Stability of A-150 Plastic Ionization Chamber Response Over a ~30 Year Period

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At the NIU Institute for Neutron Therapy at Fermilab, the clinical tissue-equivalent ionization chamber response is measured every treatment day using a cesium source that was configured to match readings obtained at the National Bureau of Standards. Daily measurements are performed in air using the air-to-tissue dose conversion factors given in AAPM Report #7. The measured exposure calibration factors have been tabulated and graphed as a function of time from 1978 to present. For A-150 plastic ionization chambers, these factors exhibit a sinusoidal variation with a period of approximately one year and amplitude of ± 1%. This variation, attributable to the hygroscopic nature of A-150 plastic, is correlated with the relative humidity of the facility, and is greater than the humidity corrections for gas described in the literature. Our data suggest that chamber calibration should be performed at least weekly to accommodate these variations.

INTRODUCTION

When the neutron therapy facility at Fermilab was first commissioned in 1976 there was little experience with day-to-day reproducibility of A-150 plastic tissue-equivalent (TE) ionization chambers for calibrating a clinical neutron beam. In the absence of a standard neutron source, a cesium-137 source was chosen as a reference standard. To facilitate frequent quality assurance measurements, a computerized data collection system was devised[(1)]. This system has been in use for nearly thirty years and has enabled acquisition of data on the long-term behavior of TE ionization chambers. This paper presents data describing the seasonal variation in chamber response associated with the hygroscopic properties of TE plastic.

MATERIALS AND METHODS

Chamber exposure factor calibrations are performed each treatment day using one of two EG&G/Far West Technologies model IC-17 ionization chambers. The calibrated chamber is then positioned in a calibration jig in the clinical neutron beam where a computer compares the signals in the ionization chamber to those of a transmission chamber in the neutron beam to determine the factor relating dose and monitor units. This system was designed to allow personnel untrained in dosimetry to perform reliable calibrations for daily treatment. The system has been documented to provide calibrations that agree with National Bureau of Standards calibrations with ratio of 0.9993 ± 0.0030[(2)].

Data have been collected for each of two A-150 chambers, serial numbers IC117 and IC120. Nylon provides ~35% (by mass) of the material of A-150 plastic and is hygroscopic. The measured exposure factors and the treatment room's relative humidity have been continuously monitored. Relative humidity measurements are determined by a goldbeater's skin hygrometer manufactured by Bacharach Instrument Co.

While the neutron therapy treatment room is air-conditioned, the humidity of the area is not otherwise controlled. The presence of air-conditioning limits summertime relative humidity levels to 55-60%, though wintertime levels can drop below 10%.

RESULTS

Figure 1 shows the variation in the Neutron Therapy's exposure factor for two chambers since January 26, 1978. The top plot shows data from chamber IC120 and the middle plot for IC117. The bottom plot displays the relative humidity which has been recorded since December 13, 1984. The data clearly show a systematic variation with a yearly period. Comparing it to the humidity in the room where the measurements are performed strongly suggests a correlation if not a causal effect. Note that humidity axis is shown inverted.

The discontinuity in IC117's data in late 1987 is due to a refurbishing of the chamber. The lower average value in 1991 is due to errors in the temperature-pressure correction. Damage to the IC117 chamber in late 1993 necessitated switching to IC120 while IC117 was being repaired. IC117 was not used again for routine daily calibrations until the middle of 2000, when operational procedures were changed to perform exposure factor measurements with both chambers on a regular basis to assist in the study of the variation phenomenon. The change in the average exposure factor of IC117 after its repair in 1993 was not unexpected, but because the repair did not involve a change in the A-150 composition, the small variation in amplitude is difficult to explain.

