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TECH. NOTE
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TECHNICAL NOTE No: MECH. ENG. 163

EFFECT OF A CYLINDRICAL STORE ON PARACHUTE DRAG AND OPENING

by

J. PICKEN, B.Sc.

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Technical Note No. Mech.Eng. 163

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ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Effect of a Cylindrical Store on Parachute Drag and Opening

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R.A.E. Ref:- ME/C2/18017/JP

SUMMARY

This note describes an exploratory wind tunnel investigation into the effect of a bluff nosed cylindrical store on the critical speeds and drag of a parachute for parachute diameter/store diameter ratios of the order of unity. It shows that these characteristics can be greatly modified by the wake of a cylinder and suggests that these modifications arise largely out of a reduction in axial velocity and the flow being directed towards the cylindrical axis in the wake. It is recommended that until more data is obtained the distance at which a parachute should be flown from its store should be preferably at least four store diameters.

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1 Introduction

Most available data on parachute characteristics have been largely obtained under approximately free stream conditions by wind tunnel experiments or by dropping parachutes with loads whose dimensions are relatively small. In certain applications, however, such as where the parachute is used primarily as a stabilising agent, the store dimensions may be comparable to those of the parachute and consequently may be expected to modify the airflow in the region of the parachute canopy. In order to investigate the extent of this effect on parachute characteristics some exploratory experiments were made in the 24 ft. wind tunnel at R.A.E.

This note describes and presents the results of these experiments which were made some time ago, 1946-1947.

2 Range of Investigation

The investigation was confined to two bluff nosed cylindrical stores and parachute diameter/store diameter ratios of the order of unity. Drags and critical speeds of porous Exeter Type 12 parachutes were measured at various distances behind the cylinders. The wake of one of the cylinders was traversed by a pitot-static comb. A mechanism to account for changes in parachute characteristics in terms of distortion of the airflow by the store is suggested.

3 Method

3.1 Stores

The stores selected for the experiments were bluff nosed cylinders made from 20 gauge mild steel plate. They were flown with their axis along the direction of the airstream. Their length was 5 ft. and the two diameters selected were 30 inches and 50 inches respectively. Thus the length/diameter ratios were 2 and 1.2. A plate was inset in the aft end of each cylinder leaving an exposed rim to which the test parachutes could be attached by means of toggles to rectangular holes spaced evenly round the rim. A rod was passed along the cylindrical axis and secured to the two end-plates. Fittings at each end of the rod provided at one end an alternative parachute attachment and, at the other, a means of attachment to the wind tunnel balance rig used in Johns' and Auterson's experiments[1]. Suspension on the axis of the tunnel was effected by means of wire bracings attached to sets of three double angle plates, located near the peripheries of the cylinders, and arranged such that the planes of the bracing were normal to the airstream (Fig.1).

3.2 Drag Measurements

To measure drag a turnbuckle was located in the cable between the balance and the forward end of the cylinder. When drag was applied this was adjusted until the cylinder was returned to a zero position defined by the sighting axis of a fixed telescope. It was assumed that the drag measured in this position was that of the cylinder and parachute and that the contribution to drag of the normal bracing wires could be neglected.

3.3 Test Parachutes and Methods of Attachment

The Exeter Type 12 parachutes used had nominal flying diameters of 3 ft. and 4 ft. The canopies and vent patches were in cotton fabric to Specification D.T.D.418(b) or D.T.D.583. Each parachute was rigged with eight braided flax lines 20 ft. long and of 150 lb nominal strength.

These lines could be attached to the peripheral rims of the cylinders or directly to the axial rod fitting at various rigging line lengths (Fig.2) which methods of attachment are referred to respectively as peripheral and single point attachments. When the single point attachment was used the rigging lines were usually whipped together at some point between the end of the rod and the canopy to form a strop, the effective rigging line length being so selected as to allow the critical speeds to lie within the available range of tunnel speeds.

3.4 Measurement of Critical Speeds

Critical opening speeds were measured by introducing the parachute in the closed state by hand at a tunnel speed at least 10 f/s above the estimated opening speed. The tunnel speed was then gradually reduced its value being followed by a Chattock manometer until the canopy opened. The critical closing speed was obtained by slowly increasing the tunnel speed with the parachute open until the parachute collapsed, the critical value again being measured by the Chattock manometer. Two or three determinations were usually made for each set of conditions.

3.5 Airflow Behind Cylinder

Fig.1 and 2 illustrate the method used to assess the nature of the airflow behind the cylinder. A pitot-static comb was connected to a heavily damped multitube manometer and was such that the axis of the pitot tubes lay along the axial direction of the tunnel. It was assumed that the velocities represented by the difference between the pitot and static pressure readings were approximately the axial components of the mean velocities at the appropriate points.

4 Conditions of Test, Results and Discussion

4.1 Airflow Behind Cylinder

A pitot-static traverse of the wake of the 50 in. diameter cylinder without a parachute was made at tunnel velocities up to 120 f/s covering the region from the cylinder axis to one cylinder diameter from it and 2 ft. to 16 ft. from its aft end. Approximate curves through points of equal axial velocity are given in Fig.4 for a tunnel speed of 120 f/s. The pattern did not appear to be affected appreciably by speed over the available tunnel range. The curves show that in the region up to five cylinder diameters from the aft end of the cylinder and within a radius of about 0.6 cylinder diameters from the cylinder axis the axial velocity component is less than a fraction 0.9 of the free stream velocity. The curves also show that in this region the mean direction of the airflow is towards the axis of the cylinder, the incidence decreasing with increasing distance from the cylinder.

4.2 Drag of Cylinders

Drag coefficients of the cylinders without parachutes were measured over the tunnel speed range and the results plotted in Fig.5. They confirm that there is no significant velocity effect over this range. Mean values independent of speed were assumed when examining the combined drag of cylinder and parachute. The similarity in drag coefficients for the two cylinders suggests that the airflow patterns round them are also similar, the slightly higher value for the 30 in. diameter cylinder being accounted for by the relatively greater skin friction arising from the larger length diameter ratio.

4.3 Effect of Distance Between Canopy and Cylinder on Critical Speeds

In assessing the wake effect on critical speeds the single point method was used to attach the parachute to the store (Fig.2) and the critical speeds were determined for various strop lengths and a range of effective rigging line lengths. The results are given in graphical form in Fig.6-10. The critical speeds quoted refer to the general airstream velocity and not the ambient velocity in the region of the canopy.

The results show that both critical speeds decrease as the distance between the parachute canopy and the cylinder is decreased. The critical closing speed at first falls more rapidly than the critical opening speed which is little affected and consequently they approach each other until at some critical distance the two values become almost coincident. For distances less than this the critical opening speed follows the critical closing speed curve. These trends are summarised graphically in Fig.11.

Duncan[2] has shown that the direction of the airflow at the periphery of a parachute generally varies with velocity the incidence generally decreasing with increasing speed because the relative porosity of most parachute fabrics increases with speed. Critical opening and closing speeds were considered appropriate to critical values of the angle of incidence. Thus in the case of the closing speed if β is the critical value for the angle of incidence at the canopy periphery and α is the actual angle then an open parachute will remain open as long as $\alpha - \beta > 0$. Because of the speed effect on porosity the relative value of the axial component of the flow velocity increases with speed and α decreases until it becomes equal to β when the parachute collapses into the squid state. This mechanism is probably similar to that which obtains in the wake of a cylinder.

