Title	Experimental study on pneumafil (II)
Sub Title	
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Publisher	慶應義塾大学藤原記念工学部
Publication year	1955
Jtitle	Proceedings of the Fujihara Memorial Faculty of Engineering Keio University Vol.8, No.28 (1955.) ,p.1(1)- 6(6)
JaLC DOI	
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Notes	
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00080028-0001

Experimental Study on Pneumafil (II)

(Received October 14, 1955)

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Abstract

Studies on the two types of pneumafils, i. e. the pneumafil fitted with a pipe of variable cross-sectional area with holes of constant diameters, and a pipe of constant cross-sectional area with holes of variable diameters, were conducted previously by the present authors for the case of three holes to find the fair coincidence of the theoretical results with experimental one. In this paper, the pneumafils having six holes were examined experimentally, and it was found that the formulae derived theoretically in the first report[1] should be corrected slightly. It is conceivable that these deviations are due to the fact that the theoretical derivations were based on simple assumptions, neglecting the frictional losses and the shock losses.

I. Introduction

Researches concerning the pneumafil have been conducted by Prof. S. Niitu, M. Kurahashi[2] at Ōsaka University, and Y. Ogawa[3] at Kanebo Company. The former survey consists of the theoretical treatment and the experimental survey with particular reference to practical application, and the latter one gives a key to the practical solution of the pneumafil problem from the experimental point of view. The present authors have undertaken the flow problem of the pneumafil, i. e. the uniformity of the weight flow of the air through each hole both theoretically and experimentally, to obtain the simple expressions applicable to the determinations of cross-sectional areas of the holes as well as those of

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1) I. WATANABE, N. HOMBO, G. OSHIMA; Proc. Faculty of Engng. Keio Univ. Vol. 4, No. 14, 1951, pp. 61/69

2) S. Niitu, M. Kurahashi; Jour. Textile Machinery Soc. Japan, Vol. 5, No. 1~12, 1952

3) Y. Ogawa; Jour. Textile Machinery Soc. Japan, Vol. 4, No. 11, 1951 and Vol. 6, No. 11, 1953

the main pipe of the pneumafil. In the first report, the authors have conducted theoretical derivation concerning the two types of the pneumafils, that is the pneumafil fitted with a pipe of variable cross-sectional area with holes of constant diameters, and the pneumafil fitted with a pipe of constant cross-sectional area with holes of variable diameters, neglecting the frictional resistances of the pipe and the shock losses, which are conceivable to occur at the downstream region of each hole. Further, the authors had conducted the experiments about the above-mentioned two types of the pneumafil fitted with three holes to find fair coincidence with the theoretical formulae obtained.

However, it is not certain that the coincidence of the formulae with the experimental results would result even if the number of holes n will exceed three. Thus, the present authors have conducted another series of experiments with pneumafils fitted with six holes. The results were that the correction to the formulae given in the first report was necessary. The cause of the deviation of the results of the theoretical survey with experimental one is considered to be due to the fact that the frictional losses and the other losses have been neglected in the theoretical treatment. In this report, the empirical formulae applicable to the pneumafil having six holes have been established.

II. Experimental Set, Experimental Results and the Considerations.

The photographic view of the experimental set is shown in fig. 1. One end of the main pipe of pneumafil is fitted to the suction side of the blower

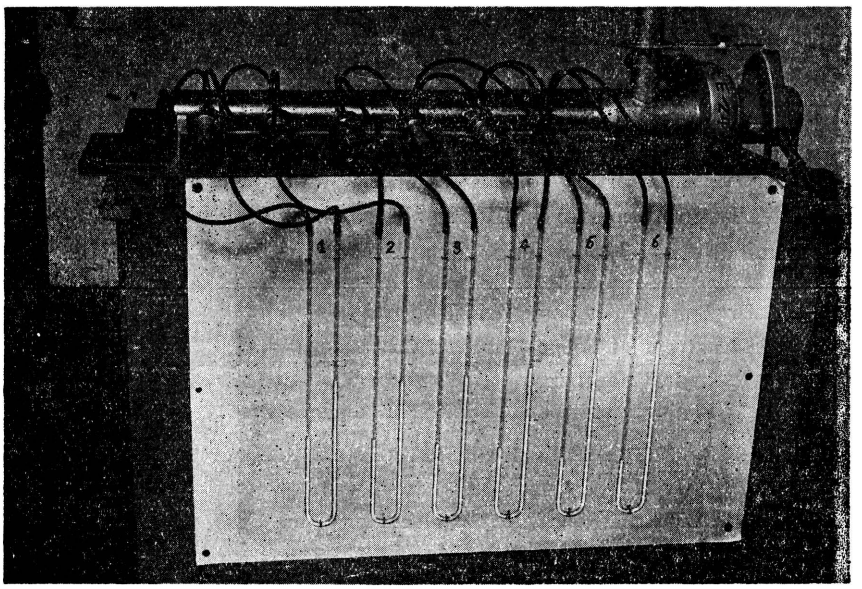

Fig. 1. Photographic View of the Experimental Set on Pneumafils

driven by an electric motor of 240W, the capacity of the blower being 1.5m³/min. The other end of the main pipe of the pneumafil is enclosed, and six small branch pipes are fitted equidistant (100mm) along the axis of the main pipe as shown in the figure. Each branch pipe is provided with round-type nozzle. Because of the constancy of the number of revolutions of the electric motor, the weight flow through each branch pipe is varied by means of the sluice valve provided at the suction eye of the blower as shown. The numbering of the branch pipe is represented using subscripts 1, 2, 3, ·· 6 from the farthest to the nearest branch pipe relative to the blower. The area of the nozzle of each branch pipe, in this case, corresponds to the area of the hole.

