characteristic of an $E2$ transition. Thus we make the assignment of pure $E2$ radiation in the case of γ_2 as well as γ_1. This conclusion is very much in line with the recently published work of Goldhaber and Sunyar,[20] who find that the first excited state of about 30 even-even nuclei has spin 2 and + parity (all spin 0 and + parity in the ground state).

Figure 15[21] summarizes the conclusions of this section.

[20] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83**, 906 (1951).
[21] D. E. Alburger and E. M. Hafner, Revs. Modern Phys. **22**, 373 (1950).

No conclusions from the data in this experiment can be derived as to the parity of Na^{24}. The spin assignment of Na^{24} comes from the recent work of Smith.[22]

I should like to express my profound gratitude to my sponsor, Professor H. L. Anderson, whose interest and encouragement made possible this work.

I would also like to express my thanks to C. Y. Fan, David Saxon, M. Goldberger, and M. Friedman for their generous help.

[22] K. F. Smith, Nature **167**, 942 (1951).

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Rocket Determination of the Ionization Spectrum of Charged Cosmic Rays at $\lambda = 41°$N

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(Received June 30, 1952)

In a V-2 rocket measurement at $\lambda = 41°$N an analysis has been made of the various components of the charged particle radiation on the basis of ionization and absorption in lead. The ionization was determined by two proportional counters, the particle paths through which were defined by Geiger counters. With increasing zenith angle toward the north, the intensity is found to be substantially constant until the earth ceases to cover the under side of the telescope. The intensity of all particles with range ≥ 7 g/cm² is 0.079 ± 0.005 (cm² sec steradian)$^{-1}$. Of this an intensity 0.012 ± 0.002 is absorbed in the next 14 g/cm². The ionization measurement is consistent with $\frac{3}{4}$ of these soft particles being electrons of $<\sim 60$ Mev, the remainder being slow protons and alpha-particles. For the particles with greater range an ionization histogram is plotted, the smaller of the two ionization measurements for a single event being used to improve the resolution. The particles divide into protons, alpha-particles, and one carbon nucleus, with $N_p/N_\alpha = 5.3 \pm 1.0$. Their absorption is exponential with mean free path 440 ± 70 g/cm² Pb. Extrapolating to zero thickness, the total primary intensity is 0.070 ± 0.005 (cm² sec steradian)$^{-1}$ with 0.058 ± 0.005 as protons, 0.011 ± 0.002 as alpha-particles, and 0.001 ± 0.001 as $Z > 2$.

INTRODUCTION

THIS paper reports on some measurements made on February 17, 1950, by apparatus flown in a V-2 rocket. The launching occured at White Sands, New Mexico (geomagnetic latitude 41°N). The purpose was to distinguish among and count the various components of the charged particle cosmic radiation above the atmosphere. For each particle which entered the solid angle of a Geiger tube telescope, the ionization was measured twice, using proportional counters for the purpose. The subsequent history of each particle in traversing lead absorbers was then recorded. In this way the poor statistics of a rocket flight were somewhat compensated by detailed knowledge of each recorded event.

THE EXPERIMENTAL METHOD

Figure 1 shows the telescope schematically. The rocket nose in which it was mounted was a conical shell of $\frac{1}{16}$-inch Al joining at the wide end and about halfway down the telescope to an Al cylinder $\frac{1}{8}$-inch thick. The coincidence ABC (which we shall abbreviate as T) defined a beam of particles which traversed the proportional counters P_1 and P_2. No event of any sort was registered unless the threefold T occured coincidently. The discharge of either group S_1 or S_2 indicated a "side" shower, as did the discharge of both counters A_1, A_2 comprising tray A or C_1, C_2 of tray C. The side showers were presumably undesired events but were registered for information. Counter trays D, E, and F beneath their respective lead absorbers covered the solid angle of T with some overlap. Thus, each selected particle was interrogated as to its range in lead within certain limits. Trays D and E were further subdivided into threefold sets and tray F into a fourfold set. In this way showers produced in the absorbers could be detected, provided of course that T was tripped.

