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A New Air Velocity Calculator.

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1. Function of Air Velocity Calculator.

In the ordinary wind-channel work the air velocity is determined usually by means of the Pitot tube. Fig. 1 is the outline of a wind-channel with a Pitot tube set in the current of air, the velocity of which is required to be measured. The inner tube of the Pitot communicates with one arm of a pressure gauge g of U-tube type, and the outer tube which is perforated at the point a is connected to the other arm of the gauge. The air velocity can be calculated from the measurement of the difference h between the two levels of water in

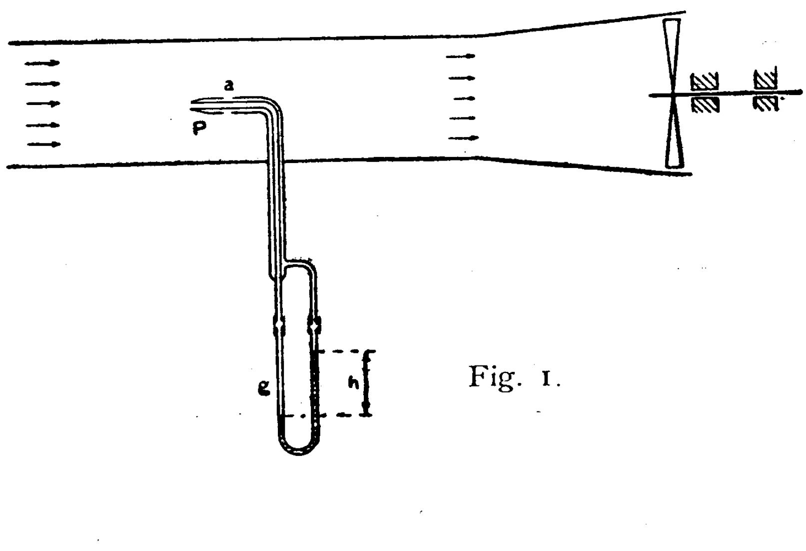


Fig. 1.

the gauge together with measurements of atmospheric pressure, temperature and humidity at the same time.

The air velocity calculator herein described is a slide rule specially constructed for the purpose of calculating immediately the air velocity mentioned above.

Let p_0 be the atmospheric pressure in kg/m^2 abs.,

H_0 the same but in mm of mercury,

t_0 the atmospheric temperature in deg. C.,

ρ_0 the density of dry air in kg/m^3,

p the absolute pressure at a point P in the wind-channel in kg/m^2,

v the air velocity at the same point in the channel in m/s,

h the difference between the two levels of water in the U-tube gauge in mm,

γ a constant, 1·40 for air.

Then, assuming the change of condition of air is adiabatic, the air velocity v at a point P in the wind-channel is given by

$$v^2=\frac{2g\gamma}{\gamma-1}\cdot\frac{p_0}{\rho_0}\left\{1-\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right\}. \qquad (1)$$

Since $\rho_0=\dfrac{1·293}{1+0·00367\,t_0}\cdot\dfrac{H_0}{760}$ (1) $\qquad$ (2)

Eq. (1) may be written

$$v=\sqrt{\frac{1+0·00367\,t_0}{1·293}\cdot\frac{760}{H_0}\cdot\frac{2g\gamma}{\gamma-1}p_0\left\{1-\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right\}}$$

$$=\sqrt{\frac{1+0·00367\,t_0}{1·293}\cdot\frac{760}{H_0}2gh\left\{1+\frac{1}{2\gamma}\left(\frac{h}{p_0}\right)+\frac{\gamma+1}{6\gamma^2}\left(\frac{h}{p_0}\right)^2\right\}}. \qquad (3)$$

Eq. (3) is an approximate expression for the air velocity v in terms of h, H_0 and t_0. The aim of this calculator is to determine v readily

(1) Kaye and Laby, Physical and Chemical Constants, p. 25.

from the given values of h, H_0 and t_0 in Eq. (3).

In some wind-channel experiments, we have to take a number of successive readings of h, and even also of H_0 and t_0, and to work out the corresponding values of v for each set of the readings. In such a case, this instrument will be found especially useful in saving the labour of repeated calculations.

2. Construction of the Calculator.

Fig. 2 shows a part of the calculator. There are four different scales on the calculator which are distinguished by the letters A, B, C and D, the scales A', A'' and A''' being continuations of A, and B', B'' and B''' of B.

