NOTE ON J. F. BRENNAN'S METHOD OF DETERMINING THE ALTITUDE IN THE ATMOSPHERE ABOVE SEA LEVEL WHERE THE FREEZING POINT OF WATER OCCURS [1]

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As regards the very simple method described by J. F. Brennan[1] for determining the position of the zero isotherm in the free atmosphere, the present author may be allowed to add some remarks as a consequence of a number of experiments and tests carried out under his supervision at the Meteorological-Hydrographical Institute at Stockholm. From these experiments I am inclined to doubt the practical applicability of the method of Mr. Brennan, at least in the simple form described in the paper.

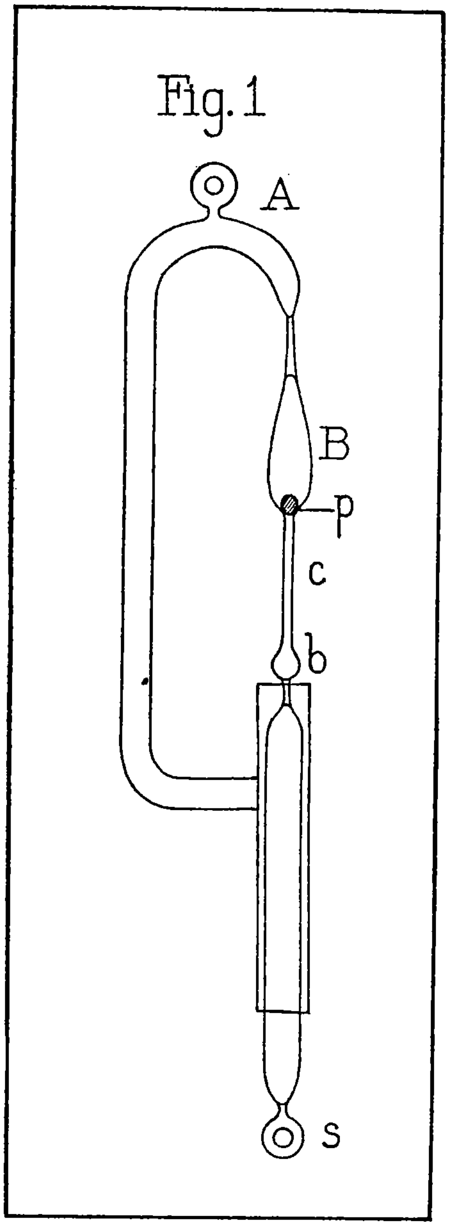

FIGURE 1.—Device for determining the height of the zero isotherm in the free atmosphere

The method is founded upon the expansion of water at freezing. The expansion is used for releasing, at the height at which freezing occurs, a paper pendant from a pilot balloon and the moment of the release is noted. For further details I may refer to the original note of Mr. Brennan.

The great difficulty in the practical application of this method is due to the fact that water does not under ordinary conditions, when no ice crystals are present, freeze at a fixed temperature. Inclosed in a small vessel of glass or metal and cooled down below zero, water freezes at times between −0° C. and −3° C., but may sometimes be cooled down to about −7° to −8° C. without freezing. In shaking the vessel or through blowing small air bubbles through the water we may reduce the probability for a considerable undercooling, but the fact remains that the water even under these conditions may freeze at temperatures varying by a couple of degrees.

Figure 1 shows the design used in our experiments. The water is inclosed in the small glass bulb *b* and in the small capillary tube *c*, connected to the glass bulb. Cooling the system below 0° C. we find that the water will at first freeze in the tube; when the water some moments later freezes in the bulb the capillary is broken and the signal attached at *s* is released from the balloon attached at *A*.

A large number of experiments were carried out in order to prevent the water from undercooling. An automatic shaking device was designed where the vertical movement of the balloon was used for driving a little "shaker." We also investigated whether the addition of powdered substances like fine grains of metals, etc., would help, but with small effect.

Considerable progress however was obtained through stirring the water in order to produce small air bubbles. It seems as if very small air bubbles present in the water would prohibit further undercooling. The smaller the air bubbles, the higher their internal vapor pressure, and the more effective they seem to be in prohibiting a considerable undercooling. The difficulty in the practical application, however, is chiefly the following: When small air bubbles are produced at a certain temperature above zero, the cooling of the water will have the consequence that air will be absorbed and at the temperature at which the water ought to freeze we run the risk that no air bubbles are present. On the other hand too large air bubbles have no or very little effect. Practically, the difficulties are so great as to make this method of preventing undercooling almost useless.

The final arrangement, which, in spite of its effectiveness, is lacking considerably in practical elegancy, consists in letting a part of the water be frozen at the start in order that undercooling may be impossible. For that purpose a second glass bulb *B* (fig. 1) was added, and the freezing of the water in this larger bulb was effected through dipping this part of the glass system, before the release of the pilot balloon, in a Dewar bottle containing a solution of solid carbon dioxide in alcohol. By including a small grain of lead *P* in the bulb *B* ice was caused to form around *P*, in the lower parts of the bulb, in immediate contact with the water in the capillary. The whole glass system was made at a cost of about half a dollar a piece at the Grave Instrument Co., Stockholm.

Experiments with this device made it clear that we may in this way easily freeze the water at a temperature variable within not more than about ±0.5° and generally at about −1° C. Trials, in which two pilot balloons were sent up in tandem and one of them released at the breakage of the glass, gave the same result, comparisons being made with the results of meteorograph ascensions. In spite of some inconveniences inherent to the arrangement of partly "prefreezing" the water, the method undoubtedly includes some advantages, and may probably be considerably improved.

During these experiments the author had the able assistance of O. Nauclèr, civil engineer, to whom sincere thanks are due.

[1] MONTHLY WEATHER REVIEW, February, 1931, vol. 59, p. 75.