It appears from 4.1 that the relative outward radial component in the wake behind the cylinder will decrease as the distance of the parachute canopy behind the cylinder is decreased thus reducing α and producing the same result as the porosity speed effect.

The effect on the opening speed is probably similar except that the angle of incidence should be regarded as increasing to a critical value. For distances less than the critical distance at which the critical opening and closing speeds tend to become coincident the opening speed must be defined by the closing speed. Above this value the variation in opening speed was probably less marked in the wind tunnel experiments because in the closed state the periphery of the canopy was relatively nearer the cylinder axis where an account of the symmetry the flow will be axial. Also because the velocity reduction is greatest in the axial region the porosity speed effect on the axial component of flow through the canopy will be greater. Thus it appears that over the range of the wind tunnel experiments the two effects on critical opening speed probably neutralised each other. It is noteworthy, however, from Fig.6-10 that the reduction in opening speed with decreasing distance between the canopy and cylinder for distances greater than the critical value appears to be greater for the larger parachute diameter/store diameter ratios. It is possible that if this ratio is increased sufficiently to allow the canopy periphery in the squid state to lie about 0.5 of a cylinder diameter from the cylinder axis, a more pronounced effect on critical opening speed would result.

4.4 Effect of Distance Between Canopy and Cylinder on Drag

In assessing the effect of the cylinder wake on parachute drag 3 ft. and 4 ft. diameter parachutes were flown behind with the 30 in. and 50 in. diameter cylinders using the single point and peripheral methods of attachment. With the latter method some difficulty was experienced by a small amplitude high frequency motion of the parachute producing relative movement and wearing of the rigging lines across the apex of the canopy which at the higher tunnel speeds rapidly resulted in their failure. The effect also seemed to be greater for the smaller distances between canopy and cylinder.

The combined drag of the parachute and cylinder was measured as described in section 3.2. The contribution to the drag made by the parachute was assumed to be the difference between this and that produced by the cylinder without a parachute at the same tunnel speed. (Fig.13 shows that this assumption is not valid when the parachute is flown at a small distance behind the cylinder). Parachute drag coefficients based on this assumption and on the tunnel velocity are plotted for various conditions against distance of the parachute from the aft end of the cylinder in Fig.12-14. A rough comparison of the effect on drag of the parachute diameter to cylinder diameter ratio and of the method of attachment is given in Table I.

Limit curves for the parachute drag coefficient derived from Fig.4 and the estimated free stream parachute drag coefficient are also shown in Fig.12 and 13. They are based respectively on the axial velocities in the plane of the canopy periphery on the cylinder axis and at the canopy periphery. They suggest that a fair assessment of parachute drag can probably be obtained by using the root mean square axial velocity, as assessed without the parachute, over the area corresponding to the plane of the canopy mouth bounded by its periphery together with the free stream parachute drag coefficient. The two measurements made at 16 ft. in Fig.12, however, do not appear to conform to this.

A speed effect on drag coefficient is also discernable which becomes more pronounced as the distance between parachute and cylinder is reduced.

This may possibly arise through a modification of shape as the closing speed is approached.

The reduction in the drag of the cylinder by the addition of a parachute close to it (Fig.13) may be analogous to the effect of a fairing.

5 Conclusions

(1) The wake of a bluff nosed cylindrical store modifies the critical speeds of a parachute. The effect probably arises largely through a change of incidence of the airflow in the peripheral region of the canopy from that which obtains under free stream conditions. In the experiments made the critical closing speed was more sensitive to the wake effect than the critical opening speed except when the parachute was flown at less than a certain critical distance behind the cylinder in which region the former defined the value of the latter. In the range of the experiments this critical distance did not exceed about two cylinder diameters.

(2) The drags of the parachute when flown behind the cylinders were less than the free air values and were approximately consistent with the root-mean-square axial velocity in the region of the canopy mouth as determined from the wake pattern of the cylinder when flown without a parachute.

(3) Rapid failure of the rigging lines at the apex occurred when they were attached directly to the periphery of the cylinder.

(4) In general the greater the distance of the parachute from the cylinder the less the parachute performance is modified by the cylinder wake.

6 Recommendations

(1) Until more quantitative data is available it is recommended that with a parachuted store where the parachute diameter is comparable with that of the store the parachute canopy should be flown preferably at a distance of at least four store diameters. In certain cases it is possible to reduce the distance between the canopy and the store to three or two diameters but no less. More representative confirmation may be obtained during particular flight trials of parachutes applied to stores.

(2) Measurements of the critical angle of incidence of flow at the peripheral hem of a parachute for closing should be made at various distances aft of a cylinder to determine whether it is in practice independent of the wake.

REFERENCES

No.	Author(s)	Title, etc.
1	Johns, T.F. and Auterson, E.I.	The Effect of Various Factors on Parachute Characteristics RAE Tech Note No. Aero 1365 June, 1944
2	Duncan, W.J.	The Cause of Spontaneous Opening and Closing of Parachutes R & M 2119 December, 1943

Attached:-

Table I
Fig.1 Neg.No.109745
" 2 SME 75216/R
" 3 Neg.No.109746
" 4 to 14 SME 75217/R to SME 75227/R

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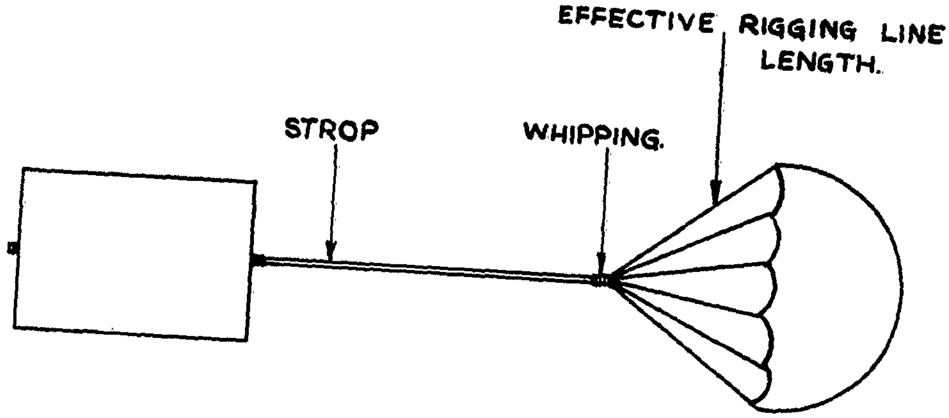
TABLE I

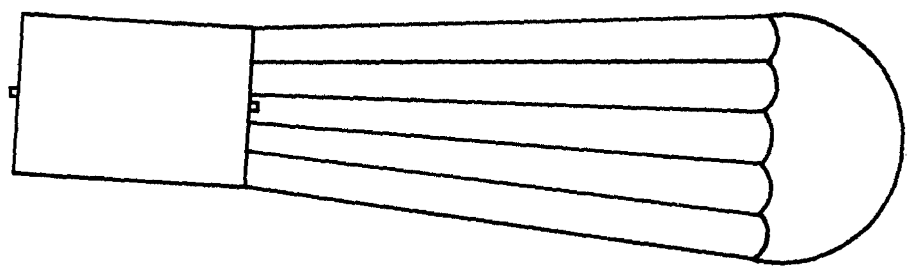
Effect of Parachute Diameter/Cylinder Diameter Ratio on Drag

