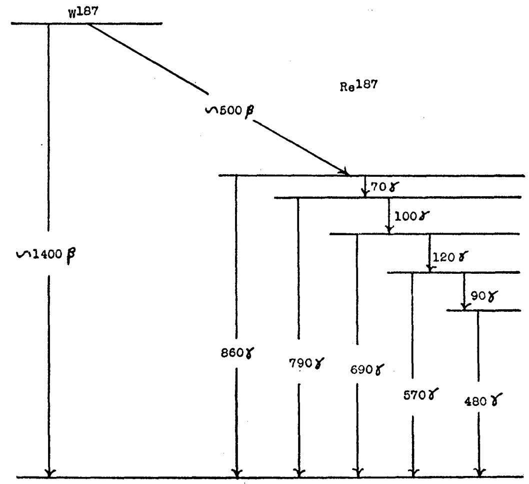

FIG. 1. Proposed energy level diagram of Re[187].

790, and 860 kev. An attempt was made to find a peak corresponding to a gamma-ray energy of 940 kev as previously reported,[3] but without success.

Figure 1 is a suggested energy level diagram for the resulting Re[187] isotope. Valley[5] has reported internal conversion electrons corresponding to gamma-rays of 85, 101, and 135 kev. It is suggested that the 90, 100, and 120 kev transitions indicated in the diagram may be associated with the gamma-rays which Valley observed. Uncertainties due to width of lines can easily account for the differences in the values. The 70-kev jump has not been observed as yet, and this scheme suggests that the region roughly between 150 and 450 kev should be examined for evidence of other possible transitions between these levels.

The gamma-rays of the 67-hour molybdenum were also studied. A typical run is shown in Fig. 2. Here again the intensity of the peaks above the Compton background was not great. Three, however, seem to be confirmed—660, 705, and 730 kev—which correspond to gamma-rays of 770, 815, and 840 kev. Since Mo[99] is in equilibrium with Ma[99], some or all of these gamma-rays may be associated with the masurium decay instead of with molybdenum, but work of Seaborg and Segrè[6] suggests that this is not likely.

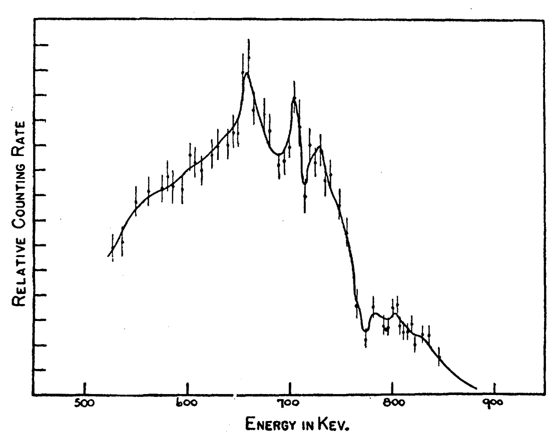

FIG. 2. Gamma-rays from 67-hour molybdenum.

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A Proposed Detector for High Energy Electrons and Mesons*

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USE can be made of the visual radiation emitted by a charged particle moving at constant speed in a medium where the phase velocity of the light is smaller than the velocity of the charged particle to detect such particles. This visual radiation was first observed by Čerenkov.[1] A theoretical investigation was made by Frank and Tamm[2]; and an independent experimental quantitative verification using monoenergetic electrons was made by Collins and Reiling.[3]

If a particle of speed β impinges on a non-absorbing dielectric, then since the speed of the particle is maintained except for collision and radiative losses, the speed of the particle will remain equal to β. On the other hand the phase velocity of electromagnetic radiation is reduced to $1/n$ where n is the index of refraction of the dielectric. Frank and Tamm have shown that under these conditions the vector potential does not cancel and that coherent radiation exists directed at an angle θ with the direction of motion of the particle such that $\cos\theta = 1/\beta n$. The radiation has an energy spectrum per unit length of dielectric

$$f(\gamma)dr - 4\pi^2 \frac{e^2}{C^2}\left(1 - \frac{1}{\beta^2 n^2}\right)\gamma d\gamma;$$

that is, provided the radiation is not absorbed, light will be given off in that spectral region where n is substantially larger than one. For glasses and plastics like Lucite these conditions are met in the visual region; and since n is practically constant there, the number of photons per unit frequency interval emitted is independent of the frequency. It is to be noted that the Čerenkov effect depends only upon the charge and speed of the particle and not on its momentum or energy. Hence since high energy electrons

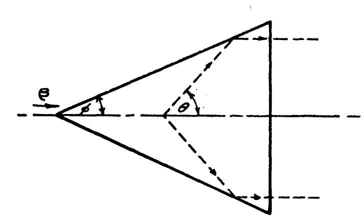

FIG. 1. Simple electron-type radiator ($n = 1.5$).

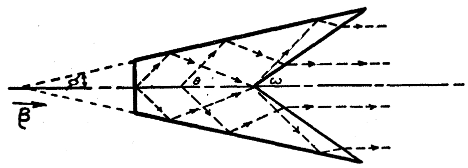

FIG. 2. Electron radiator design for optimum optical properties ($n=1.4$).

