INSTRUMENTS AND METHODS

A CALORIMETER FOR MEASURING THE FREE WATER CONTENT OF WET SNOW

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MANY methods have been suggested for the determination of the free water in wet snow. (A list of the literature on the subject will be found at the end of Williams's paper.[1]) However, the calorimetric method seems to be the only one now widely used, since the alternative methods depend on uncontrollable, or even unknown, factors. The calorimetric method consists in determining the amount of heat required to melt the ice when the figure so obtained, divided by the latent heat of fusion of ice, gives the ice content. The amount of free water contained in the wet snow is then the difference between the weight of the wet snow taken and that of the ice found. Twenty years ago the present author designed a calorimeter suitable for use in the field.[2] Like many calorimeters, it consisted of a copper container holding hot water into which the wet snow was dropped, but it was soon found that such a calorimeter presented three disadvantages:

(1) The sample of wet snow must be taken by a sampler and transferred from this to the calorimeter. It was difficult to ensure that every particle of snow and water was so transferred.

(2) Speed is essential in effecting the transfer to avoid excessive loss of heat from the calorimeter, and this is often difficult to achieve.

(3) A stirrer is essential to ensure rapid melting of the snow, and this not only complicates the design but also entails a continuous and unknown loss of heat during the experiment.

These three disadvantages were overcome by making the apparatus in two parts, viz. A and B as shown in Fig. 1. They consist of thin copper vessels, each having a wide round mouth, A′ and B′, made of brass and tapered to make an air-tight joint (as shown in the figure), which can be easily pulled apart. While A is square in cross-section, B is round. A thermometer, T, the top and bottom of which are bent at right angles to the scale, is fitted to A, the bulb passing into a small channel formed in the bottom. Into this the thermometer is fitted with a water-tight seal by dental cement. A and B are insulated, except at the mouth, by a 2 cm. jacket of porous polystyrene, M, which in turn is encased by a thin steel shell. The jacket is in two parts, so that both containers can be withdrawn from it, and the jacket on A has a long narrow window through which thermometer, T, can be read.

The method of determination is as follows: A known quantity (about 250 cm.^{3}) of water at about 50° C. is run into container A which is then corked and placed in its section of the jacket where it loses only 0·1° C. per minute. The sample of wet snow (70-100 g.) is collected in B by pushing the sharp mouth of the latter into the snow cover. B, with its content of snow, is then weighed on a small balance placed in a hollow dug into the snow cover. The container is then corked and placed in its section of the jacket. Container A is shaken well to ensure even heat distribution and the temperature, T_1° C., is read. Both containers are uncorked, joined as shown in Fig. 1, and reversed so that the hot water in A flows into B and melts the snow therein. Complete mixing of the water is secured by reversing the containers three or four times and the temperature is then read on the thermometer as T_2° C. Now: Let W_1 g. denote the quantity of hot water in container A, w_1 g. the water equivalent of container A

