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# A Diagnostic-Level Whole-Body Counter

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A system of whole-body counters is under development at the Medical Division, Oak Ridge Institute of Nuclear Studies (ORINS), for use over a large range of activities. These counters allow retention and other clinical studies to be performed over a continuous range of sensitivity from therapeutic doses down to natural body background levels.

The upper limit of activity for a therapeutic dose of $^{131}I$ or $^{198}Au$ normally given to patients at the ORINS hospital is about 150 mC. The lower limit for a whole-body counting system is that region where the isotopic activity becomes relatively undiscernible from the background count for reasonable counting times. For the usual clinical radionuclides emitting medium-energy gamma radiations this lower limit occurs in the nanocurie region ( $1 \times 10^{-9}$ curies). Thus, if this entire activity range is to be completely covered, an instrument-sensitivity range of more than 100,000,000 to 1 is required.

Initially, a single counter to cover this broad range of activities was considered, but this attempt was soon abandoned because the detecting system required would have been very awkward to build and use; moreover, there was the possibility of compromising the high-sensitivity region of the counting range by a high-dose patient's sneezing or otherwise contaminating the single counter. As a result of these and other considerations, the construction of a series of three separate counters was decided upon, each with overlapping activity ranges of about 1,000 to 1. Figure 1 shows the coverage afforded by each of these whole-body counting instruments. All three counters are now in clinical operation. The high-level counter has been described earlier (1), and the design of the diagnostic-level counter is the subject of this report. A report on the low-level counter is in preparation.

## DEVELOPMENT

The requirements for this diagnostic or medium-level counter called for bridging the sensitivity gap between the lower range of the high-level counter and the upper limit of the low-level installation. For $^{131}I$ the required sensitivity

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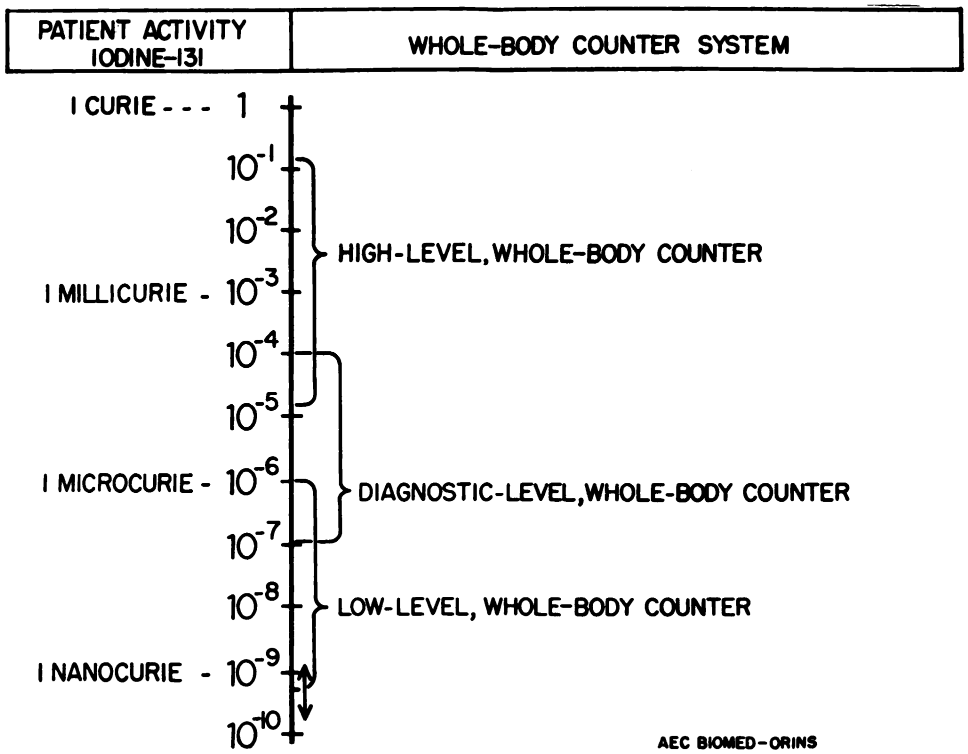