Parachute Diameter ft.	Cylinder Diameter ft.	$\frac{\text{Parachute Diameter}}{\text{Cylinder Diameter}}$	Distance Between Canopy and Cylinder in Units of Parachute Diameter	Method of Attachment	$\frac{\text{Total Drag}}{\frac{1}{2}\rho V^2} \times \frac{1}{A}$ where A is: Area of Cylinder Cross Section	$\frac{\text{Total Drag}}{\frac{1}{2}\rho V^2} \times \frac{1}{A}$ where A is: $\frac{\pi}{4}\left(\text{Nominal Parachute Diameter}\right)^2$	$\frac{\text{Total Drag} - \text{Cylinder Drag}}{\frac{1}{2}\rho V^2 \frac{\pi}{4}\left(\text{Nominal Parachute Diameter}\right)^2}$	Estimated Parachute Drag Coeff. in Free Air
4	2.5	1.6	4	Peripheral	3.54	1.38	1.05	-
4	2.5	1.6	4	Single Point	2.54	0.99	0.65	0.96
3	2.5	1.2	5.3	Peripheral	2.09	1.45	0.85	-
4	4.17	0.96	4	Single Point	1.36	1.47	0.55	0.96
3	4.17	0.72	5.3	Single Point	1.27	2.43	0.82	0.91

FIG.1. 50 inch CYLINDER SUSPENDED IN 24 ft. WIND TUNNEL



SINGLE POINT AT ATTACHMENT



PERIPHERAL ATTACHMENT

FIG. 2. METHODS OF ATTACHING PARACHUTES TO CYLINDERS

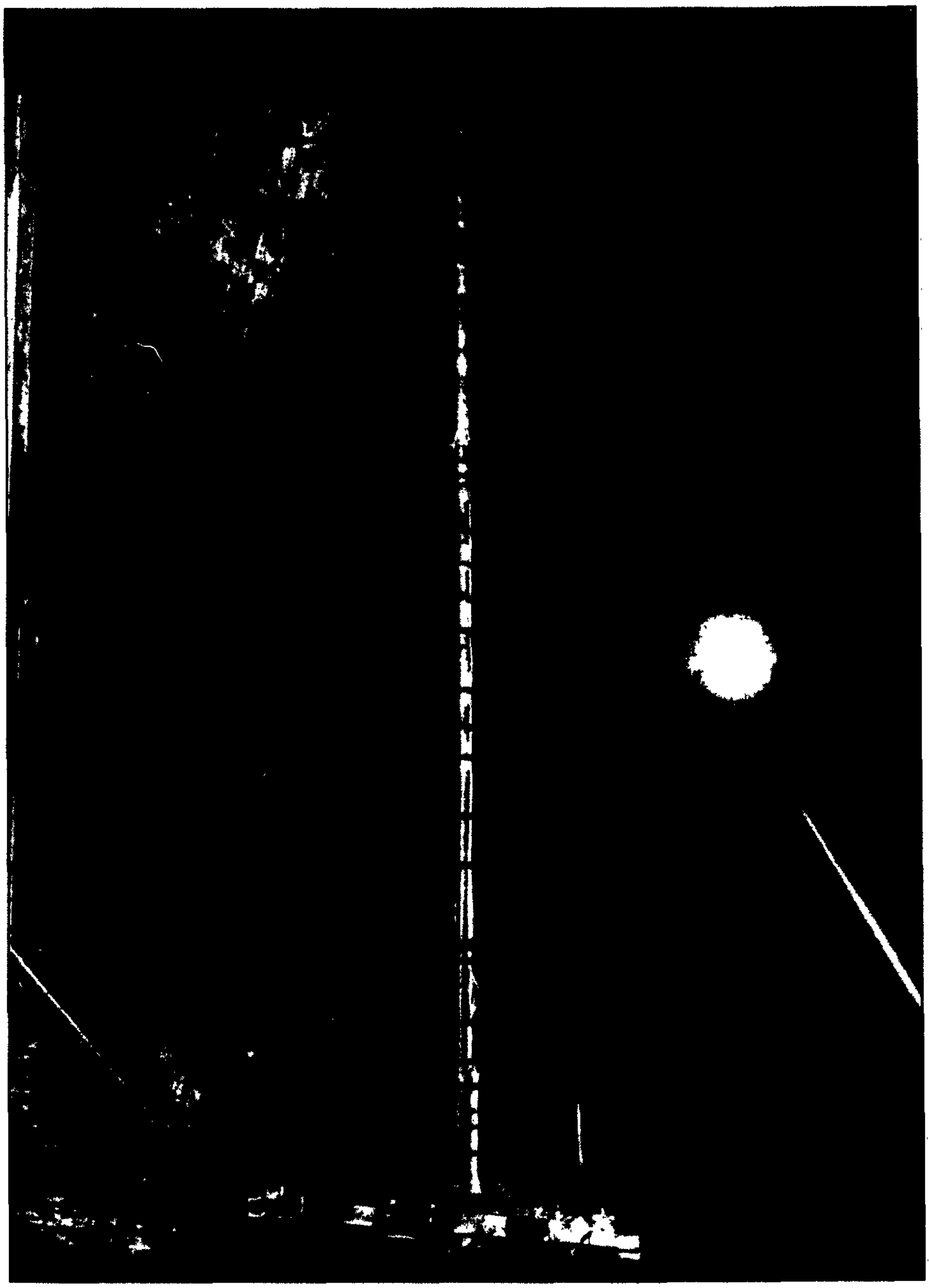
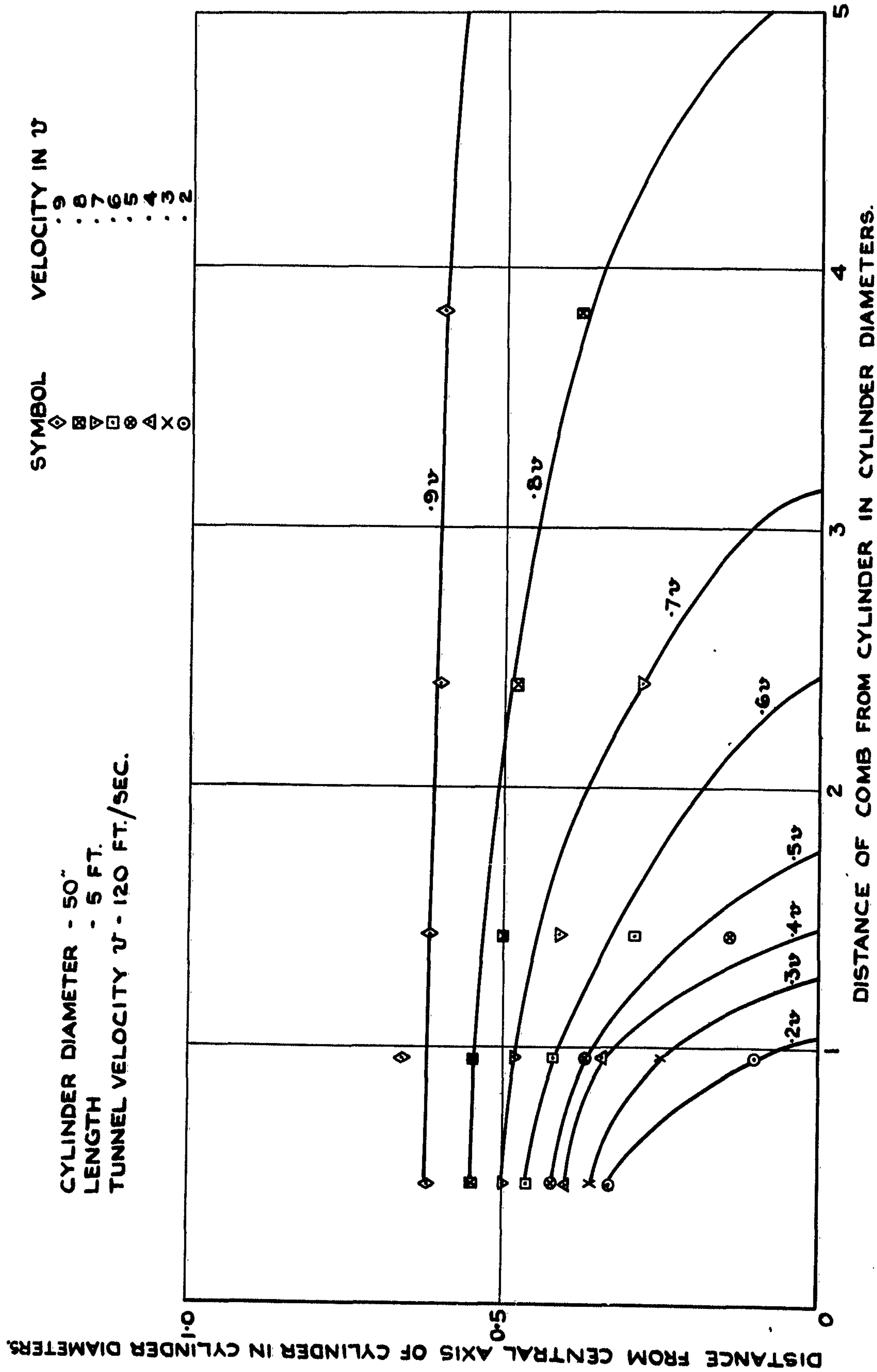
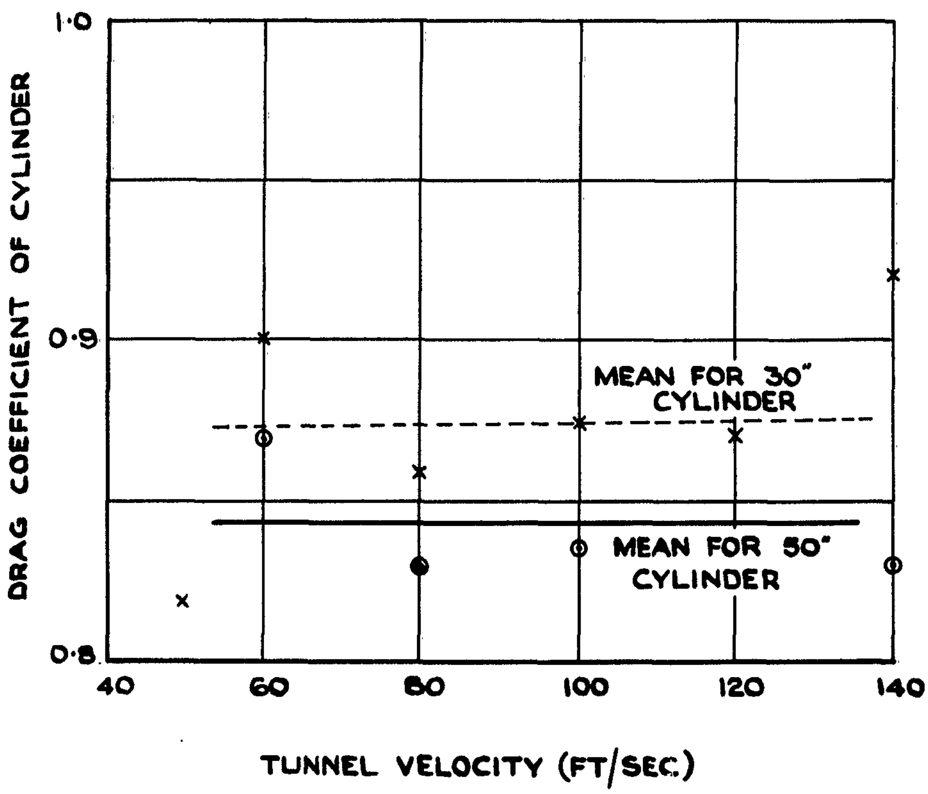


