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SOME MEASUREMENTS OF AIRFLOW THROUGH WOOD CRIBS

by

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FIRE RESEARCH STATION

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SUMMARY

The resistance to air flowing through cribs of varying specific surface, although only of one porosity, viz. $\frac{1}{2}$, has been measured, and it has similarities with a conventional law for packed beds. One of the coefficients in the law for cribs, however, is lower than that for packed beds because, presumably, the presence of through passages facilitates the flow. The results have been obtained to allow estimates to be made of how the burning behaviour of cribs is affected by their design.

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MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

SOME MEASUREMENTS OF AIRFLOW THROUGH WOOD CRIBS

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Introduction

Because cribs are frequently used as fuel in experimental fires it is necessary to know their burning properties when these control fire behaviour in a way which might be different from, say, furniture.

The burning rate of wood cribs is dependent on the available air supply, and if this is not limited by the openings in the compartment, in which the crib is situated, the resistance offered by the crib itself to the movement of gases within it is important. This note describes a few simple experiments made to assess this resistance to air flow.

Description of Cribs

Four cribs were made with all the sticks lying horizontally, as shown in Plate 1a, each stick was 21.6 cm long and of square section, the four stick sizes being 2.5, 1.3, 1.0, and 0.6 cm. The sticks were glued at their points of contact and each crib built to a height of about 22 cm to make a cubical stack. The sticks were spaced apart at a distance equal to their own thickness, i.e. a 1:1 spacing. So far only this one value of porosity has been studied.

Measurements were made of the actual sizes of some of the crib sticks. For the 2.5 and 1.3 cm sizes, good agreement with the nominal dimensions was found, but for the two smaller sizes the thickness varied by up to 25 per cent above and below the nominal.

Experimental equipment

The cribs were placed, in turn, in a wind tunnel of 23 cm square section, in which air velocities of up to 180 cm/s could be produced. The general arrangement of the equipment is shown in Fig. 1 which gives a horizontal section along the middle of the tunnel.

The pressure drop across the crib in the direction of air flow was measured by an inclined tube water manometer with which pressure could be read to 0.13 mm equivalent vertical height of water column. The manometer

was used differentially, by communicating with the tunnel both up and downstream from the crib. Both the tubes terminated in an open end facing into the wind and located in the centre of the tunnel cross-section. A vane anemometer also located centrally in the tunnel upstream of the anemometer and the crib, recorded the air velocity.

Experimental procedure and Results

The crib was first placed in the tunnel so that the air flow was normal to the plane of the crib as shown in Plate 1a and corresponded to horizontal flow in the crib. The pressure drop across the crib was measured for air velocities in the range 21 to 183 cm/s. The measurements were repeated with the crib turned over on its side so that the air flow was normal to the plane of Plate 1b and corresponded to vertical flow within the crib. The mean values of pressure drop for horizontal and vertical flow are shown in Figures 2 and 3. A further set of readings was taken with two 2.5 cm stick cribs in series, one of them placed as in Plate 1a, the other as in Plate 1b, to check whether the resistance of two cribs in series was the sum of the resistances of the cribs as measured individually. This was found to be so, see Fig. 4, where the ordinates of curves A and B add up approximately to those for curve C.

Discussion

In Figures 2 - 4, the experimental points form a definite relation between pressure drop and air velocity thus showing that the equipment and measuring techniques were sufficiently refined for their purpose. Some experimental points for the crib made from the thinnest (0.6 cm) sticks are, however, not in line with the rest.

For the following discussion we define

Δh = pressure drop across crib in $g\,cm^{-1}\,s^{-2}$

d = stick thickness in cm.

l = stick length - 21.5 cm.

u = velocity of air in the wind tunnel in cm/s.

ρ = density of air taken as $1.3 \times 10^{-3}\ g/cm^3$.

ϵ = the porosity of the bed

s = the specific surface of the sticks in the crib

and $d_h = 6/s$

Dimensionless friction factors are commonly defined in terms of the dimensionless ratio of pressure drop to kinetic head, viz. $\Delta h / \rho w^2$ and geometric ratios such as, here, h/d and ε . The friction factor can then be obtained as a function of the Reynolds No. Thus Ergun[1] has used a friction factor for packed beds as

$$f = \frac{\Delta h}{\rho w^2} \frac{\epsilon^3}{1-\epsilon} \frac{d_p}{l} = \frac{A(1-\epsilon)}{R_2} + B$$

where d_p is a characteristic size of the contents of the bed, viz. $6/s$ where s is the specific surface and R_2 is $w d_p/\nu$ where ν is the kinematic viscosity of the fluid. A and B are constants. Here $\epsilon = \frac{1}{2}$ for a 1:1 spacing, and $d_p = 2d$

$$\text{Hence } \Delta h\, d^2/\rho l w = \alpha + \beta\, w d$$

and accordingly the data have been plotted for the four cribs in Figures 5 and 6 which show that the results for the different stick sizes can be correlated by a simple linear relation.