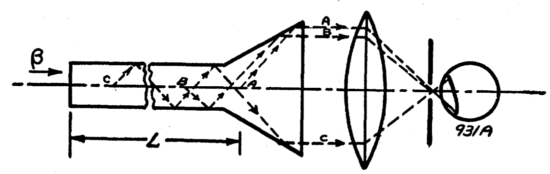

FIG. 3. Practical arrangement of electron (or meson) detector.

(greater than 100 Mev) and mesons are very penetrating, a considerable amount of light can be emitted by the passage of even one particle in a properly designed geometrical unit.

Figure 1 shows a simple cone made say of Lucite ($n_D=1.5$, $n_F-n_C=0.008$). If an electron enters along the axis from the left, all the light emitted will be reflected by the cone into a parallel beam of light if $\phi=\theta/2$. If a condensing lens with diaphragm arrangement is used as shown in Fig. 2, then light emitted at angles differing from θ will not reach the photo-multiplier. Such a unit acts therefore as a telescope. The optical system also reduces the background radiation. The loss in the original particle resulting from Čerenkov radiation is about 1 kev per cm; whereas the loss due to collisions and non-coherent radiations is of the order of 2 Mev per cm for a 100-Mev electron. One might at first expect that the recombination radiation in the dielectric would swamp out any coherent radiation. This, however, is not true, otherwise Čerenkov and Collins and Reiling would not have been able to get their photographs.

For electrons of energy sufficient to penetrate a reasonable length of dielectric, β will always be practically one. Hence for a Lucite electron detector, θ is always 48° 10′ and $\phi=24°\ 5'$. On the other hand a meson of mass 200 will have the following values of β and ϕ for 50, 100, and 200 Mev mesons: 0.73, 0.864, 0.942; 12° 2′, 19° 44′, 22° 30′. Hence an electron detector should not detect mesons unless their energy is in excess of 200 Mev (not possible in a 300-Mev synchrotron). Similarly meson detectors of given energy range sensitivity are possible. Finally, since the detector depends only upon speed, the use of a magnetic field either directly or with a cloud chamber to measure momentum should give a good measure of meson mass.

Figure 3 shows a somewhat better geometry from the standpoint of optics in that the emergent ray comes out at Brewster's angle (the electric vector is always in the radial plane). The smaller ϕ, the smaller is the color dispersion. This is not serious, however, even in the geometry of Fig. 1, where the dispersion between the F and C lines is only 0.4.

Figure 2 shows a practical geometry. The length L can be made as long as required and the cone angle is the same as in Fig. 1. An estimate of the output of the device can readily be made. One expects to get 212 photons per cm of path. Taking L as 20 cm, we should get approximately 4240 photons. If all of these arrive at the photo-multiplier and using 1.2 percent as the efficiency (obtained by using the sensitivity as quoted by the RCA tube handbook for the 931A), there should result a charge pulse at the output of the multiplier of 8.2×10^{-11} coulomb (amplification of 1,000,000). Taking the combined output capacity of the 931A (6.5 $\mu\mu$f) plus the input capacity (13.5 $\mu\mu$f) of a video amplifier as 20 $\mu\mu$f, this should give as the upper limit an output pulse of 0.4 volt. The pulse length of the original photons can be obtained from a consideration of the geometry as 8×10^{-10} sec. This will be lengthened by transit time in the multiplier tube to a total pulse length of about 10^{-9} sec.[4] Theoretically, therefore, the video amplifier should have a band pass approaching 1000 mc providing that it does not itself introduce new noise. The noise arising from the photo-multiplier is evenly distributed over the region under consideration; and some idea of the noise can be obtained from the figure of maximum dark current of the 931A as published in the RCA handbook, it being recognized that much better performance than this figure can be obtained. A dark current on the output of the 931A of 0.25μ amp corresponds to 0.16 electron in 10^{-7} sec., the resolving time of a practical 10-mc video on the output. Since the radiating particle should result in releasing 51 electrons at the first electrode, one can readily see that noise is completely negligible unless the coherency of the radiator is sufficiently reduced.

The choice of material for the radiator is dependent upon the following considerations: (1) it should consist of as low an atomic number as possible in order to have low stopping power for the primary particle; (2) it should have a high value of n to be an efficient radiator; (3) n should be large and the material transparent particularly in the ultraviolet region; (4) the material should have homogeneous optical properties; and (5) color dispersion should be small. Lucite and Plexiglass are suitable though more expensive substances like lithium fluoride would be better.

Test units are being built, and the performances of these and the results of more elaborate analysis will be published as soon as they become available.

* The research described in this letter was supported in part by Contract N5Ori-78, U. S. Navy Department.

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Effect of Direct-Current Potential on Initiation of Radiofrequency Discharge

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November 6, 1946

IN the course of development of radar duplexing systems at the start of the war I observed an effect which was unexpected and which to my knowledge has not been reported.