FIG.3. PITOT STATIC COMB

FIG. 4

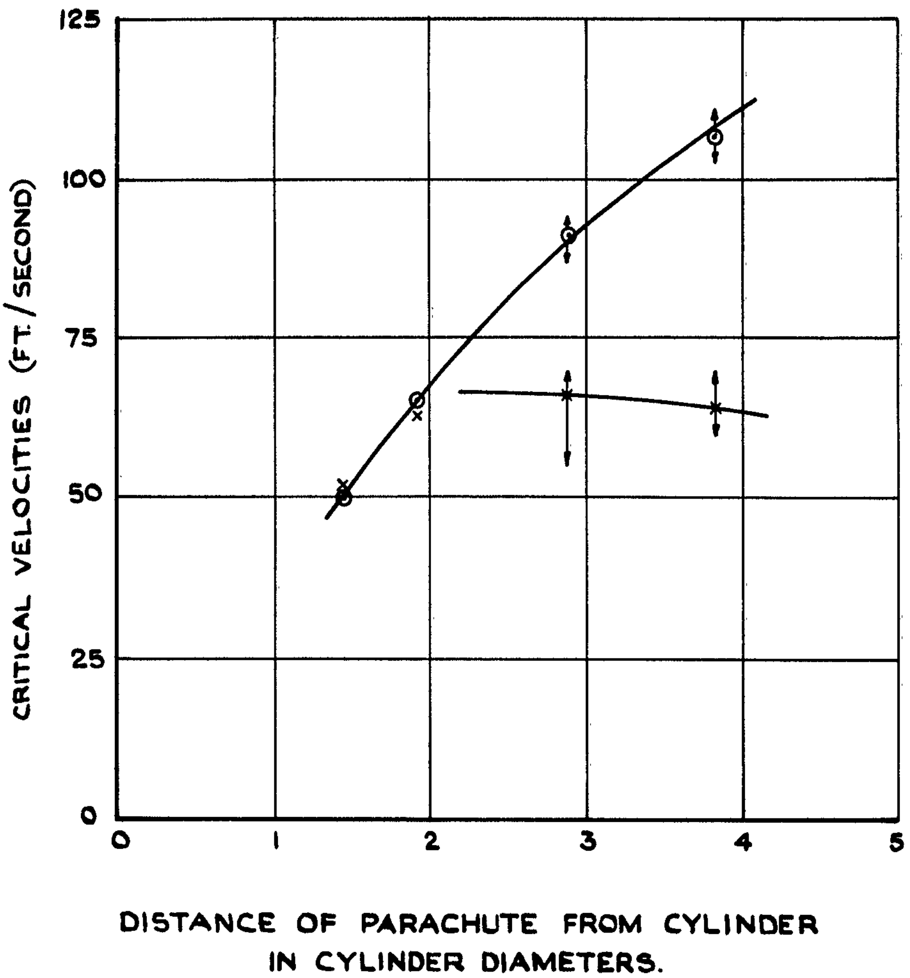


FLOW IN WAKE OF CYLINDER



SYMBOL	CYLINDER DIAMETER
×	30 INS.
⊙	50 INS.

