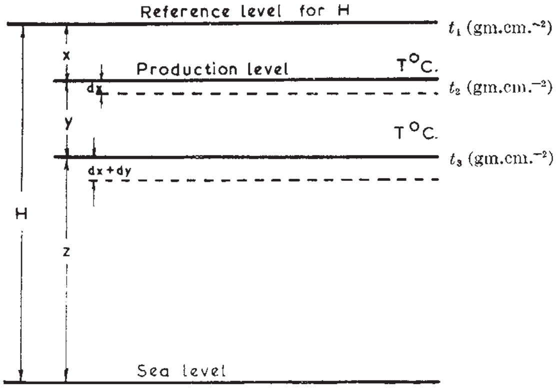
chosen to represent the average atmospheric depth of meson production, and T is the temperature just below this level. A bar above a quantity denotes its mean value.

The first term of equation (1) is due to the absorption in the atmosphere. The second term is due to the decay of mesons in flight. The third term was first introduced by Duperier[1]. The observed positive correlation was interpreted as being due to competition between decay and capture of the π-mesons. The probability of decay into a μ-meson is :

$$P \approx 1 - \rho L_\pi / R_\pi, \tag{2}$$

where ρ is the density of the air, L_π is the mean range of the π-mesons before decay and R_π is the mean free path for nuclear absorption. It is assumed that $\rho L_\pi \ll R_\pi$, as is the case in the upper atmosphere. Equation (2) shows that this effect must give rise to a positive correlation between I and T. However, the corresponding temperature coefficient, $c_1 = \mathrm{d}P/\mathrm{d}T$, could not account for more than one-third of the observed effect[2].

I wish to point out and discuss two other effects which may together be responsible for the apparent discrepancy. In order to simplify the discussion, we will assume that all π-mesons are produced at the same atmospheric depth of t_2 gm.cm.$^{-2}$ (see diagram). Because of the short mean life of the π-mesons, most μ-mesons will be produced very close to the same level. The two other pressure-levels shown in the diagram will also be used in the discussion. The variable H in equation (1) denotes the height of the level at t_1 gm.cm.$^{-2}$, and T denotes the mean temperature between this level and that at t_3 gm.cm.$^{-2}$.



If the levels t_1 and t_2 do not coincide, the height of the meson-producing layer will be a function of both H and T. This will give rise to an additional temperature coefficient :

$$c_2 = \frac{1}{L_\mu} \frac{\mathrm{d}x}{\mathrm{d}T}, \tag{4}$$

where L_μ is the mean range of the μ-mesons before decay. If $t_2 > t_1$, then $c_2 > 0$, and vice versa.

When traversing the atmosphere, the μ-mesons lose energy, and their apparent mean life will decrease. Therefore, between the levels t_2 and t_3 the mean range L_μ' before decay will be greater than the mean range L_μ'' between t_3 and sea-level. If now T increases, the distance y must increase while z must decrease, which gives rise to a positive temperature effect. Hence

$$c_3 = \left(\frac{1}{L_\mu''} - \frac{1}{L_\mu'}\right) \frac{\mathrm{d}y}{\mathrm{d}T} \tag{5}$$

will give an estimate of the order of magnitude of this effect.

As Duperier[2] has measured c for the two cases $t_1 = 50$ mb. and $t_1 = 100$ mb., we will also calculate c for these two values of t_1. For the same reason we chose $t_3 = 200$ mb. (1 mb. = 1·02 gm.cm.$^{-2}$). As the meson-producing radiation is absorbed exponentially[3], with a mean range of 120 gm.cm.$^{-2}$, the average depth of production is $t_2 = 120$ gm.cm.$^{-2}$. The value of L_μ has been calculated from Duperier's height coefficient[2], $b = 3{\cdot}48$ per cent per km., which gives $L_\mu = 28{\cdot}8$ km. From the known energy loss of the μ-mesons in the atmosphere, we then get $L_\mu' = 33{\cdot}4$ km. and $L_\mu'' = 28{\cdot}2$ km. Then we use the relation $L_\pi / L_\mu \approx \tau_\pi / \tau_\mu$, where τ_π and τ_μ are the real mean lives of the two kinds of mesons, to obtain $L_\pi = 0{\cdot}363$ km. For R_π we use the geometric mean free path, which is 60 gm.cm.$^{-2}$ in air. Thus we have certainly not under-estimated c_1. The values of τ_π, τ_μ and other necessary constants were taken from Rossi's recently published book[3].

The results are, in per cent per deg. C. :

	$t_1 = 100$ mb.	$t_2 = 50$ mb.
c_1	0·052	0·052
c_2	0·019	0·090
c_3	0·008	0·008
c	0·079	0·150
Duperier	0·075 ± 0·010	0·143 ± 0·015

Duperier's results have been included for comparison. The agreement is very good. However, one must not forget that the calculations were based upon a very simplified model of the cosmic radiation. It is quite possible that the results of a more exact calculation would not agree so well with the experimental temperature coefficient ; such a calculation is now in progress.

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Scatter Fringes of Equal Thickness

IT is possible to test an optical system by means of white-light interference between two or more wave-fronts which have been scattered by equivalent obstacles out of the same collimated beam.