The proportional counters contained argon with 2 percent of CO_2 and were filled to atmospheric pressure. Figure 2 is a plot of multiplication *vs* voltage obtained by irradiating the active region with γ-radiation and measuring the current with a vibrating reed electrometer. The counters behaved identically, although this was actually not essential to the reduction of flight data. The counters were operated finally at a multiplication ~ 2000. The stability of voltage was not a problem at any time.

The electronic coincidence circuits were of the diode

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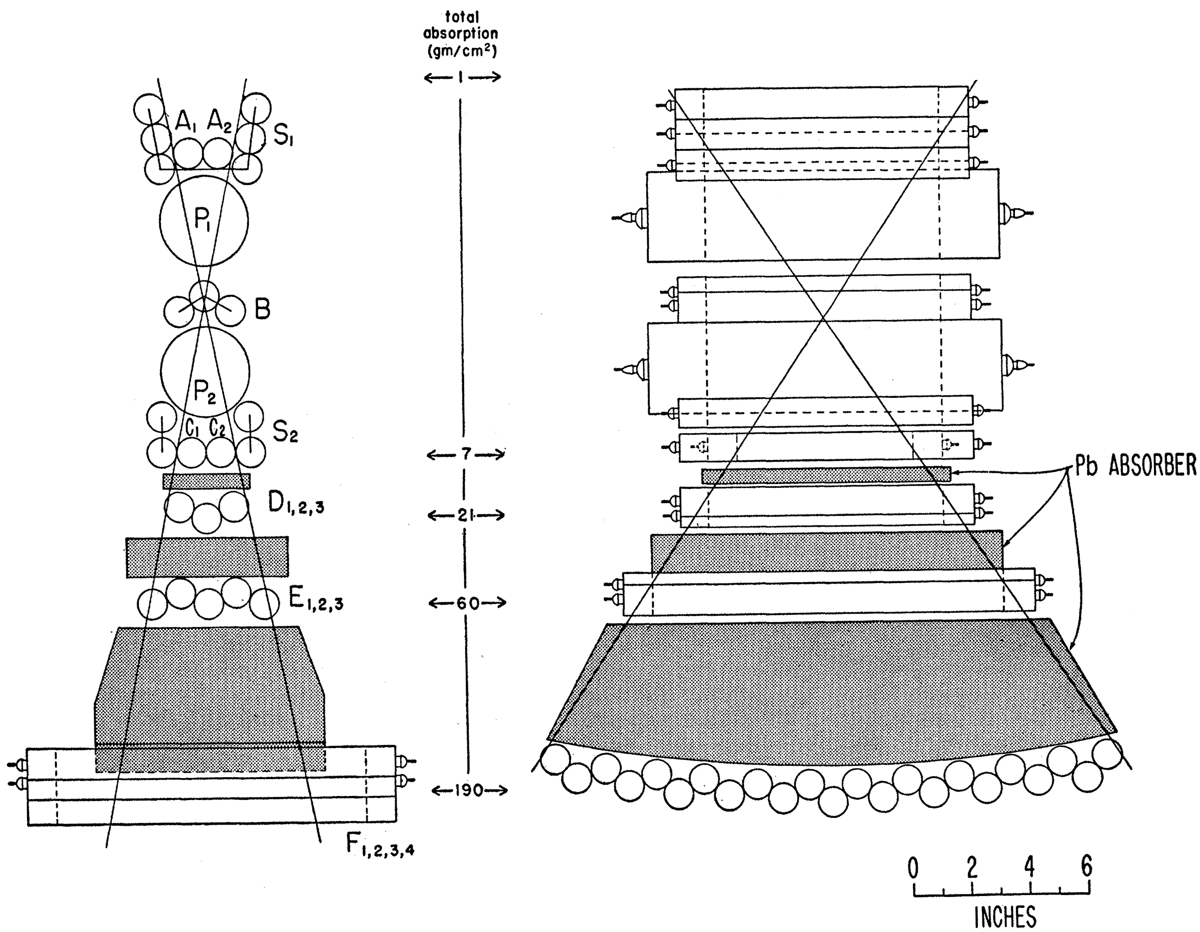