α and β are the intercept and slope respectively in Figures 5 and 6. We can compare this with the equation given by Ergun for the flow in packed beds which, for these cribs, can be written

$$\frac{\Delta h\, d^2}{\rho l w} = \frac{A}{2}\nu + 2B\, w d$$

With ν as 0.18 cm^2/s we have A and B as given in Table I

	A	B
Vertical flow	150 - 250	0.28
Horizontal flow	90	0.17

In vertical flow the air flow is at right angles to all sticks. In horizontal flow it is parallel to half of them and the friction factor is about a half. Ergun's values for randomly packed spheres are 150 and 1.75 respectively for A and B.

The values of B are substantially lower than Ergun's, no doubt due in part to the presence of direct through passages. The value of A for vertical flow is of the same order as Ergun's.

No attempt has yet been made to find how the frictional resistance varies with ϵ. These data are currently being used in an attempt to correlate the burning behaviour of cribs with their design properties.

Reference

1) ERGUN, S. Chem. Engng. Prog., 1952, 48 (2) 89-94.

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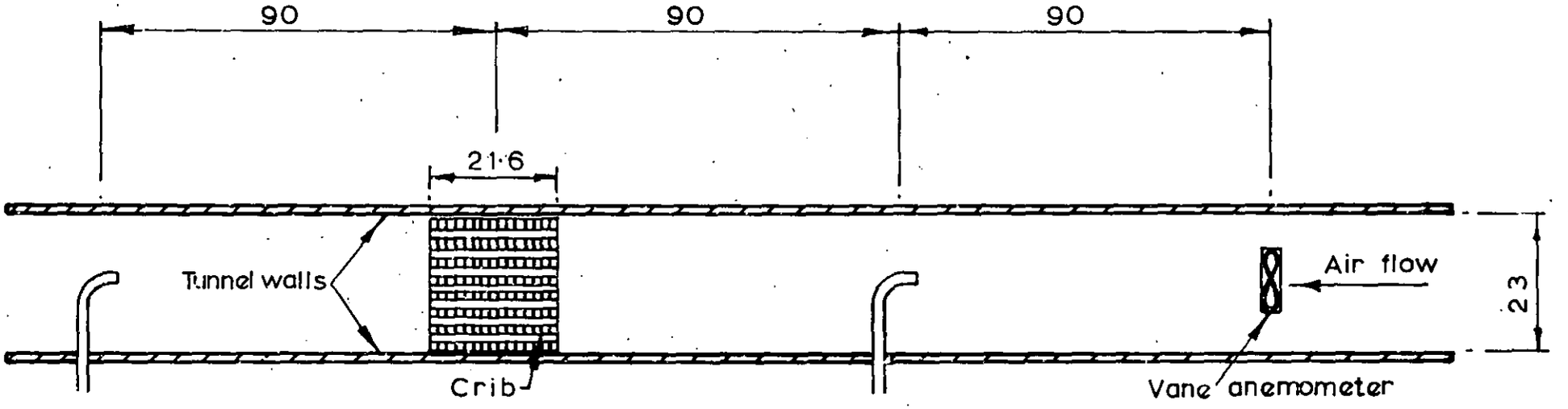


