end of the side-arm *C* to prevent aerial contamination of the perfusate and to reduce the air flow into the tube *F*. The soil sample (30–50 gm. of soil crumbs) or small glass beads were placed in the tube *D* on a pad of glass wool and another pad was placed on top to prevent puddling of the soil. The rubber bung was replaced and 300 ml. 0.01 *M* ammonium sulphate was introduced into the flask via the side-arm.

Fig. 1. Soil perfusion apparatus

The new apparatus was only 25 cm. high and could be housed in a small space as it did not require the support of a retort stand. The soil column was easily removed after the experiment by gentle shaking and the apparatus could be acid cleaned and then later sterilized in one piece, thus eliminating many of the breakages which occurred when assembling and dismantling the earlier models. The apparatus required no extensive adjustment prior to perfusion and worked for long periods without supervision. Finally, the apparatus was cheap and easy to make. The new design should be useful where large numbers of perfusers are used and the available incubator space is limited. Further details of the rate of nitrification by soils in this apparatus will be reported in greater detail elsewhere.

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- ¹ Lees, H., and Quastel, J. H., *Biochem. J.*, **40**, 803 (1946).
² Audus, L. S., *Nature*, **158**, 419 (1946).

Thermal Conductivity of Soil

IN a recent communication¹ J. Webb overlooks that his calculation of the thermal conductivity of a cubic arrangement of spheres is based on an inadmissible simplification and in consequence he is led to a false conclusion. This is true also of Gemant's² article which is criticized by Webb. A rigorous analytical treatment of the identical problem in electrical conductivity was published by Lord Rayleigh³. Full elaboration of the theory, however, meets with mathematical difficulties.

Rayleigh's approximate formula leads to 0.00033 cal. cm.⁻¹ sec.⁻¹ deg. C.⁻¹ for the thermal conductivity in the numerical example discussed by Webb. From other considerations^{4,5} it follows that this value is approximately 30 per cent too low. The value for a mineral dry soil at the same porosity (47.6 per cent) is about 0.0005 cal. cm.⁻¹ sec.⁻¹ deg. C.⁻¹ (ref. 4) and therefore practically of the same magnitude. It is trivial that both systems are not quite comparable because they have different geometry.

The theory of thermal conductivity of granular materials with special reference to soils has been discussed by me^{4,5}. An approximate method for calculating the thermal conductivity of soils from their composition, moisture content and dry density has resulted. The method has been tested against a large body of consistent experimental results.

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¹ Webb, J., *Nature*, **177**, 989 (1956).

² Gemant, A., *J. App. Phys.*, **21**, 750 (1950).

³ Rayleigh, W. R., *Phil. Mag.*, v. **34**, 481 (1892).

⁴ Vries, D. A. de, *Med. Landbouwhogeschool Wageningen*, **52**, 1 (1950).

⁵ Vries, D. A. de, Annexe 1952–51, *Bull. Inst. Int. du Froid, Paris*, 113 (1952).

IN his article, Gemant directs attention to the non-rigorous nature of his method of determining the thermal conductivity of soil. His method, which I adopted in the communication to which Dr. de Vries refers, assumes that the lines of heat flow are parallel. Quite obviously, an assumption of this kind will introduce errors which will increase as the ratio of the conductivities of the two phases increases. For dry soil this ratio is of the order of 160:1, and the error involved in using my formula is very considerable.

For water-logged soil the ratio of the conductivities of the two phases is of the order of 7:1, and my formula yields the value 0.00486 cal. sec.⁻¹ cm.⁻¹ deg. C.⁻¹, which compares with an observed value quoted by Gemant of 0.005 cal. sec.⁻¹ cm.⁻¹ deg. C.⁻¹.

It would appear probable, then, that my formula would prove adequate for a composite material, in which conducting spheres are embedded in a matrix of lesser conductivity, provided that the ratio of the conductivities of the two components does not exceed say 10:1. This may be of little practical significance; but to my mind it justifies, to some extent, Gemant's treatment of the capillary wedge-shaped rings in damp as opposed to water-logged soil.

In my communication, I should perhaps have stressed the non-rigorous nature of the derived formula, instead of assuming that the interested reader would automatically consult Gemant's article in which the approximation is commented upon.

My purpose in writing initially was to challenge the validity of Gemant's method of determining the conductivity of dry soil. In this method, the air-phase conductance is neglected, and consequently it becomes difficult to reconcile the infinite value of the thermal resistivity of the hypothetical dry soil with the finite observed value for an actual dry soil. Gemant was forced to assume that the spheres were chipped to facilitate heat flow from solid to solid.