width of the ring-shaped zone. If, neglecting the effect (b), one calculates the values of S and α giving the best resolution for a given luminosity (product of the solid angle ω by the area of the source) one finds that the optimum conditions are $\alpha=40° 25'$, and $S/D=11.4(\Delta\alpha)^2=0.172\omega^2$ ($\Delta\alpha$ in radians, ω in steradians). The inverse resolution is then given by $\Delta p/p=0.156\omega^2$ (so that, approximately, $S/D=\Delta p/p$). Under these conditions, $\frac{4}{5}$ of the Δp are produced by the width of the source and $\frac{1}{5}$ by the residual spherical aberration. The radius of the ring focus is $0.544D$ and the distance of its plane from the source is $1.63D$.

The relative importance of the neglected (b) effect may be roughly evaluated by saying that its contribution to the width of the ring-shaped zone (if the first limiting diaphragm is at the point of maximum distance of the rays from the axis) is about $0.17\omega^2$ of the total width—e.g., for $\Delta\alpha=2°$ (that is a solid angle $\omega=0.572$, more than 4.5 times that of Witcher) this contribution is only 1.4 percent.

It would seem that a spectrometer made on such a design and having the same resolving power as that of Witcher should have a luminosity more than 7 times greater.

[1] C. M. Witcher, Phys. Rev. **60**, 32 (1941).
[2] S. Frankel, Phys. Rev. **73**, 804 (1948).

Measurements of Radio Frequency Resistance of a Piece of Columbium Nitride through the Transition

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THE purpose of this investigation was to ascertain the relationship between DC resistance and RF resistance of columbium nitride through the transition from a normal state to a superconducting state. The DC resistance has been measured accurately by potentiometer methods, but the actual RF resistance has not been ascertained up to now.

The first method of approach to measure the RF resistance was to build an oscillating circuit including the strip of columbium nitride under test and measure the decay time of oscillations once built up in the tank circuit. If then the resistance of the CbN changes abruptly over the transition range, one would expect a correspondingly large change in the losses of the circuit and hence in its ringing time. This method, however, had to be abandoned because it was found that at low temperatures the losses in the condenser of the tank circuit change in an unpredictable fashion and overshadow the change in CbN resistance.

Accordingly the following method has been used to determine the RF resistance of CbN over the transition range. The Q of a coil with and without the strip of CbN in series was measured both above and below the transition temperature of the CbN. Assuming all the losses in the circuit to be series losses, the difference between the measurements with and without the CbN gives them the additional resistance introduced by the CbN at the frequency considered. Within the limits of experimental error the RF resistance of the CbN strip was found to be exactly equal to the DC resistance measured at the same temperatures. This holds true at frequencies of from 600 to 1000 kc.

This result was to be expected because of the relatively large ohmic resistance per cm length of CbN above the transition. For such a high value of resistance the skin effect is essentially negligible. The apparatus as used was not delicate enough to measure the differences in resistance when the strip of CbN is almost completely superconducting. Theoretical computations, however, have indicated that a change in resistance can be expected when the d.c. resistance of the strip falls down to approximately 10^{-2} ohm or below. However, the absolute magnitude of the difference is too small to be noticeable, if curves of resistance *vs.* temperature are plotted for varying frequencies up to 1 mc. It can thus be assumed, that, for all practical purposes, the DC and RF transition curves of the CbN are identical.

Variation of Penetrating Showers with Altitude

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PRELIMINARY results have been obtained from an experiment designed to determine the dependence on altitude of penetrating showers. The equipment used as a detector of these showers is similar in principle to the various arrangements used in recent experiments of Broadbent and Janossy,[1] and Jason and George.[2,3] Five trays of Geiger-Mueller counters are arranged as shown in the accompanying figure (Fig. 1); each counter has an active length of ten inches, and is one inch in diameter. There is a thickness of four inches of lead over tray A, between trays A and B, and between trays B and C, and a thickness of three inches on the sides of trays D. The eight counters in trays D are effectively connected in parallel, while fast addition circuits are used in the other trays to select coincident discharges of two or more counters in each tray.

The events recorded can be represented by the following symbols: $A_1B_1C_1$, $A_1B_1C_1D_1$, $A_2B_2C_2$, $A_2B_2C_1$, $A_1B_2C_2$, $A_2B_2C_2D_1$, $A_1B_2C_2D_1$, where, for example, $A\alpha B\beta\cdots$ indicates a simultaneous discharge of α or more counters in tray A, β or more counters in tray B, and so on.