Tube to manometer
External diameter 0·6
Internal diameter 0·5

Tube to manometer
External diameter 0·6
Internal diameter 0·5

Note :-
All dimensions in centimetres

FIG.1. PLAN OF WIND TUNNEL WITH CRIB

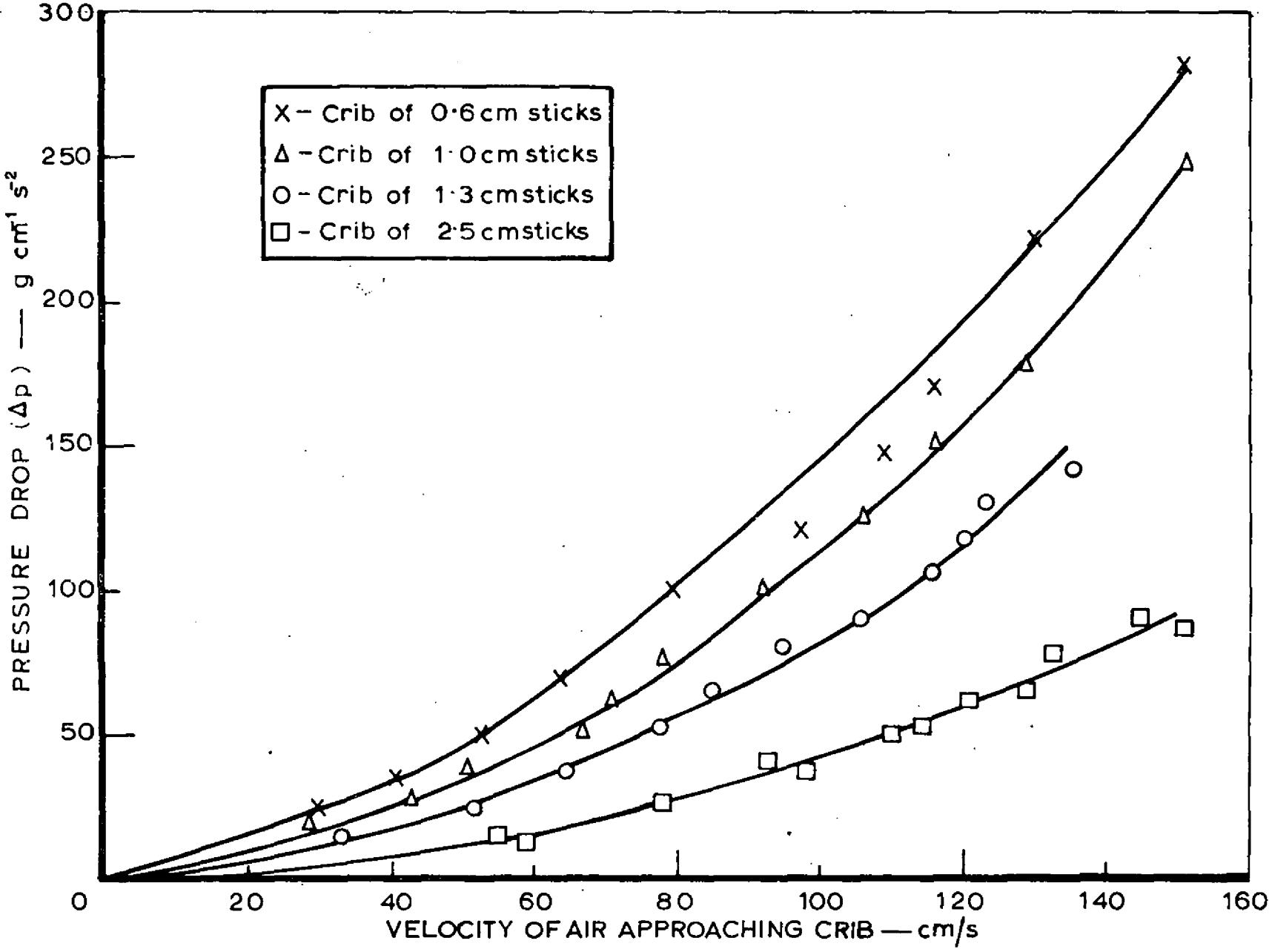


FIG.2. PRESSURE DROP FOR UPRIGHT CRIBS (STICKS HORIZONTAL)