FIG. 5. EFFECT OF VELOCITY ON DRAG COEFFICIENT OF CYLINDER WITHOUT PARACHUTE.



PARACHUTE DIAMETER - 3 FT.

EFFECTIVE LENGTH OF LINES - 6 FT.

POROSITY - 45 FT./SEC.

CYLINDER - 50" DIAMETER.
5 FT. LONG.

$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER.}} = 0 \cdot 72$

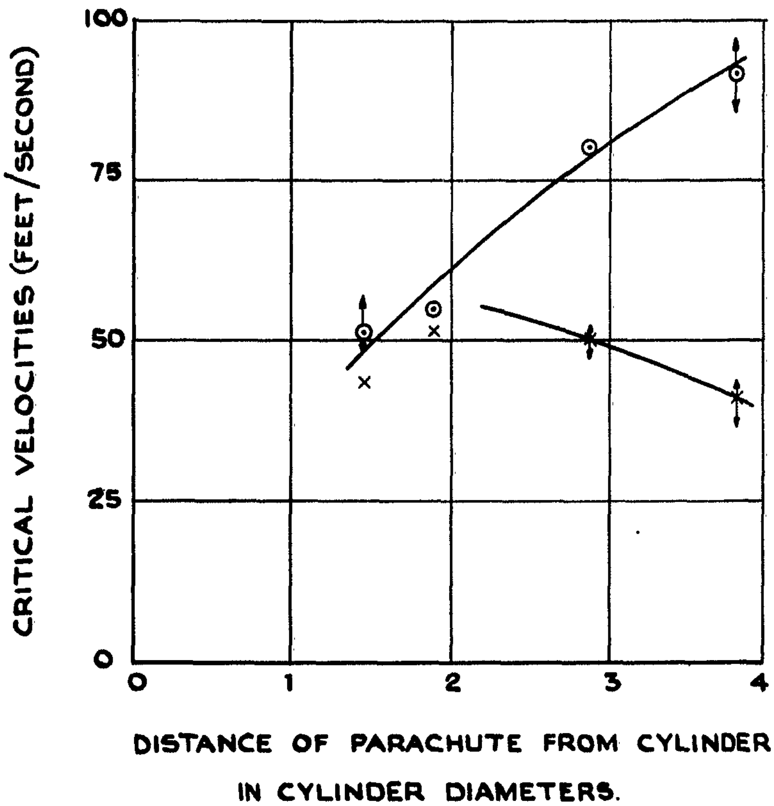
SINGLE POINT ATTACHMENT.

× - MEAN OPENING SPEED.

⊙ - MEAN CLOSING SPEED.

↕ - RANGE OF MEASUREMENTS.

FIG. 6. EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON CRITICAL OPENING AND CLOSING VELOCITIES.



PARACHUTE DIAMETER - 3 FT.

EFFECTIVE LENGTH OF LINES - 4·5 FT.

POROSITY - 45 FT/SEC.

CYLINDER - 50" DIAMETER
5 FT LONG

$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER}} = 0{\cdot}72$

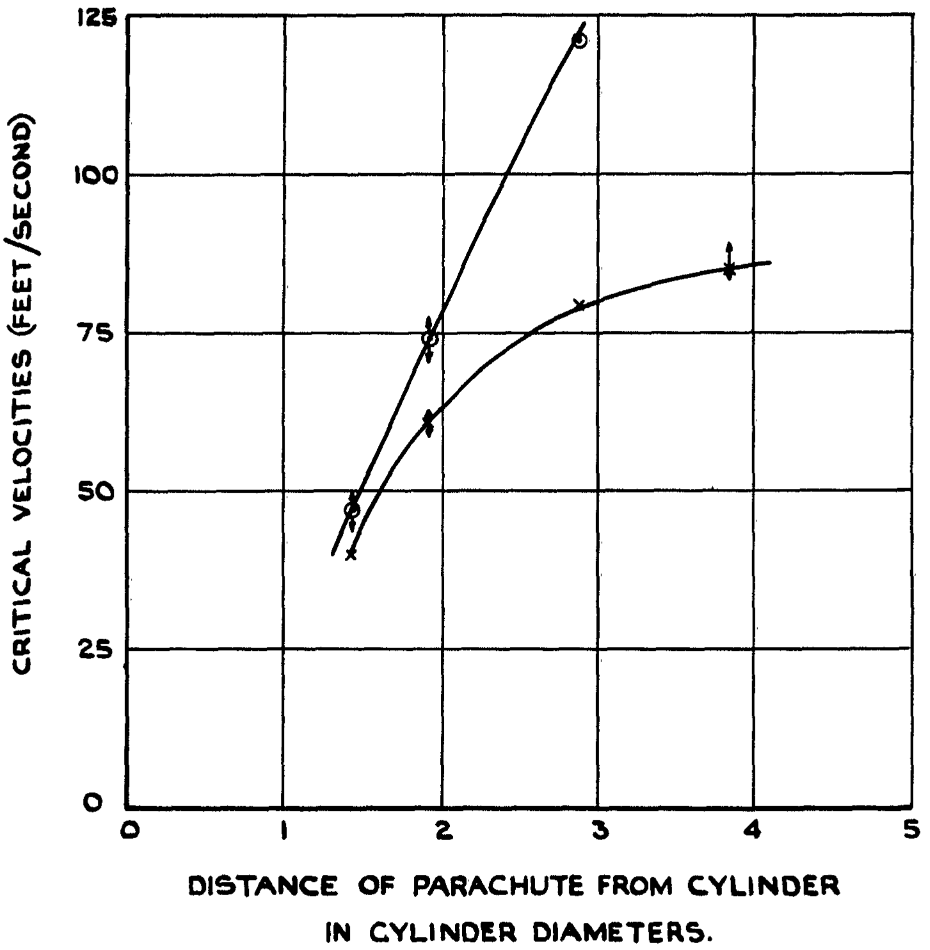
SINGLE POINT ATTACHMENT

× - MEAN OPENING SPEED

⊙ - MEAN CLOSING SPEED

↕ - RANGE OF MEASUREMENTS.

FIG. 7. EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON CRITICAL OPENING AND CLOSING VELOCITIES.



PARACHUTE DIAMETER - 4 FT.

EFFECTIVE LENGTH OF LINES - 4 FT.

POROSITY - 30 FT./SEC.

CYLINDER - 50" DIAMETER.
5 FT. LONG.