The equipment was operated on the ground at Lexington, Massachusetts (altitude: 300 ft.) and in a B-29 airplane flying at altitudes of 15,000, 20,000, 25,000, and 30,000 feet; all measurements were taken at a geomagnetic latitude of about 53°. The rates of coincidences of the types $A_1B_1C_1D_1$, $A_2B_2C_2$, $A_2B_2C_1$, and $A_1B_2C_2$ are plotted as a function of atmospheric depth in g cm^{-2}; the standard deviations have been indicated wherever they exceed 5 percent.

In interpreting the results, one may make the following assumptions:

(1) Chance coincidences are completely negligible. This follows from the fact that the resolving time for selection of coincidences is less than 2 μsec.
(2) Ordinary air showers have a negligible effect. This is to be expected in consequence of the thick lead shielding. The fact that the observed events vary with altitude much more rapidly than air showers is a good indication that this assumption is valid.
(3) Triple knock-on processes of mesons contribute only a small amount to the observed rate of $A_2B_2C_2$. This needs to be demonstrated only at sea level, since the meson intensity increases with altitude much more slowly than the observed rate of $A_2B_2C_2$. At sea level, an upper limit for the number of events $A_2B_2C_2$ caused by triple knock-on processes can be computed by assuming that the rates of $A_2B_2C_1$ (or $A_1B_2C_2$) are entirely due to double knock-on processes. Under this assumption, and considering the rate of $A_1B_1C_1$ (1180 per hour), one calculates a triple knock-on rate of 0.03 per hour, as compared with the observed rate of 0.2 per hour for the event $A_2B_2C_2$. Since, as pointed out below, it is probable that only one-half of the events $A_2B_2C_1$ (or $A_1B_2C_2$) are caused by double knock-on processes, the knock-on contribution to the rate of $A_2B_2C_2$ is probably less than that given above.

The experimental results are then interpreted in the following way: At all altitudes, the event $A_2B_2C_2$ is the result of nuclear interactions in which penetrating particles are produced. The experimental points indicate an exponential variation with depth corresponding to an absorption thickness for the primary agent of about 120 g cm^{-2}. It appears quite significant that (at all altitudes) the rate of the event $A_2B_2C_2D_1$ (not shown in Fig. 1) is found to be only about 8 percent less than the rate of $A_2B_2C_2$. This suggests large multiplicity and large angular divergence in the production of secondary penetrating particles.

The rates of $A_2B_2C_1$ and $A_1B_2C_2$ at high altitudes follow roughly the same exponential dependence on depth as the rate of $A_2B_2C_2$, but deviate from this exponential behavior near sea level. One explains this result by assuming that for these events double knock-on processes become relatively important in the lower atmosphere. This is confirmed by the observation that the ratio of the rate of $A_2B_2C_1D_1$ to the rate of $A_2C_2B_1$ is over 0.9 at high altitudes, but only about 0.5 on the ground. Since double knock-on processes have a negligible probability of discharging trays D, one may conclude that about half of the counts recorded on the ground in the case of $A_2B_2C_1$ are due to double knock-on processes. The situation is similar in the case of $A_1B_2C_2$.

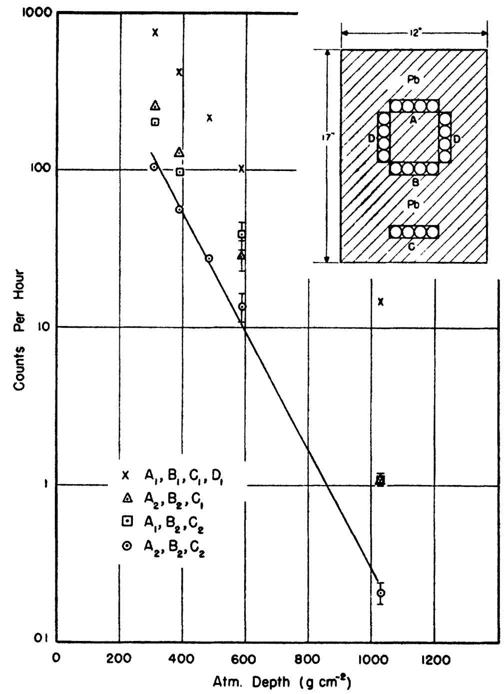

FIG. 1.

It is interesting to note that, at high altitudes, the event $A_1B_1C_1D_1$ varies with depth almost as rapidly as the event $A_2B_2C_2$. This indicates that, at least at high altitudes, most of the events $A_1B_1C_1D_1$ are also caused by nuclear interactions.

While it is believed that most of the events observed are produced by penetrating showers originating in the lead block, it is not possible, from the data presented here, to ascertain the contribution of penetrating showers from the atmosphere. This question has recently been studied by Jason and George,[3] and the writer is planning to investigate it further.

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[3] E. P. George and A. C. Jason, Nature **161**, 248 (1948).