The Science Reports of the Kanazawa University, Vol. V, No. 1, pp. 21—26, October, 1956

Flow of Air through a Pile of Textile Fabric

By

Tatsumi TERADA and Yasuko KONTANI

(Received September 20, 1956)

The rate of flow of air through a sheet of fabric was given by S. Saito and H. Uchida(1) as follows,

$$Q=K(\triangle P)^{\frac{1}{n}} \tag{1}$$

where Q is the volume of air in c. c. passing through unit area (cm^2) per sec., $\triangle P$ the pressure difference (g/cm^2) of air on both sides of fabric, and K and n are constants respectively, depending upon fabric used. One of the authers(2) found that the equation (1) was also applicable to his cases and he could derive it by substituting the coefficient of resistance of air flow $\varphi(R)=kR^{-m}$ into well known equation for air flow through a tube, where $\varphi(R)$ was a function of Reynold's number R, k a constant number depending upon the construction of fabric and $0\leqq m\leqq 1$. Besides, the constant K was expressed as follows,

$$\mathrm{K}=\left(\frac{2\mathrm{r}^{3-n}}{kl\eta^{2-n}\rho^{n-1}}\right)^{\frac{1}{n}} \tag{2}$$

in which r was the equivalent radius deduced from the whole area of holes per cm^2, l its flow length, η the coefficient of viscosity, ρ the density of air, and $n=2-m$.

To make clear the universality of n and k, peculiar characters of flow length l and the effective radius r, and also to know the limit of application of the equation (1), some experiments were carried out with a pile consisting of the pieces cut off from a sheet of fabric. The apparatus used was similar to the previous paper.(3) Its essential part was large Mariotte bottle T filled with water, the bottom of which was connected to a water pipe provided with a cock C_1 for the regulation of the velocity of air through the pile. The upper end of the bottle was connected to a cylindrical tube A by a pipe via a storage tank B, across the top A_0 of the tube the pile S to be tested was placed as shown in Fig. 1. The experimental procedure was also similar to the previous one.

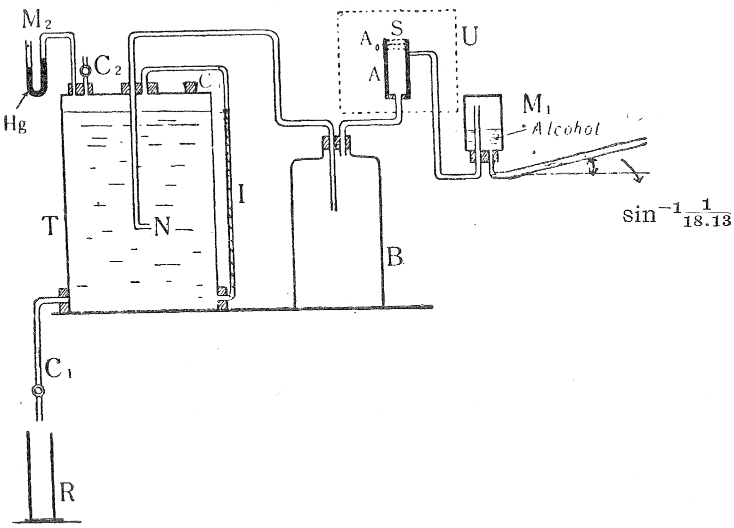

Fig. 1 Schematic diagram of experimental arrangement.

The kinds of the fabric studied were Fujiette, Nylon-Taffeta, Broad, Habutai (16-Monme) and Salan, and the most of them were plain with the exception of salan twilled 1/2. Under the experimental conditions that the temperature was 22°±2°C and the relative humidity 68±3%, the relations of $\triangle P$ in mmH_2O with Q in c.c./cm² min., corrected to atomcspheric pressure, were obtained for various number of sheets, and they were plotted in Fig. 2-1 etc. By means of these figures, we were able to get the value of n and K for each pile.