$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER}} = 0{\cdot}96$

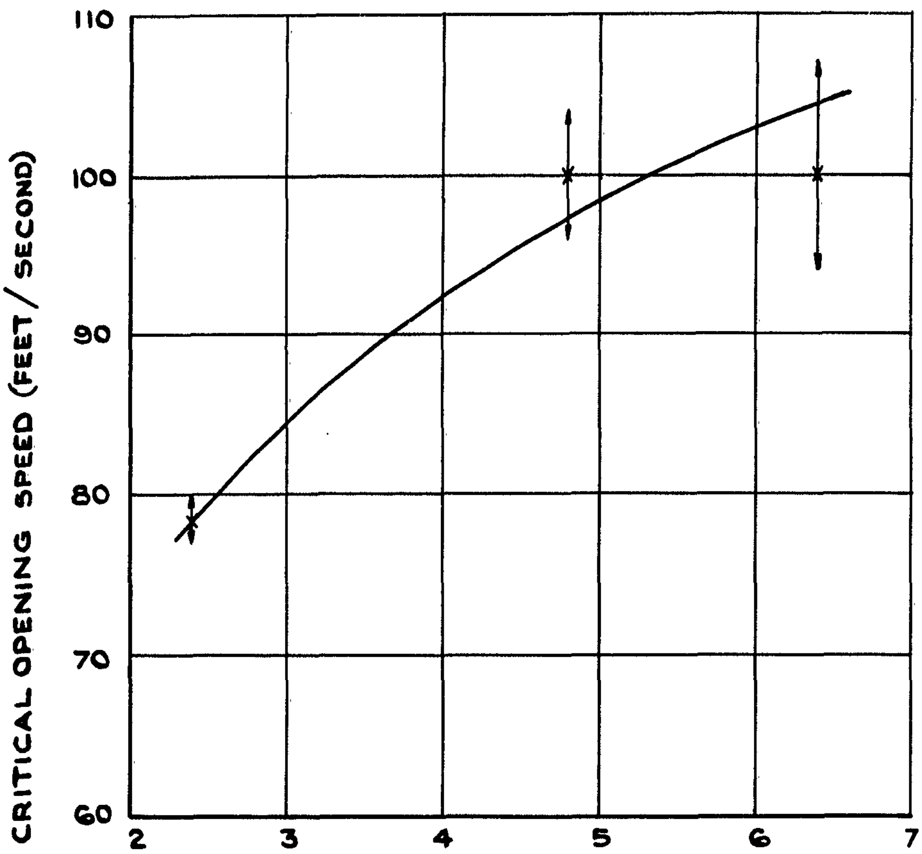
SINGLE POINT ATTACHMENT

× - MEAN OPENING SPEED

⊙ - MEAN CLOSING SPEED

↕ - RANGE OF MEASUREMENTS.

FIG. 8. EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON CRITICAL OPENING AND CLOSING VELOCITIES.



DISTANCE OF CANOPY FROM AFT END OF CYLINDER IN CYLINDER DIAMETERS

PARACHUTE DIAMETER - 4 FT.

EFFECTIVE LENGTH OF RIGGING LINES - 3 FT.
POROSITY -- 30 F/S
CYLINDER DIAMETER - 30"
LENGTH - 5 FT.

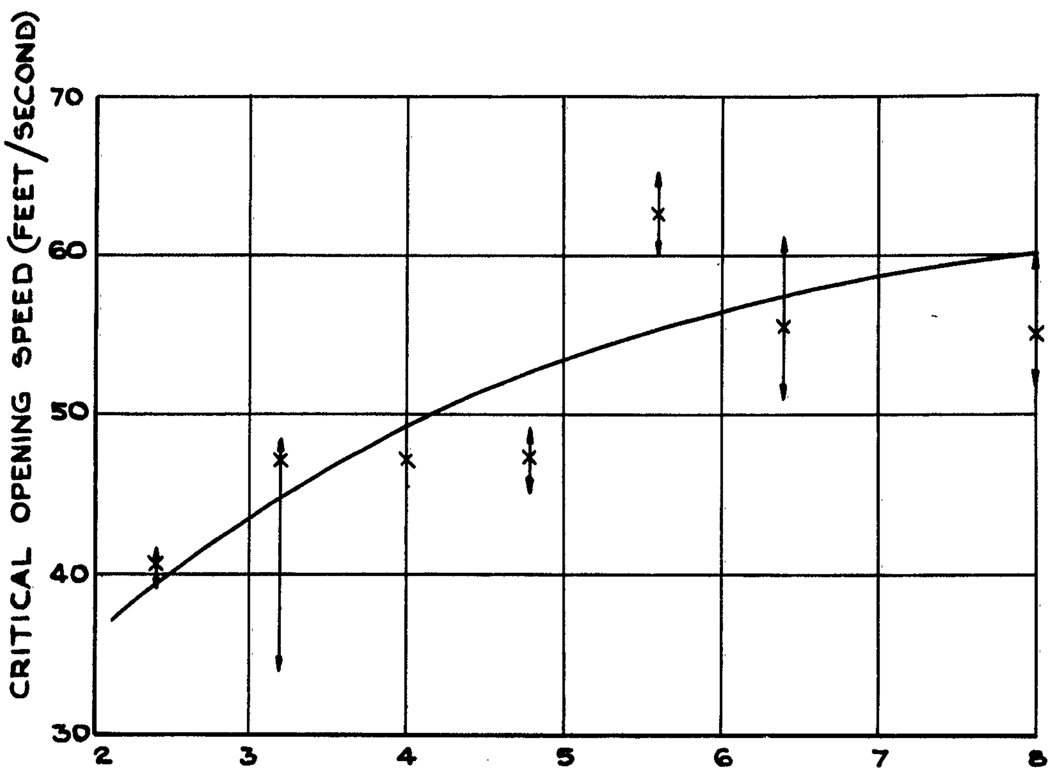
$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER}} = 1{\cdot}6$

SINGLE POINT ATTACHMENT

× - MEAN VALUE

↕ - RANGE OF MEASUREMENTS.

FIG. 9. EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON CRITICAL OPENING SPEED.



DISTANCE OF CANOPY FROM AFT END OF CYLINDER IN CYLINDER DIAMETERS

PARACHUTE DIAMETER - 4 FT.

EFFECTIVE LENGTH OF RIGGING LINES - 6 FT.
POROSITY - 45 F/S
CYLINDER DIAMETER - 30"
LENGTH - 5 FT.

$$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER}} = 1{\cdot}6$$

SINGLE POINT ATTACHMENT

× - MEAN VALUE

↕ - RANGE OF MEASUREMENTS.

FIG. 10. EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON CRITICAL OPENING SPEED.