Now Eq. (3) can be written in the form

$$\log f_1(h) - \log (v^2) = \log H_0 - \log f_2(t_0), \tag{4}$$

where

$$f_1(h) = h\left\{1 + \frac{1}{2\gamma}\left(\frac{h}{p_0}\right) + \frac{\gamma+1}{6\gamma^2}\left(\frac{h}{p_0}\right)^2\right\} \tag{5}$$

and

$$f_2(t_0) = \frac{1 + 0{\cdot}00367\,t_0}{1{\cdot}293}.\ 760.2g. \tag{6}$$

The values of $\log f_1(h)$, computed for certain equidistant values of h, are plotted on A to a certain uniform scale of reference, not shown here, and are denoted by the corresponding values of h. The scale B is a similar representation of the function $\log(v^2)$ to the same uniform scale of reference and is denoted by the values of v. Similarly the functions $\log H_0$ and $\log f_2(t_0)$ are represented by the scales C and D, respectively.

Hence at any position of the slide, within the limits of each range of graduations, any two values $f_1(h)$ and v^2, and consequently also H_0 and $f_2(t_0)$, opposite to each other, must have the same ratio, and this enables us to determine any one of the four quantities v, h, H_0 and t_0 if the remaining three be given.

The range of each scale is as follows:—

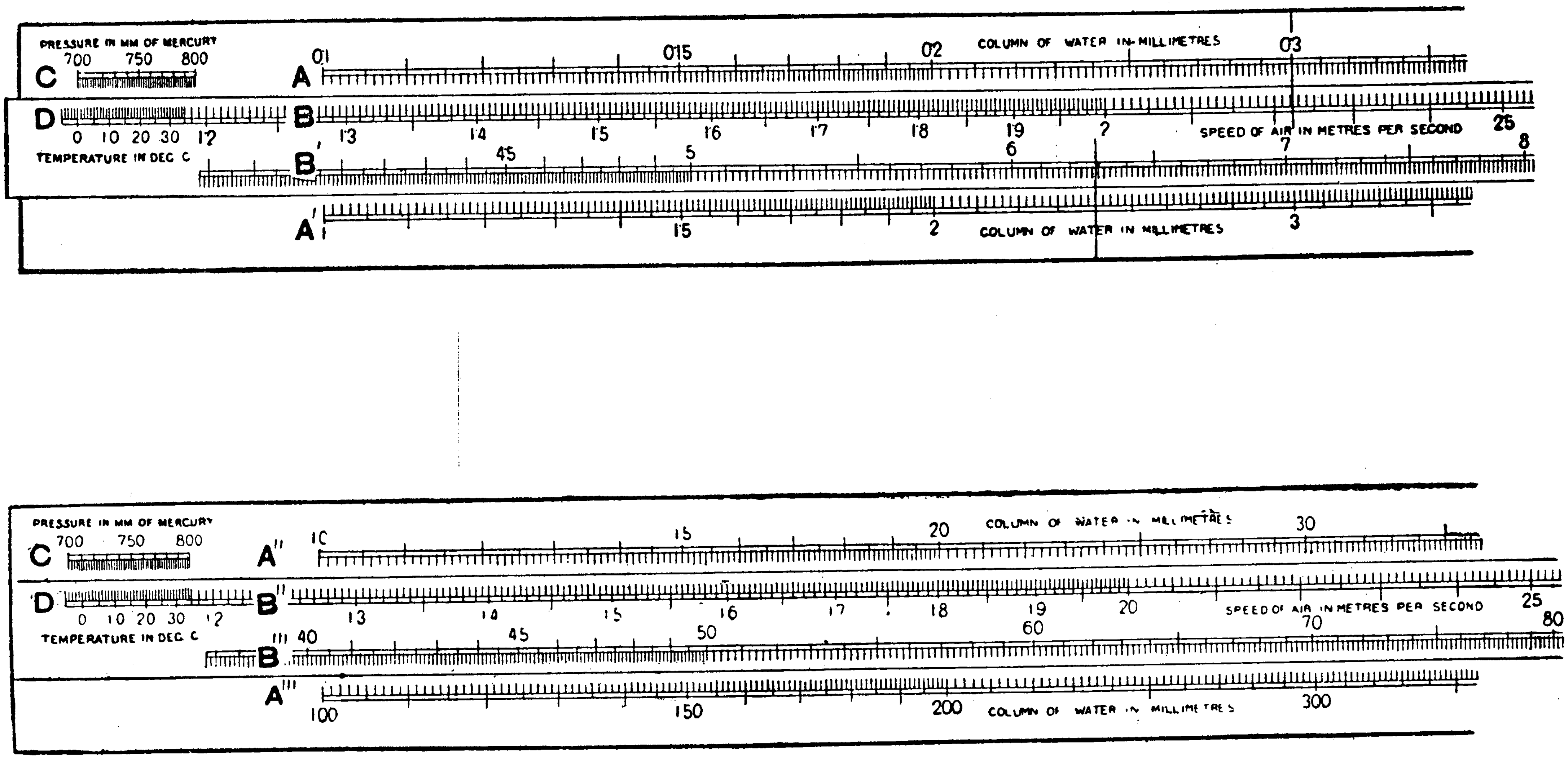
Values of	h	in the scale	A	are from	0·1	to	1·0 mm,
,,	h	,,	A'	,,	1·0	,,	10 mm,
,,	h	,,	A''	,,	10	,,	100 mm,
,,	h	,,	A'''	,,	100	,,	1000 mm,
,,	v	,,	B	,,	1·2	,,	4·4 m/s,
,,	v	,,	B'	,,	3·8	,,	14 m/s,
,,	v	,,	B''	,,	12	,,	44 m/s,
,,	v	,,	B'''	,,	38	,,	140 m/s,
,,	H_0	,,	C	,,	700	,,	800 mm,
,,	t_0	,,	D	,,	$-5°$	,,	35° C.