FIG. 1. Diagram of telescope.

type,[1] with resolving times ~5 μsec. The proportional counter pulses were separately amplified, gated by a pulse derived from the event T, stretched to 20 milliseconds for radio telemetering,[2] and then annihilated. By using high and low sensitivity scales the range $0 \leq I \leq 35I_0$ was covered with good accuracy. Here I_0 is the most probable ionization of a fast singly charged particle in one proportional counter. The ionization system was calibrated with the sea-level hard component.

Figure 3 shows two sections of the flight telemetering record with various events identified on the basis of ionization and penetration.

The zenith angle of the rocket, hence of the telescope, was determined to $\pm 2°$ by motion picture photography of the horizon using a simple sort of wide-angle lens (~110° angular aperture). The rocket's azimuth was determined by land marks and by the position of the sun's image during parts of the flight. Gyroscopes confirmed the camera data.

[1] Howland, Schroeder, and Shipman, Rev. Sci. Instr. **18**, 551 (1947).
[2] N. R. Best, Electronics **23**, No. 8, 82 (1950).

INTENSITY OF THE TOTAL RADIATION

The rocket rose to a maximum height of 150 km, 220 seconds after launching. At the maximum, the zenith angle was 68° and continuing a nearly linear increase with time. The azimuth angle was 10° west of geographic north (19.5° west of geomagnetic north) and slowly turning toward geographic north. The azimuth of the rocket may be generally summarized in the statement that whenever the telescope was not nearly vertical, it pointed nearly north.

Table I is a summary of data without regard to ionization. They are divided into five 50-second intervals starting at 68 seconds from take-off. At that time the atmospheric depth was 2.5 g/cm² and decreasing about 20 percent per second. The range of zenith angle variation is listed for each time interval. The rows of the table refer to events of different penetration, $TDEF$, for example, denoting penetration of the total absorber. The supports and counter walls are an appreciable part of the absorber for events of small penetration, but are lumped together with the lead as g/cm². In each time interval for each type of event we list the number of events R to be retained because they are not associated

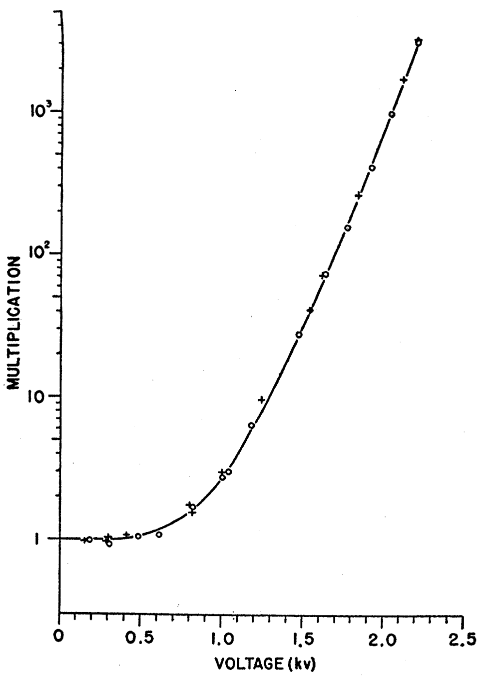

FIG. 2. Multiplication *vs* voltage for the proportional counters.

with showers above the absorber (i.e., no A_1A_2, C_1C_2, S_1, or S_2). The columns marked Δ, list events deleted for the opposite reason. The following observations may be made:

(1) The total number of retained events R does not change within statistics in the first three intervals comprising the zenith angle spread $6°\leq\theta\leq 63°$ and leads to a value 0.079 ± 0.005 $(\text{cm}^2 \text{ sec sterad})^{-1}$ for the intensity from the neighborhood of the vertical for 7 g/cm^2 telescope thickness and rocket skin. This is in agreement with the measurements of others.[3]

(2) The total intensity apparently increases abruptly by a factor of 1.5 for the last two intervals $63°\leq\theta\leq 101°$. The increase is nearly all in the penetrating component *TDEF*, and examination of the ionization shows it attributable mainly to partizles of $Z=1$.