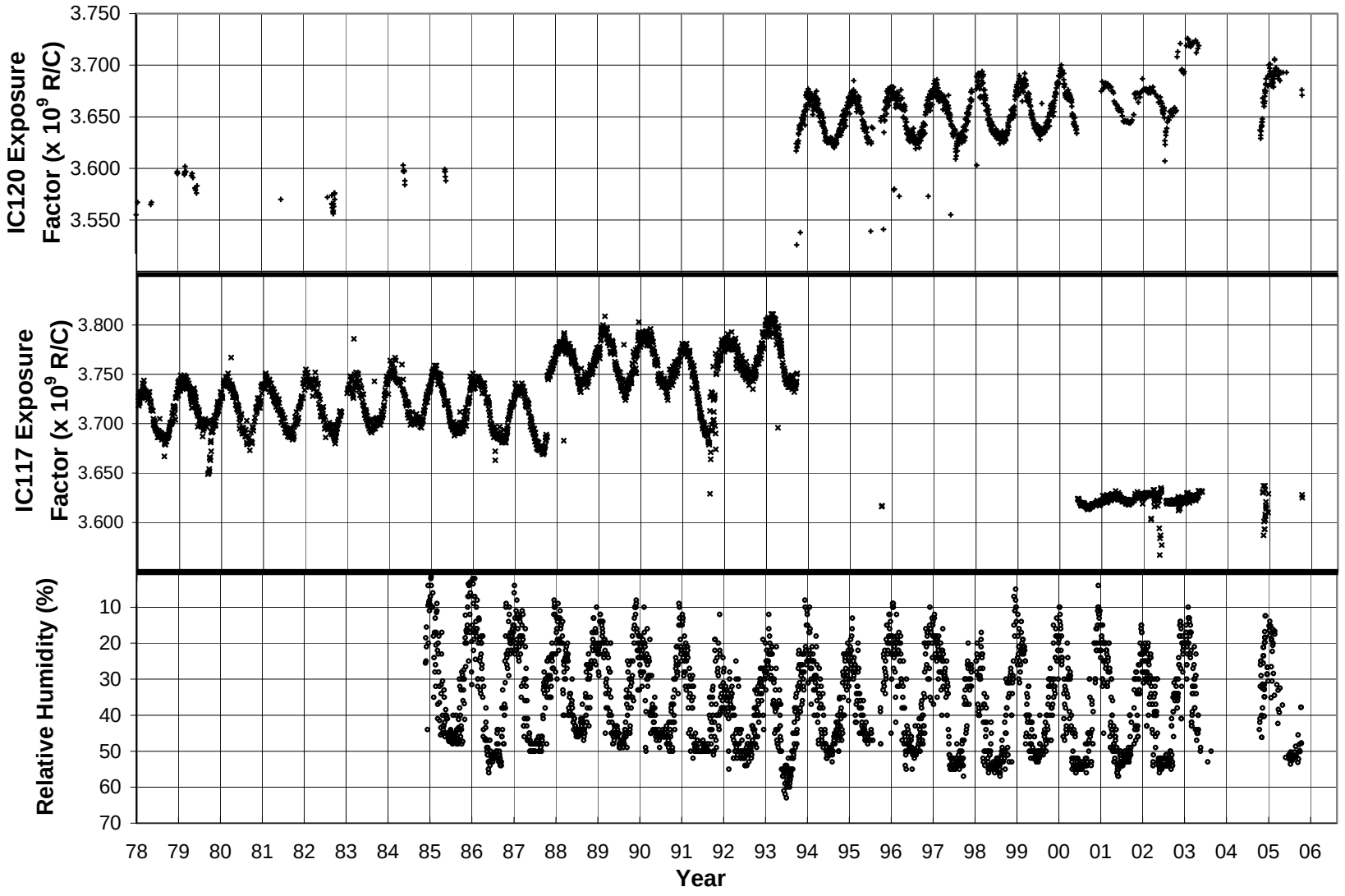

Figure 1. A time plot of the exposure factor for ionization chambers IC120 (top) and IC117 (middle) and the relative humidity (bottom). Note that the scale for the relative humidity is inverted.