**Fig. 1.** Sensitivity ranges for the ORINS whole-body counters.

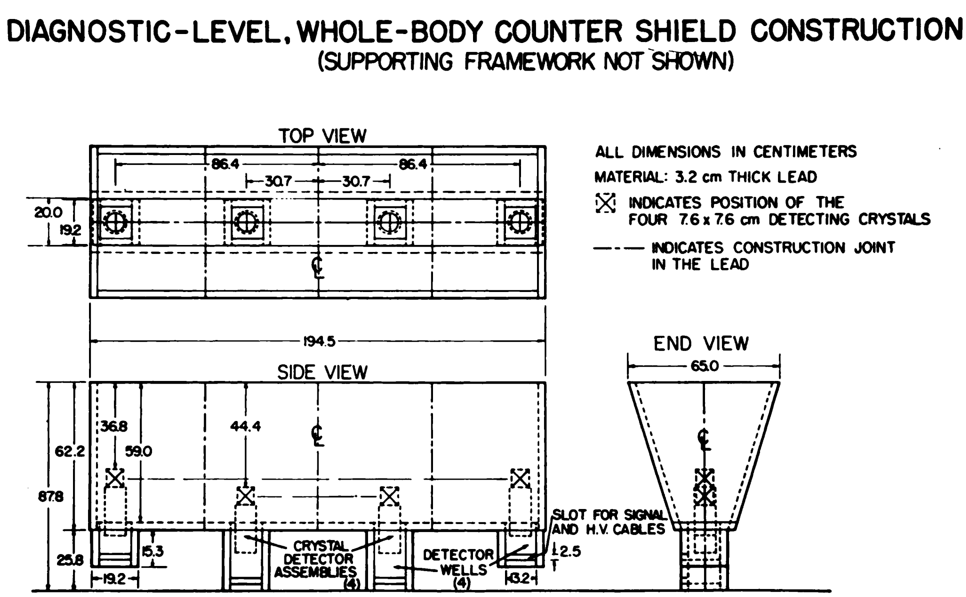


**Fig. 2.** Diagnostic-level, whole-body counter collimator construction (supporting framework not shown).

span was from 0.1 to 100 $\mu$C with some overlap on both ends. The high-level counter (1) achieves a reasonable uniformity in response over the length of the patient by having the detector far enough away from him so that variations in distance cause only slight counting changes due to inverse-square-law effects. To achieve the higher sensitivity required for the diagnostic-level counter, the subject-to-detector distance was reduced, and uniformity of sensitivity had to be obtained some other way. Calculations based on data from the high-level counter showed that to achieve enough sensitivity, the distance had to be reduced and the number and size of the detectors had to be increased. Estimates indicated that if four 7.6 cm $\times$ 7.6 cm detecting crystals were placed about 50 cm from the center line of the subject, the counting sensitivity would be increased by a factor of more than 200. Moreover, judicious positioning of the four detectors, with proper distances and spacings, would result in a field of reasonably uniform response. With these factors in mind the shield and detector design shown in Fig. 2 was made.

This shield was constructed from sheets of lead to form a long trough. The purpose of this configuration was to limit the view of the detectors roughly to the solid angle subtended by the subject lying just above the opening. The lead thickness of 3.2 cm was selected because it gives an attenuation factor of more than 200 to 1 at an energy of 500 keV. Admittedly, the selection of this thickness was rather arbitrary, but in practice it reduces the unwanted background

