designed so that the technical difficulties are no greater than in experiments[3,4] which have already been made with π-mesons and show that the proportion of particles surviving a round journey of 800 cm. must be less than 0·36 if Dingle's views are correct, whereas the value to be expected on an orthodox interpretation of relativity theory is 0·41 and 0·47 for 73 MeV. and 100 MeV. particles respectively. The 'journey' suggested here is not the same as that proposed by Crawford[6], to which objections can be raised on the ground that the 'travellers' do not return to their starting point. Crawford does not seem to be aware that the experiment with π-mesons which he suggests has already been done.

In the fuller account, some considerations suggested by the proposed experiment will be examined, and an attempt made to show that Dingle's theory is not consistent with the principles of special relativity as they apply to unaccelerated motion in an inertial frame.

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Jan. 12.

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Experimental Determination of Atmospheric Infra-red Radiation

In a recent communication[1], Mr. J. L. Gergen gives a brief account of his 'black ball' radiometer, and in comparing measurements of atmospheric radiation so made with those described by us[2] states that they "are not in agreement". A fuller account of our work has now appeared[3] with more information than was available to him at the time of writing.

In the atmosphere, which for this purpose we consider to be plane and uniformly stratified, we may consider that at any height z there are two independent radiation streams: an upward stream U_z, and a downward stream D_z. In the atmosphere, the significant factor is whether the atmosphere is cooling or heating as a result of these streams, and a simple analysis would show that this is given by the (one-dimensional) divergence, $\frac{d}{dz}(U_z - D_z)$. This can best be determined by calculating or measuring the values of both U_z and D_z and then taking their differentials. Thus measurements of these quantities are, at the present state, the most useful kind of atmospheric radiation data.

It is unfortunate that Mr. Gergen's 'black ball' measures, in effect, U_z *plus* D_z, since the temperature T of the black ball is determined by the equivalent black-body temperature of the combined fluxes, that is to say $\left(\frac{U_z + D_z}{2\sigma}\right)^{1/4}$ (neglecting the spherical effects). Whether this is greater or less than the air temperature at the same place does not have great significance, and since it is very difficult to separate the contributions of U and D, it is not possible to calculate $U_z - D_z$ or the divergence. To put it another way, Mr. Gergen states that he is observing the places in the atmosphere where the air is being heated or cooled, whereas he is really observing the places where a black-body would be heated or cooled. Since the atmosphere at any level is far from being a black-body, the radiation equilibrium temperature of a black-body is not the equilibrium temperature of the atmosphere. Clouds are 'grey'; thus the black ball would indicate correctly the effects of radiation on a thin cloud layer.

It is to direct attention to the above important defect of the 'black ball' techniques that we write; we would, however, like to comment on Mr. Gergen's comparisons between our measurements and some made at Minnesota but unpublished. For our part, we think that our calibrations were not equivocal and that, within the limitations we indicate in our paper, our measurements are correct in absolute value. It is important to note, too, that calculations of radiation fluxes at high levels are sensitive to the accuracy of the humidity data available. For the measurements we have made at Farnborough, we had the advantage of the assistance of the Meteorological Research Flight; simultaneous measurements of air temperature and humidity were made. So far as we know, the Meteorological Research Flight remains the only organization which can measure the humidities found at high levels. We do not know what humidities were used at Minnesota, nor what corrections were made for variation of carbon dioxide path-lengths with height in their calculations.

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The relations which indicate the manner in which the black ball temperature-differences are related to the radiative divergence will appear in a forthcoming paper in the *Journal of Meteorology*, and as shown there, the cooling rate is positive when the black ball difference is positive, and vice versa. The exact numerical relations are, however, still somewhat questionable and require further study.

I am happy to have received the more complete analysis of the work by Drs. Brewer and Houghton, and, of course, as they state, their experimental results also bear out the fact that the radiation chart requires revision. My comment on their previous work must not be regarded as a criticism of their experimental methods, which were most thorough and careful, but on the accuracy of the determination of upward or downward fluxes (or equivalently, the radiation temperatures) when measured with a spectrally selective device. Drs. Brewer and Houghton have made the first careful determination of atmospheric infra-red radiation and deserve all credit for having made a significant advance in the understanding of the heat balance for the Earth.

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