(3) The rate of *deleted* events increases monotonically with θ to a value in the fourth and fifth time intervals 2.4 times that in the first. This increase is not specific

TABLE I. Summary of events without regard to ionization.[a]

Time (sec)		68–117		118–167		168–217		218–267		268–317	
Zenith angle		6°–19°		19°–42°		42°–63°		63°–82°		82°–101°	
Event	Range (g/cm²)	R	Δ	R	Δ	R	Δ	R	Δ	R	Δ
T	$7\leq X<21$	6	4	4	4	8	14	9	7	7	9
TD	$21\leq X<60$	1	11	1	11	5	10	7	18	3	23
TDE	$60\leq X<190$	11	8	8	15	5	19	4	31	10	25
TDEF	$190\leq X$	21	15	20	19	25	18	40	33	36	34
Total		39	38	33	49	43	61	60	89	56	91

[a] The columns marked Δ represent events accompanied by a shower above the absorber and are to be discarded finally. The columns marked R represent the opposite case and are to be retained.

[3] Winckler, Stix, Dwight, and Sabin, Phys. Rev. **79**, 656 (1950); J. A. Van Allen and S. F. Singer, Phys. Rev. **78**, 819 (1950).

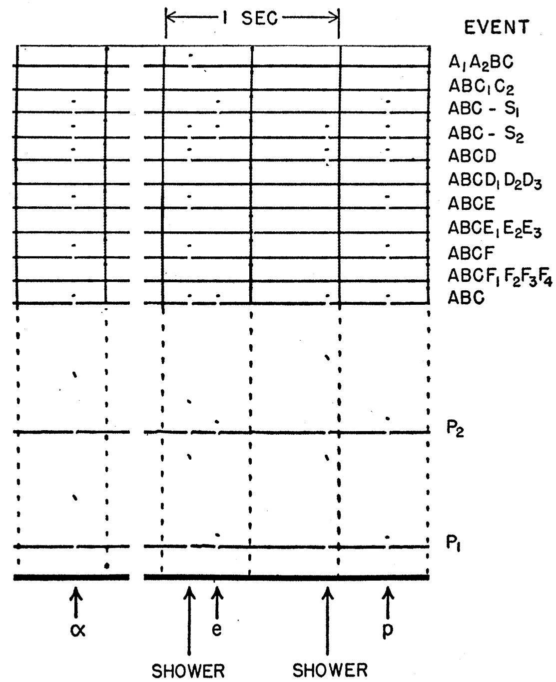

FIG. 3. Two samples of the telemetering record. The low sensitivity scales of ionization do not appear on this record. The particle marked α penetrates at least 190 g/cm^2 Pb without a detectable shower and ionizes at about $4I_0$. The particle marked p has the same history except that the ionization is $\sim I_0$. The particle marked e stops in the first absorber with ionization $\sim I_0$ and is considered an albedo electron. Two events showing showers above the lead fall in the Δ class (deleted events).

to any particular type of event but changes in about the same ratio for all except the softest particles T. Excluding these, the increase in Δ is found to be strongly associated with showers below the lead. Thus, comparing 6°–42° with 63°–101°, the increase in Δ, *TDEF* is 33 per 100 seconds while the increase in the subclass of these events which show showers somewhere below the lead is found to be 25 per 100 seconds. This suggests that the increase in Δ events is caused by nuclear interactions in the lead due to primaries coming from outside of the solid angle of T. Figure 4 illustrates the

