SHORTER CONTRIBUTION

551.508.26 : 551.508.71

On the Lag of Thermometer Exposed in the Air of Variable Temperature and Variable Wind Velocity

by

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(Received June 20, 1952)

Abstract

The equation of heat transfer between the thermometer and the air in which it is exposed is solved graphically, assuming the air temperature and wind velocity fluctuation to be sinusoidal and the thermometer lag coefficient to be inversely proportional to the square root of wind velocity. Two examples are given, one of which is the case of constant air temperature and variable wind velocity, and the other the case of variable air temperature and variable wind velocity.

The influence of wind velocity fluctuation upon the thermometer lag seems to be of negligible order even for large percentages of fluctuation.

1. Introduction

Several discussions have been conducted by different authers ([1], [2] and many others) concerning the influence of wind velocity since the introduction of the world-famous aspiration psychrometer by R. Assmann in 1901. The discussions are mostly concentrated in the theoretical and experimental treatment of the psychrometer constant, or merely on the observations of psychrometer indications.

In the present paper the fundamental equation of heat transfer between the thermometer and the air in which it is exposed, is solved graphically by isocline method, assuming the thermometer lag coefficient to be inversely proportional to the square root of the wind velocity. This assumption seems to be well established by many authors even for wet-bulb thermometers ([3] for example). The graphical integration is here, of necessity, carried out for some numerical examples, but the conclusions deduced from them will, to a certain extent, afford a clue to the discussion of psychrometers, dew-point recorders and probably, hair-hygrometers.

2. Equation of heat transfer

The equation of heat transfer between the thermometer of temperature θ and the air of temperature θ_a surrounding it is given by

(1) $$\sigma\frac{d\theta}{dt}=\theta_a-\theta\ ,$$

where t denotes time and σ the lag coefficient of the thermometer.

Let us assume the variation of wind velocity to be

(2) $$V=V_0\left(1+S_w\sin\frac{2\pi}{T_w}t\right)\ ,$$

where V_0 is the mean velocity, S_w the amplitude and T_w the period of fluctuation, and that of the air temperature to be

(3) $$\theta_a=\theta_{a0}\left(1-S_a\sin\frac{2\pi}{T_a}t\right)\ ,$$

where θ_{a0} is the mean temperature, S_a the amplitude and T_a the period of fluctuation.

Naturally these two assumptions cannot be regarded to cover all cases to be encountered in temperature observations, and they express only one example combined with a descending cold air mass with severe wind outblow.

The lag coefficient of the thermometer may be written in the form

(4) $$\sigma=K/\sqrt{V}\ ,$$

where K means the lag coefficient at $V=1$.

Then we shall simplify (1) by writing $t_1=t/T_w$, $\theta_1=\theta/\theta_{a0}$ and $\tau=T_w/T_a$ and we get

(5) $$\frac{K}{T_w\sqrt{V_0(1+S_w\sin 2\pi t_1)}}\frac{d\theta_1}{dt_1}=1-S_a\sin 2\pi\tau t_1-\theta_1.$$

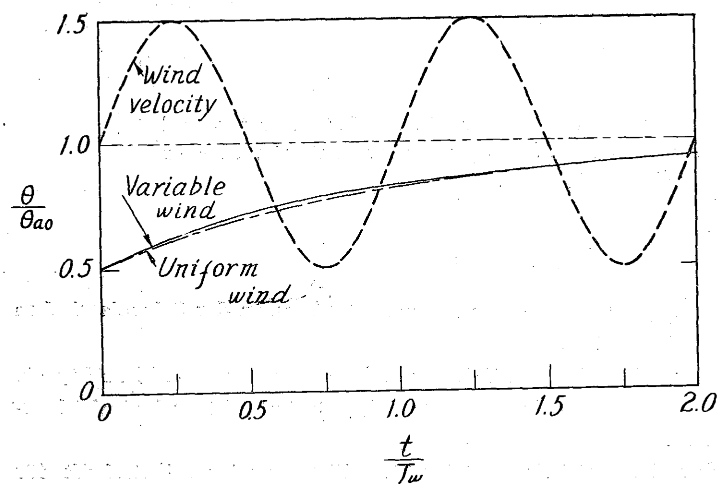

Fig. 1.
Lag of thermometer exposed in the air of constant temperature and variable wind velocity ($S_w=0.5$, $S_a=0$) together with the case of uniform wind velocity ($S_w=0$, $S_a=0$).

3. Examples

a) Constant air temperature and variable wind velocity.

If we take the case in which $K/T_w\sqrt{V_0}=1$, $S_w=0.5$, $S_a=0$, $\tau=1$ and $\theta_1=0.5$ for $t_1=0$ we have the result illustrated in Fig. 1. In the figure the case of uniform wind velocity viz., $S_w=0$, which is easily integrable, is also shown. Even in this severe fluctuation of wind velocity, the thermometer temperature differs from that for uniform wind velocity only by 5% (0.5°C for initial temperature difference of 10°C between the thermometer and air temperature) just after a short lapse of time from start, and the difference vanishes rapidly.

b) Variable air temperature and variable wind velocity.

With the same assumptions as before except $S_a=0.5$ and $\theta_1=1$ for $t_1=1$ we get the result illustrated in Fig. 2. In the figure the case of uniform wind velocity viz., $S_w=0$ which is easily integrable is also shown. The tendency is quite similar to the preceding example and gives the maximum difference of 3% of the initial air or thermometer temperature, in the second wave.

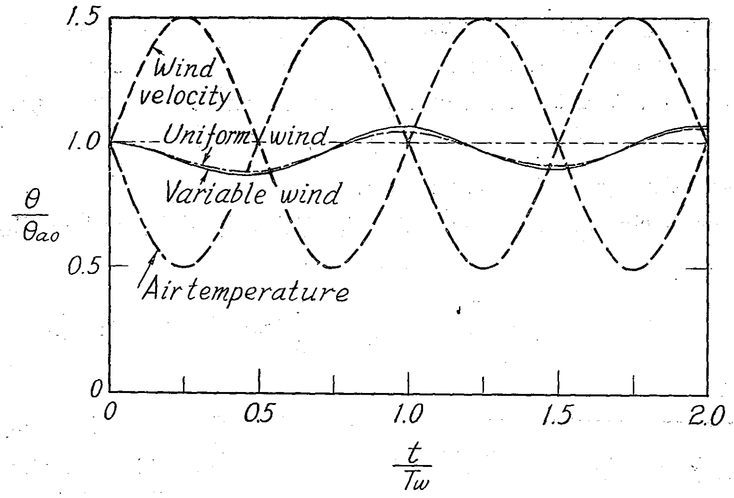

Fig. 2. Lag of thermometer exposed in the air of variable temperature and variable wind velocity ($S_w=0.5$, $S_a=0.5$) together with the case of uniform wind velocity ($S_w=0$, $S_a=0.5$).

References

[1] Berger, P. 1935: Remarques au sujet des "Assmann", Annalen der Schweizerischen Meteorologischen Zentralanstalt.

[2] Shimizu, I. 1952: Influence of Ventilation Velocity of Psychrometer upon Humidity (in Japanese), Journal of Meteorological Research, **4**, (Central Meteorological Observatory, Tokyo), p. 76.

[3] Rössler, F. 1950: Ueber die Trägheit von feuchten Thermometern, Zeitschrift für Meteorologie, **4**, p. 274.