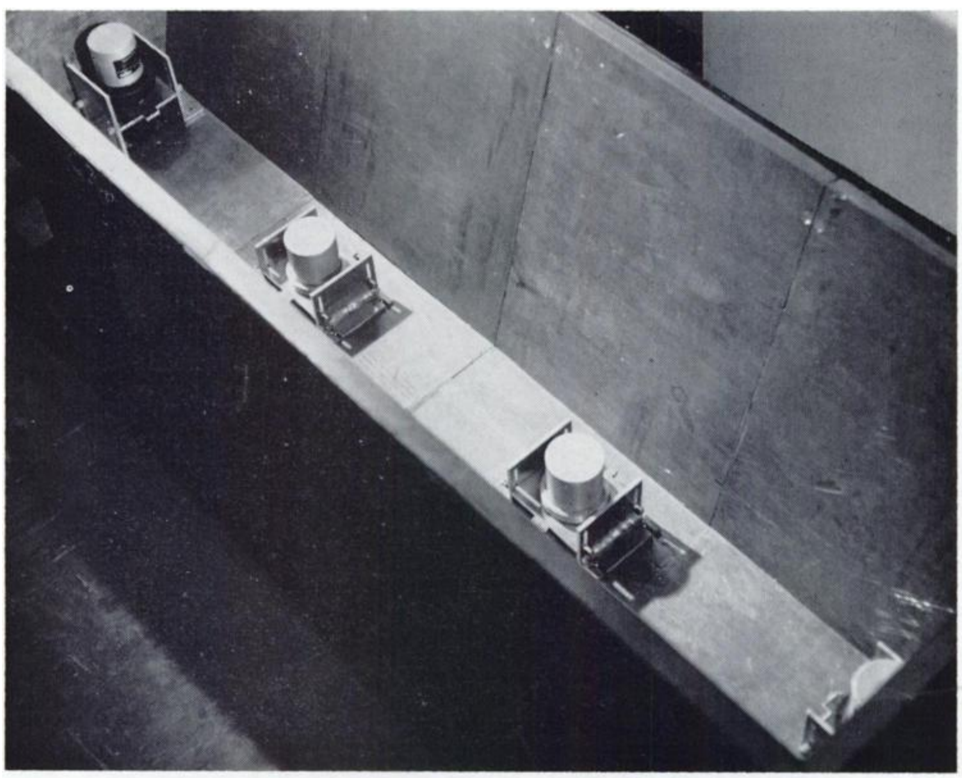

**Fig. 3. Arrangement of detectors (looking down into shield).**

enough to allow the counter to operate effectively over its required sensitivity range. The inside dimensions of the upper mouth of the shield are 58.5 cm wide by 188.0 cm long. The brackets supporting the detectors were made so that the height of each detector is adjustable to permit final trimming of the sensitivity characteristic. Assuming a subject having a 25-cm front-to-back thickness, the experimentally chosen working distances, to his 12.5 cm center line, are 66 cm for the two inner crystals, and 58 cm for the end ones. By placing the two end crystals nearer the subject in this manner, a good degree of compensation is obtained for the fall-off in response toward head and feet that would result with a row of crystals at uniform height. Figure 3 shows the inside of the shield and the arrangement of detectors. The finished shield weighs approximately 3000 lb and is supported from the floor by a simple steel framework.

In operation, the patient lies over the detector-shield assembly on a Transaver X-ray stretcher,[1] which has considerable mechanical flexibility, and more importantly, a supporting surface made of a thin, radiolucent alloy. Gamma rays emitted from the patient therefore pass down into the detector system with very little absorption. The stretcher also has swiveling legs so that it may be used to move a nonambulatory patient from his bed to the counter with only one complete transfer involved (Fig. 4).

[1]Available from any x-ray supply company

**Fig. 4. Patient in counting position on the Transaver stretcher.**

All counts detected by the four crystals are summed into one single-channel analyzer system. The electronic instrumentation uses a charge-sensitive preamplifier so that the effects of capacitance in the rather long, interconnecting coaxial cables are minimized. Spectrometry is normally used because a sizeable amount of scattered radiation is generated by the gamma rays from the subject impinging on the sides and bottom of the lead collimator. The ouput of the spectrometer drives a decade scaler. In choosing a spectrometer system for this counter, electronic stability is important. Since four detectors are to be calibrated for gamma energy, setting the gain for each detector and having it stay there is desirable; otherwise, much of the working day can be spent adjusting and fretting over the several gain controls.

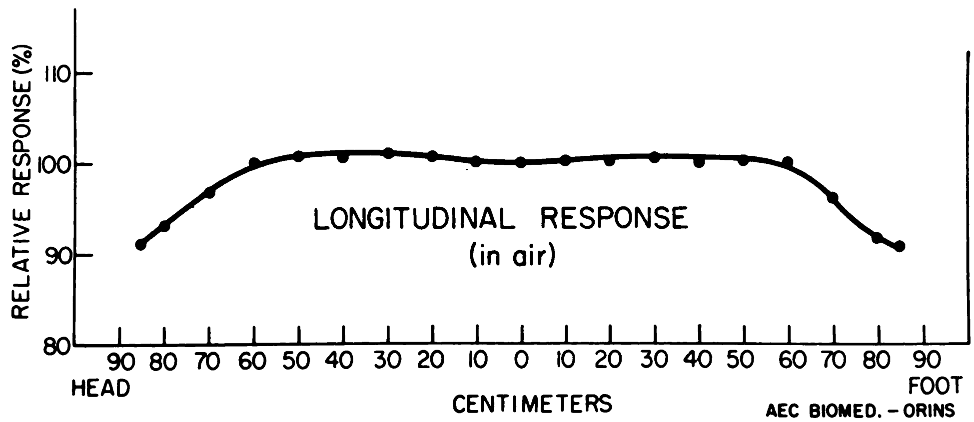


Fig. 5. Plot of longitudinal response along the length of the bed.