(1) Experiments on pneumafil fitted with a pipe of variable cross-sectional area with holes of constant diameters.

Experiments were conducted with three main pipes, provided with constant inner diameter of branch pipe $D=16.7$mm and constant diameter of round type nozzle $d=8.0$mm. The main pipes used are shown in figs. 2, 3, and 4. Of these, the main pipe shown in fig. 2 is of rectangular section, while others are of

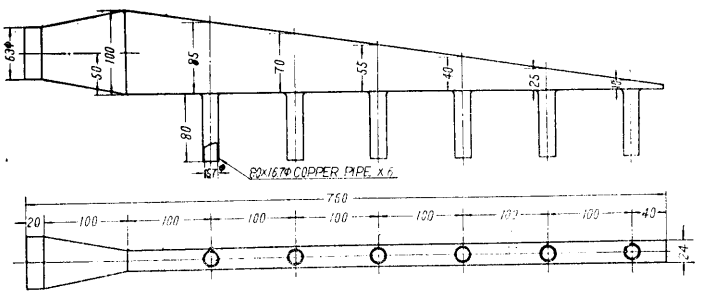

Fig. 2.
Pneumafil fitted with a Pipe of Variable Cross-sectional Area.

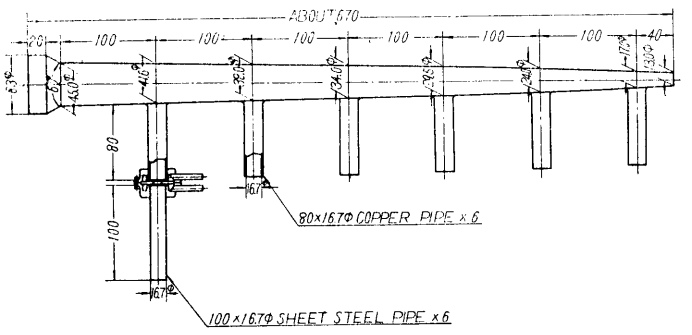

Fig. 3.
Pneumafil fitted with a Pipe of Variable Cross-sectional Area

circular section.

The experimental results with the main pipe shown in fig. 2 are plotted in fig. 5.

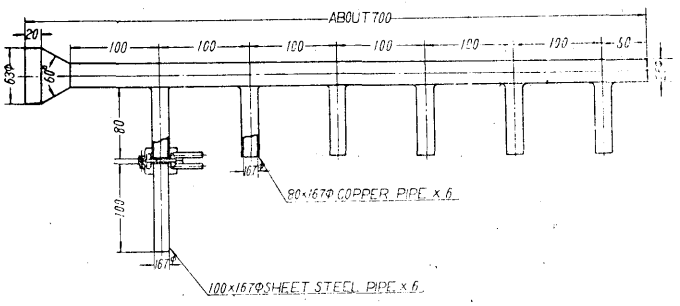

Fig. 4.

Pneumafil fitted with a Pipe of Constant Cross-sectional Area

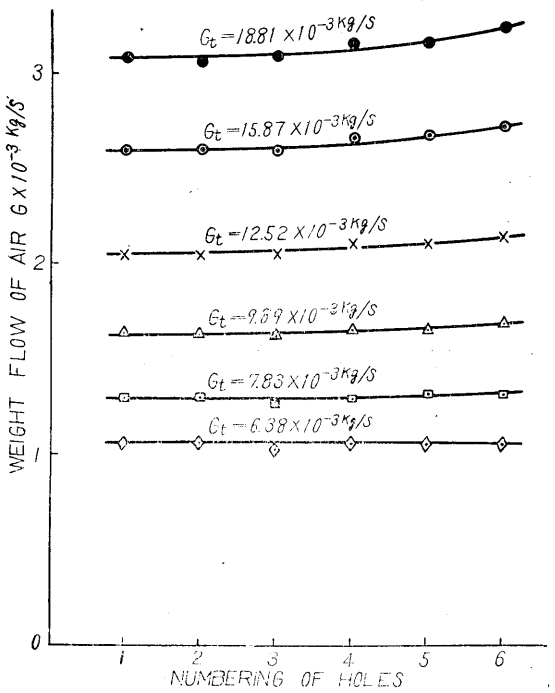

Fig. 5

Similar results are obtained using other main pipes. The condition that the constant weight flow of air is sucked in through each hole or nozzle is obtained from these experimental results. Thus, the empirical formula is

$$Y_F = 1.571n - 0.571 \qquad (1)$$

where $Y_F = F_n/F_1$, and F_n denotes the cross-sectional area of the nth hole, F_1 being the cross-sectional area of the 1st hole. In the first report, the theoretical relation $F_1/F_n = 1/n$ was obtained. It is seen that the eq. (1) shown above shows some discrepancies with the condition $F_1/F_n = 1/n$. Rewritting eq. (1) in the following form, i.e.