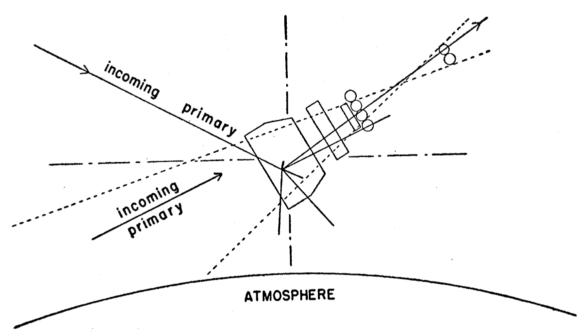

FIG. 4. The particle coming in from the upper left produces a shower in the lower absorber and an event classified as Δ, *TDEF*. The figure also serves to illustrate the cause of the apparent increase in intensity with zenith angle as the effective atmospheric layer ceases to shade the telescope from radiation as at the lower left.

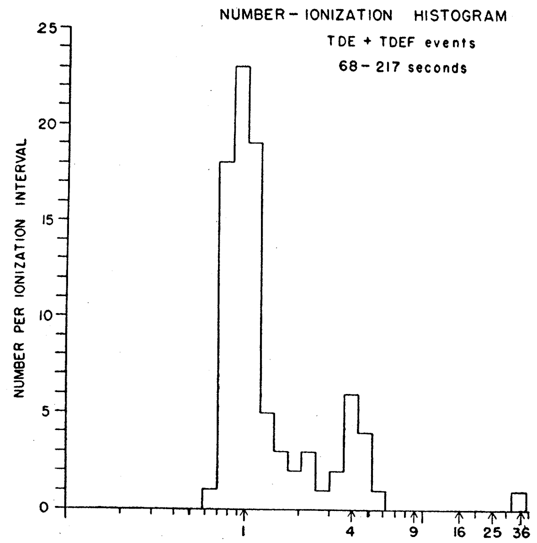

FIG. 5. Distribution in ionization for 150 seconds of flight, of particles which produce a count below 60 g/cm^2 Pb. There are two ionization measurements of each particle. The smaller of the two is plotted in this histogram. I_0 is the most probable ionization of a fast singly charged particle in one proportional counter.

process which becomes more probable with increasing θ. With the aid of this figure one may also visualize the main cause of the increase in retained events R for $\theta > 60°$. During the time of interest the tangent to the earth lies 12° below the plane $\theta = 90°$. The effect of the atmosphere is to decrease this dip angle to 10° for the process to be considered. The angular aperture of the telescope is $\pm 35°$ in one plane and $\pm 6°$ in the other. The rocket rolled about its axis with a period of about 20 seconds. After the zenith angle reached 45° it was possible, depending on the roll angle, to receive radiation through both ends of the telescope, the effect becoming serious for $\theta > \sim 65°$. The particles going through the bottom end must penetrate all the lead to register, thereby showing up as $TDEF$ events as observed. A calculation gives qualitative agreement but does not rule out some increase in the intensity of the penetrating component near the (north) horizon.[4]

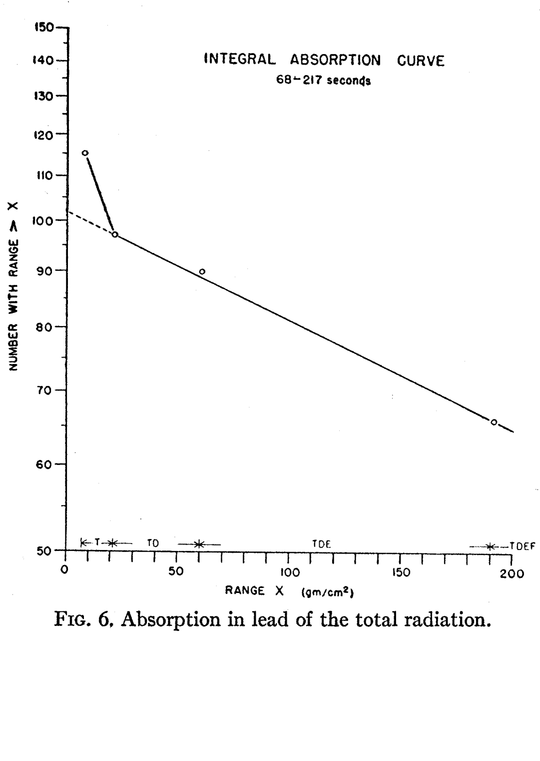

FIG. 6. Absorption in lead of the total radiation.