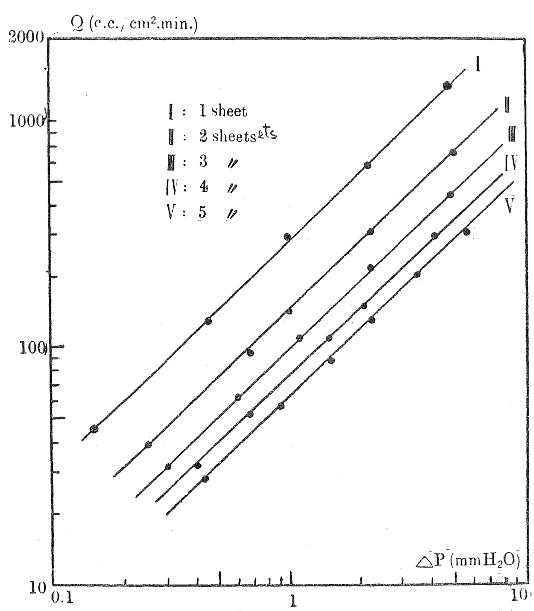

Fig. 2-1 Fujiette

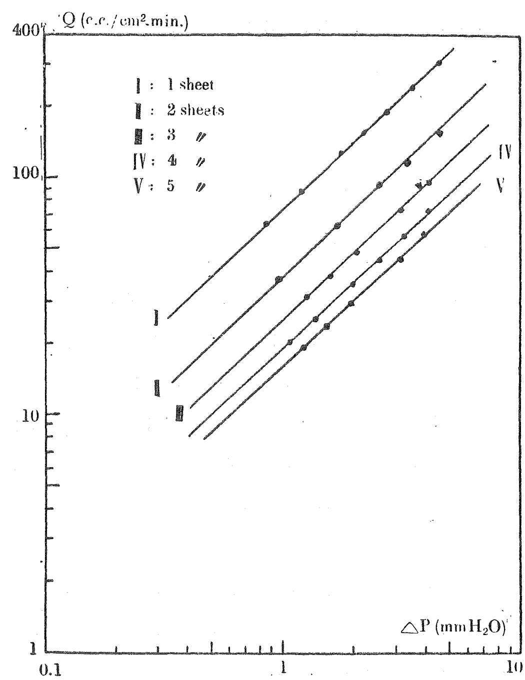

Fig. 2-2 Nylon-Taffeta

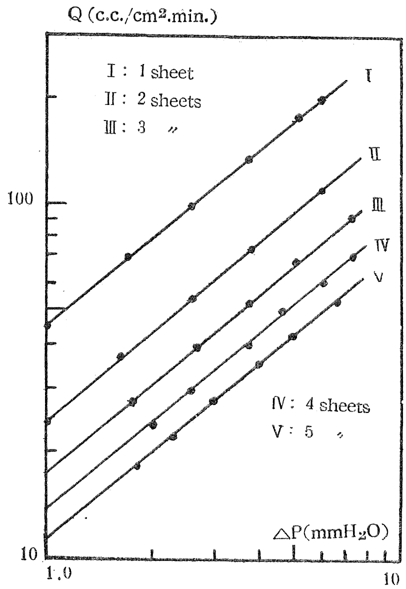

Fig. 2–3 Broad

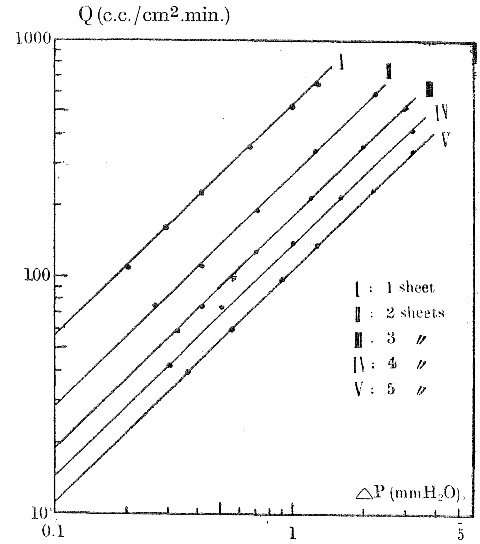

Fig. 2–4 Habutae–16 monme

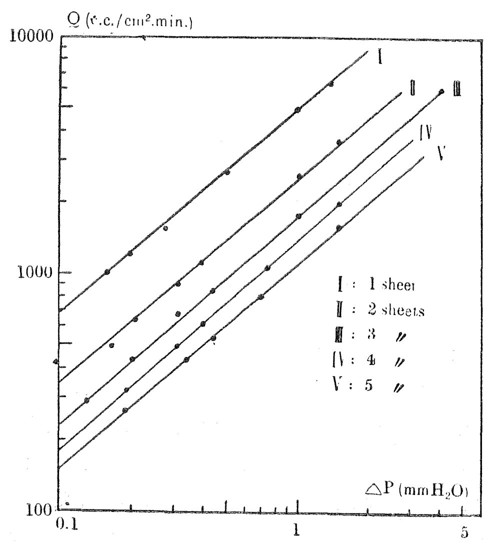

Fig. 2–5 Salan

The curves labelled (A) in Fig. 3 (Fujiette etc.) show the relations between the value of n and the number of sheets N and the solid curves labelled (B) in them express the experimental relations of K and N. From these, it is plain that n remains constant for a kind of textile fabric and has not strong connection with N, while the value of K