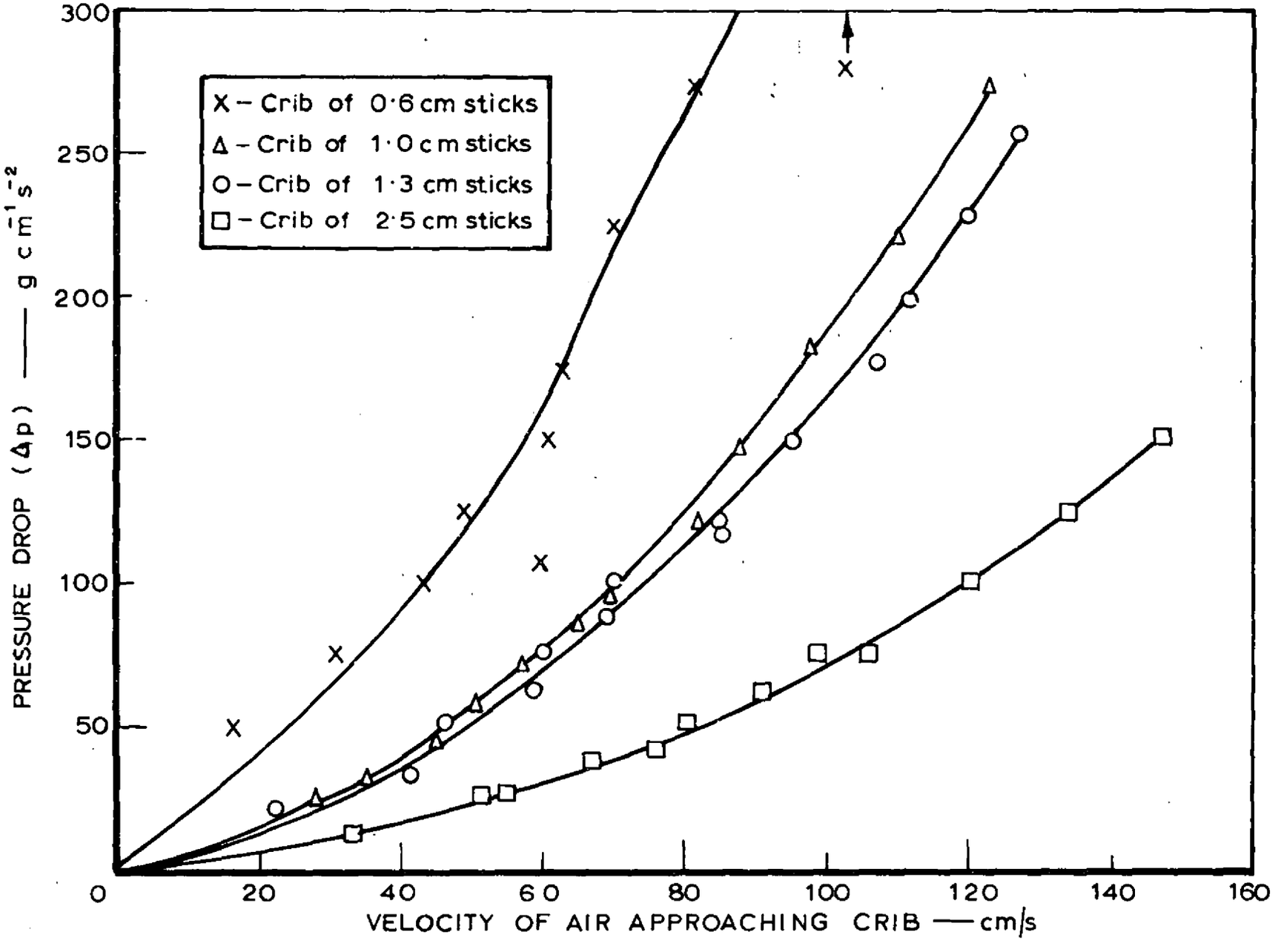


FIG. 3. PRESSURE DROP FOR CRIBS ON THEIR SIDES (STICKS VERTICAL)