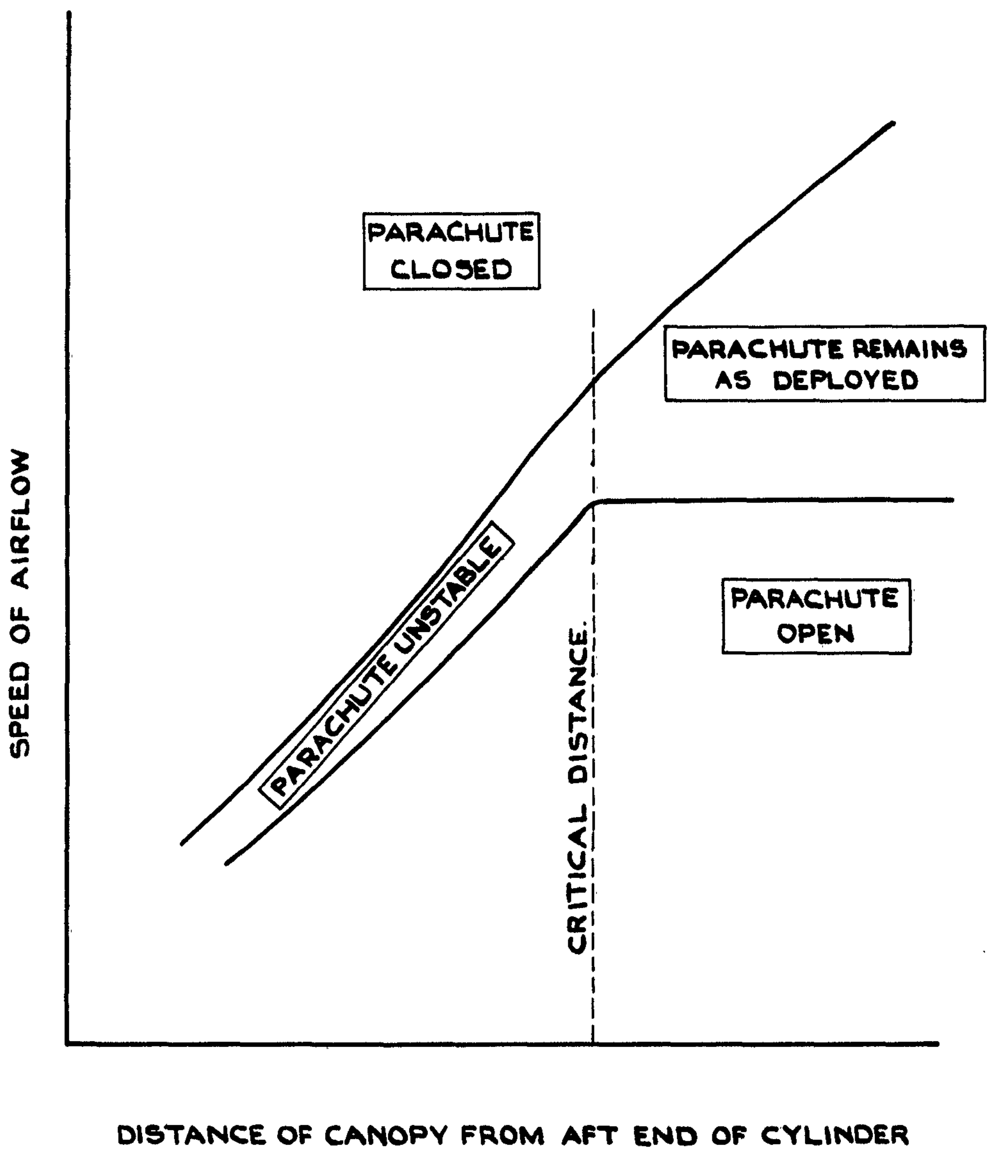


FIG. 11. EFFECT OF WAKE OF CYLINDER ON CRITICAL SPEEDS OF PARACHUTE. (DIAGRAMMATIC)

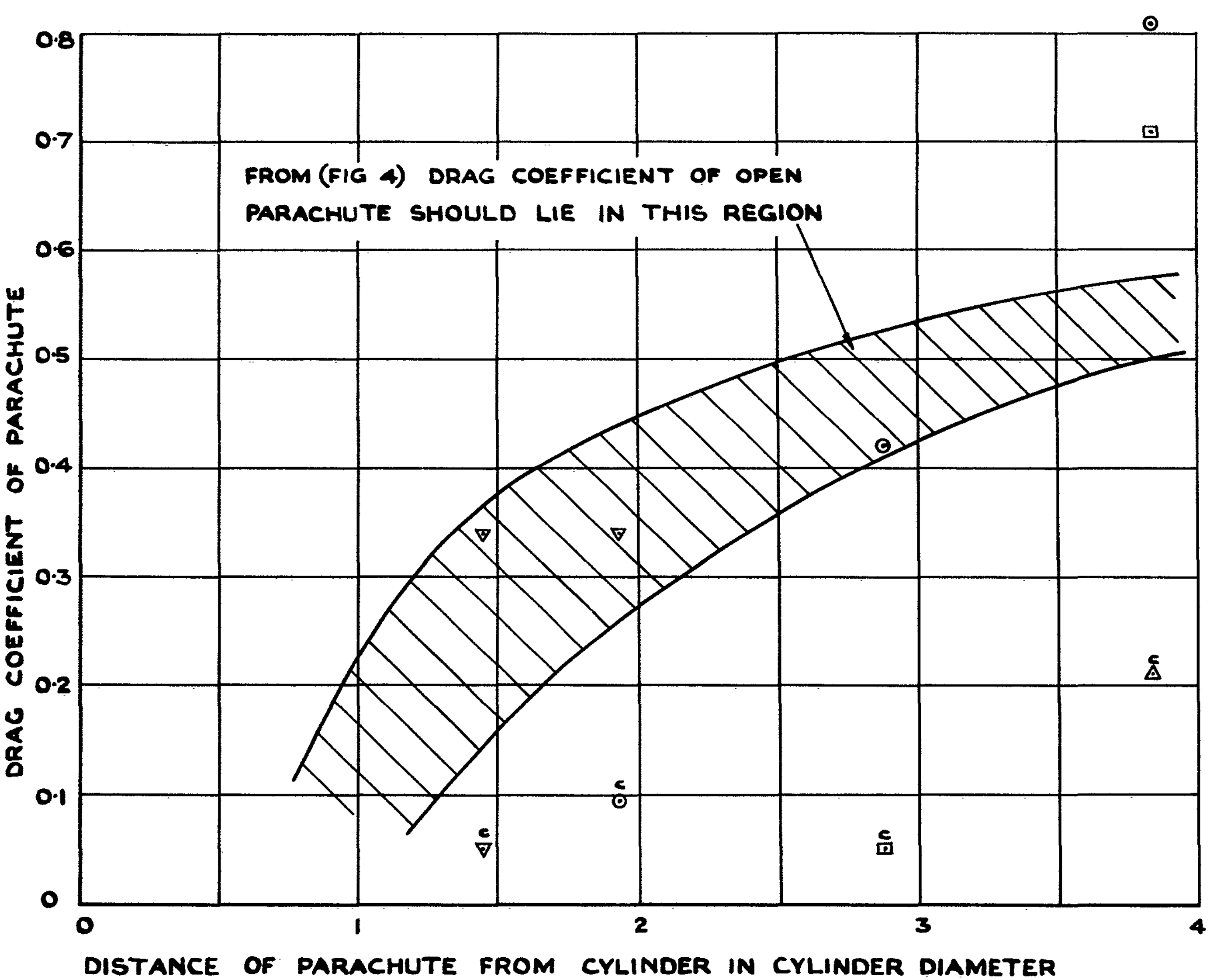
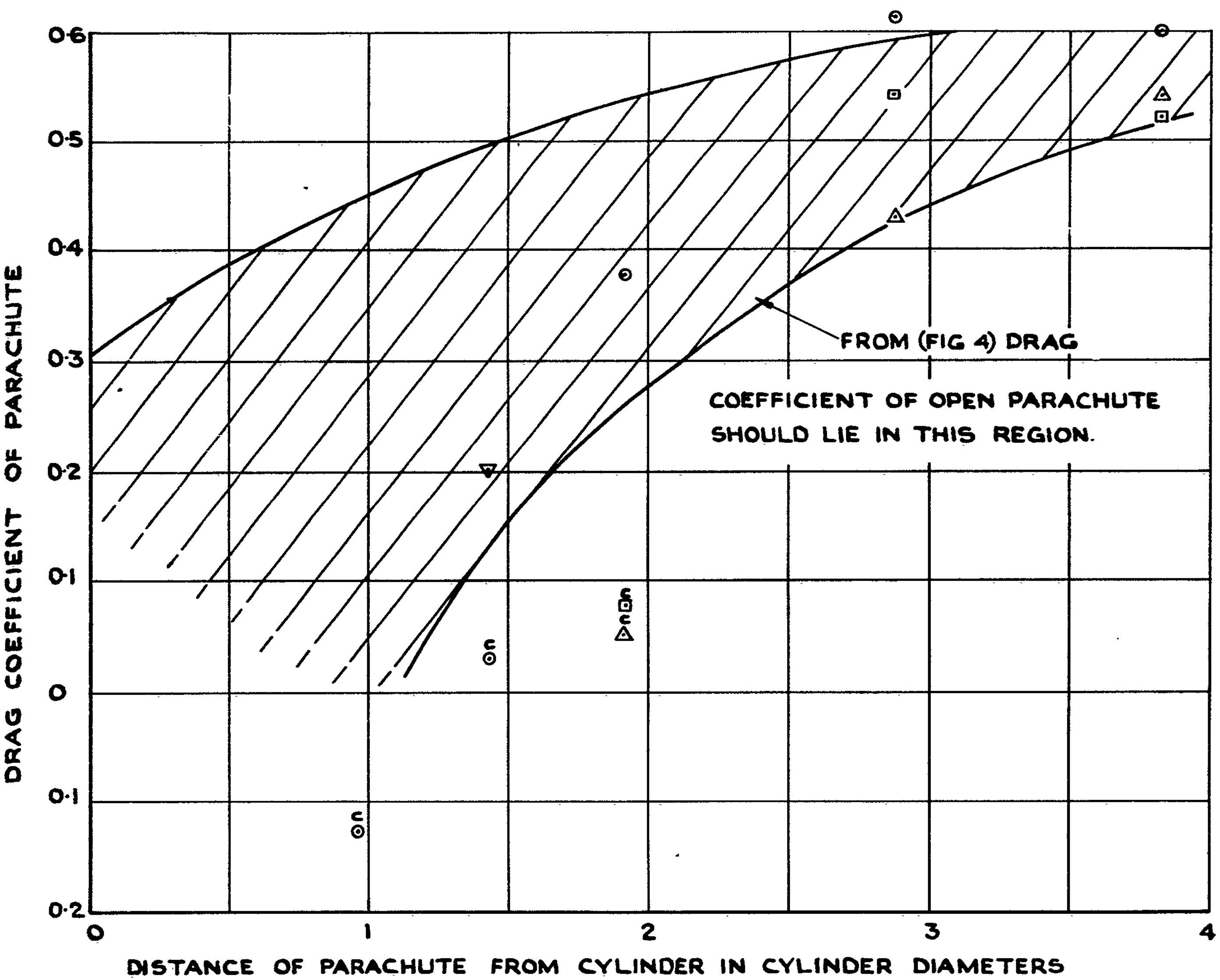