In calculating Eq. (5) p_0 was assumed constant and was taken equal to 10330 kg/m² the error in v due to this approximation is very small, being within about 0·1 percent in the graduated range of this calculator. The term involving h^2 in Eq. (5) is also very small and, to the order of approximation, can be neglected quite safely. The density of water was taken to be unity for all pressures and temperatures.

3. Use of the Calculator.

The use of this calculator is very simple. For Example, given the atmospheric pressure $H_0=750$ mm and the temperature $t_0=20°$ C. To find the air velocities corresponding to the differences of the water columns $h=0·3$ and 2·4 mm.

Now set the scale D against the scale C so that 20° appears just opposite to 750 mm, as shown in Fig. 2, then the required air velocities are read off on the scales B and B' just opposite to 0·3 and 2·4 mm on the scales A and A' respectively. Thus we obtain the required air velocities 2·223 and 6·29 m/s. Generally in this calculator, if we set the given t_0 opposite to the given H_0, the values



PRESSURE IN MM OF MERCURY
700 750 800
C
D
0 10 20 30
TEMPERATURE IN DEG C
A
B
B'
A'
COLUMN OF WATER IN MILLIMETRES
SPEED OF AIR IN METRES PER SECOND
A''
B''
B'''
A'''

Fig. 2.

v and h for the given conditions H_0 and t_0, always appear just opposite to each other on the scales A and B.

4. Correction for Humidity.

The density of dry air ρ_0 in the expression (2) may be replaced by ρ_0', the density of damp air, which may be derived from the expression.

$$\rho_0' = \rho_0 \frac{H_0 - 0{\cdot}378\, p_m}{H_0} \text{ (1) } \doteqdot \frac{1{\cdot}293}{1+0{\cdot}00367\, t_0} \cdot \frac{H_0 - \frac{3}{8} p_m}{760}$$

where p_m is the pressure of water vapour in the air in mm of mercury. Thus for damp air, we may use $H_0 - \frac{3}{8} p_m$ instead of H_0, on the scale C, Fig. 2.

Tôkyô, September 1921.

(1) Kaye and Laby, p. 21.

第二號

大正十一年六月發行

抄　　錄

風速計算器

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風洞に於ける實驗てピトー管と水のU管とを使用して氣流の速度を測定する場合には,U管の兩腕の水柱の差と大氣の溫度及び壓力とを讀みて次の式から速度を計算するのが通常である:—

$$v=\sqrt{\frac{1+0{\cdot}00367\,t_0}{1{\cdot}293}\cdot\frac{760}{H_0}2gh\left\{1+\frac{1}{2\gamma}\left(\frac{h}{p_0}\right)+\cdots\cdots\right\}}$$