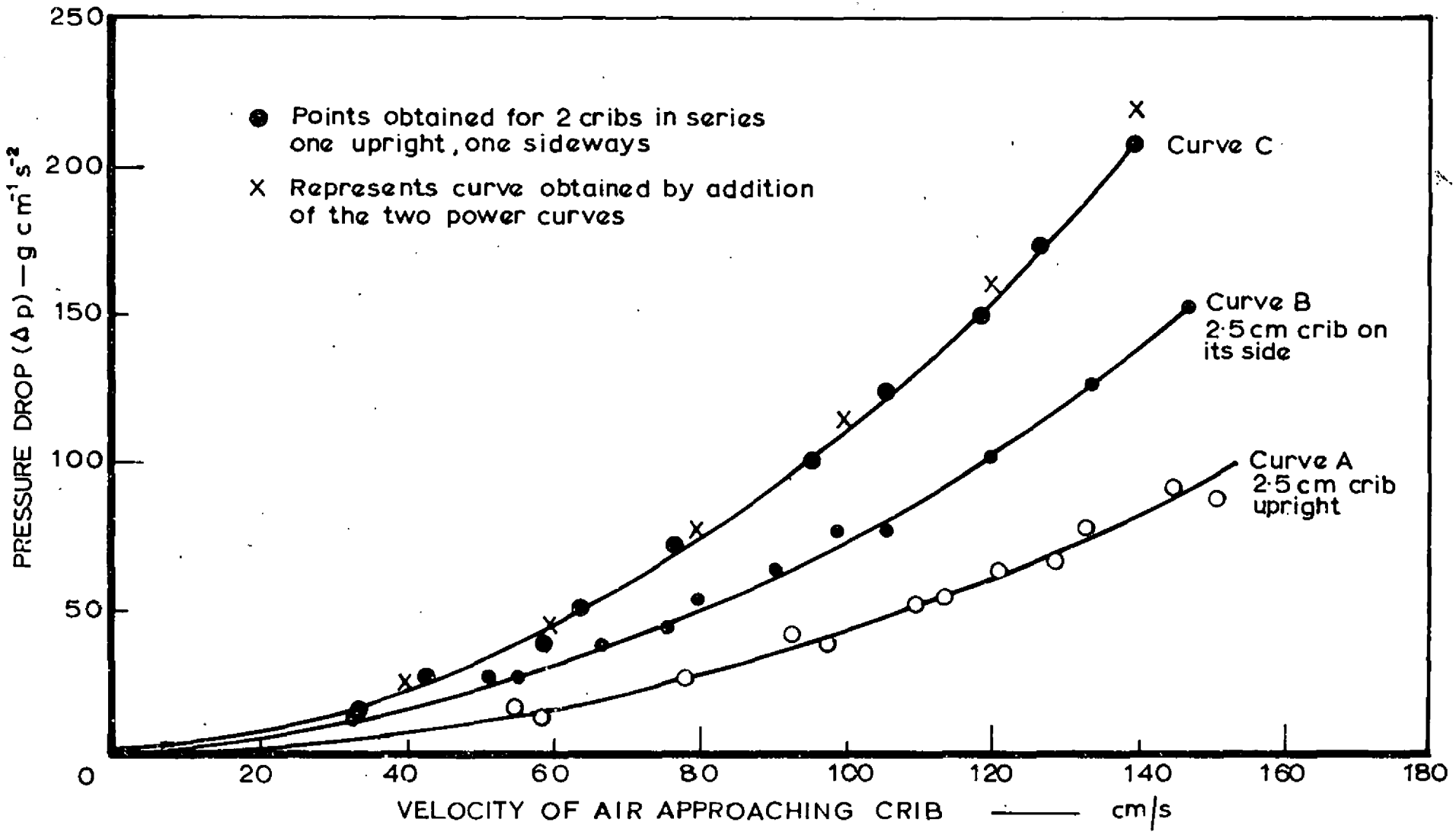