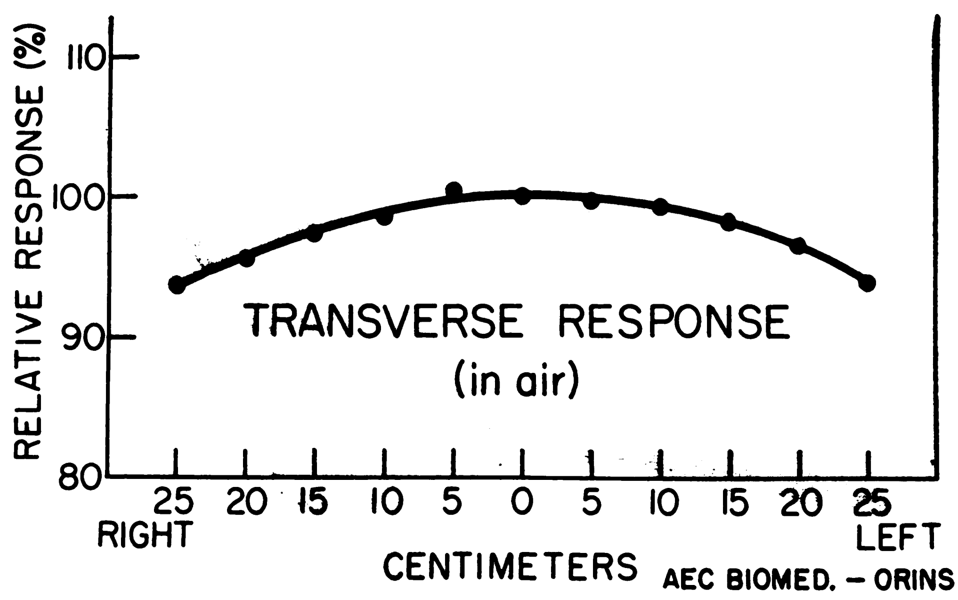


Fig. 6. Transverse response across the bed.

TABLE I. SENSITIVITY CALIBRATION RESULTS*

| *Activity*† ($\mu C^{131}I$) | *Net Counts/Min* |
|---|---|
| 0.1 | 191 |
| 0.25 | 458 |
| 0.5 | 896 |
| 1.0 | 1,725 |
| 2.5 | 4,273 |
| 5.0 | 8,314 |
| 10 | 16,527 |
| 25 | 40,580 |
| 50 | 77,494 |
| 100 | 143,857 |

*Background counts were subtracted to give the net counts in this table. A typical background for a spectrometer passband of 300 to 390 keV is 1,147 cpm.

†Nuclide was $^{131}I$ dissolved in an 8-liter, water-filled plastic bottle.

