rate, April 1, 1977, R/sec.
 F = remaining fraction of ¹³⁷Cs, from t=0 (April 1, 1977) to date of calibration.
 $\int t$ = integration time, sec.
 N_C = IC sensitivity, R/C at 760 torr and 22°C.
 TPC = temperature-pressure correction factor.
 $= \left(\frac{273.15 + T(^{\circ}\text{C})}{273.15} \right) * \left(\frac{1013.25 \text{ mbar}}{P(\text{mbar})} \right)$

ΔQ = collected charge, C.

Note that no corrections for charge collection efficiency or recombination losses are needed since NBS calibrates the ICs at +600V (our operating voltage) and at photon dose rates comparable to ours.

The ¹³⁷Cs source and shield were received on August 1, 1975.¹⁰ Until September 13, 1977, the ¹³⁷Cs source and structure were used only as a

reproducible photon field. IC calibrations were made by comparing the $(dV/dt)_{\text{corr}} = (dV/dt) \cdot \text{TPC}$ from the charge integrator for the various ICs and then using the 149-TG as a reference.

On June 28, 1977¹¹ using the NBS calibration of 3/29/77, and the analysis of 26 measurements of $(\Delta V/\Delta t)_{\text{corr}}$ taken between December 21, 1976 and June 23, 1977,¹² the average exposure rate over the volume of IC-17, serial #149TG, on April 1, 1977, was calculated to be 0.8669(4) equivalent ^{60}Co R/sec. This is called ^{60}Co equivalent exposure, since the IC had been calibrated at NBS in a ^{60}Co photon beam.

IT MUST BE EMPHASIZED THAT THIS CONSTANT AND FUTURE CALIBRATIONS MADE WITH THIS SYSTEM APPLY ONLY TO EG&G AND FWT MODEL IC-17 SPHERICAL IONIZATION CHAMBERS, MADE OF A-150 TE-PLASTIC, HAVING WALLS 0.2 INCH THICK.

It took until September 13, 1977¹³ to use this known photon field to calibrate IC-17 ICs absolutely.

Over the years, the IC-17, serial number 149TG, was rebuilt several times and sent to NBS for calibration in their ^{60}Co beam. Before and after the trip to NBS, this IC was calibrated at Fermilab. Then the average of the "before" and "after" calibration factors were used to compare with the NBS calibration. A resume of these intercomparisons follows,

| NBS CALIB DATE | FERMILAB CALIB BEFORE | AFTER | NBS CAL | $\frac{\text{BEFORE} + \text{AFTER}}{2 \cdot \text{NBS}}$ |
|----------------------|-----------------------------|----------|------------|---|
| 5/17/78 | 3.403(0) | 3.404(7) | 3.421 | .9950 |
| 5/28/79 | 3.406(5) | 3.410(0) | 3.399 | 1.002(7) |
| 7/21/80 | 3.807(3) | 3.803(4) | 3.804 | 1.000(5) |
| 2/19/82 | 3.836(6) | 3.828(7) | 3.830 | 1.000(7) |
| 8/ 2/84 | 3.776(8) | 3.769(6) | 3.782 | .9977 |

Average ratio 0.9993

Standard deviation 0.0030

Conclusions. Over the period from September 1977 to August 1984, the IC-17 IC

photon calibration system has performed without a single down-time or any other malfunction. The averaged ratio of its calibrations versus NBS calibrations is a very respectable 0.9993 ± 0.0030 .

This system has allowed personnel untrained in ionometry to easily perform daily accurate IC photon calibrations before calibrating the neutron beam prior to patient treatment at the Fermilab Neutron Therapy Facility.

REFERENCES

1. M. Awschalom, R. Goodwin, L. Grumboski, I. Rosenberg, M. Shea, "High Precision in Dose Delivery: Routine Use of a Microcomputer," chapter in Biomedical Dosimetry: Physical Aspects, Instrumentation, Calibration, Vienna: IAEA, 1982.
 2. Date of first reference to Cs-source around Dosim I-p10, Sep 23, 1975.
 3. EG&G, Goleta, CA. They no longer make these ionization chambers.
 4. FWT, Far West Technology, Inc., Goleta, CA 93117. chamber under the same designations.
 5. TC reader, Fluke Model 2100-A-10-S-C-02.
 6. Digital Barometer, Barocel Model 1018.
 7. R. W. Goodwin, R. F. Kocanda and M. F. Shea, A Method for Implementing Microprocessor-Controlled systems, IEEE Trans. Nucl. Sci. NS-23, 297 (1976).
 8. R. W. Goodwin and M. F. Shea, The Microprocessor Based Control System for the Fermilab Cancer Therapy Facility, IEEE Trans. Nucl. Sci. NS-25,496(1978).
 9. M. Awschalom and I. Rosenberg, "Neutron Beam Calibration and They have EG&G molds and drawings and make the same ionization 10. Safety Section, Radioactive Source Records, 8/85.
- Treatment Planning", Fermilab TM-834, Dec. 1978, Appendix 14.
11. M. Awschalom, logbook #4, pg. 117.
 12. M. Awschalom, logbook #4, pg. 115.
 13. Dosimetry logbook IX, pg. 6.