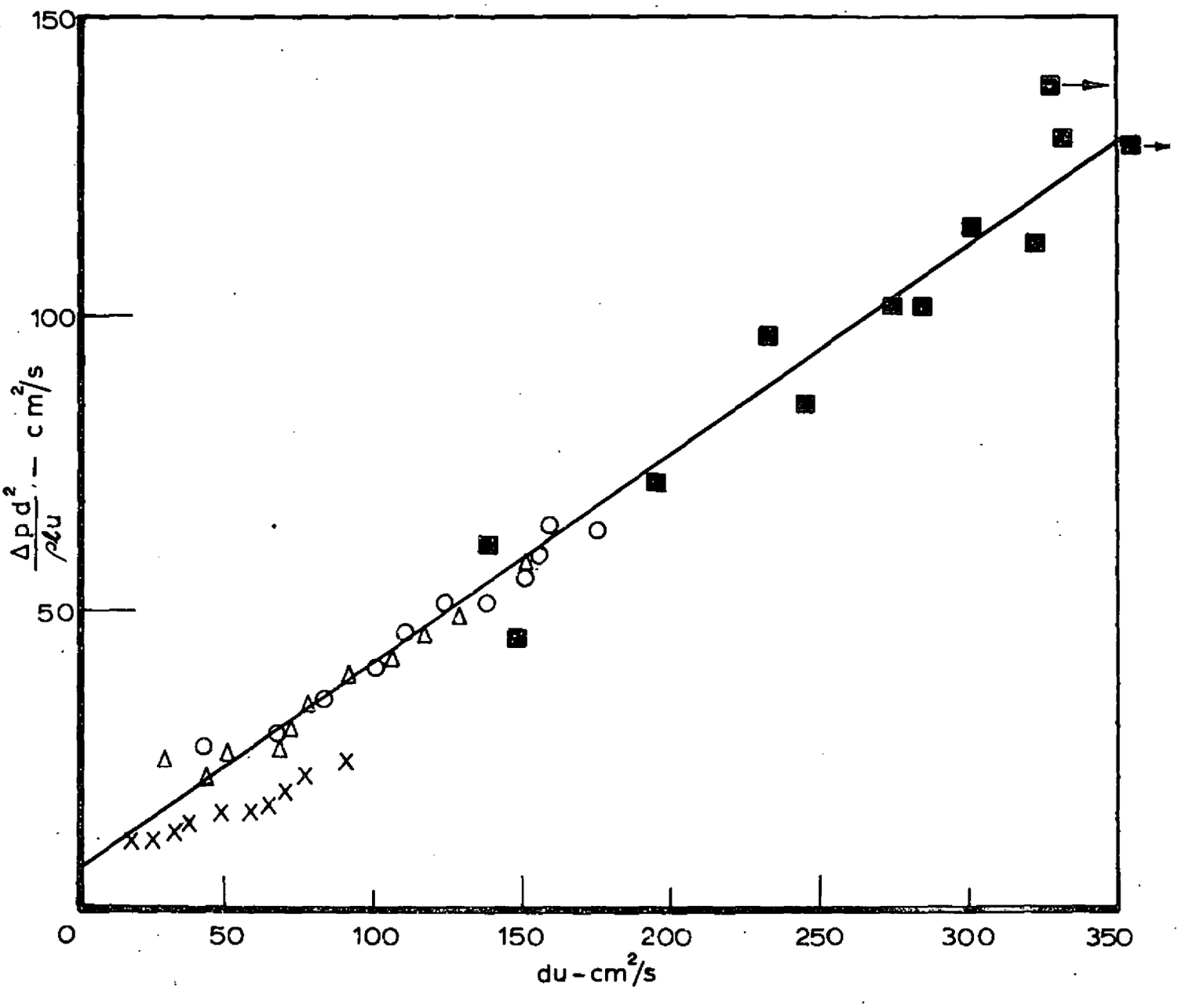