FIG. 12 EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON PARACHUTE DRAG.



PARACHUTE DIAMETER - 4 FT.
EFFECTIVE LENGTH OF RIGGING LINES - 4 FT.
POROSITY - 30 FT./SEC.
CYLINDER - 50" DIAMETER
- 5 FT. LONG

$\frac{\text{NOMINAL PARACHUTE DIAMETER}}{\text{CYLINDER DIAMETER}} = 0{\cdot}96$

SINGLE POINT ATTACHMENT

SYMBOL	VELOCITY FT./SEC.
▽	40
⊙	60
⊡	80
△	100

C - DENOTES PARACHUTE IN THE CLOSED STATE.

FIG. 13 EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY AND CYLINDER ON PARACHUTE DRAG.

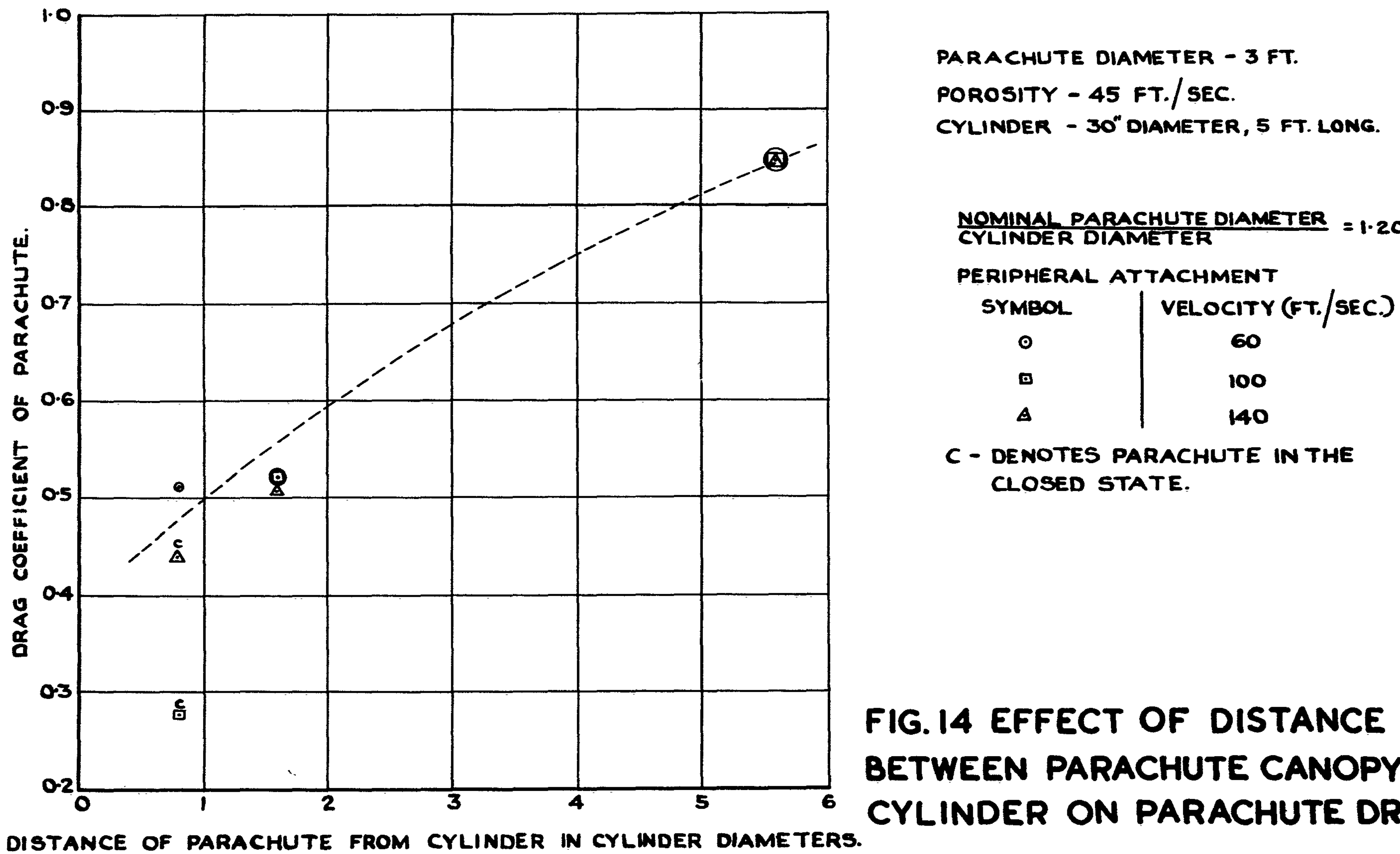


FIG. 14 EFFECT OF DISTANCE BETWEEN PARACHUTE CANOPY & CYLINDER ON PARACHUTE DRAG.

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EFFECT OF A CYLINDRICAL STORE ON PARACHUTE DRAG AND OPENING

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