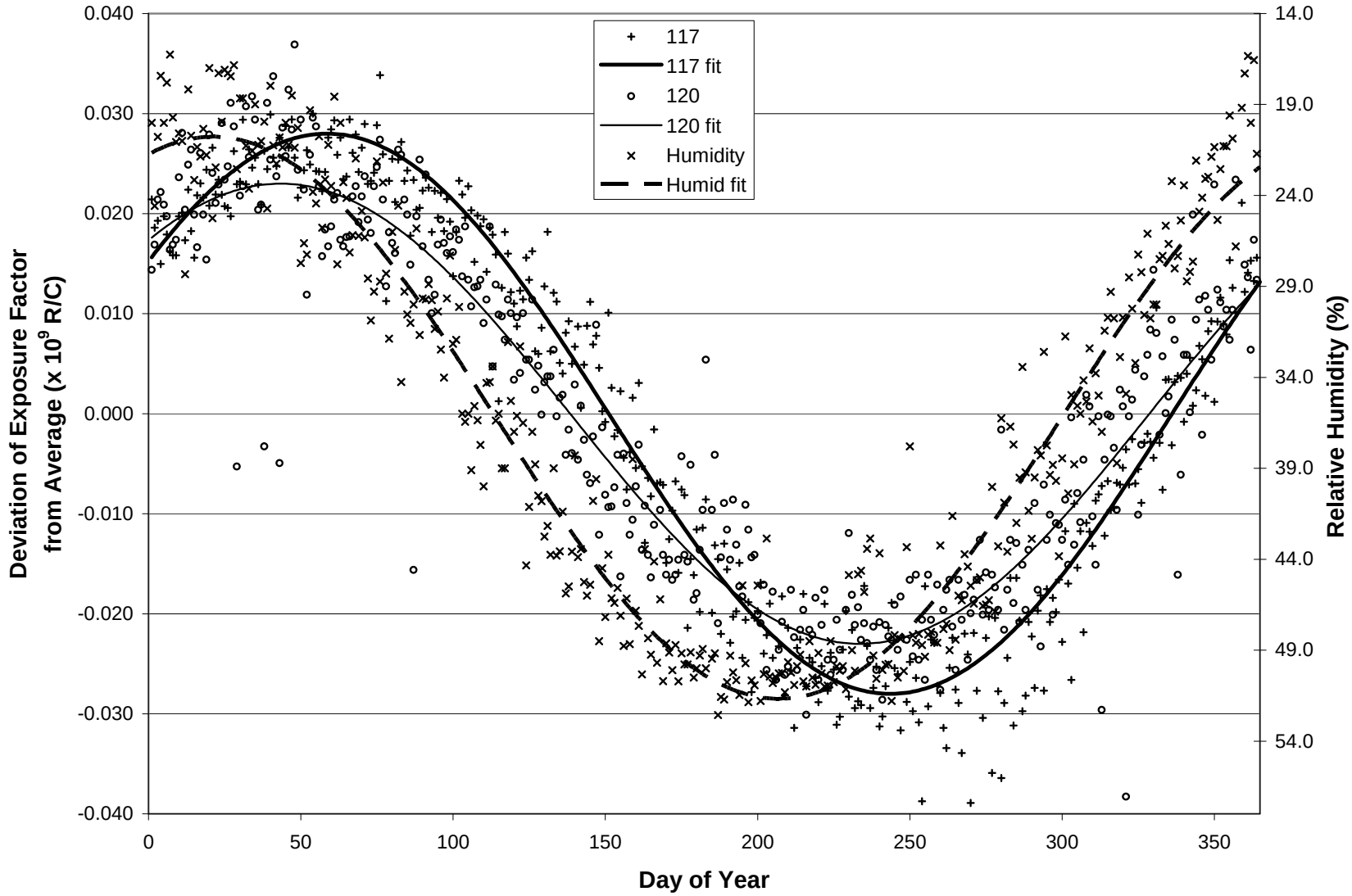

Figure 2. The deviation of the exposure factor for IC117 and IC120 from long term averages and the relative humidity, and fits, merged into a single period. The averages for each day of the year are subtracted from long term averages and plotted. The relative humidity axis is inverted.

Figure 2 shows the deviation of the average response from a long term mean for each of the two chambers and the humidity for each day of the year covering a period from Jan. 1978 to May 2003. The humidity scale (on the right) again is inverted. The average exposure factor for each chamber for each day of the year was calculated, as was the average humidity reading for each day of the year. Two stable time periods for chamber IC117 and one period for IC120 were chosen and the mean exposure factors were calculated. These values are shown in Table 1. The plot in figure 2 compares each daily average value of the exposure factor to the mean value for that time period.

Table 1. Average exposure factors (x 10^9 R/C) used to determine daily deviations.

Date Range			Ionization Chamber	Mean Exposure Factor
26-Jan-78	-	26-Oct-87	117	3.716
29-Oct-87	-	11-Oct-93	117	3.760
12-Oct-93	-	13-May-03	120	3.652

As a result, one can see that the response of the chambers is inversely proportional to the relative humidity. There is also a lag in their response to the change in humidity. The plot also shows a fit to a sine function for each set of data. The offsets of the fits were compared to determine lag for each chamber. For chamber IC117, this lag is approximately 38 days and for IC120 it is 20 days. This is consistent with the phenomenon reported in reference 3. When the humidity changes, there is a brief change in response, approximately 10-20 minutes, while changes occur on the inner surface of the chamber. We have observed this but are not explicitly reporting on it here. Following that immediate change, there is a much slower (many days) transition to equilibrium as the nylon absorbs or releases water and correspondingly, the volume changes.

SUMMARY AND CONCLUSIONS

The hygroscopic nature of A-150 plastic leads to seasonal variations in the exposure calibration factor. We have monitored the exposure factor on an almost daily basis for nearly 30 years and the relative humidity for over 20 years. Our data suggest that performing chamber calibration on a weekly, if not daily, basis can accommodate for these variations to maintain consistency in the neutron dose delivered to patients.

REFERENCES

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