APPENDIX

Calibrations of IC-149TG

These are records of calibrations done "before" and "after" the ionization chamber's trip to NBS for calibration in their ⁶⁰Co-bea

Roman-Arabic numbers in reference column, (ref.), mean dosimetry logbook and page numbers respectively.

NBS Calibration, May 17, 1978

Note: The ionization chamber became leaky and no NBS certificate was issued. An informal report was obtained by telephone.

| <u>BEFORE</u> | | | <u>AFTER</u> | | |
|---------------|----------------|-------|--------------|----------------|-------|
| Date | Cs-Cal. | Ref. | Date | Cs-Cal. | Ref. |
| 3/ 6/78 | 3.402 | X-112 | 6/ 1/78 | 3.406 | X-247 |
| 3/ 8/78 | 3.403 | X-116 | 6/ 7/78 | 3.404 | X-257 |
| 3/11/78 | 3.405 | X-121 | 6/ 8/78 | 3.404 | X-257 |
| 3/13/78 | 3.403 | X-121 | | | |
| 3/14/78 | 3.404 | X-126 | | | |
| 3/15/78 | 3.402 | X-131 | | | |
| 3/17/78 | 3.402 | X-133 | | | |
| Ave | 3.403(p<+.0012 | | Ave | 3.404(7)±.0012 | |

("Before" + "After")/2*NBS = 0.9950

NBS Calibration, May 28, 1979

| <u>BEFORE</u> | | | <u>AFTER</u> | | |
|---------------|----------------------|---------|--------------|----------------------|---------|
| Date | Cs-Cal. | Ref. | Date | Cs-Cal. | Ref. |
| 5/ 9/79 | 3.407 | XIII-48 | 6/ 6/79 | 3.411 | XIII-49 |
| 5/10/79 | 3.408 | id | 6/ 7/79 | 3.410 | id |
| 5/15/79 | 3.406 | id | 6/20/79 | 3.409 | XIII-84 |
| 5/16/79 | 3.405 | id | | | |
| Ave. | 3.406(5) \pm .0013 | | Ave. | 3.410(0) \pm .0007 | |

("Before" + "After")/2*NBS = 1.002(7)

NBS Calibration, July 21, 1980

| <u>BEFORE</u> | | | <u>AFTER</u> | | |
|---------------|----------------------|---------|--------------|----------------------|-------|
| Date | Cs-Cal. | Ref. | Date | Cs-Cal. | Ref. |
| 6/26/80 | 3.806 | XIV-277 | 8/ 6/80 | 3.802 | XV-33 |
| 7/ 1/80 | 3.806 | XV-7 | 8/ 7/80 | 3.811 | XV-35 |
| 7/ 2/80 | 3.806 | XV-9 | 8/13/80 | 3.803 | XV-41 |
| 7/ 4/80 | 3.811 | XV-15 | 8/21/80 | 3.803 | XV-59 |
| Ave. | 3.807(3) \pm .0025 | | Ave. | 3.803(4) \pm .0026 | |

("Before" + "After")/2*NBS = 1.000(4)

NBS Calibration, February 19, 1982

| <u>BEFORE</u> | | | <u>AFTER</u> | | |
|---------------|----------------------|----------|--------------|----------------------|----------|
| Date | Cs-Cal. | Ref. | Date | Cs-Cal. | Ref. |
| 2/11/82 | 3.837 | XVII-224 | 2/23/82 | 3.830 | XVII-234 |
| 2/12/82 | 3.837 | id | 2/24/82 | 3.830 | id |
| 2/15/82 | 3.834 | XVII-225 | 2/25/82 | 3.829 | id |
| 2/16/82 | 3.838 | id | 2/26/82 | 3.825 | id |
| 2/17/82 | 3.837 | id | 3/ 1/82 | 3.829 | XVII-238 |
| | | | 3/ 1/82 | 3.829 | id |
| Ave. | 3.828(7) \pm .0019 | | Ave. | 3.828(7) \pm .0019 | |

("Before" + "After")/2*NBS = 1.000(7)

NBS Calibration, August 2, 1984

| <u>BEFORE</u> | | | <u>AFTER</u> | | |
|---------------|----------------------|--------------|--------------|----------------------|----------|
| Date | Cs-Cal. | Ref. | Date | Cs-Cal. | Ref. |
| 6/ 5/84 | 3.779 | XXII-89 | 8/17/84 | 3.770 | XXII-229 |
| 6/ 8/84 | 3.776 | XXII-114/115 | 8/20/84 | 3.768 | XXII-229 |
| 6/11/84 | 3.777 | XXII-118/119 | 8/22/84 | 3.770 | XXII-232 |
| 6/12/84 | 3.776 | XXII-120/122 | 8/23/84 | 3.770 | XXII-234 |
| 6/13/84 | 3.777 | XXII-130/132 | 8/27/84 | 3.768 | XXII-238 |
| 6/19/84 | 3.776 | XXII-161 | 8/28/84 | 3.771 | XXII-242 |
| | | | 8/30/84 | 3.770 | XXII-244 |
| Ave. | 3.776(8) \pm .0012 | | Ave. | 3.769(6) \pm .0011 | |

("Before" + "After")/2*NBS = 0.9977