但し　v ＝ 風洞內の氣流の速度, 米/秒

　　　h ＝ U管の兩腕に於ける水柱の差, 粍

　　　t_0 ＝ 大氣の溫度, 攝氏

　　　H_0 ＝ 大氣の壓力, 粍, 水銀柱

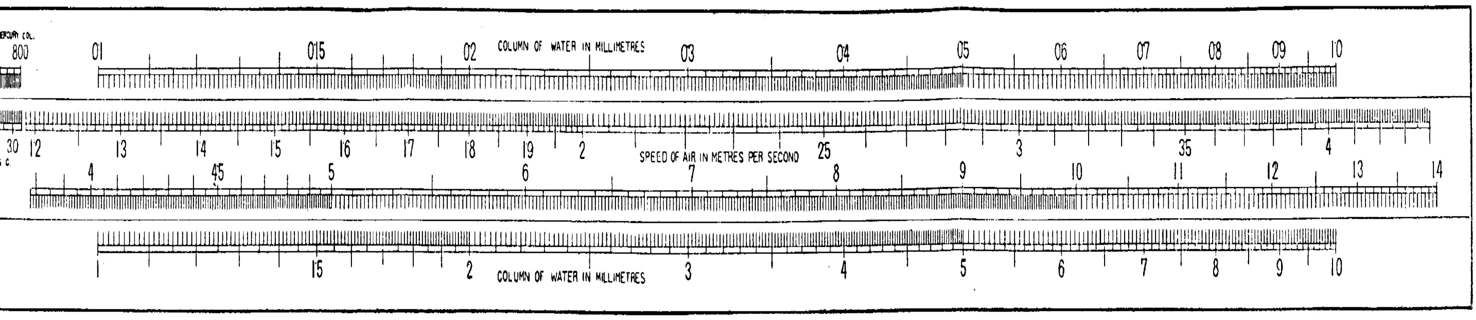
　　　$\gamma = 1{\cdot}40$, 　$p_0 = 10330$.

然し一々此の計算をするのは甚だ手數であるにより上の式を直ちに解くことが出來る樣に一種の計算尺を作つた. 附圖第一に示したのはこれである.

この計算器の使用法は極く簡單である. 例へば大氣の壓力 $H_0=750$ 粍, 溫度 $t_0=20$ 度のとき 水柱 $h=2{\cdot}4$ 粍に相當する風速を求める. 第二圖に示した通り中央の遊尺を動かし氣壓目盛りCの 750 の線と溫度目盛り D の 20 の線とを一致せしめる. 水柱 h の目盛り A′ の 2·4 に一致した風速目盛り B' の 6·29 米/秒は求むる速度である.

附圖第一に於て中央の遊尺を切り離す代りに Divider てこれと同等の方法を採ればよろしい.

大氣中の水蒸氣に對する補正をするには氣壓目盛Cに於て H_0 の代りに $H_0-\frac{3}{8}p_m$ を用ゆればよろしい. 但し p_m とは大氣中に於ける水蒸氣の壓力を水銀柱の粍て表はしたものである.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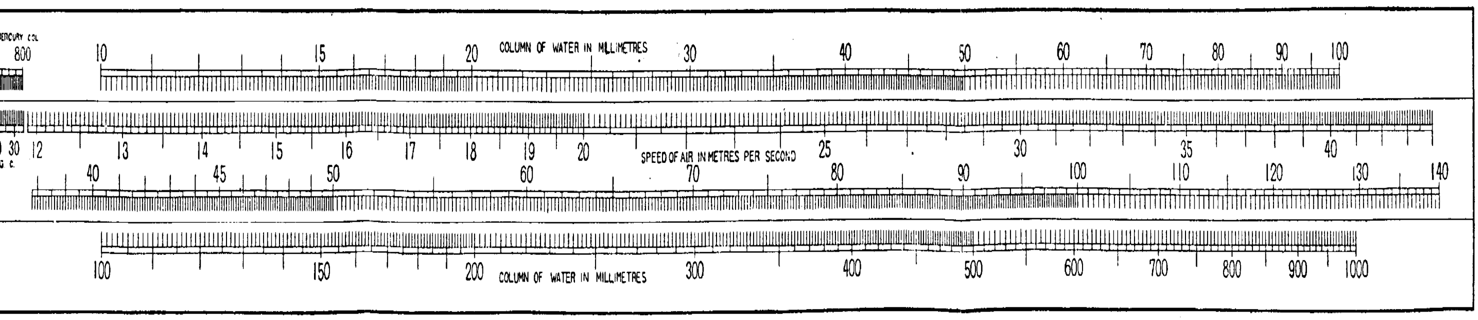
COLUMN OF WATER IN MILLIMETRES
SPEED OF AIR IN METRES PER SECOND
COLUMN OF WATER IN MILLIMETRES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