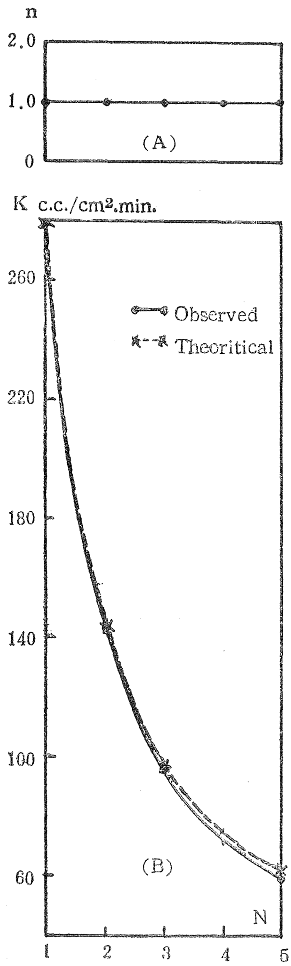

Fig. 3-1 Fujiette

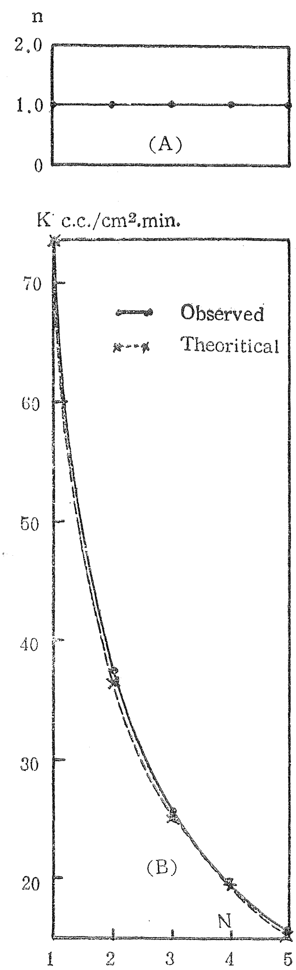

Fig. 3-2 Nylon-Taffeta

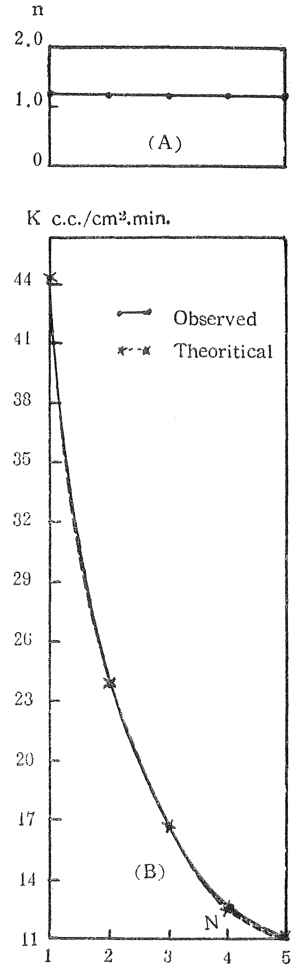

Fig. 3-3 Broad

decreases rapidly with the number of sheets N.

As shown in the previous paper,(2) the value of n does not differ greatly from unity for the most fabric when the quantity of air passing through a sheet is comparatively small and the air becomes laminar flow. The curves I (for one sheet) in Fig. 2 ought to be obtained under these circumstances. Needless to say, the pressure drop across each sheet decreases with the number of sheets under the constant pressure difference between both sides of a pile. The other curves II, III, IV, V in Fig. 2 have been obtained under such conditions and air may be laminar flow. If the air passing through the pile is laminar flow peculiar to the textile fabric itself, the value of n obtained for the pile remains at its own constant as if it were the cases of a sheet with lower pressure drop, and thus has not great bearing upon the number of sheets.

Now, the fact that the value of K decreases rapidly with the number of sheets is worth consideration. Let us assume that $\frac{r^{3-n}}{k}$ is constant. Then, we get the following