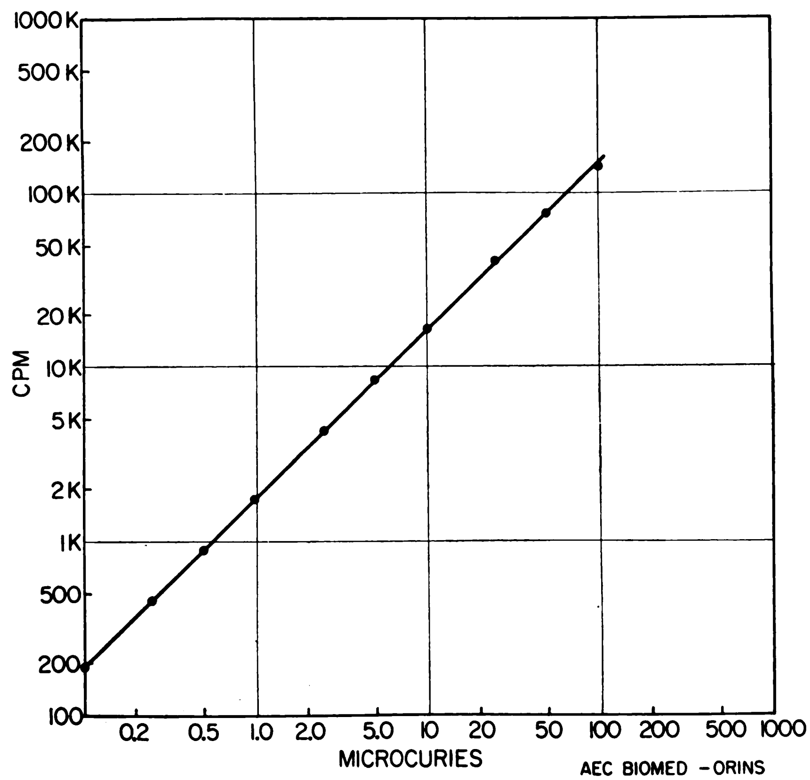


**Fig. 7. Counting rates versus phantom activity for diagnostic-level whole-body counter. Increasing activities of $^{131}I$ were thoroughly mixed into an 8-liter, water-filled bottle, which was then counted at the center of the bed.**

## CALIBRATION

After the height of the various crystals was adjusted to give the best response, a series of measurements was made in air to determine how uniform the response was. A small source was moved in 10 cm steps from the head end to the foot at a distance of 12.5 cm above the stretcher; the resulting counts, plotted in Fig. 5, indicate that, until end effects are encountered at the head and foot of the shield, the response is reasonably uniform. A plot of transverse response measured across the center of the bed is shown in Fig. 6. Here again the curve is reasonable until the limits of the stretcher are encountered.

Measurements were also made to determine the linearity of counting rate versus activity of the source. As in the high-level, whole-body counter (1), an 8-liter polyethylene bottle filled with water was used. Known amounts of $^{131}$I were thoroughly mixed with the water content of the bottle and counted at the center of the stretcher. The counts obtained are given in Table I and plotted in Fig. 7. The results show that over the design range of 0.1 to 100 $\mu$c this counter gives a reasonably uniform response.

The response of the present system has been carefully evaluated in phantoms and patients toward determining what types of errors are to be expected and possible methods for correcting them (2).

## OPERATION

Although this counter has only recently been put into operation, the first results are encouraging.

Whole-body retention counts and phantom studies using $^{131}$I, $^{51}$Cr, and $^{198}$Au have begun. Routine practice using this counter is similar to that of the high-level counter described earlier. A known dose is administered to the patient, and from the same stock bottle an appropriate known amount of activity is also introduced into an 8-litter, water-filled bottle that serves as a standard. Ordinarily, counts are made by counting the patient, standard bottle, and background consecutively. From these counts the values for percentage retention are computed. Some of these studies may run for a week or more and the standard bottle gives a good check on instrument performance over these long periods of time. For radioisotopes with short physical or biological half-lives, counts may be made at hourly intervals, if desired. With $^{131}$I over an activity range from 1 to 100 $\mu$C; a counting time of only 1 min is required. Ten-minute counts are required for good statistics at 0.1 $\mu$C.

## CONCLUSION

This diagnostic-level counter has a distinct advantage in that it allows whole-body retention studies to be made simultaneously with other clinical tracer investigations. In contrast to the low-level whole-body counters now in use in many installations, it is relatively inexpensive to construct. Moreover, the subject is in an unconfined, comfortable position, and the counting times are short.

This counter is subject to the same response problems caused by absorption, inverse-square variations, and changing radioisotope distributions observed in other whole-body counters. A first step has been made in this counting system toward reducing some of these errors by making the response reasonably uniform in air. Other designs such as adding a duplicate shield and detector array over the patient should be tried.

In spite of these limitations, however, our experience with phantoms and some initial patient studies indicates that this will be a useful instrument for following whole-body retention and other measurements in the diagnostic dose range.

## REFERENCES

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2. Presented at the Eleventh Annual Meeting, Society of Nuclear Medicine. See abstract: Kakehi, H. and Hayes, R. L.: Counting Characteristics of a Medium-level Whole-body Counter. *J. Nuclear Med.* **5**:372, 1964.