FIG.4. PRESSURE-VELOCITY CURVES FOR 2·5 cm CRIBS, UPRIGHT, SIDEWAYS AND BOTH IN SERIES



■ - Crib of 2·5 cm sticks
O - Crib of 1·3 cm sticks
Δ - Crib of 1·0 cm sticks
X - Crib of 0·6 cm sticks

} 1:1 spacing
Cribs are 21·6 cm cube (approximately)

Slope = 0·35

FIG. 5. PRESSURE — VELOCITY RELATION FOR HORIZONTAL AIR FLOW IN CRIBS

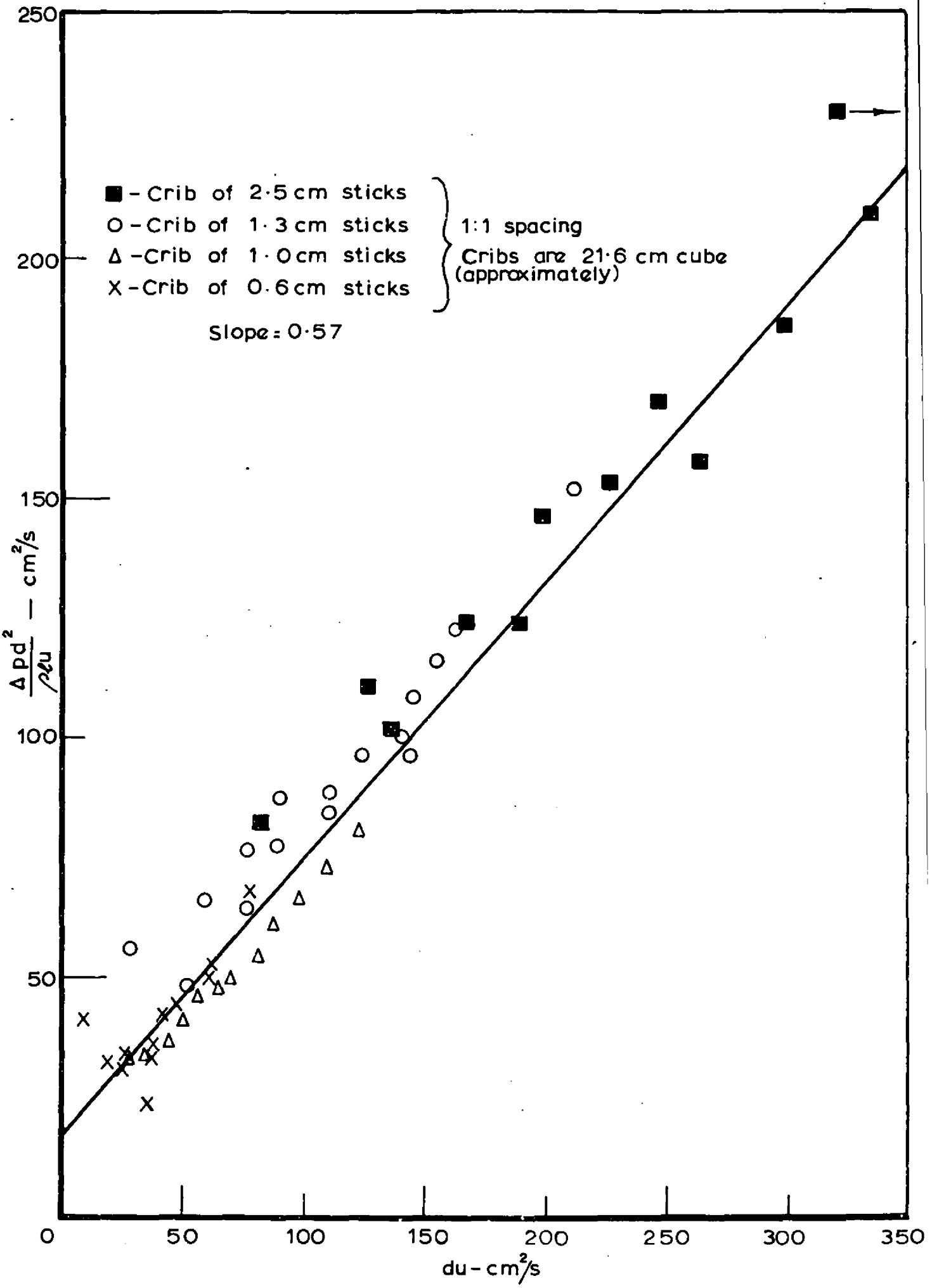
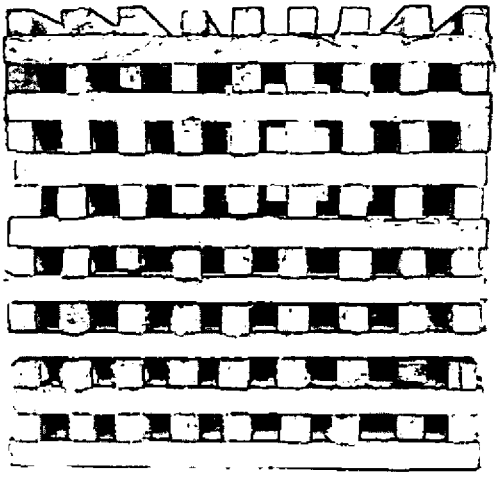
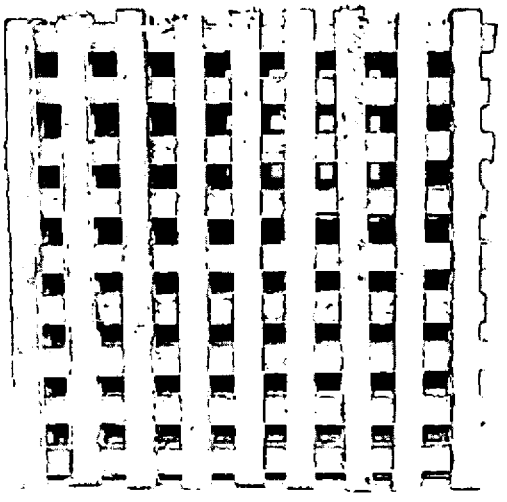


FIG.6. PRESSURE – VELOCITY RELATION FOR VERTICAL AIR FLOW IN CRIBS



(a) Crib elevation



(b) Crib plan

PLATE 1