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April 19, 1961

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U. S. ATOMIC ENERGY COMMISSION
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A large number of measurements of natural environmental radiation in various parts of the United States were obtained by this laboratory during 1957 and 1958 with a 20-liter air filled polyethylene-walled ionization chamber at atmospheric pressure. The ionization current was measured with a vibrating reed electrometer connected as a continuously reading voltmeter driving a pen recorder. Power for the electrometer and recorder was obtained from an alternating current inverter operated from a 12 volt automobile storage battery. The entire assembly was secured to a wooden carrying board as shown in Figure I.

The requirement for power and the physical dimensions of this equipment necessitated that it be used inside an automobile sedan. Essentially identical field conditions of loading and ionization chamber orientation were maintained at all times in the sedan. It was assumed initially that the attenuation due to the shielding effect of the automobile was relatively small and the results of the first extensive surveys were published without correction for this effect. Subsequent improvement in the measuring apparatus and the measurement technique resulted in a more detailed investigation of those factors which might have introduced systematic errors into the early measurements. This paper discusses the error introduced by
making measurements with equipment inside an automobile. The results have been utilized in correcting previously published data so that these numbers could be integrated and compared with later measurements made at the same and other locations. The ionization chamber presently in use is completely portable, eliminating the problems associated with the restricted maneuverability and radiation attenuation introduced by the automobile.

In analyzing the attenuation produced by the automobile, the penetrating external natural background radiation may be considered to be made up of two components, a cosmic ray component, $C$, and a terrestrial gamma ray component, $T$. The subscripts, $i$ and $o$, will designate measurements inside and outside the automobile.

If $B$ represents the total background in $\mu$R/hr, then

$$B_i = T_i + C_i$$
$$B_o = T_o + C_o$$

Let $K_t$ be the transmission factor of the car to the terrestrial component such that

$$T_i = K_t T_o$$

and let $K_c$ be the transmission factor of the car to the cosmic component such that

$$C_i = K_c C_o$$

We did not have direct measurements of $C_o$ on the ground but instead used measurements made in an airplane, extrapolated to the altitude at
ground level. These extrapolated values will be designated \( C_p \), so that

\[
C_p = K_p C_0
\]  

(5)

where \( K_p \) is the transmission factor of the airplane to cosmic rays.

Applying equations (2) through (5) to (1) and rearranging, we get

\[
\frac{B_i}{C_p} = K_t \left( \frac{B_o}{C_p} \right) + \frac{K_C - K_t}{K_p}
\]  

(6)

and

\[
\frac{B_i}{B_o} = K_t + \frac{K_C - K_t}{K_p} \left( \frac{C_p}{B_o} \right)
\]  

(7)

It was thought desirable to make measurements over a range of background levels where the relative contribution of the cosmic and terrestrial components to the total radiation field would be significantly different. A location was found on Twelfth Avenue in New York City (locations 5-8 in Table I) where the natural background is about three times as great as is ordinarily encountered in the area. Examination with a survey meter showed that this was due to the Belgian block paving of the road and a granite block retaining wall on one side of the street which rises about thirty-six feet above the sidewalk in some places. Measurements were made at four different locations along the street. \( B_i \) and \( B_o \) were obtained by direct measurement using the 20-liter ionization chamber equipped with a Lindemann-Ryerson electrometer,\(^4\) shown in Fig. II. The time of discharge of the condenser was determined at least twice for each polarity of the applied voltage, giving readings of the radiation field with a probable error of approximately 0.5 \( \mu r/hr.\)\(^4\) Readings to obtain \( B_i \) were first taken inside the automobile, a late-model Chevrolet sedan. The instrument was then removed and placed at the same location after the automobile was driven some distance away and measurements were made to determine \( B_o.\)
The same procedure was followed at St. Nicholas Terrace (locations 1-4 in Table I) where the background is much lower, and at three locations (9-11) in Pelham, New York, where the magnitude of the background falls between the values at Twelfth Avenue and those at St. Nicholas Terrace.

The cosmic-ray component, $C_p$, was calculated for the pressure altitudes at which the measurements were made using an extrapolation of a least-squares fit for data from a similar ionization chamber obtained at 4000 to 18000 foot altitudes.\(^3\)

The basic data obtained from the measurements are listed on Table I.