IONIZATION DISTRIBUTION

In Fig. 5 we have plotted a number-ionization histogram for the combined class of events $TDEF$ and TDE for the first three time intervals listed in Table I. Of the two ionization measurements for each event we have chosen the smaller. It is known[5] that the general shape of the energy loss and ionization distribution in cases like the present, where the particle loses very little of its energy in the measuring instrument, is a Gaussian curve with a tail toward high energies. Taking the smaller of two measurements greatly diminishes the tail. The ionization scale is logarithmic, the interval size increasing proportionally with the ionization. Monoenergetic groups of different Z have distributions of nearly equal width on such a plot.

TABLE II. Intensities of the various components.

	Present measurements	Measurements of others
Total ionizing particle intensity (range$\geq$7.0 g/cm^2)	0.079$\pm$0.005	0.082$\pm$0.002[a] 0.073$\pm$0.006[b]
Total primary intensity (extrapolation to zero g/cm^2, Fig. 6)	0.070$\pm$0.005	
Proton/alpha ratio	5.3 $\pm$1.0	
Primary proton intensity	0.058$\pm$0.005	
Primary alpha-particle intensity	0.011$\pm$0.002	
Primary $Z>2$ intensity	0.001$\pm$0.001	(8.3$\pm$0.7) $\times 10^{-4}$ [c]
Albedo particle intensity (7$\leq$range $\leq$21 g/cm^2)	0.012$\pm$0.002	
Electrons ($<\sim$60 Mev)	0.008$\pm$0.002	
Slow protons	0.003$\pm$0.001	
Slow protons or alpha-particles	0.001$\pm$0.001	

Intensities in (cm^2 sec steradian)$^{-1}$

[a] Range$\geq$34 g/cm^2 Pb at 15 g/cm^2 depth [Winckler, Stix, Dwight, and Sabin, Phys. Rev. **79**, 656 (1950)].
[b] Range$>\sim$4 g/cm^2 Cu in rocket [J. A. Van Allen and S. F. Singer, Phys. Rev. **78**, 819 (1950)].
[c] Primary $Z\geq 6$ intensity at $\lambda = 41.7°$N [Kaplon, Peters, Reynolds, and Ritson, Phys. Rev. **85**, 295 (1952)].

The proton peak at $I/I_0 \sim 1$ and the alpha-particle peak centered about $I/I_0 \sim 4$ may be seen clearly. One particle was observed with $Z=6$ and none between this and the alpha-particle group. The statistics do not, however, permit conclusions to be drawn regarding the presence of Li, Be, or B primaries. The division into alpha-particle and proton peaks is uncertain by a few particles, but using $I/I_0 = 2.5$ as a dividing line we get a ratio of 5.3 protons for each alpha-particle.

The event TD corresponding to a range $21 \leq X < 60$

[4] A similar increase with θ in a rocket flight has been reported by S. F. Singer, Phys. Rev. **77**, 729 (1950). The explanation given here seems to apply to his observations.

[5] E. J. Williams, Proc. Roy. Soc. (London) **A135**, 108 (1932); L. Landau, J. Phys. (U.S.S.R.) **8**, 201 (1944); N. Bohr, Det Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd. **18**, No. 8 (1948).

g/cm^2 occurs only once in each of the first 50-second intervals of Table I and 5 times in the third for a total of 7 to be considered. On the other hand, 31 cases are deleted because of showers above the absorbers. Thus there is some doubt as to whether all the events are real. A histogram of them shows 6 in the $Z=1$ category and 1 in the $Z=2$. They will not therefore affect the proton/alpha-particle ratio obtained above. With some reservation we shall consider them as primaries which stop without producing penetrating secondaries. According to Camerini *et al.*[6] such events (O_p in their notation) have still some probability of occurrence for the primary energies at this latitude (>4 Bev for vertical incidence).