$$\frac{F_1}{F_n} = \frac{1}{n + (n-1)\mu} \qquad (2)$$

we notice that eq. (2) coincides with eq. (1) when $\mu = 0.571$. The relation $F_1/F_n = 1/n$ was derived theoretically neglecting the frictional resistances and other losses, and showed fair coincidence with experimental results so far as the number of holes n does not exceed three. We find that the condition yields

to eq. (2) in the case of $n=6$. The eq. (2) means larger area of F_n than that given by the relation $F_1/F_n=1/n$. In other words, it implies that the frictional losses and so on should be taken under considerations in these cases. It is concluded that the pneumafil of this type must be designed by eq. (1) or (2) when number of holes becomes larger.

(2) Experiments on pneumafil fitted with a pipe of constant cross-sectional area with holes of variable diameters.

In this case, the main pipe shown in fig. 4 as well as the main pipe shown in fig. 6 were used. The main pipe shown in fig. 6 was also used in such a manner,

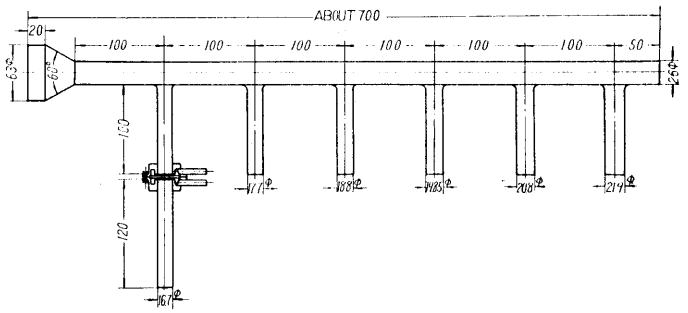

Fig. 6.
Pneumafil fitted with a Pipe of Constant Cross-sectional Area.

that the order of the magnitudes of the holes is reversed compared with that shown in the figure. As mentioned above, the area ratio of each branch pipe and the corresponding round type nozzle was selected constant. These area ratios were selected to be equal to the value in the pneumafil shown in fig. 4, so that the flow coefficient α of each round-type nozzle amounts to the same value.

The experimental results thus obtained resemble to those shown in fig. 5. The condition, that the weight flow of air through each individual hole or nozzle becomes equal, reveals us, that the relation obtained theoretically for $n=3$ in the first report, holds no longer. Thus the relation obtained previously, i. e.

$$(\lambda^2)^{n-1}A_n^2\left\{1-\frac{1}{n^2\dfrac{F^2}{\alpha^2A_1^2}-(n^2-1)}\right\}=A_1^2\left(1-\frac{\alpha^2A_1^2}{F^2}\right) \tag{3}$$

must be corrected, where A_1 and A_n denote the cross-sectional areas of the hole or nozzle farthest from the blower and the nth hole respectively. It was found that the following empirical formula gives the correct value of A_n in this case.

$$\lambda^{n^{2\cdot9}_{3\cdot1}}A_n^2\left\{1-\frac{1}{n^2\dfrac{F^2}{\alpha^2A_1^2}-(n^2-1)}\right\}=A_1^2\left(1-\frac{\alpha^2A_1^2}{F^2}\right) \tag{4}$$

where $\lambda=1.010$ and $\alpha=0.847$.

The evaluation by eq. (4) is somewhat tedious. Another formula which satisfies the same condition for equal weight flow of air through each hole is represented as follows.

$$Y=1-0.0018n^{2.41} \tag{5}$$

where Y denotes the diameter of the nth hole when the diameter of the first hole, i. e. the farthest hole from the blower equals to unity.

III. Conclusions

The following conclusions have been derived as the results of the present experimental studies.

(1) For pneumafils with three or less holes, the formulae given in the first report may be used with sufficient accuracy. For pneumafils, in which the number of holes n amounts to six, however, the formulae given in the first report hold no longer.

(2) For the case of $3<n\leqq6$, the pneumafil may be designed in the following manner. (a) For pneumafils fitted with a pipe of variable cross-sectional area with holes of constant diameters, eq. (1) or (2) may be used for the determination of the cross-sectional areas of the main pipe. (b) For pneumafils fitted with a pipe of constant cross-sectional area with holes of variable diameters, the eq. (4) or (5) is recommended. It is necessary to note that eq. (4) and (5) give the cross-sectional area and the diameter of each hole respectively.