<table>
<thead>
<tr>
<th>Location</th>
<th>Barometric Pressure (in. Hg)</th>
<th>$B_i$ (μr/hr)</th>
<th>$B_0$ (μr/hr)</th>
<th>$C_p$ (μr/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.03</td>
<td>9.91</td>
<td>11.07</td>
<td>3.773</td>
</tr>
<tr>
<td>2</td>
<td>29.80</td>
<td>9.24</td>
<td>10.30</td>
<td>3.900</td>
</tr>
<tr>
<td>3</td>
<td>30.02</td>
<td>9.77</td>
<td>11.59</td>
<td>3.779</td>
</tr>
<tr>
<td>4</td>
<td>29.80</td>
<td>10.07</td>
<td>11.92</td>
<td>3.900</td>
</tr>
<tr>
<td>5</td>
<td>30.12</td>
<td>17.90</td>
<td>22.13</td>
<td>3.725</td>
</tr>
<tr>
<td>6</td>
<td>30.12</td>
<td>17.28</td>
<td>22.61</td>
<td>3.725</td>
</tr>
<tr>
<td>7</td>
<td>30.11</td>
<td>19.39</td>
<td>22.61</td>
<td>3.730</td>
</tr>
<tr>
<td>8</td>
<td>29.60</td>
<td>20.38</td>
<td>24.42</td>
<td>4.014</td>
</tr>
<tr>
<td>9</td>
<td>30.13</td>
<td>10.31</td>
<td>12.05</td>
<td>3.718</td>
</tr>
<tr>
<td>10</td>
<td>30.04</td>
<td>10.79</td>
<td>12.97</td>
<td>3.768</td>
</tr>
<tr>
<td>11</td>
<td>29.94</td>
<td>10.74</td>
<td>13.75</td>
<td>3.823</td>
</tr>
</tbody>
</table>

The pressure was obtained at each location by using a Kollsman altimeter. The values for $K_t$ and $\frac{K_p - K_t}{K_p}$ were determined from a least-squares
fit of the data using both equations (6) and (7) (see Figures III and IV).

The results are as follows:

From (6), \( K_t = 0.783 \pm 0.032 \) (8)

\[
\frac{K_c - K_t}{K_p} = 0.207 \pm 0.137
\]

From (7), \( K_t = 0.765 \) (9)

\[
\frac{K_c - K_t}{K_p} = 0.278
\]

No standard deviations are given for the values in equation (9) since the data do not correlate well to the least-squares fit (see Figure IV), although the results are in reasonable agreement with (8).

Since the shielding of the plane and the car to cosmic radiation are not significantly different, we assume that \( K_c = K_p \) in equation (8). This gives \( K_c = K_p = 0.99 \). It should be noted that the approximate equality of \( K_c \) and \( K_p \) requires that \( K_c \) be very close to unity. If \( K_c \) were as small as 0.9, \( K_p \) would take the value of approximately 0.6 from the above equation, an unreasonably low value considering the nature and thickness of the fuselage of the airplane and the relatively high energy of the cosmic radiation.

From the preceding results, it is concluded that the automobile attenuates the terrestrial component on the average to 0.78 ± 0.03 of its value outdoors and that the cosmic ray ionization intensity is not materially affected. These results, while not strictly applicable to all types of automobiles and car loadings, suggest that the attenuation factor is significant when absolute readings of external natural radiation are attempted inside an automobile or when inside readings are compared with those made outside.
REFERENCES


20 LITER IONIZATION CHAMBER WITH VIBRATING REED ELECTROMETER

FIG. I
20 LITER IONIZATION CHAMBER WITH LINDEMANN RYERSON ELECTROMETER

FIG. II
LEAST SQUARES FIT

\[ \frac{B_1}{C_p} = 0.7831 \frac{B_0}{C_p} + 0.2069 \]

FIG. III
LEAST SQUARES FIT

$$\frac{Bi}{B_0} = 0.2777 \frac{Cp}{B_0} + 0.7651$$

FIG. IV