The T events appear to be a real phenomenon but not attributable to primaries. Of the 18 listed in the first three columns of Table I, 11 have ionization consistent with their being low energy electrons, 5 with protons, and 2 with protons or alpha-particles. It has not been found possible to explain away any but a quite small fraction as due to events in the rocket skin, counter walls, or absorber below. On the other hand, they are considerably too numerous to be regarded as stopped primaries having no penetrating secondaries. We conclude that they are returning particles of the earth's albedo. They form 15 percent of the incoming charged particle radiation. This compares to 13 percent found to be absorbed in 2 cm Pb by Golian and Krause[7] and 22 percent by Perlow and Shipman[8] in 2 cm Pb. The latter experiment probably had insufficient shower protection.

[6] Camerini, Davies, Fowler, Franzinetti, Muirhead, Lock, Perkins, and Yekutieli, Phil. Mag. 42, 1241 (1951).

[7] S. E. Golian and E. H. Krause, Phys. Rev. 71, 918 (1947).

ABSORPTION IN LEAD

It is instructive to plot as in Fig. 6 an integral absorption curve of the total charged radiation. The number of counts at a given thickness is not independent of the number at another thickness, only the difference being independent. The line drawn has therefore somewhat better statistical basis for its slope than the numbers might seem to imply. The T events appear as an extra group. The main portion of the curve corresponds to an absorption mean free path of 440 ± 70 g/cm^2 in lead.

Table II lists the intensities of the various components. The total primary intensity is obtained by extrapolating to zero thickness the main portion of the absorption curve of Fig. 6. The proton and alpha-particle intensities are obtained by applying the ratio 5.3 mentioned before to this number. The events of type T are considered as albedo particles.

The authors wish to acknowledge the aid given by their colleagues in the Rocket Sonde Research Branch, Naval Research Laboratory, and by personnel of the White Sands Proving Grounds. We are especially indebted to T. A. Bergstralh, C. A. Schroeder, C. Y. Johnson, H. M. Caulk, and P. R. McCray.

[8] G. J. Perlow and J. D. Shipman, Jr., Phys. Rev. 71, 325 (1947).

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The Superconductive Transition in Tantalum

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The construction of small coreless coils allows the simultaneous measurement of resistive and magnetic transitions in tantalum. As is the case with the other "hard" superconductors, these measurements give evidence of the presence of "filaments" in the metal. The results are explained on the basis of a modification of a two-phase model used previously, and critical field-temperature curves are derived for the bulk metal and for the filament material.

MAGNETIC and resistance measurements have been made on tantalum wire supplied by Fansteel Metallurgical Corporation that had been cold drawn to a diameter of 0.25 mm and heated in high vacuum at 2800°K for 100 hours. To prevent distortion and work hardening of the very soft wire resulting from this treatment, close fitting search coils were preformed and then slipped onto the specimen.[1] Nickel terminals were spot welded to the ends of the specimen, the potential and current leads being soft soldered to the nickel. This arrangement allowed magnetic and resistive measurements to be made simultaneously on the same specimen. Resistance measurements over the range 5°K to 300°K were made in a modified Collins A. D. Little cryostat[2] with a galvanometer amplifier[3] as the measuring instrument. θ-values based on the Bloch-Grüneisen formula were obtained from these measurements, the value of 210°K over a large part of the range comparing with the value of 245°K derived from the specific heat measurements. These results together with the low value of the residual resistance ($R/R_0=0.008$ and 0.0074 in the two specimens) suggest that the metal had a rather high degree of physical and chemical purity.

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[1] H. Preston-Thomas, (to be published).

[2] D. K. C. MacDonald, Phil. Mag. 43, 479 (1952).

[3] D. K. C. MacDonald, J. Sci. Instr. 24, 323 (1947).