Consider, for example, an optical system in which a small portion of the field is strongly illuminated with white light. If a screen of moderate scattering power (say, a microscope slide which has been aluminized while in contact with a piece of lens tissue) is introduced into the entrance pupil, then the observer sees the remainder of the field stop illuminated by a diffuse diffracted halo. If a second exactly conjugate screen is placed in the exit pupil so that it appears identical with the image of the first screen except for imaging errors and for some relative displacement, white-light fringes are formed on the field stop by the two scattered beams.

Where the first screen is seen imaged without sensible error, for example, by a plane mirror, the fringes observed are of equal inclination, well-known examples being Newton's diffusion fringes and Quetelet's rings. If, on the other hand, the first screen is being imaged by an imperfect system and is adjusted to nominal coincidence with its fellow, corresponding fringes of equal optical thickness are produced. Light scattered by the first screen suffers distortion by the system to form the error wave-front; but the second or reference wave-front is substantially free from error since its parent beam has traversed that system in concentrated fashion. The fringe pattern therefore represents the wave-front error with which the entrance pupil is being imaged on to the exit pupil, a bright achromatic fringe covering those portions of the field for which the transit time is the same as for the directly illuminated patch.

The practical possibilities of these fringes of equal thickness do not seem to have been explored. For optical testing they have one advantage in that they do not lose contrast in the presence of considerable tilt or asphericity. Of particular interest is their application to imaging systems of unit magnification such that one screen is (1) imaged by a through type or autostigmatic system on to an identical replica; (2) imaged back on to itself enantiostigmatically; or (3) repeatedly imaged on to itself in a multiple-beam arrangement.

Preliminary experiments on the first two types suggest that the fringes may be useful for testing large mirrors, camera lenses and microscope objectives, and possibly for interference microscopy. The fact that the fringes are self-compensating for path-length and, in the second case, for odd azimuthal errors suggests various engineering applications. Further investigation is taking place.

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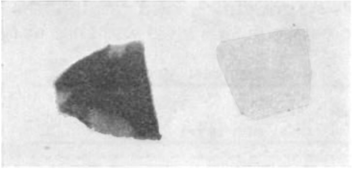
Kramer and Russell Effects with Single Crystals of Zinc

A short while ago, Kramer[1] directed attention to the fact that abraded or worked metal surfaces emit negatively charged particles which can activate an open-ended Geiger–Müller counter operated in air. Kramer assumed the particles to be electrons, emitted owing to phase changes occurring on the freshly disturbed metal surface. Haxel, Houtermans and Seeger[2] confirmed these observations, but offered an explanation based on adsorption phenomena. Gobrecht and Barsch[3] brought forward evidence that changes of phase are not directly responsible for the phenomenon. Work at the Mechanical Engineering Research Laboratory confirmed the previous observations, but also established by measurements of ionic mobility that the particles triggering the counter are oxygen-molecule ions. It was further found that the 'active' areas behave essentially as having a lower work function than is usually ascribed to the particular metal. Abraded specimens or evaporated films gave thermionic counts at lower temperatures and photoelectric counts at longer wave-lengths than aged or unabraded surfaces of the same metal.

Experiments carried out with single crystals will illustrate this. Single crystals of zinc (kindly given to us by Dr. A. J. W. Moore) were cleaved in the (0001) plane. One of the cleaved surfaces was abraded, whereas the other was left undisturbed. Both surfaces were investigated by means of an open-ended Geiger–Müller counter operating at a pressure of 10 cm. of mercury (9 cm. mercury of air + 1 cm. mercury of ethyl alcohol). The response of the two surfaces to daylight through glass (with most of the ultra-violet wave-lengths cut off) was determined. Great care was taken to make the geometrical and illumination conditions identical in both experiments, and alternate counts were taken from the two surfaces in order to take account of the decay of the response. To eliminate stray fields from the counter, a zinc grid was interposed between counter and specimen and operated at a positive potential so that the field between the specimen and grid was 20 V./cm. Under these conditions, the cleaved surface gave 40 counts/min., whereas the cleaved and abraded surface gave 275 counts/min.

The cut-off wave-length for the photoelectric response of zinc lies normally well in the ultra-violet at about 3000 A. The fact that the cut-off wave-length had been shifted into the visible spectrum to about 5000 A. indicates that the abrasion process produces, on the surface, areas of low work function, possibly by the intermingling of oxide and metal phases.

The behaviour of the surfaces was further checked by means of the Russell effect, which, as has previously been suggested[4], is usually associated with surfaces giving Kramer counts. Another single crystal of zinc was treated as in the previous experiment. Both the cleaved and the cleaved and abraded surfaces were exposed to an Ilford *Q* plate for 20 hr. After development the image shown in the accompanying photograph was obtained. The cleaved and abraded surface gave a very dark image, whereas the cleaved surface gave scarcely any image.



(*a*) Cleaved (*b*) Cleaved and abraded

These and other experiments of similar nature lead us to believe that the abrasion of metals causes the formation of sites of low work function, and that these sites are responsible for the so-called Kramer effect.

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The New Classical Electrodynamics

Except for a gauge-fixing condition, Dirac's recent theory[1–3] corresponds to the natural form of Maxwell–Lorentz electrodynamics for very fine-grained streams of charged corpuscles all with the same constant mass μ and charge ε; the velocity field in the stream is supposed to be continuous and differentiable. The ratio μ'/ε is written k; here μ' is the measure of μ in energy units: $\mu' \equiv \mu c^2$. (We call this first special form of the theory the *superconductive theory*, since