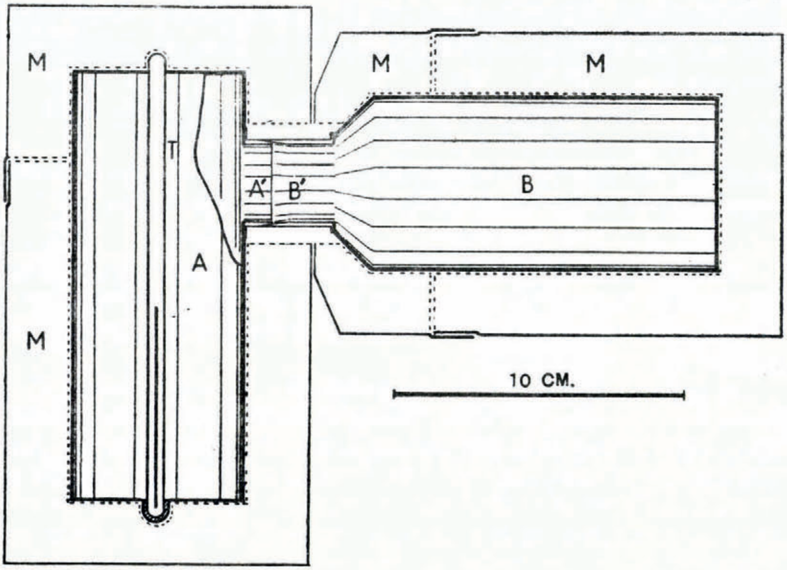

Fig. 1. Calorimeter composed of two copper containers

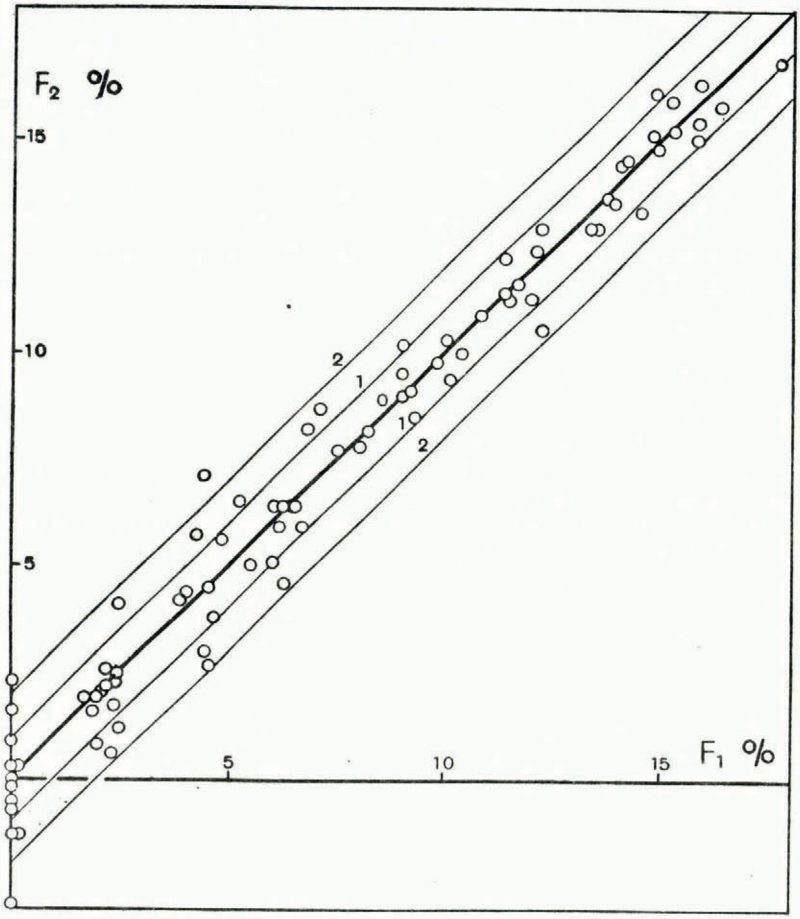

Fig. 2. F_1 = *predetermined value of the free water content of an artificially made wet snow.* F_2 = *free water content determined experimentally on the same wet snow by the use of the calorimeter*

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itself including the thermometer T, W_2 g. the quantity of wet snow taken into container B, and w_2 g. the water equivalent of container B. Then the quantity of ice, I g., contained in the wet snow is:

$$I = \frac{(T_1 - T_2)(W_1 + w_1) - T_2(W_2 + w_2)}{79 \cdot 4},$$

where the number 79·4 (cal./g.) is the latent heat required to melt one gram of ice. The free water content of wet snow, F, expressed in per cent is given by:

$$F = 100\{1 - (I/W_2)\}.$$

With a calorimeter made in two parts the disadvantages (1) and (2) are eliminated, since one of the two parts takes the place of the sampler. Disadvantage (3) is also overcome since there is no stirrer for mixing, and reversing the combined containers is a much more efficient method than using a stirrer.

In order to ascertain how accurately the free water content, F, could be determined with the new calorimeter, the author made the following series of experiments: A known quantity, M g., of dry snow at a temperature below 0° C. was placed in container B, which was held in a mixture of snow and water for a prolonged period so that the snow within it became dry at a temperature of 0° C. A known quantity, m g., of water at 0° C. was added so that the contents of the container became a wet snow having a known value, F_1, for its free water content, viz. 100 $m/(M+m)$ %. This wet snow was then put through the calorimetric test, giving a result F_2.

In Fig. 2, F_2 is plotted against F_1 when, if there were no experimental error, all the points should lie on the thick straight line 0. The thin lines indicate the errors in F_2, i.e. the deviations of F_2 from F_1 of 1 per cent in the case of lines 1, and 2 per cent in the case of lines 2. In Fig. 2 there are 84 points of which 63 lie between the two lines 1, which implies that the majority of the results, obtained in the field with this calorimeter, for the free water content, F, of wet snow will be accurate within the limit of 1 per cent.

In conclusion it should be noted that the temperature of the water placed in container A should not exceed 50° C. When the hot water and snow are mixed the air enclosed in the tightly closed calorimeter is cooled so that its pressure is reduced. If the temperature of the hot water is higher than 50° C., the reduction of pressure may be sufficient to cause the walls of the container to collapse.

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REFERENCES

1. Williams, G. P. A field determination of free water content in wet snow. *Canada. National Research Council. Division of Building Research, Research Paper* No. 26, 1956, p. 16-20.
2. Yosida, Z. A method of determining the thaw water content in snow layer. *Journal of the Faculty of Science, Hokkaido University*, Ser. 2, Vol. 3, No. 4, 1940, p. 91-102.