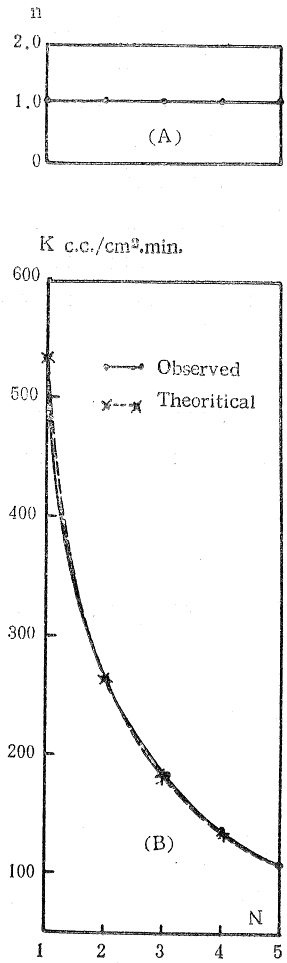

Fig. 3–4 Habutae 16–Monme

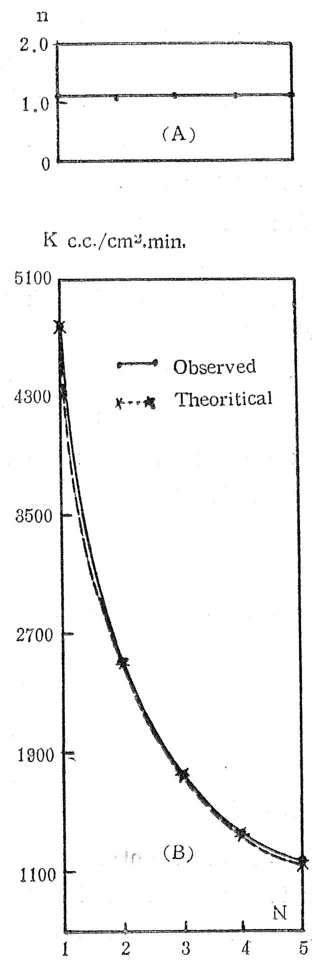

Fig. 3–5 Salan

relation between K and l from the equation (2),

$$\frac{K_1}{K_i}=\left(\frac{l_i}{l_1}\right)^{\frac{1}{n}} \tag{3}$$

where K_1 is the value of K for a sheet with flow length l_1 and K_i the value for i sheets with resultant flow length l_i. For our cases, it is natural to put

$$l_i=il_1. \tag{4}$$

Consequently, we obtain

$$\frac{K_1}{K_i}=i^{\frac{1}{n}}$$

or

$$K_i=K_1 i^{-\frac{1}{n}} \tag{5}$$

The value of K_i corresponding to i sheets of pile is calculated by the equation (5) when K_1 and n are given. Thus, the dotted curves in Fig. 3 (Fujiette etc.) are obtained. From the figures, it seems to us that these observed and theoretical curves are fairly at one, (B) in Fig. 3-1 excepted, and that there is no great mistake in our assumption that $\frac{r^{3-n}}{k}$ is constant. The fact that the theoretical values of K for Fujiette are a little greater than those observed may be attributted to influence of deformation of Fujiette, for the decrease of flow velocity Q has been observed in the past often when the distance between 2 sheets was slightly increased in a ductile manner. This point is still under our investigation.

Now, it may be stated that the equations (1) and (2) are also applicable to a pile when the resultant flow length l_i is taken into consideration, and that n and $\frac{r^{3-n}}{k}\left(\fallingdotseq\frac{r^2}{k}\right)$ are constants depending upon a kind of textile fabric, and having little connection with the number of sheets.

Summary

The equations to air flow through various fabric were expressed as follows

$$Q=K(\triangle P)^{\frac{1}{n}}$$

and

$$K=\left(\frac{2r^{3-n}}{kl\eta^{2-n}\rho^{n-1}}\right)^{\frac{1}{n}}$$

where Q is the flow velocity in c.c./cm^2 min., $\triangle P$ the prcssure drop in mmH_2O across fabric, n a constant number depending mainly upon the size of effective radius r deduced from the whole area of the holes, η the coefficient of visccsity, l the flow length, ρ the density of air and k is constant.

In the present paper, it has been shown that the equations described above are also applicable to a pile of i sheets of textile fabric when the resultant flow length l_i which is equal to il_1 is used, and that n and $\frac{r^{3-n}}{k}\left(\fallingdotseq\frac{r^2}{k}\right)$ are respectively the proper constants for its construction, having little connection with the number of sheets.

In conculsion, we wish to thank Mr. Y. Nahoyama, President of Ishikawa Seisakusho, Mr. T. Kuruma, Engineer of Ishikawa Prefecture, Mr. M. Morie, Director of Hokuyo Textile Industrial Co., Mr. T. Shibata, Chief-Engineer of Ishikawa Textile Club, for their kindness of offering of many samples. Thanks are also due to Mr. M. Yoshimura and Mr. M. Takemura, Assistant Professors of Kanazawa University, for valuable advice and to Mr. S. Mori for his great assistance.

References

(1) S. Saito and H. Uchida, J. Text. Ind. (Sen-i Kōgyō Gakkaishi) 2 (1936), 247.

(2) T. Terada and K. Tanaka, Sci. Rep. Kanazawa Univ. 3 (1955) 237.

(3) T. Terada and K. Tanaka, Ibid.